Profiling Biodiesel Produced from African Mahogany Seed at 1% NaOH Catalyst and Multiple Methanol Molar Ratios.

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Abstract

The need for new renewable energy resources and its utilization as sustainable solution for transport fuel, respiratory health and environmental problems drives this study. This study involved chemical profiling of African Mahogany (AM) methyl esters fatty acid (ME-FA) produced at multiple of two times, three times and four times seed oil to methanol molar ratios (MR). The key factors kept constant were 1% NaOH catalyst concentration at 60°C processed in 1 hour. The oil yield from African mahogany seed kernel was 44.88% by weight. The percent free fatty acid was reduced serially from 34.78 mg (KOH)/g (of the oil) by H_2SO_4 acid esterification to 0.46 mg (KOH)/g (of the oil). This was followed by the 1% NaOH transesterification at different multiples of oil to methanol molar portions. The chemical profiles of the biodiesel yields were characterised using the gas chromatograph and mass spectrometer (GCMS) system. The results indicated increasing yields of ME-FA at 71.73% for AM at MR – 1:6, 85.96% for AM at MR – 1:9 and 84.37% for AM at MR – 1:12. Similarly, the essential component of Octadecenoic acid methyl ester increased from 16.55% in crude AM oil to produce biodiesels at 40.25%, 40.80% and 43.21% for the biodiesel samples. Thus, a mathematical model $y = 10.505x + 47.048$ ($MR = 1 < x < 5$) was established.

Keywords: Methyl ester fatty acid, Biodiesel Yield, African mahogany, Oil-Methanol molar ratio, Chemical profile.

1.0 INTRODUCTION

Biodiesel as green source of renewable energy can be a sustainable alternative for diesel fuel. The biodiesel as used transport fuel can contribute significantly to mitigate the emission of harmful gases causing environmental pollution and respiratory health problems (Karpagam *et al.*, 2015; Kaisan *et al.,* 2016; Aderibigbe *et al.,* 2020). African mahogany (AM) seed, which hitherto, have little economic value, has high oil content which makes it a potential renewable energy resource. Therefore, it is imperative that the viability of this largely under-utilized feedstock is assessed for biodiesel production. Biodiesel sourced from plant seeds oil has yield higher energy content compared with animal-based oil (Henok *et al*., 2019; Bulus *et al*., 2016).

The objective of this study is to produce biodiesel from African Mahogany seed oil at 1.00 wt. % NaOH catalyst concentration using multiple methanol molar ratios, while keeping other key factors are maintained constant. As supported by Bulus *et al*., (2016); Ogundare *et al.,* (2017); Samani *et al.,* (2019), the chemical profiling of biodiesel produced will help to justify the impact of molar ratio on the conversion productivity of biodiesel from the AM seeds oil.

The stoichiometric reaction for the production of biodiesel requires one mole of oil (triglyceride) and three moles of alcohol (Methanol), to produce three moles of methyl ester fatty acids (ME-FA) and one mole of oil (glycerol) as expressed graphically in Equation 1. (Kaisan *et al.,* 2016; Bahl and Bahl, 2010).

$$\underset{\text{Triglyceride+Large Excess}}{R{-}COOR' + R''OH} \xrightarrow{H^+ \text{ or } R''O^-} \underset{\text{Methyl Esters+Glycerol}}{R{-}COOR'' + R'OH} \quad (1)$$

The common practice is that the crude AM oil is acid-esterified to lower its FFA percentage content. Consequently, alkaline based transesterification of the esterified oil is conducted using excess and or multiple alcohol rations.

2.0 MATERIALS AND METHODS

2.1 Materials

The key material or feedstock for this study is African Mahogany seed kernel sourced from tropical trees in Kagoro and environs in Kaura Local government area of Kaduna State – Nigeria. The oil yield from the AM seed kernels extracted using mechanical expeller press is 44.88% by weight. Commercial crude oil yields from seed kernels usually vary from 14% to 43% by weight. (Mulugetta, 2009; Kaisan *et al.,* 2016 and Ishaya *et al.,* 2018). This implies that crude AM oil has high commercial viability biodiesel production.

The main reagents used the study processes were methanol (CH_3OH), propan-2-ol (C_3H_7OH), sulphuric acid (H2SO4), 0.1M potassium hydroxide (KOH) pellets and sodium hydroxide (NaOH) pellets. The reagents were of analytical grade (Assay 99.5%) manufactured by BHD Chemical Ltd, Polle, England, and sourced from Cardinal Nig. Ltd, Kwagila – Zaria, Nigeria and were used as received.

The major equipment utilized for this work were Gas Chromatograph and Mass Spectrometer (G.C.M.S.) machine (QP2010nc Plus), expeller oil press (6YL-100, GB/T19007-2000idt ISO 9001:2000), conical flasks, magnetic stirrer, hot plates, thermometers, stop clock, aluminium foil paper.

