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GCMS and FTIR Spectroscopy Characterization of *Luffa Cylindrica* Seed Oil and Biodiesel Produced from the oil

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Abstract The need for replacement of fossil fuel with more efficient fuels that are eco-friendly and renewable (biodiesel) was the basis for the present study. *Luffa cylindrica* seed oil (LCSO) was extracted through solvent extraction using petroleum ether as a solvent between 60 and 80 °C The produced oil was used for the production of biodiesel (LCBD) via two-stage transesterification . The percentage yield of the extracted oil and biodiesel were 17.3 and 18.8 % respectively. The physico-chemical properties were within ASTM recommended values, indicating a quality fuel production. GC-MS chromatograms of LCSO and LCBD indicated the presence of acridine,9-anilino acid, 11-octadecanoic acid, (methyl ester), methyl stearate and benz (a) anthracene, 6,7,12-trimethyl, 15-octadecanoic acid, methyl ester, methyl stearate, eicosanoic acid, serine methyl ester, and N-[2-oxo-4-phenylbutyryl]. Also, IR spectroscopy analyses of LCSO and LCBD revealed the presence of O-H, C-H, C=O, O-C, =C-H and C-N in LCSO and N-H, O-H, C-H, C=O, C-O, C-N, =C-H stretches in LCBD. The study drew results and findings and concluded that *Luffa cylindrica* seed oil is an excellent feed stock for the production of biodiesel.

Key Words: *Luffa cylidrica seed oil, biodiesel, transesterification, characterization*

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1.0 Introduction

The dependence of nations on petroleum-based fuels generated several consequences including environmental pollution, increased economic burden, increased future risk and other consequences (Hanny & Hirata 2008). Hydrocarbon based fuel are non biodegradable

(although they produce CO_2 and H_2O) if the combustion is complete) and nonrenewable (indicating that future risk of scarcity can endanger economic development. The quest for a sustainable clean environment, renewable and biodegradable fuel has led to intensive research into alternative energy sources which will suit these qualities (Adebayo *et al*., 2016; Adesina and Amoo, 2013). Plant and animal fats have been accepted as sources of clean and ecofriendly fuel, (Adebayo *et al.,* 2016). Biofuel is a mono-alkyl ester produced through transesterification of vegetable oils or animal fats (Usha & Prajapati, 2017). The traditional industrial steps associated with the production of biodiesel from vegetable oils involve solvent extraction of the oil from the seed, refining, and transesterification to improve the qualities of the biodiesel (Babalola, *et al*., 2014).

Luffa-cylindrica (sponge gourd) is a flowering plant species which belongs to the family, Cucurbitaceae (gourds). The plant is abundant in Nigeria but the seeds and oil are not consumable. In Nigeria, *Luffa cylindrica* plant grows in the wild, abandoned building structures and perimeter fences. The plant is a climbing stem, with hairy smooth vine reaching a length of five or more meters (Gafar *et al*., 2012). Reported studies on physicochemical properties of *Luffa cylindrica* seed oil have indicated that the oil has significant potential for biodiesel production (Okure *et al*., 2018, Babalola, *et al*., 2014, Adebayo *et al*., 2016, and Gafar *et al*., 2012).

In spite of the prevailing knowledge of biodiesel as a better alternative to fossil fuels, several countries have not fully adopted the technology due to ease of obtaining hydrocarbon fuels, cost and other factors associated with the production processes. According to Hanny and Hirata (2008), a cost-effective process of producing biodiesel involves the use of cheap feedstock such as inedible oils and fats of plant and animal origin. Also, waste food oil and by-products of the refining vegetables oils could serve as good substitute. Therefore, However, literature us scanty on the adoption of this method. There is an envisaging future risk that can be aggravated by increasing population, environmental pollution from fossil fuel and the scarcity of the products. Hence the aim of this study is to produce and characterise oil and biodiesel from *Luffa cylindrica* seed oil

2. 0 Materials and Methods

2.1 Sample collection and preparation

Matured dry fruits of *Luffa cylindrica* were harvested between the months of December 2018 and February 2019 at Federal Housing Estate, Abak Road, Uyo, Akwa Ibom State, Nigeria. The dry fruits were mechanically broken to remove the seeds. The *Luffa cylindrica* seeds were air dried and grinded.

2.2 Extraction of the oil from *Luffa cylindrica* seeds

Oil was extracted from the grounded seeds through solvent extraction using petroleum ether as solvent and at a temperature range of 60 to 80 □C. 560 g of the sample was soaked in petroleum ether, squashed in a borosilicate container, and filtered in order to separate the petroleum ether fraction (which also contain the oil from the *Luffa cylindrica* seed cake. The filtrate was kept overnight in a fume cupboard, the settled debris at the bottom was removed by decantation. The filtrate was kept in an oven at the temperature of 70 ^oC to get rid of petroleum ether leaving behind dark green colour oil (*Luffa cylindrica* seed oil-LCSO).

2.2 Percentage yield

Percentage yield of oil extracted was calculated using the formula,

$$\%yield = \frac{Weight\ of\ extract}{Weight\ of\ sample} \times \frac{100}{1} \quad (1)$$

2.3 Saponification Value

The saponification value (SV) of the oil estimated using the AOAC (1990) method and the equation used for the calculation was:

$$SV = \frac{(S-B)\times(N-M)}{W_0} SV = \frac{(S-B)\times(N-M)}{W_0} \quad (2)$$

where S is the sample titre value, B is the blank titre value, N is the normality of 0.5 M KOH while W_0 is the weight of the oil.

2.4 Flash Point

The flash point of the sample was determined using Pensky Martens Flash Point apparatus according to (ASTM, D93, 2000). Flash point of a fuel is defined as the temperature at which it will ignite when exposed to flame or spark.

