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Evaluation of Bio-Fuel Characteristics of Pyrolytic Oil Produced from *Gmelina arborea*, and *Cordia millenii* Sawdust

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Abstract: Pyrolysis is that the thermal decomposition of biomass into liquids, gases, and char (solid residue) within the absence of oxygen. Pyrolytic products are also used as fuels, with or without prior upgrading, or they could be utilized as feedstock for chemical or material industries. Bio-oil was produced from sawdust of *Gmelina arborea*, and *Cordia millenii* in an exceedingly fixed-bed slow pyrolysis reactor under two temperature regimes (500°C and 600°C). The bio-oil produced was characterized by proximate analysis, CHN-elemental analysis, pH in solution, bomb calorimetric for higher heating value. The results of the proximate analysis revealed that the fixed carbon content) within the bio-oil samples strongly trusted the intensity of the thermal treatment (i.e. higher temperatures and longer residence times within the pyrolysis process). the actual yield in fixed carbon values ranged from 25.00 to 61.67% recorded in *Gmelina arborea* and 23.33 to 58.33, recorded for *Cordia milenii*. The results of the study shows that there is no significant difference between the chosen sawmill wood residues used at different temperature range. High percentage ash content of 40.00 it had been recorded in *Gmelina arborea* at lower temperature of 500°C, while *Cordia milenii* has the lower mean percentage ash content of 31.67% at lower temperature of 500°C and least percentage average of 21.67% at higher temperature of 600°C. The norm for percentage of volatile matter ranged from 20.00 to 45.00 try to 13.33 to 35.00% which indicated that *Cordia milenii* has higher mean percentage volatile matter at 500°C while *Gmelina arborea* at 600°C has the tiniest amount mean percentage volatile matter. The results of the calorific value revealed the upper and lower mean for the heating value of the bio-oil which ranged from 23083.22 to 26725.74, and 20305.98 to 25637.17 (Kj/kg) for *Cordia milenii* and *Gmelina arborea* at 500°C and 600°C respectively. The ultimate analysis showed the variations within the basic composition of the chosen sawmill wood residues used. The FT-IR spectra of bio-oil samples obtained from different temperatures exhibited identical peaks but these spectra differed within the relative intensity of some bands.

Keywords: Pyrolysis, Bio-oil, Sawdust, Temperature Regimes, Fuel

1. Introduction

Pyrolysis of biomass are often described because the direct thermal decomposition of the organic matrix within the absence of oxygen to urge an array of solid, liquid and gas products. Pyrolysis method has been used for commercial production of an outsized range of fuels, solvents, chemicals and other products from biomass feedstocks. Conventional pyrolysis consists of the slow, irreversible, thermal decomposition of the organic components in biomass. Slow pyrolysis has traditionally been used for the assembly of charcoal [1]. Energy conversion and management of biomass at moderate temperatures has generally been accustomed obtain high yield of liquid products. Fast pyrolysis is characterized by high heating rates and rapid quenching of the liquid products to terminate the secondary conversion of

the products [2]. Bio-oil are often a substitute for fossil fuels to return up with heat, power and/or chemicals. Boilers and furnaces (including power stations) are often fueled with bio-oil within the short term; whereas, turbines and diesel engines may become available on the somewhat long run. Upgrading of the bio-oil to a transportation fuel is technically feasible but needs further development. Transportation fuels like methanol and Fischer-Tropsch liquids (the so-called synthetic diesel) comes from bio-oil, using the bio-oil as a gasifier feedstock instead of the bulky biomass, and might save transportation costs. Furthermore, there is a good range of chemicals that will be extracted or derived from the bio-oil.

1.1. Generations of Biofuel

1.1.1. First Generation Biofuels

First generation biofuels are biofuels made of sugar, starch, oil, or animal fats using convectional technology (UN biofuels report). The basic feedstocks for the assembly of first-generation biofuels are often seeds or grains like wheat, which yields starch that's fermented into bioethanol, or sunflower seeds, which are pressed to yield fat that can use in biodiesel. The feedstocks could instead enter the animal or human natural phenomenon, and since the worldwide population has risen their use in producing biofuels has been criticized for diverting food aloof from human natural phenomenon, leading to food shortages and price rises.