2.2 Methods

The crude AM oil was profiled using the gas chromatograph and mass spectrometer, the results obtained was used to guide the esterification of the oil. The transesterification was then conducted at different oil to methanol molar ratios of 1:6, 1:9 and 1:12, in accordance with the procedure reported by Samani *et al.,* 2019. The was conducted while maintaining the reaction factors such as catalyst concentration, temperature and time at 1% NaOH, 60°C, and 1 hour respectively (Kaisan *et al.,* 2016; Ogundare *et al.,* 2017; Khan *et al.,* 2012; Wub *et al.,* 2011). The catalyst function was to break the bond between the heavier alcohols being glycerine to the fatty acid chains for formation of another esters.

2.2.1 Esterification

Free fatty acid (FFA) was determined as ten gramme (10 g) of African mahogany (AM) oil was added to 240 g of propan-2-ol. This mixture was titrated against 0.1 M potassium hydroxide. A blank titration was performed by titrating 240.0 g of propan-2-ol against 0.1 M potassium hydroxide. The FFA value and acid value (AV) of the oil were evaluated using equations 2 and 3. The FFA value determination / esterification process cycle was repeated to convert some FFA in the oil to biodiesel and to achieve an AV of ≤ 0.5% for an efficient alkaline transesterification process (Ibrahim *et al.*, 2014; Dullius *et al.,* 2015; Litinas *et al.,* 2020).

$$\text{FFA} = \frac{\text{KOH Titre Value x Molarity of KOH x Molar Mass of KOH}}{\text{Mass of oil}} \quad (2)$$

where, v is the titre value.

$$\text{Acid Value (A.V.)} = \frac{\%\text{FFA}}{2} \quad (3)$$

2.2.2 Transesterification procedure

Two hundred and forty gramme (240 g) of the esterified oil was mixed with 52.08 g of methanol in a conical flask such that the oil to alcohol molar (MR) is 1:6 (that is two times the stoichiometric ratio), 2.4 g of NaOH as catalyst was added to the methanol – oil mixture and the blend was heated with continuous stirring at 60°C on a hotplate for 60 minutes to produce the biodiesel. The biodiesel production process was repeated at oil to methanol ratios of 1:9 and 1:12, such that the oil mass was kept constant at 240 g, while the methanol masses were 78.18 g and 104.22 g respectively. The reaction products were poured into separating funnel and allow to settle and sediment for 24 hours. The reaction products were poured into separating funnel and allow to settle and sediment for 24 hours. The heavier biodiesel was drained, leaving the glycerol. Subsequently the biodiesel was dried of water and stored in a dry dark environment to avoid microbe growth and other contamination (Ibrahim *et al.*, 2014; Samani *et al.,* 2019).

2.2.3 Chemical profiling of the AM biodiesel by gas chromatography

The chemical composition of the biodiesel samples was determined using QP2010nc PLUS GCMS system. For each biodiesel sample, one micro-litre (1 μl) of the Analyte was injected but only 10^{-2} μl was taken into the column via the Pre-column for band brooding of the solutes. The gas chromatography system was equipped with a 30 m by 0.25 mm i.d. DB-5MS capillary electrophoresis column with a 0.25 μm film thickness. The oven temperature was initially held at 70°C for 5 minutes and increased by 10°C per minute progressively to 250°C, kept for 5 minutes, then increased to 280°C at 10°C per minutes, and held for 5 minutes. The injection heater transfer line temperatures were maintained at 250°C, while the ion source (70 eV) temperature was maintained at 200°C. The analyte was atomized and introduced into the column at a purge flow rate of 3ml/min. The carrier/purge gas was helium set at a column (trap) flow rate of 1.80 ml/min at a pressure of 116.9 kPa, with the total flow (analyte) rate of 40.8 ml/min and linear velocity of ion of 49.2 cm/second. Injector split ratio was set at 20:1 to narrow and focus the positively charged ions as a beam, based on the vapour pressure of solutes to elute. The start mass-charge ratio (m/z) was set at 30, while End mass-charge ratio (m/z) was set at 350. The total scan time was set at 24 minutes with equilibrium time of 3 minutes, having event time of 0.5 s at scan speed of 666 Hz.