2.5 Acid Value (AV)

The Acid Value (AV) was calculated using the expression

$$AV = \frac{TV \times N \times M}{Wo} AV = \frac{TV \times N \times M}{Wo} \quad (3)$$

where TV is the titre value, N is the normality of 0.1 M of KOH, M is the molar mass of KOH and W_0 is the weight of the oil

2.6 Iodine value (IV)

The Iodine Value (IV) was calculated using equation 4

$$IV = \frac{(B-S \times N \times 12.69}{Wo} IV = \frac{(B-S \times N \times 12.69}{Wo} \quad (4)$$

where B is the blank titre value, S is the sample titre value, N is the normality of sodium thiosukphate and W is the weight of the oil

2.7 Peroxide value (PV)

The peroxide value (PV) of the oil was estimated using equation 5

$$PV = \frac{(S-B \times N \times 100}{Wo} PV = \frac{(S-B \times N \times 100}{Wo} \quad (5)$$

where B is the blank titre value, S is the sample titre value, N is the normality of sodium thiosulphate and W is the weight of the oil (g)

2.8 Refractive index

The refractive index was determined using Abbe Refractometer.

2.9 Specific gravity

The specific gravity of the oil was calculated as the ratio of the weight of a specified volume of the oil to the weight of an equal volume of water according to equation 6

Specific gravity= Weight of 5 ml of oil Weight of 5ml of water (6)

2.10 Cetane number, and viscosity

Cetane number, and viscosity of (*Luffa cylindrica* seed oil- LCSO) and *Luffa cylindrica Luffa cylindrica* seed oil biodiesel was determined using the method recommended by the American Society of testing and Materials (ASTM) standards.

2.11 Production of biodiesel

2.12 Pre-treatment of Luffa cylindrica seed oil (LCSO) for esterification:

Pre-treatment process was done using 500 ml Erlenmeyer flasks as batch reactors. The reactants were added and the flask closed with a rubber stopper. A thermometer was placed through a stopper to monitor the temperature inside the reactor. Hot plate with a magnetic stirrer was used for heating and mixing the reactor contents. Mixing and stirring was applied at 600 rpm. This was to overcome mass transfer during biodiesel production (Hamed et al., 2008).

2.12.1 Acid catalysed esterification

The crude Luffa cylindrica seed oil was heated to 50 °C with continuous stirring to homogenize the oil. Concentrated tetraoxosulphate (IV) acid (2 %) the weight of oil was added to methanol (61.6 mL3), heated and stirred for one hour to a maximum temperature of (60-65 o0C) not exceeding the boiling point of methanol (Hamed et al., 2008). The methanol - acid mixture was transferred into the pre-heated oil (Hamed et al., 2008);Soares *et al.,* 2011).

The reaction time of one hour was adopted, based on the recommendation of Canakci and Van Gerpen 2001b). The reaction mixtures were turned into a separating funnel to settle for three hours. A clear separation in different layers was observed, the top layer contained mainly water and methanol and the bottom layer contained esterified oil Ghadge and Raheman, 2005). The esterified layer was used in the transesterification step. Increasing the reaction time beyond one hour does not have a significant effect on reducing the acid value. This is due to inhibition of the reaction by water formed during esterification of free fatty acid (Hamed *et al.,* 2008).

2.12.2 Alkaline (KOH)-catalyzedtransestirification

The stoichiometric requirement for transesterification was 3:1 mole of alcohol to triglyceride to produce three moles of ester and one mole of glycerol. Transesterification is a reversible reaction; hence for the reaction to go to completion, the molar ratio of alcohol should be higher than stoichiometric requirement. The esterified oil (30.1 mL^3) from the acid catalyzed step was reacted with methanol (128.8 mL^3) at a temperature range of (60 -65 ^{0}C) with 0.54 g of KOH added (2% weight of esterified oil). The KOH was added to the methanol, and heated to 60 ^{o}C. The mixture was then added to the esterified oil and stirred for two hours. The reaction products were poured into a separating funnel and allowed to separate for four hours. Two distinctive layers was observed, the top layer containing methyl ester (biodiesel) and the lower layer glycerol, excess KOH and unreacted methanol.

2.12.3 Biodiesel washing and drying

Warm de-ionized water at 50°C was added to the separated biodiesel, and the mixture was shaken vigorously to remove residual KOH, methanol and soap as possible bye-product. Soaps produced could cause an increase in viscosity, and the appearance of gels, and also make the separation of glycerol difficult (Ghadge & Raheman (2005), Qian *et al*., (2008), Ika *et al*., (2013). The water was allowed to drain through the bottom of the separating funnel. This was carried out five times until a clear biodiesel was obtained. Anhydrous Calcium chloride ($CaCl_2$) was added to the biodiesel and heated gently at 50°C for ten minutes to remove any remaining moisture. The anhydrous Calcium chloride was later separated from the biodiesel to obtain dry LCBD biodiesel. The weight of the biodiesel was obtained to calculate its percentage yield.

2.13 GC-MS analysis

The samples (100 µl) were extracted from the reaction mixture at the specified time intervals and examined by Gas Chromatograph, using Flame ionisation detector (Agilent, 7890 A). The GC machine contained a HP-5 capillary column supplied by Agilent with the dimensions 30 m × 0.32 mm× 0.25 µm. The samples were centrifuged for 3 minutes at 11,500 ×g, and then the top layer of the sample was isolated for GC analysis. With heptadecanoic acid methyl ester serving as the internal standard for analysis, exactly 30 µl of the sample was thoroughly dissolved in 270 µl of n-hexane, and then mixed with 300 µl of 1 g/l heptadecanoic acid methyl ester (n-hexane as the solvent). The column temperature was held at 170°C for 0.5 minutes and gradually increased to 200 □C at a heating rate of, 3°C/minute, and then reheated to 260 □C at a rate of 20°C/minute. The injector temperature was set at 250 °C while the temperature of the detector was maintained at 260 °C.