Among the instance are Bio-alcohols, Biodiesel, edible fat, Bio ethers, Biogas, Syngas and Solid biofuels.

1.1.2. Second Generation Biofuels

Second-generation biofuel production processes can use an expansion of non-food crops. These include waste biomass, the stalks of wheat, corn, wood, and special-energy- or biomass crops (e.g., Miscanthus). Second-generation biofuels use biomass to liquid technology [3], including cellulosic biofuels from non-food crops [4]. Many second-generation biofuels are under development like biohydrogen, biomethanol, DMF, Bio-DME, Fischers-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel.

1.1.3. Third Generation Biofuels

Algae fuel, also called oilgae or third-generation biofuel, is also a biofuel from algae. Algae are low-input, high-yield feedstocks to provide biofuels. supported laboratory experiments, it claimed that Algae can produces up to 30 times more energy per acre than land crops like soybeans [5] but these yields have yet to be produced commercially. With the upper prices of fossil fuels (petroleum), there's much interest in algaculture (farming algae). One advantage of the various biofuels over most other fuel types is that they are biodegradable, so relatively harmless to the environment if spilled. Algae fuel still has its difficulties though, as an example to produce algae fuels it must be mixed uniformly, which, if done by agitation, could affect biomass growth [6].
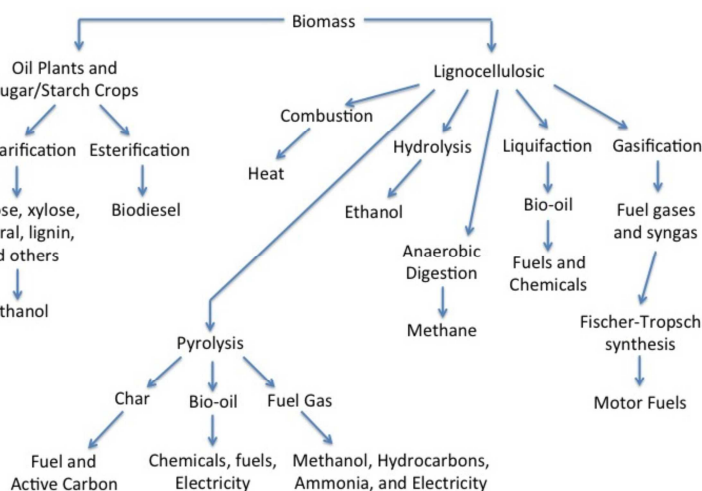

Figure 1. *Schematic of Biomass Conversion Technologies.*

1.2. Advantages of Pyrolysis

Pyrolysis of agricultural residues can help meet renewable energy targets by displacing fossil fuels and, thereby, cater to concerns about warming. Pyrolysis offers more scope for recovering products from agricultural waste than burning. When agricultural residues are burnt directly in an exceedingly furnace/boiler, the sole real practical product is heat; however, once they're pyrolyzed first, bio-oil, gases and biochar can't only be used as a fuel but is additionally purified and used as a feedstock for petrochemicals and other

applications. the utilization of the biochar for soil amendment and as a carbon-sequestering, climate-mitigating agent is gaining worldwide attention. Pyrolysis has the advantage of low capital investment and a liquid final product which is in a position to be transported and converted via catalysis to fuels and valuable products like food flavorings, fertilizers, resins, and other specialty chemicals that are fully compatible with existing petroleum infrastructure. This provides significant economic advantages over ethanol which needs parallel infrastructures. Furthermore, all pyrolysis products is employed within the pyrolysis system. The alarming poor

energy supply and distribution has necessitated renewed research into alternative source of energy. Although, Nigeria is an oil producing country, but it focused on exporting of petroleum and import refined petroleum products since refineries within the country operate below 10% production capacity [7]. The high prices of oil which features a disproportionate impact on the country economy requires diversification of the energy sector and improve economic power of people through the employment of biofuel as an alternate energy source. Also, there are serious environmental pollution problems related to the use of fuel. there's therefore must identifying the sustainable energy options for energy production without polluting the environment.