The generated report indicated the retention time for each peak or component (in minutes). To determine the area and percent composition for each peak, the triangularisation method as shown in Equation (4) are used to find the area under each curve or peak (which shape look like a triangle) using

$$\text{Area} = (\text{height}) \text{ x } (\text{width at } \tfrac{1}{2} \text{ height}) \qquad (4)$$

Therefore, the areas under the curve/peak were used to calculate percentage of a component in the composition of the mixture using Equation 5. (Ibrahim *et al.,* 2014).

$$\text{Component } X\,\% = \frac{\text{Area under peak } X}{\text{Total graph area}} \text{ x } 100 \qquad (5)$$

The reports in standard GCMS report format were generated from the analysis for each of the biodiesels. The reports include the chromatograms, mass spectra, peaks report (TIC), and spectrum comparison search results. These reports were used in the synthesis to develop the table for each oil peaks report. Also, a mathematical model estimates the quantitative behavior of this biodiesel production system, can be used for tractable interpolation and extrapolation of results. The polynomial equation shows the relationship of the dependent variable (Y) as a function of the independent variable (X) as expressed in the general Equation (6) as defined by

$$Y = Co + C_1X^1 + C_2X^2 + \ldots\ldots + C_kX^k \qquad (6)$$

where Y = biodiesel yield, C = Constants and X = oil to alcohol molar ratio.

3.0 RESULTS AND DISCUSSION

The AM crude oil acid value was 34.78 mg KOH/ g of oil. This high AV makes the convention alkaline-catalysed transesterification route not feasible. Therefore 5-runs consecutive acid-catalysed esterification was conducted to reduce the FFA of the oil to 13.46, 10.46, 4.20, 1.22 and finally to 0.46 mg KOH/ g by converting some FFA to methyl ester fatty acids. The final 0.46 mg KOH/ g of AM oil used for transesterification was within the acceptable limits of ≥ 0.50 mg KOH/ g according to the American Society for Testing Materials - ASTM - D6751 standards (Ishaya *et al.*, 2018). This result is in conformity to similar cases that produces 96.6 – 98.0 % yields of methyl esters by lowering the high acid values. Zanthoxylum bungeanum seed oil AV was reduced from 45.51 to 1.16 mg KOH/g at MR – 1:24 and Karanja oil containing FFA up to 20% processed at MR – 1:6 has AV reduced to ≥ 0.5 mg KOH/g, thereby benefitting from faster reaction time and lower production cost, compared with single stage alkaline-catalysed biodiesel production (Zhang and Jiang, 2008; Das *et al*., 2008).

Consequently, the AM crude oil and biodiesels produced at MR – 1:6, MR - 1:9 and MR – 1:12 were profiled using Gas Chromatography (GC) and the individual peak results are graphically presented in Figures 1 to 4. Also, each peak in the GC graphs was analysed and identified using both the total ionization charge (TIC) peak report and the mass spectrometer (MS) data to generate the resulting information as indicated from Table 1 to Table 4.

The profile of the methyl ester fatty acid in the oils as quantified and qualified by GC-MS is one of the key factors that determines oil suitability as biodiesel. The profile for these oils analysed ranges from Decanoic acid, methyl ester ($C_{11}H_{22}O_2$, Molecular weight:186) to Docosanoic acid, methyl ester ($C_{23}H_{46}O_2$, Molecular weight:354). Normally, the essential chemical components that is C_{16} to C_{19} in diesel from biological oils are low. Predictably, African mahogany seed's crude oil has ME-FA content of 21.97% as indicated by peaks 1, 2, 4, 5, 6 and 8 in Figure 1 and Table 1. Methyl esters of E)-9-octadecenoic acid ($C_{18}H_{34}O_2$) at peak-6 with retention time (RT) of 18.013 minutes was the predominant ester in the mixture having the highest value of 8.874 %, followed by 11-octadecenoic acid ($C_{19}H_{36}O_2$) at peak-4 with RT of 17.427 minutes at 6.450 %.

For AM biodiesel produced at MR – 1:6, from Table 2, the highest methyl esters compositions start from peaks 9, 5, 3, 6, 7 to peak 11. These peaks were identified as Octadecanoic acid methyl ester (17.040 %); 11-Octadecenoic acid, methyl ester (14.940 %); Hexadecanoic acid, 15-methyl-, methyl ester (11.600 %); 9,12,15-Octadecatrienoic acid, methyl ester (8.264%); Cyclopentaneundecanoic acid, methyl ester (7.420 %) and Pentanoic acid, 10-undecenyl ester (4.040 %) respectively.

Also for AM biodiesel obtained at MR – 1:9 from Table 3, starting from the highest methyl esters present as in peaks 5, 6, 3, 4 and 2. The composition of the peaks were identified as 9-Octadecenoic acid (Z)-, methyl ester (31.880 %); Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans- (14.610 %) ; Pentadecanoic acid, 14-methyl-, methyl ester (10.720 %); 11-Octadecenoic acid, methyl ester (10.240%) and Heptacosanoic acid, methyl ester (9.030 %) respectively.

Similarly, for AM biodiesel processed at MR – 1:12, from Table 4, starting from the highest methyl esters present in this oil are in peaks 6, 7, 5, 2 and 3, identified as 9-Octadecenoic acid (Z)-, methyl ester (29.180%); Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans- (14.800%); 11-Octadecenoic acid, methyl ester (11.610 %); Pentadecanoic acid, 14-methyl-, methyl ester (10.460 %) and Tridecanoic acid, methyl ester (7.176 %) respectively.