2.14 Infra-red spectroscopy analysis

The *Luffa cylindrica* seed oil (LCSO) and *Luffa cylindrica* seed oil biodiesel (LCBD) were analysed for their functional groups using Agilent Cary 630 Fourier Transform Infra-Red Spectrometer equipped with LED lamp, quartz cuvettes, 1 cm optical path as specified by Standard Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) content in diesel fuel oil using mid infrared spectroscopy (FTIR-ATR-PLS Method) 2014, (ASTM D7371-14, 2014).

4.0 Results and Discussions

Physicochemical parameters of oil extracted from *Luffa cylindrica* seed are presented in Table 1.

The percentage yield of *Luffa cylindrica* seed oil was 17.3 % (Table 1). The value is comparable to 15.57, 12.30 and 14.08 % reported by Adebayo *et al*. (2016), Audu *et al*. (2013 for the same seed. However, the value is less than the mean value of 39.10 ± 0.20% reported by Adewale *et* al. (2012) and that reported by Okure *et* al. (2018).

Table 1: Physicochemical characteristics of *Luffa cylindrica* seed oil

Parameters	LCSO	LCBD
Percentage yield	17.3 %	18.8 %
Saponification value, SV (mg KOH)	168	165
Specific gravity	0.92	0.875
Refractive Index	1.35	
Iodine Value (IV)	130	106
Acid Value	20.62	1.48
Flash point	134	130
Viscosity	4.9	3.237
Cetane number	60.0	50.8

The percentage yield of the produced biodiesel Adewale *et al*., 2012 was 18.8 % (Table 1) This value is less than 98 % reported by Adewale *et al*., (2012), and 92.06 % reported by Okure *et al*. (2018). Abayeh *et al*. (2013) stated that low yield of oil may be due to inability of the extraction process to completely remove the oil from the seed. Percentage yield value of 99 % has been reported by Hamed *et al*. (2008) using 9.2:1 molar ratio and 0.5% KOH. Ma and Hanna (1999) indicated that higher oil yield can be obtained in a shorter time using higher molar ratios. Consequently, molar ratio, concentrations of the catalyst (KOH) and their interaction can affect the biodiesel yield (Hamed *et al*., 2008). The results obtained by Ramadhas *et al.* (2005) for biodiesel produced from rubber seed oil showed a maximum conversion at 9:1 molar ratio and 0.5% NaOH in the second step. According to Vicente *et al*. (2004) the expected biodiesel yield with reference to the

initial weight of vegetable oil should be nearly 100% if there is no saponification or neutralization of the free fatty acid in the vegetable oil. Saponification and neutralization reaction produce soap by reacting with the oil and hence reduces biodiesel yield (Hanny and Hirata, 2008). This may account for the relatively low biodiesel yield obtained in this work when compared to results obtained by some other authors. Other factors that might have affected the yield are longer reaction time and lower molar ratios of the oil and alcohol; and the concentration of the catalyst (KOH).

4.3 Iodine Value (IV): Iodine value of 130 and 106 were recorded for LCSO and LCBD respectively, as shown in Table 1. The iodine value of LCDO was slightly higher than 101 obtained by Kumar and Padam, (2013). Iodine value is a useful parameter in studying oxidative rancidity of triacylglycerols. The higher the iodine value, the higher the degree of unsaturation and the possibility of rancidity, (Kumar & Padam, 2013).

4.4 Acid Value: Acid values of 20.62 and 1.48 were obtained for LCSO and LCBD respectively; these are presented in Table 1. The acid value can affect transesterification with methanol using an alkaline catalyst and interferes with the separation of fatty acid ester and glycerols. This makes a two-stage process of esterification and transesterification a better option for converting the oil to biodiesel (Usha and Tilak, 2017).

4.5 Specific gravity: Specific gravity of LCSO and LCBD were 0.92 and 0.875 respectively (Table 1). The values were within the standard range of (0.87–0.90) expected for biodiesel (Usha and Prajapati 2017). The closeness of the specific gravity of the biodiesel obtained from this study to that of pure automotive gas oil, AGO (i.e, 0.8) indicated good ignition property (Bamgboye & Oniya 2012).

Density of 98 g/L was obtained for LCBD (Table 1). High-density biodiesel or its blend can lead to incomplete combustion and particulate matter emissions.

The cetane number of LCBD was 50.8 as shown in Table 1. The value was slightly higher than the minimum standard of 49 recommended for biodiesel by the Technical Standard of the European Union (Bamgboye and Oniya, 2012). Based on cetane number, the biodiesel seems suitable as Automotive Gas Oil.

4.8 Colour of biodiesel produced

The colours of *Luffa cylindrica* seed oil and biodiesel produced were dark green and bright yellow respectively.

4.9 Acid catalysed esterification

Acid catalysed transesterification result of *Luffa cylindrica* seed oil was used to produce biodiesel from *Luffa cylindrica* seed oil using methanol. The methanol produced nucleophile ($^{-}OCH_3$) (Fernando, *et al*., 2018) Low conversion to biodiesel was obtained using 2 % of catalyst to oil ratio. This might be due to water formation during esterification of free fatty acid. Esterification process might be improved by continuous removal of water (Hamed *et al*., 2008). Similarly, the alkaline catalysed transesterified step produced a low percentage (18 .8 %) conversion at 2 % of catalyst to oil ratio. This could be attributed to longer reaction time, indicating that a shorter reaction time may be required for alkaline catalysed transesterification.