2. Materials and Methods

2.1. Sample Collection and Preparation

Sawdust samples of Gmelina arborea, and Cordia millenii (200 gramms each) were collected from Forestry Research Institute on Nigeria sawmill, the saw dust were oven-dried at $103\pm2°C$ for twenty-four hours to 12% moisture content. Four replicates of bio-oil were produced at each temperature regime for every of the samples.

2.2. Bio Oil Production

The metallic container (pyrolytic chamber) was filled with 200 grammes of the samples of every species and placed inside the Reactor which was connected to a condenser. Two different temperature regimes were used i.e. 500°C and 600°C. The evolving gas was distilled within the condenser to make pyrolytic oil which was collected inside a conical flask.

Figure 2. Pyrolyser Experimental Set-Up.

2.3. Fuel Characterization Examination

To characterize the bio oil and char, the following tests were performed using standard test.

2.3.1. PH Determination

The pH of the condensate was determined with the use of MICROFIED SM-3H pH meter which has an electrode that was calibrated with two buffer solutions.

2.3.2. Density Determination

The density of a material is defined as mass per unit volume of sample. Electronic weighing balance was used to weigh the samples while measuring cylinder was used to determine the volume.

$$\text{Density (g/cm}^3) = \frac{\text{Mass}}{\text{Volume}}$$

Where: M = mass of the bio-oil obtained (g), V = volume of bio-oil obtained (cm^3).

2.4. Proximate Analysis of the Bio-Char

Proximate analysis was carried out to determine the following:
1) Percentage Ash Content.
2) Percentage Volatile Matter.
3) Percentage fixed Carbon.
4) Heating Value.

2.4.1. Percentage Ash Content

Two grams of oven-dried sample was kept in furnace at temperature of 550°C for three hours and was weighed after cooling. The percentage ash content was calculated thus:

$$\%\text{Ash} = \frac{D}{B} \times 100$$

Where: %A = Percentage ash, D = Weight of ash, B = weight of oven dried sample.

2.4.2. Percentage Fixed Carbon

The percentage fixed carbon was calculated by subtracting the value of percentage volatile matter and ash content from 100%. It was calculated according to the formula below:

$$\% \text{ fixed carbon} = 100\text{-}(\%V + \%A)$$

Where %V = Percentage Volatile Matter.
% A = Percentage Ash Content.

2.4.3. Percentage Volatile Matter

Two grams of pulverized sample was weighed into crucible before transferred into muffle furnace at 550°C. This was left for 10minutes; the content was later cooled in dessicator and weighed to determine the percentage volatile matter with the formula below:

$$\text{Volatile Matter (\%)} = \frac{B-C}{B} \times 100$$

Where B = Weight of oven dried samples, C = Weight of sample after 10minutes in the furnace at 550°C.

2.4.4. Heating Value

The heating value or calorific value of a substance, usually a fuel or food is the amount of heat energy released during the combustion of a specified amount of sample. The calorific value is a characteristic for each substance. It is measured in unit of the substance, usually mass, such as Kcal/kg, KJ/kg, J/mol, and Bt/m³. Heating value is usually determined by the use of a bomb calorimeter but due to in

availability of bomb calorimeter estimation method was used. Heating value was calculated using the formula below:

$$HV = 2.326 \, (147.6C + 144V) \, Kj/kg$$

Where HV = Heating Value, C = Percentage fixed carbon = Percentage Volatile Matter.

2.5. Chemical and Thermal Characterization of Oil

2.5.1. Determination of Acid Value

This was done according to the study of Pearson and Songstad [8]. Two grams of oil was weighed into a dried 250ml Erlenmeyer flask. Thirty millilitres of a solution made of equal volumes of 95% ethanol and diethyl ether was added to dissolve the oil. The sample solution was then titrated with 0.1N methanolic potassium hydroxide solution with the addition of 0.5ml phenolphthalein solution until a slight pink colour persisted for 15 seconds. Blank titration without oil was also carried out under the same condition.

$$\text{Acid value} = \frac{\text{Titration} \; (\text{ml x } 5.61)}{\text{Wt of sample used}} \quad \text{mg KOH/g oil.}$$

2.5.2. Pour Point

The temperature at which the oil pour was determined by putting samples inside test tube, then placed in a freezer and the lowest temperature at which the pouring occur was recorded as the pour point.