The catalyst concentration was kept at 1.00 % NaOH to maintain the rate of chemical reaction. However, transesterification process which is

TABLE 3: AM Biodiesel Peaks Report, MR – 1:9, including % Biodiesel Components.

Peak No.	Retention Time (min)	Peak Area (A)	Area (%)	Biodiesel Fraction	Biodiesel Area (%)	Compound Systematic Name (Fatty Acid)
1	13.633	2,445,901	0.27	0.80	0.216	Decanoic acid, methyl ester
2	15.782	81,391,170	9.03	1.00	9.030	Heptacosanoic acid, methyl ester
3	15.855	96,606,668	10.72	1.00	10.720	Pentadecanoic acid, 14-methyl-, methyl ester
4	17.493	92,280,155	10.24	1.00	10.240	11-Octadecenoic acid, methyl ester
5	17.774	287,367,317	31.88	1.00	31.880	9-Octadecenoic acid (Z)-, methyl ester
6	17.819	131,723,888	14.61	1.00	14.610	Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans-
7	18.220	49,617,003	5.50	0.00	0.000	Oxalic acid, 2-ethylhexyl hexyl ester
8	19.283	24,624,759	2.73	0.40	1.092	9-Octadecenoic acid (Z)-
9	19.434	28,107,986	3.12	1.00	3.120	Eicosanoic acid, methyl ester
10	19.575	15,518,002	1.72	1.00	1.720	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-
11	20.794	72,231,836	8.01	0.20	1.602	Pentanoic acid, 10-undecenyl ester
12	20.929	19,508,201	2.16	0.80	1.728	Pentafluoropropionic acid, tridecyl ester
Biodiesel @ MR – 1:9		901,422,886	100	***Biodiesel Total %=***	**85.958**	

TABLE 4: AM Biodiesel Peaks Report, MR – 1:12, Including % Biodiesel Components.

Peak No.	Retention Time (min)	Peak Area (A)	Area (%)	Biodiesel Fraction	Biodiesel Area (%)	Compound Systematic Name (Fatty Acid)
1	5.237	21,309,026	2.71	0.00	0.000	Glycerol
2	15.777	82,313,048	10.46	1.00	10.460	Pentadecanoic acid, 14-methyl-, methyl ester
3	15.838	70,597,319	8.97	0.80	7.176	Tridecanoic acid, methyl ester
4	16.606	5,113,788	0.65	0.00	0.000	n-Hexadecanoic acid $$ Palmitic acid
5	17.490	91,402,185	11.61	1.00	11.610	11-Octadecenoic acid, methyl ester
6	17.746	229,738,252	29.18	1.00	29.180	9-Octadecenoic acid (Z)-, methyl ester
7	17.794	116,523,843	14.80	1.00	14.800	Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans-
8	18.203	38,403,594	4.88	0.00	0.000	Oleic Acid $$ 9-Octadecenoic acid (Z)-
9	19.276	18,391,105	2.34	0.40	0.936	Oxalic acid, 2-ethylhexyl hexyl ester
10	19.426	23,025,396	2.92	1.00	2.920	Eicosanoic acid, methyl
11	19.568	11,052,932	1.40	1.00	1.400	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-
12	20.786	60,860,441	7.73	0.60	4.638	Pentanoic acid, 10-undecenyl ester
13	20.924	14,440,436	1.83	0.40	0.732	Pentafluoropropionic acid, tridecyl ester
14	22.737	4,069,241	0.52	1.00	0.520	Heptacosanoic acid, methyl ester
Biodiesel @ MR– 1:12		787,240,606	100	***Biodiesel Total %=***	**84.372**	

Table 1: Crude AM Oil Peaks Report including percent Biodiesel Components.

Peak No.	Retention Time (min)	Peak Area (A)	Area %	Biodiesel Fraction	% Biodiesel Area	Compound Systematic Name (Fatty Acid)
1	15.713	75,110	1.41	0.80	1.128	Decanoic acid, methyl ester
2	16.357	805,931	1.98	1.00	1.980	Hexadecanoic acid, methyl ester
3	16.440	3,691,107	9.05	0.00	0.000	n-Hexadecanoic acid
4	17.427	2,628,082	6.45	1.00	6.450	11-Octadecenoic acid, methyl ester
5	17.628	502,863	1.23	1.00	1.230	Octanoic acid, 8 -hydroxy -, methyl ester
6	18.013	6,029,130	14.79	0.60	8.874	E)-9-Octadecenoic acid methyl ester
7	18.170	17,863,165	43.81	0.00	0.000	9-Octadecenoic acid (Z) -
8	18.304	4,704,971	11.54	0.20	2.308	10-Undecenoic acid, octyl ester
9	19.665	2,690,419	6.60	0.00	0.000	6-Octadecenoic acid, (Z) -
10	20.727	1,285,996	3.15	0.00	0.000	9-Octade cenal $$ (9E) -9-Octadecenal
Crude African Mahogany AM		40,776,774	100	***Biodiesel Total %=***	**21.970**	

Table 2: AM Biodiesel Peaks Report, MR – 1:6 Including % Biodiesel Components.