5.0 GC-MS of *Luffa cylindrica*Seed Oil (LCSO)

Figs. 1 to 3 show the GC-MS spectrum of acridine, 9-anilino, 11-Octadecenoic acid, methyl ester and methyl stearate, in *Luffa cylindrica s*eed oil at different concentrations as recorded in Table 2. Gafar *et al*. (2012) identified the presence of stearic acid, palmitic acid and cis-9-cis-12-linoleic acid in *Luffa cylindrica* seed oil. The presence of palmatic acid and linoleic acid in *Luffa cylindrica* seed oil has also been confirmed by Okure *et al*. (2018). *Luffa cylindrica* seeds have excellent physicochemical properties suitable for manufacturing of cosmetics, drying agent for paints, food processing as well as for the production of biodiesel (Okure *et al*., 2018). *Luffa cylindrica* seed oil can also be used in cosmetics as sunscreens, sunless tanning products, anti-aging products and facial moisturizers. It has antifungal, anti-inflammatory and anti-tumor properties (Onyegbule, *et al*., 2018). It prevents synthesis of certain proteins and is toxic to skin cells (Gafar *et al*., 2012; Sangh, *et al* 2012). According to Su *et al*. (2006) acridine, 9-anilino in *Luffa cylindrica* seed oil could serve as potent antitumor and also in production of acridine dye. 11-octadecenoic acid also present in *Luffa cylindrica* seed oil is

commonly used as a bacterial biomarker. Methyl stearate is a fatty acid methyl ester and an octadecanoate ester. It has a role as a metabolite. Methyl stearate is used as a non-ionic surfactant in various experiments in helping to solubilize a variety of chemical species by dissociating aggregates and unfolding proteins. These compounds when properly isolated and purified can be of great importance in nutrition, pharmaceutical as well medicinal formulations and other industrial applications.

Table 2: GC-MS of *Luffa cylindrica* Seed Oil (LCSO)

Peak	Retention Time	Area	Compound	Reference	Formula	Weight (g/mol)
1	30.2893	12.6811	Acridine,9-anilino-	130961	$C_{19}H_{14}N_2$	270.3
2	33.899	63.8748	11Octadecenoicacid,methyl ester	155736	$C_{19}H_{36}O_2$	296.4879
3	34.2944	23.4441	Methyl stearate	157885	$C_{19}H_{38}O_2$	298.5

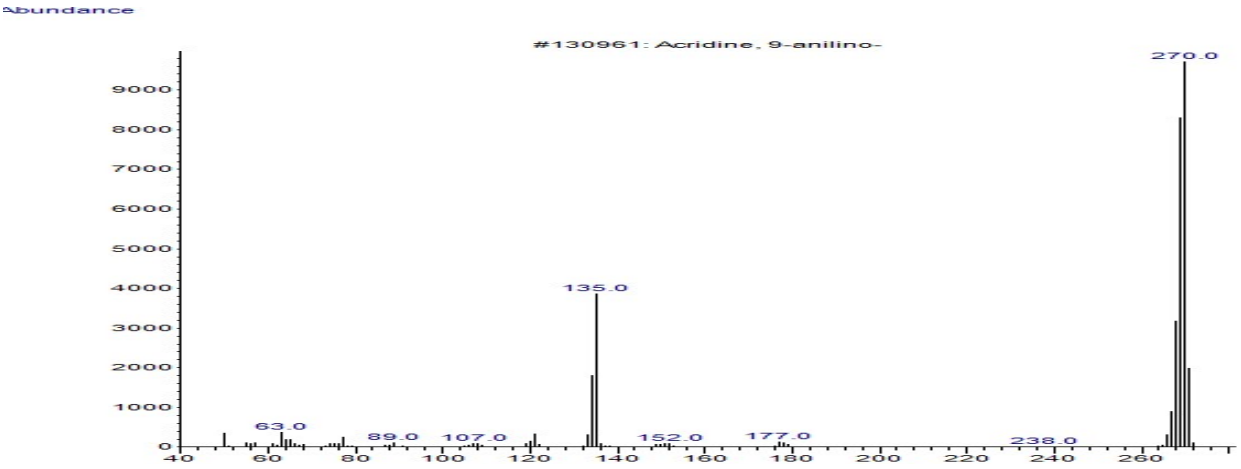

Fig.1: GC MS spectrum of Acridine, 9-anilino- in *Luffa cylindrica* seed Oil (LCSO)

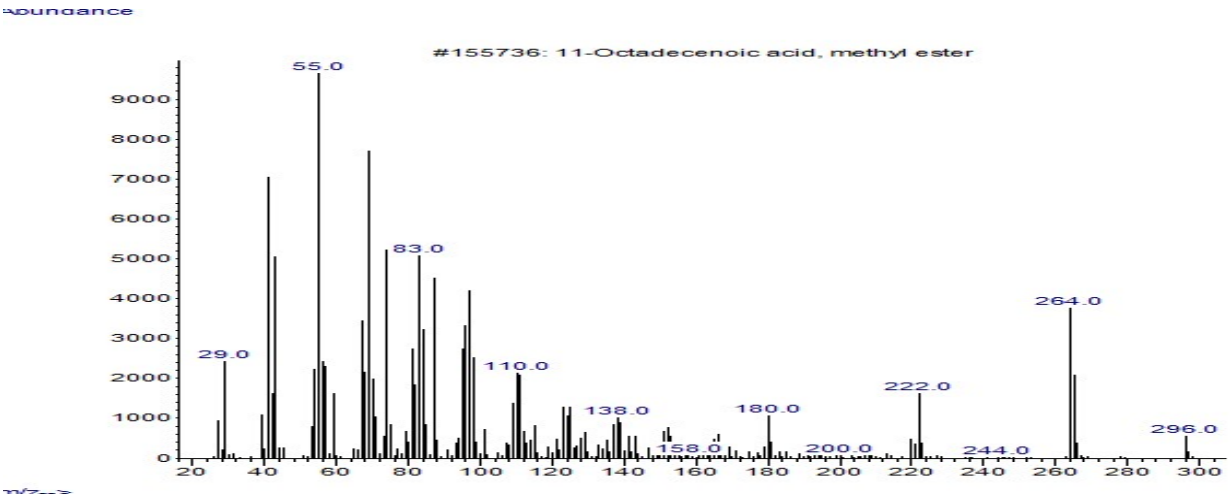

Fig.2: GC MS spectrum of 11-Octadecenoic acid, methyl ester in *Luffa cylindrica* seed Oil (LCSO)