2.5.3. Elemental Analysis of Bio-Oil

Ultimate analysis is performed to determine the elemental composition of the materials. It was carried out using a LECO CHNS 932 elemental analyzer which provides carbon, hydrogen, nitrogen, sulphur percentage composition of the selected samples. When the sumation of these compositions is subtracted from 100, it gives oxygen percentage composition.

2.5.4. Compositional Analysis (FT-IR)

Spectroscopic analysis using photo spectrometer was performed using PERKIN ELMER 1600 series model to know the functional group present in the bio-oil.

3. Result

3.1. Physical Properties of Pyrolytic Oil

The pyrolytic oil yield from the selected wood species (*Gmelina arborea* and *Cordia milenii*) at two different temperature regimes (500°C and 600°C) was shown in Figures 3-7. The physical properties assessed includes bio-oil yield (g/cm^3), pH, Acidic value, pour point and Density (g/cm^3) of the pyrolytic oil were assessed.

There was general increase in the volume of oil yield as the temperature increases from 500°C to 600°C. The volume of the oil ranged between 35.97 to 49.33 and 38.00 to 72.33, for *Gmelina arborea* and *Cordia milenii* respectively (Figure 3).
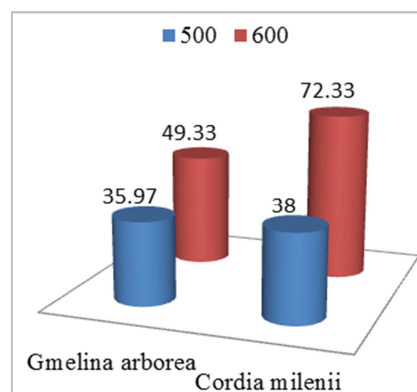

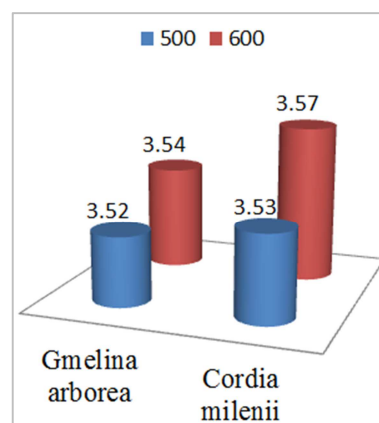***Figure 3.*** *Bio-oil yield (cm^3).*

Figure 4. *PH.*

Figure 4 presented the highest and least mean of the pH of pyrolytic oil yield which ranged from 3.53 to 3.57 and 3.52 to 3.54 for Gmelina arborea and Cordia milenii, respectively. There is significant difference in the pH of bio-oil liquid produced at 500°C and 600°C for the selected sawmill wood residues at P < 0.05 level of significance (Table 1).

The highest and lowest mean value for acidic value of liquid produced from Gmelina arborea and Cordia milenii ranges from 3.91 0.27 to 5.49 4.82 and 5.79 4.40 to 7.62 4.58 respectively (Figure 5).
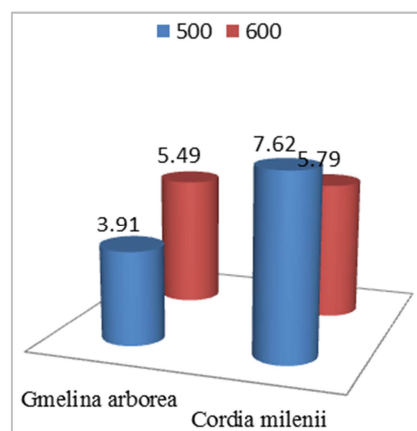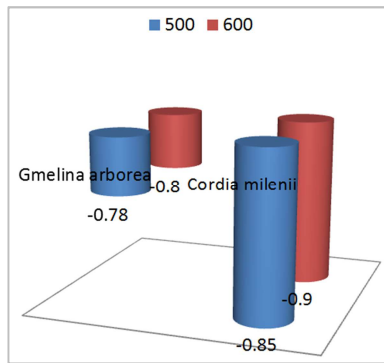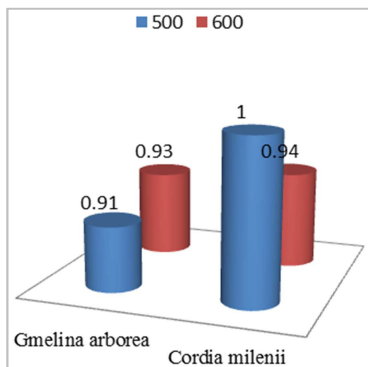

Figure 5. *Acidic value.*

Figure 6. Pour point.