Peak No.	Retention Time (min)	Peak Area (A)	Area (%)	Biodiesel Fraction	Biodiesel Area (%)	Compound Systematic Name (Fatty Aci
1	11.352	1,042,896	0.10	1.00	0.100	Decanoic acid, methyl ester
2	13.652	1,494,980	0.14	1.00	0.140	Hexadecanoic acid, 15-methyl-, methyl este
3	14.984	127,264,267	11.60	1.00	11.600	Pentadecanoic acid, 14-methyl-, methyl este
4	15.814	111,924,554	10.21	0.00	0.000	n-Butyric acid hydrazide
5	17.129	163,850,541	14.94	1.00	14.940	11-Octadecenoic acid, methyl ester
6	17.418	113,347,226	10.33	0.80	8.264	9,12,15-Octadecatrienoic acid, methyl ester
7	17.472	81,338,969	7.42	1.00	7.420	Cyclopentaneundecanoic acid, methyl ester
8	17.568	71,310,999	6.50	0.00	0.000	9,12-Octadecadienoyl chloride, (Z,Z)-
9	17.811	186,939,242	17.04	1.00	17.040	Octadecanoic acid, methyl ester
10	18.021	33,422,406	3.05	0.00	0.000	9-Octadecenoic acid (Z)-
11	18.207	44,339,071	4.04	1.00	4.040	Pentanoic acid, 10-undecenyl ester
12	19.145	13,232,977	1.21	0.20	0.242	Pentafluoropropionic acid, tridecyl ester
13	19.307	29,522,525	2.69	1.00	2.690	Eicosanoic acid, methyl ester
14	19.432	26,590,034	2.42	1.00	2.420	Heptacosanoic acid, methyl ester
15	19.572	10,179,181	0.93	1.00	0.930	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-
16	20.718	39,767,786	3.63	0.20	0.726	Pentanoic acid, 10-undecenyl estercis
17	20.783	35,330,200	3.22	0.20	0.644	Pentanoic acid, undecenyl ester
18	22.728	5,848,186	0.53	1.00	0.530	Triacontanoic acid, methyl ester
Biodiesel @ MR– 1:6		1,096,746,040	100	***Biodiesel Total %=***	**71.726**	

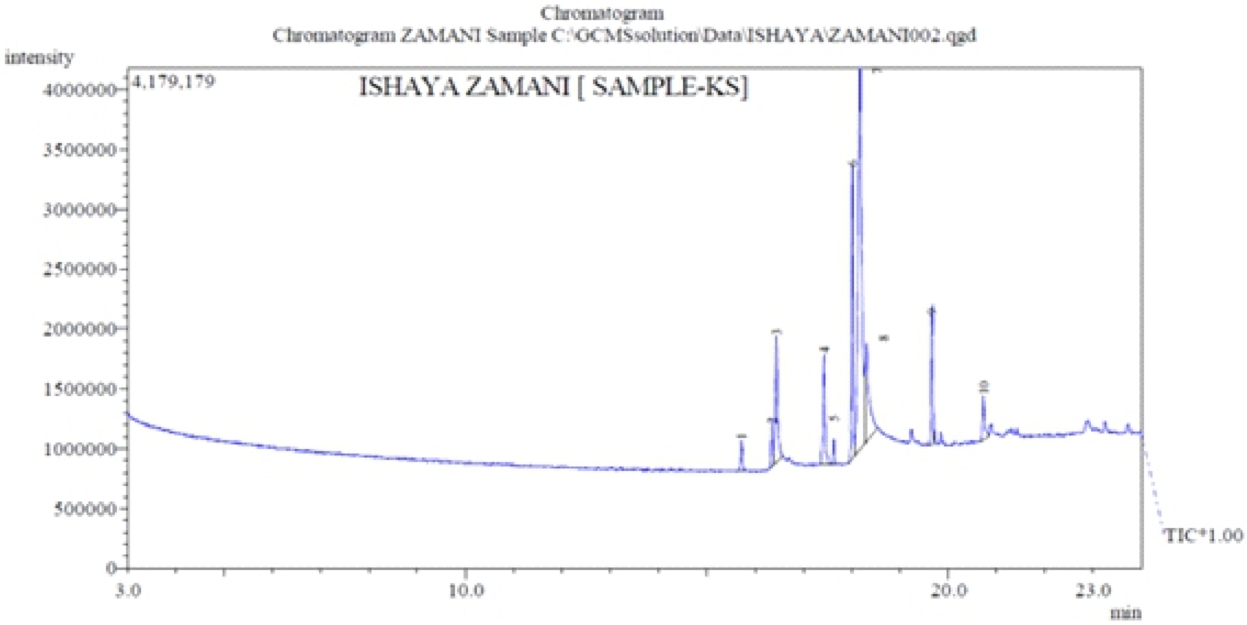

Figure 1: Gas Chromatograph of the *African Mahogany* (AM) seed crude oil.