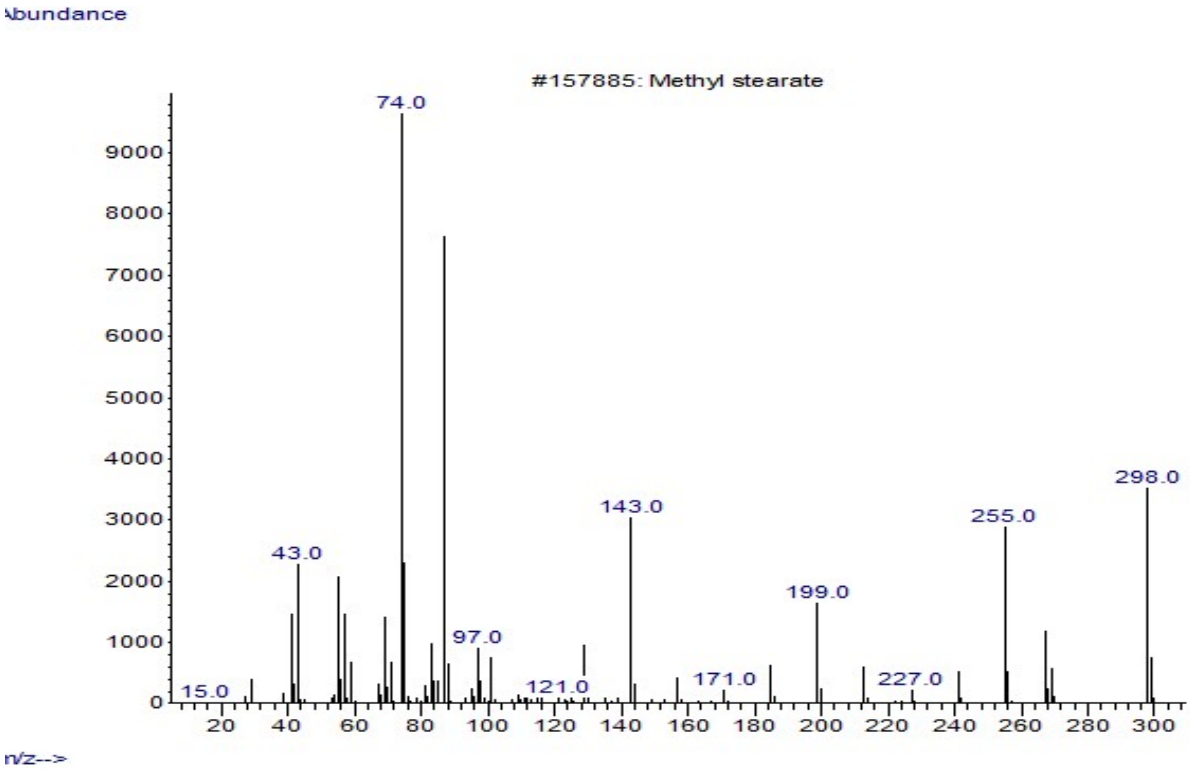

Fig. 3: GC MS spectrum of Methyl stearate in *Luffa cylindrica* seed Oil (LCSO)

The GC-MS analysis of *Luffa cylindrica*seed oil biodiesel (LCBD) indicated the presence of benz(a)anthracene, 6,7,12-trimethyl, 15-octadecenoic acid, methyl ester, methyl stearate, eicosanoic acid, methyl ester and serine methyl ester, N-[2-oxo-4-phenylbutyryl] (Table 3), Figs. 4 to 8 show the GC-MS spectra of Benz (a) anthracene, 6,7,12-trimethyl, 15-octadecenoic acid, methyl ester, methyl stearate, eicosanoic acid, methyl ester and serine methyl ester, N-[2-oxo-4-phenylbutyryl respectively. Comparison of concentrations of compounds identified in the GC-MS of LCSO and LCBD before and after transesterification indicated that methyl stearate did not undergo any chemical change. The methyl esters of saturated fatty acids account for higher cloud point, cetane number and better biodiesel stability (Hamed *et al*., 2008).

Table 3: GC-MS of *Luffa cylindrica* Seed Oil Biodiesel (LCBD)

Peak	Retention Time	Area	Compound	Reference	Formula	Weight (g/mol)
1	30.4064	16.5618	Benz(a)anthracene- 6,7,12-trimethyl	131016	$C_{21}H_{18}$	270.4
2	34.0161	46.026	15-Octadecenoic acid, methyl ester	155729	$C_{19}H_{36}O_2$	296.5
3	34.4774	34.1791	Methyl stearate	157885	$C_{19}H_{38}O_2$	296.4879
4	37.8894	1.56	Eicosanoic acid, methyl ester	184596	$C_{21}H_{42}O_2$	326.56
5	41.6602	1.6732	Serine methyl ester- N-[2-oxo-4-phenylbutyryl]-	138842	$C_4H_9NO_3$	119.12