The result presented in Figure 6 revealed the highest and lowest mean values for the pour point of liquid produced which ranged from -0.85 to -0.90 and -0.78 to -0.80 for *Cordia milenii* and *Gmelina arborea* respectively.

Figure 7. Density of bio-oil (g/cm³).

The result presented in Figure 7 shows significant higher value of density of pyrolytic oil yield 1.00 to 0.94 (g/cm³) in *Cordia milenii* to 0.91 to 0.93 (g/cm³) recorded in *Gmelina arborea*. The result of analysis of variance showed that there was significant difference in the densityvalue of the pyrolytic liquid at temperature of 500°C and 600°C.

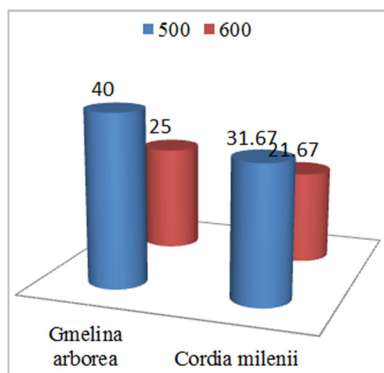### 3.2. Proximate Analysis of Bio-char Produced from Selected Sawmill Wood Residues

Figure 8. % Ash content.

Proximate analysis of pyrolytic oil produced from the selected wood species shows that Higher percentage ash

content of 40.00 was recorded in Gmelina arborea at lower temperature of 500°C, while Cordia milenii has the lower mean percentage ash content of 31.67 at lower temperature of 500°C and least percentage mean value of 21.67 at higher temperature of 600°C (Figure 8).

The mean value for percentage of volatile matter ranged from 20.00 to 45.00 and 13.33 to 35.00 which indicated that *Cordia milenii* has higher mean percentage volatile matter at 500°C while *Gmelina arborea* at 600°C has the least mean percentage volatile matter. This variation is further illustrated in Figure 9.
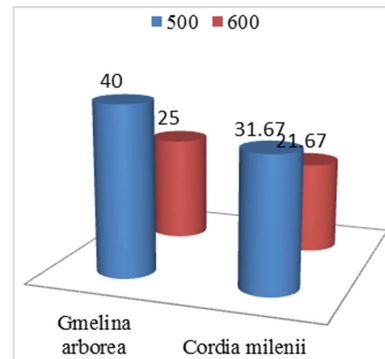

Figure 9. % Ash content.

The mean value for percentage of volatile matter ranged from 20.00 to 45.00 and 13.33 to 35.00 which indicated that *Cordia milenii* has higher mean percentage volatile matter at 500°C while *Gmelina arborea* at 600°C has the least mean percentage volatile matter. This variations is further illustrated in Figure 10.
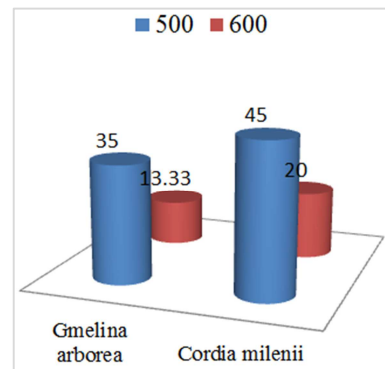

Figure 10. % Volatile matter.

The result presented inof figure 9 revealed the higher and lower mean for the heating value of the bio-oil which ranged from 23083.22 to 26725.74, and 20305.98 to 25637.17 (Kj/kg) for *Cordia milenii* and *Gmelina arborea* and respectively.

The result of the proximate analysis presented in figure 10 reveals higher biochar recovery (90.47) after pyrolysis process was recorded in *Cordia milenii*. *Gmelina arborea* recoded the lower mean bio char recovery after pyrolysis process and it ranged from 74.70 to 60.30.