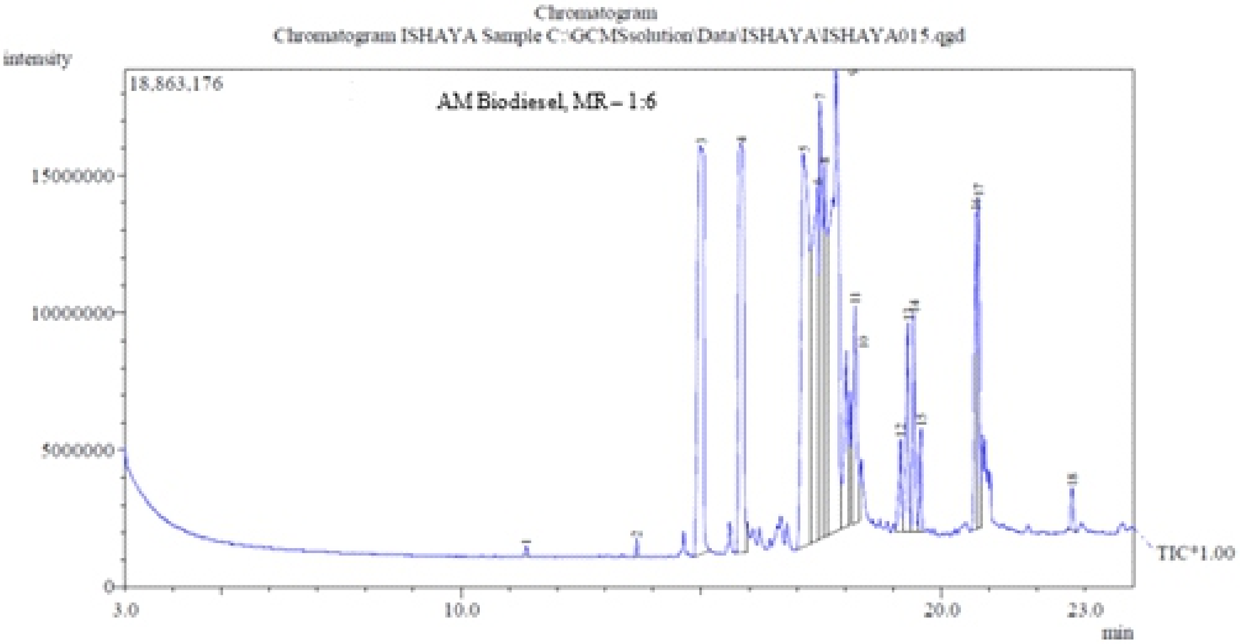

Figure 2: Gas chromatograph of the AM seed oil Biodiesel Sample - MR-1:6.