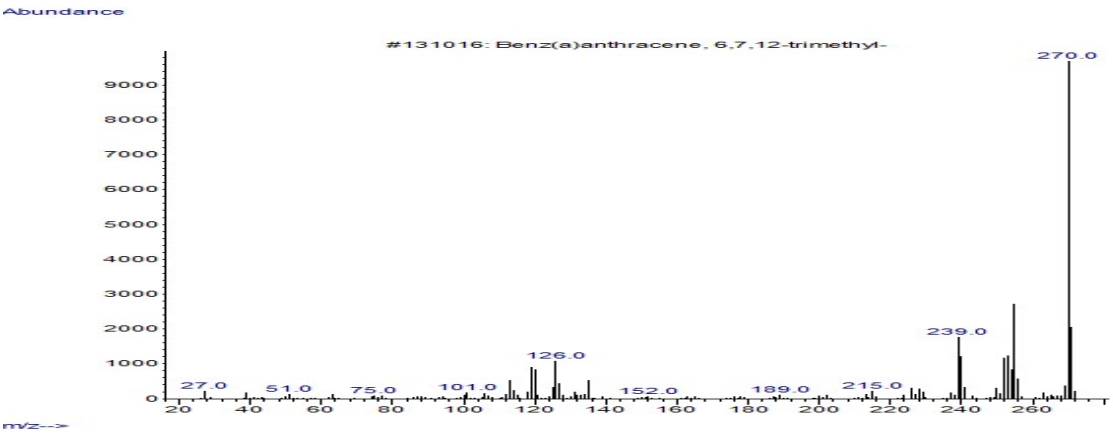

Fig. 4: GC MS spectrum of Benz (a)anthracene, 6,7,12-trimethy

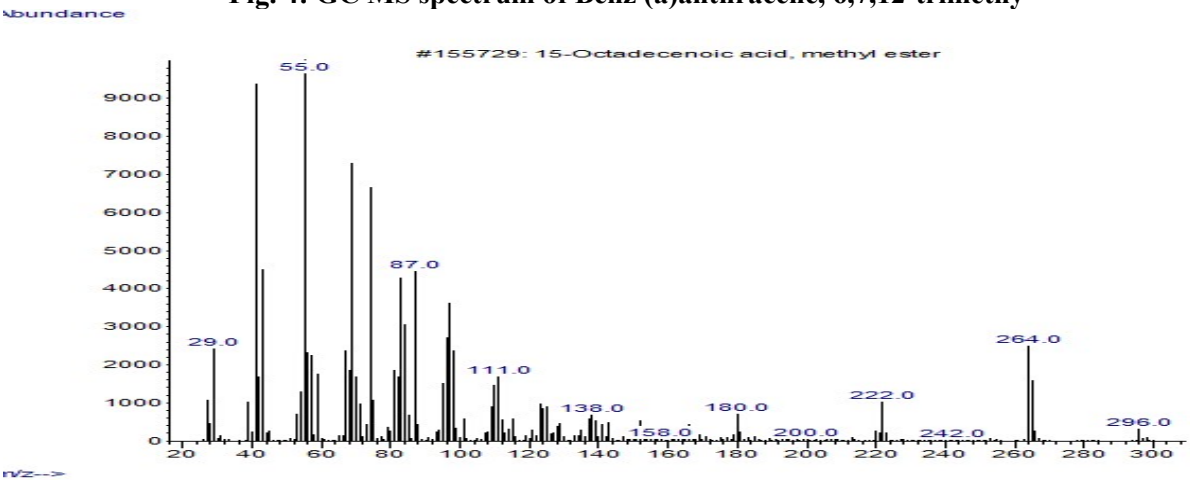

Fig.5: GC MS spectrum of 15-Octadecenoic acid, methyl ester in *Luffa cylindrica*Seed Oil Biodiesel (LCBD)

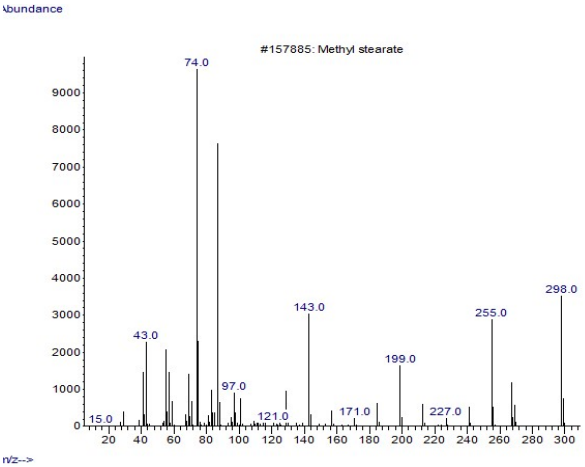

Fig.6: GC MS spectrum of Methyl stearate in *Luffa cylindrica*Seed Oil Biodiesel (LCBD)

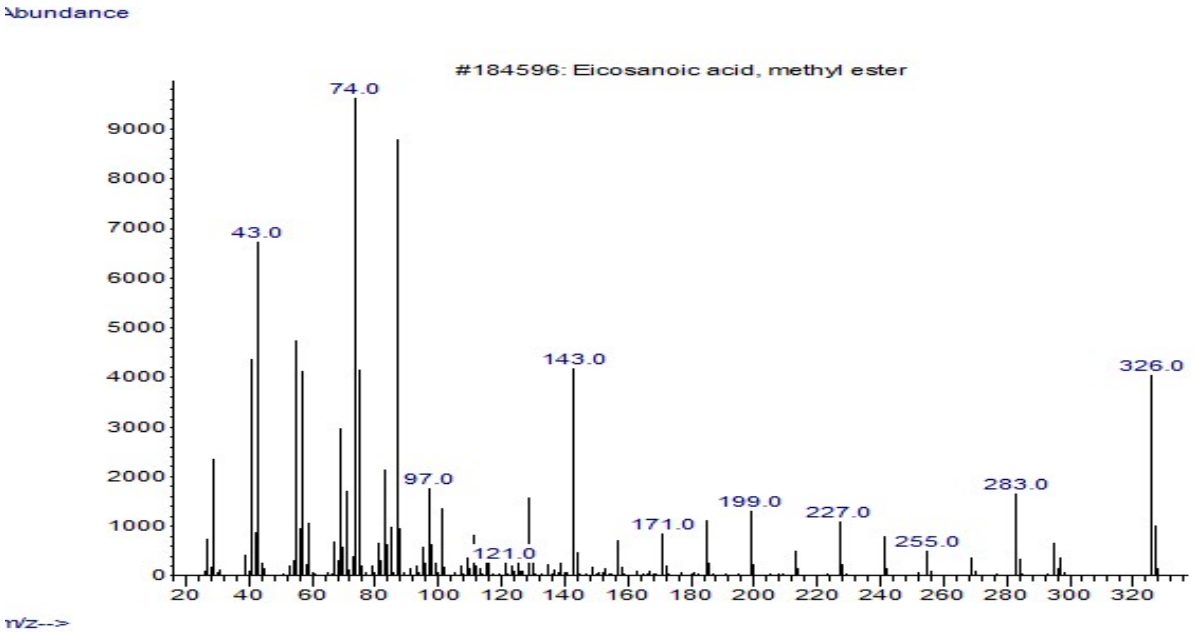

Fig. 7: GC MS spectrum of Eicosanoic acid, methyl ester in *Luffa cylindrica*Seed Oil Biodiesel (LCBD)