3.3. Elemental Analysis of the Bio-oil

The results of the elemental composition (carbon, hydrogen, nitrogen, surphur and oxygen) of the pyrolytic oil is presented in Figures 11 and 12. This revealed the content of the selected sawmill wood residues.
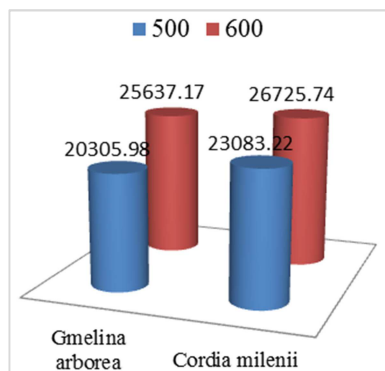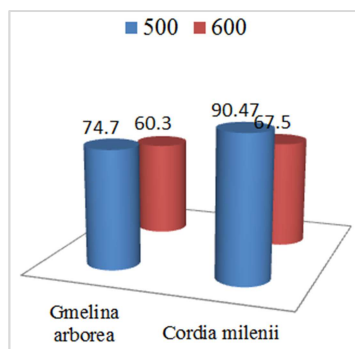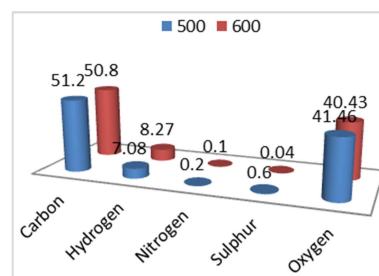

Figure 11. *Heating value.*

Figure 12. *Biochar.*

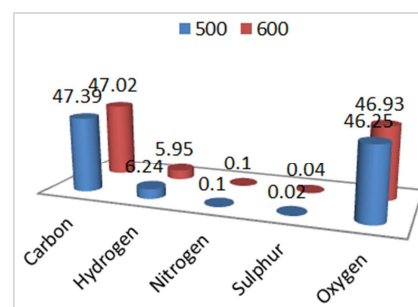**Figure 13.** *Elemental components of pyrolytic oil of G. arborea.*

Figure 14. *Elemental components of pyrolytic oil of C. milenii.*
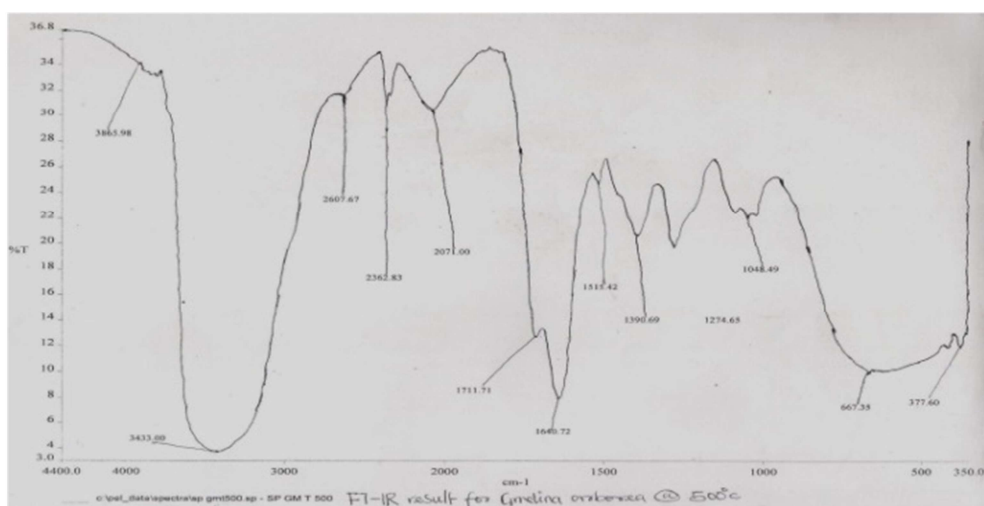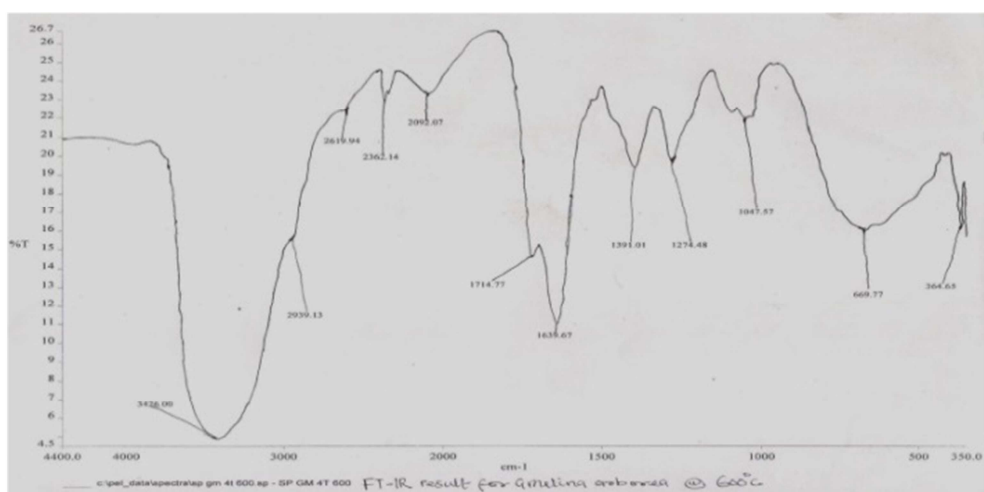
3.4. Compositional Analysis of the Bio-oil