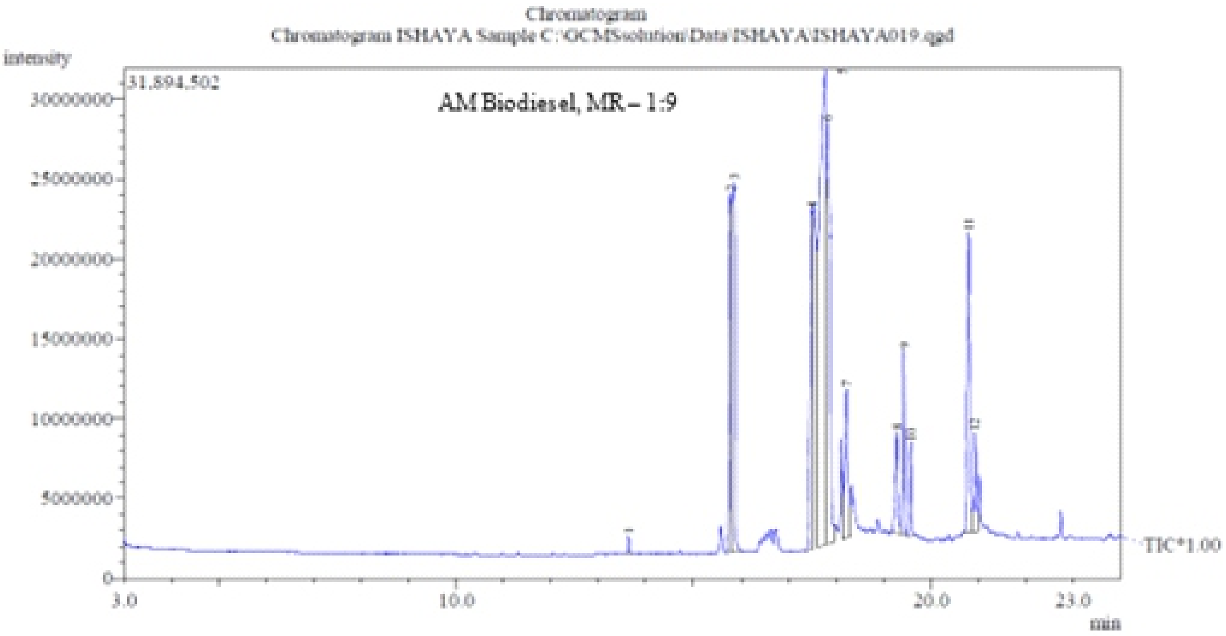

Figure 3: Gas chromatograph of the AM seed oil Biodiesel Sample - MR-1:9.

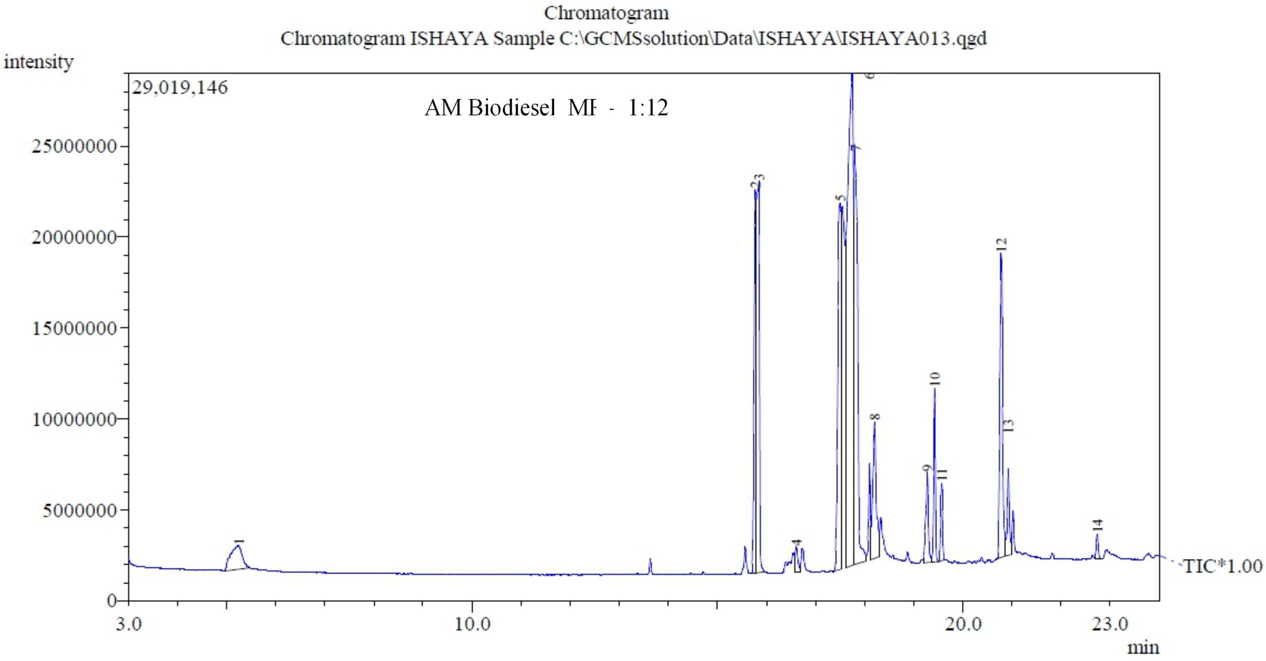

Figure 4: Gas Chromatograph of the AM seed oil Biodiesel Sample - MR-1:12.

second order of chemical reactions tends to completeness quickly due to the proportional excess supply of methanol. This led to the increases noticed with essential ME-FA components as the MR increases. This profile trend is similar to those reported by Ogundare *et al.,* 2016; Aderibigbe *et al.,* 2020; George *et al*., 2020.

Thus, for these biodiesels produced at MR – 1:6, MR – 1:9 and MR – 1:12, the ME-FA yields increases were: 71.73 %, 85.96 % and 84.37 % as shown in Tables 2, Table 3, and Table 4, respectively. Also, these are in conformity with the results obtained from similar biodiesel production research works by Bulus *et al.,* 2016 and Samani *et al.,* 2019. Also, methyl ester octadecenoic acids group, as one of the most desired ME-FA compositions in AM increase from 16.55% in the crude AM oil to 43.21% in the biodiesels, as the oil to methanol molar ratios was increased. Also, other methyl esters fatty acid group present in the oil followed similar trends. A line graph of biodiesel yields, against the three molar ratios is shown in Figure 5.