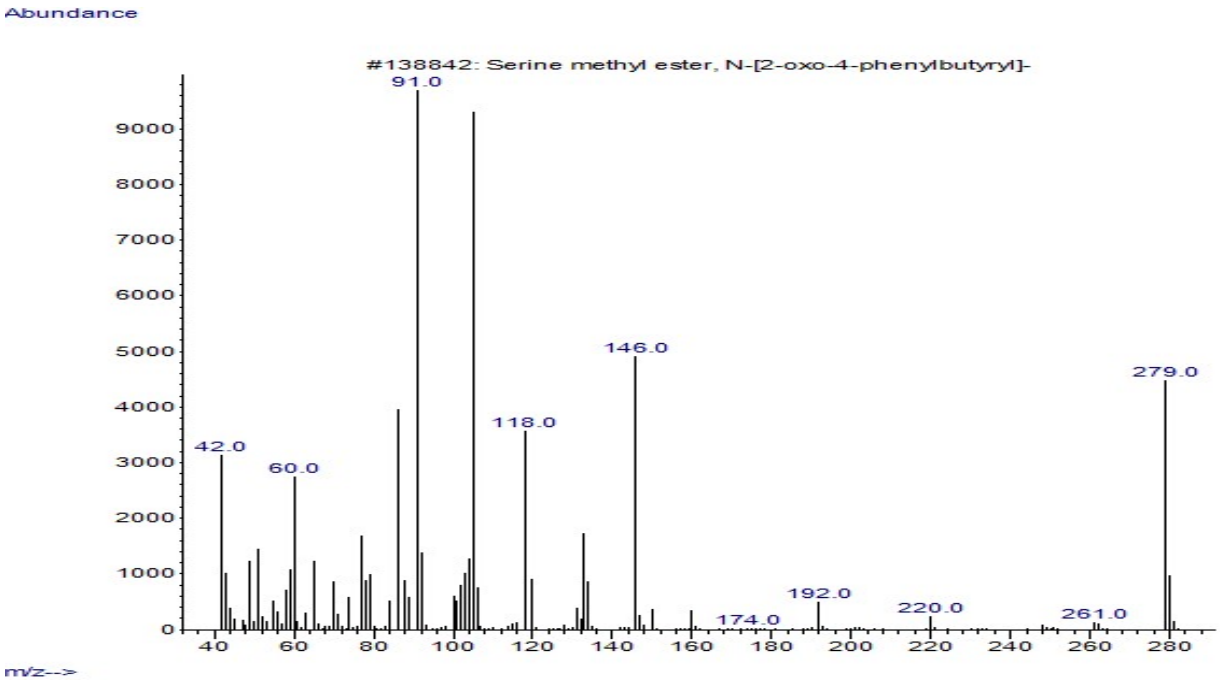

Fig. 8: GC MS spectrum of Serine methyl ester, N-[2-oxo-4-phenylbutyryl]- *Luffa cylindrica* Seed Oil Biodiesel (LCBD)

FTIR spectra of *Luffa cylindrica* seed oil and *Luffa cylindrica seed oil* biodiesel are presented in Figs. 9 and 10 respectively. IR spectroscopy analysis of LCSO and LCBD revealed the following functional groups: O-H, C-H, C=O, O-C, =C-H, C-N and N-H, O-H, C-H, C=O, C-O, C-N, =C-H stretches respectively at wavenumber range of 4000-650 cm^{-1}

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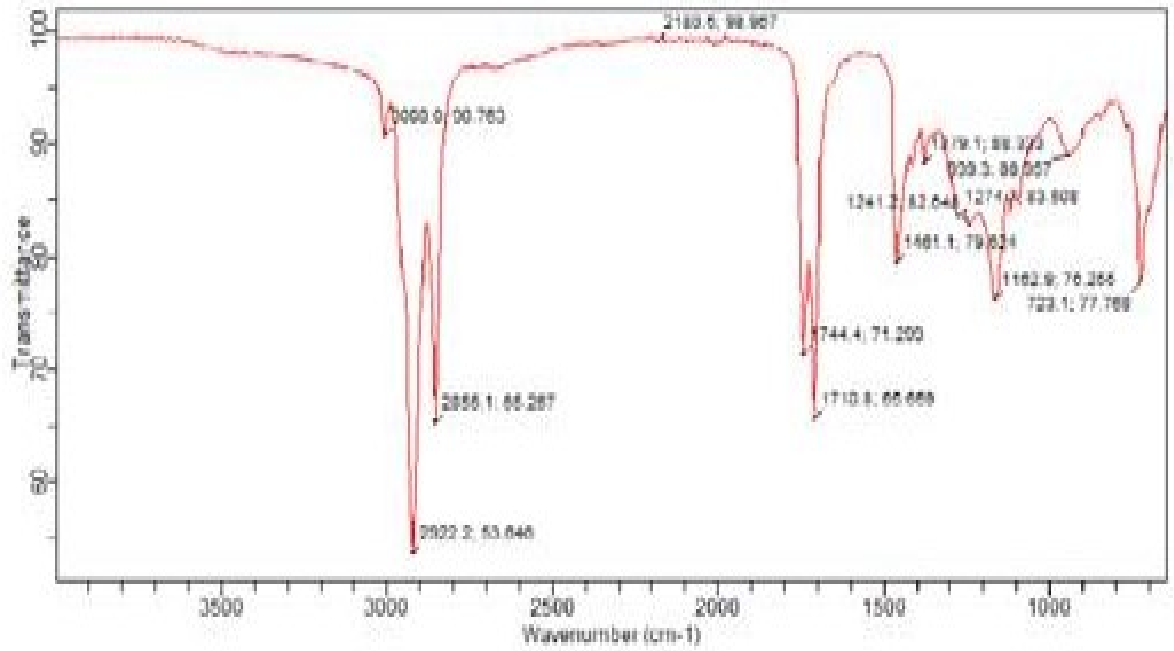