Thus, the mathematical model of ME-FA yield from AM is expressed in Equation (6) with unity level of confidence (Ishaya *et al.,* 2019).

$$y = 10.505x + 47.048 \text{ at } CC = 1.00\%, (MR = 1 < x < 5) \quad (7)$$

The mathematical trend indicate that the biodiesel yield increases with increases in MR at constant catalyst concentration of 1% NaOH at 60 °C and 1hour reaction time for *African mahogany* (AM) seed oil. The increased yield was facilitated by the availability of excess methanol, which due to lower molecular weights are readily bonded with the fatty acids ionized chains, that have highly heavier molecular weights, thereby inhibiting the tendencies for reversible and other secondary reactions.

4.0 CONCLUSION

In this work, the methyl ester fatty acid content in African mahogany crude oil and biodiesels produced were profiled. The ME-FA yields of the AM crude oil was 21.97% and those of biodiesels produced at multiple molar ratio portions were 71.73%, 85.96% and 84.37% expressed as $y = 10.505x + 47.048$, bounded at MR = $1 < x < 5$. The major ME-FA components in the optimal biodiesel yield, as the chemical compositions are profiled are 9-Octadecenoic acid (Z)- methyl ester 31.88%, Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans- 14.61%, 11-Octadecenoic acid, methyl ester 10.24%, and Heptacosanoic acid, methyl ester 9.03%. The Methyl ester octadecenoic acids group increases progressively from 16.55% in the crude AM oil to 43.21% in the

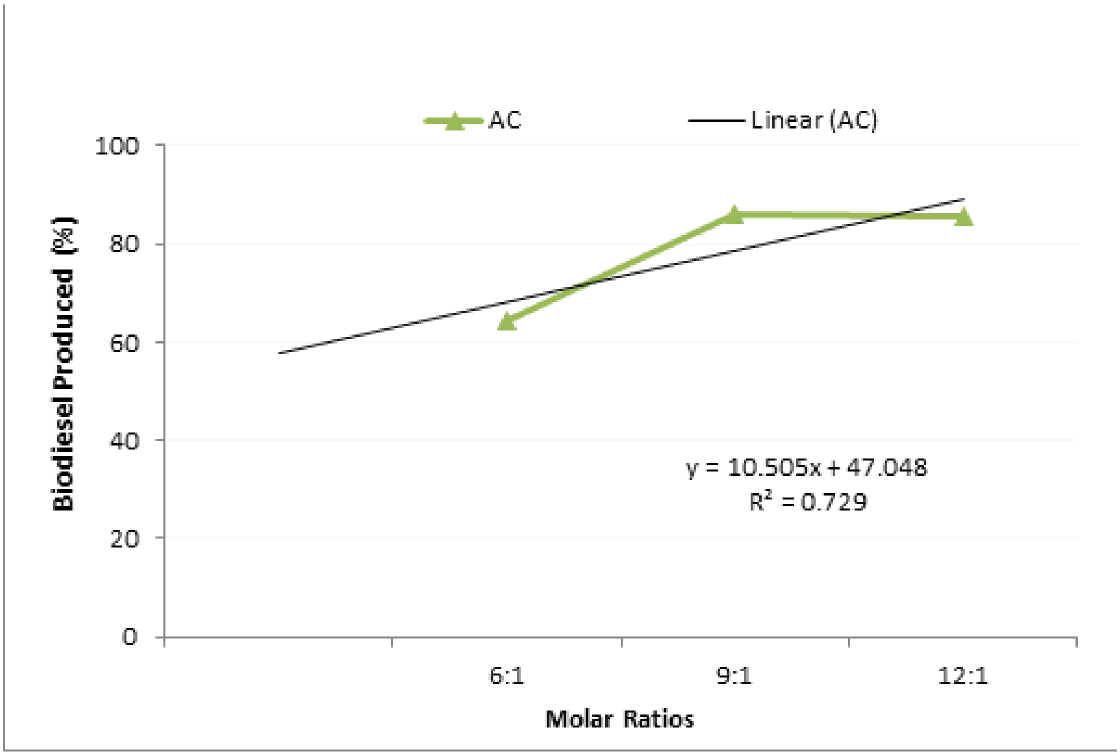

Figure 5: AM Yield Optimization at Constant CC = 1% with varied Molar Ratio

biodiesels with increased molar ratio. The results verified that the yield of AM biodiesel generally increases with increase of oil to alcohol molar ratio at constant temperature, time, and catalyst concentration. Thus, African mahogany seed is a suitable feedstock for commercial biodiesel production.

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