Fig. 9: FTIR spectrum of (*Luffa cylindrical* seed oil - LCSO)

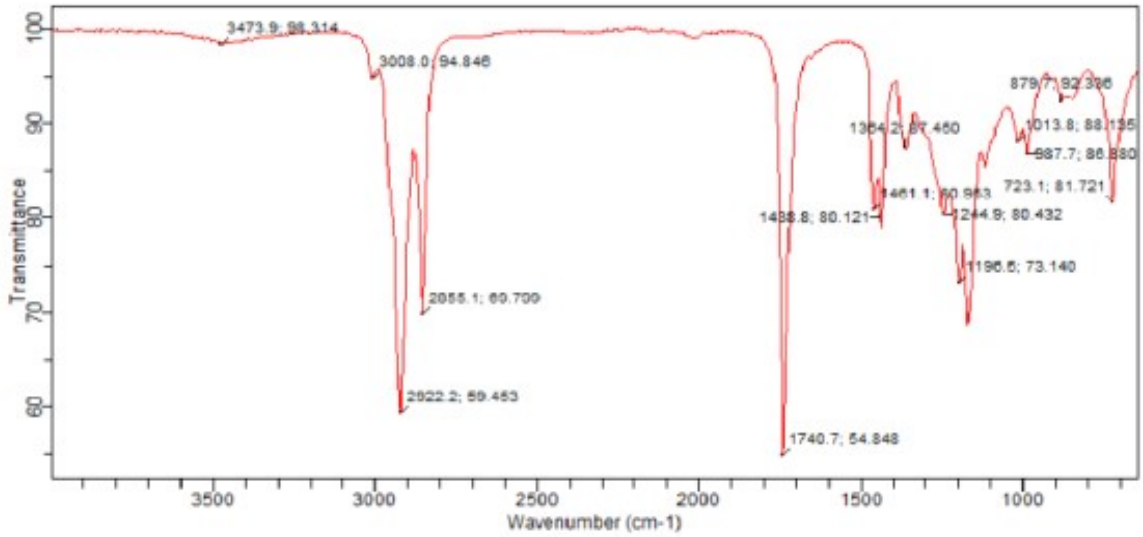

Fig. 10: IR spectrum of (*Luffa cylindrical seed oil* biodiesel -LCSBD)

From the results obtained, the peak observed at 3008 cm^{-1} is due to O-H stretch while the peak at 2922.2 and 2855.5 cm^{-1} are assigned to C-H stretches in alkane. At 2180 and 1744 cm^{-1} C=O stretch for esters and C=O stretch (due to H-bond in 1^{o} or 2^{o} carboxylic acid were observed. Oli *et al*. (2014), stated–that oil and seed coat oil contain mainly unsaturated compounds. The IR spectra of *Luffa cylindrica* seed oil (LCSO) also revealed the presence of = C-H bending vibrations at 939 and 723 cm^{-1} respectively. The presence of oxygenated groups: O-H, C=O, C-O as shown in Tables 2-3 and Fig. *Luffa cylindrica* seed oil biodiesel can help to mitigate air pollution by reducing vehicle carbon monoxide emissions, enhance cetane number and lessen photochemical reactivity of evaporated organic components.

Table 4: Wave number and assigned functional groups in FTIR spectrum of *Luffa cylindrica* seed oil (LCSO)

Wave number (cm^1)	Assignment	Functional group
3008	OH stretch	Carboxylic acid
2922	C-H stretch	Alkane
2855	C-H stretch	Alkane
2180	C-H stretch	Methyl Silane
1744	C=O Stretch	Esters
1710	C=O Stretch (H-bonded)	1°or 2°carboxylic acid
1461	C-H bend	Alkane
1379	C-H stretch	Butane
1274	O=C Stretch	Carboxylic acid
1241	C-N stretch	
1162	C-N stretch	Amines/amides

Table 5: Wave number and functional group assignment for the FTIR spectrum of biodiesel produced from -*Luffa cylindrica* seed oil

Wave number cm^{-1}	Assignment	Functional group
3473	N-H 1° or 2° amine	Amines & Amides
3008	OH from C-acid	Carboxylic acids
2922	C-H stretch	Alkanes
2855	C-H stretch	Alkanes
1740	C=O Stretch	Saturated Aldehyde
1438	C-H bend vibrational	Alkanes
1364	C=O stretch	Ketone
1244	C-O stretch	Alcohol
1196	C-N stretch	Amines/amides
1013	C-N stretch	Amines/amides
987	C-O stretch	Alcohol
879	=C-H bend	Alkene
723	=C-H bend	Alkene

4.0 Conclusion

The acid and base catalysed transesterification is an effective method for the production of biodiesel from *Luffa cylindrica* seed oil. The physicochemical parameters of the produced biodiesel were within ASTM recommended limits, which presented *Luffa cylindrica* seed oil as a good source of quality biodiesel. The presence of 15-octadecenoic acid, methyl ester, methyl stearate, and eicosanoic acid were observed in the biodiesel. The observed oxygenated groups (O-H, C=O, C-O) in the biodiesel can enhance combustion and reduce air pollution compared to automotive gas oil (AGO). From the results and findings of the present study, it is highly recommended that the commercial value of this seed oil can be evaluated through further research.

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