The graphical representations of FT-IR spectrum of the liquid obtained from pyrolysis of *G. arborea* and *C. milenii* wood residues from sawmill at different temperature range are shown in Figures 15-18 while Tables 1 and 2 indicated the functional groups of the selected sawmill wood residues with their corresponding frequencies (cm^{-1}) that were identified from FT-IR spectrum.

Table 1. *Functional groups present in sawmill wood residue of Gmelina arborea as determined by FT-IR analysis.*

Temperature (°C)	Frequency (cm^{-1})	Functional Groups	Class of compounds
500	3600-3200	O-H stretch N-H stretch	Phenol, primary amine, secondary and water impurities
	3300-2500	O-H stretch	Carboxylic acid
	2500-2000	C≡N	Benzo-nitrile
	1775-1650	C=O stretch	Carboxylic acid, ketones, aldehyde, esters, benezene derivatives
	1680-1575	C=C stretch	Alkanes
	1570-1515	N-H bend	Secondary amide
	1490-1325	C-H bend O-H bend	Alkanes, Alcohols, phenols
	1300-950	O-H bend	Alcohols, phenols, aromatics
		C-H stretch	Esters, alcohol
	900-650	≡C−H bend	Alkynes
		C=C	Aromatic compounds, alkenes
600	3600-3200	O−H stretch	Phenol, secondary alcohol
		N−H stretch	Primary amine
	3300-2500	O−H stretch	Carboxylic acid
		C−H stretch	Alkanes, alcohols, ethers
	2500-2000	C≡N	Benzo-nitrile
	1775-1650	C=O stretch	Carboxylic acid, ketones, aldehyde, esthers, benzene derivatives
	1650-1575	C=C stretch	Alkanes
	1490-1325	C−H bend	Alkanes
		O−H bend	Alcohols, phenols
	1300-950	O−H bend	Alcohols, phenols, aromatics
		C−H stretch	Esters, alcohol
	900-650	C=C	Alkenes, aromatics
		≡C−H bend	Alkynes

Table 2. *Functional group present in sawmill wood residue of Cordia milenii as determined by FT-IR analysis.*

Temperature (°C)	Frequency (cm⁻¹)	Functional Groups	Class of compounds
500	3600-3200	O−H stretch	Phenol, sec. Alcohol
		N−H stretch	Primary amine
	3200-2500	O−H stretch	Carboxylic acid
	2500-2000	C≡N	Benzo-nitrile
	1775-1680	C=O	Carboxylic acid, ketones, aldehyde, esthers
	1650-1575	C=C stretch	Alkenes
	1590-1515	N−H bend	Secondary amide
		C−H bend	Alkanes
	1490-1325	O−H bend	
		O−H bend	Alcohol, phenols
	1300-950	C−H stretch	Alcohols, phenols
			Alcohols
	640-600	≡C−H	Alkynes, aromatics
600	3600-3200	O−H stretch	Phenol, sec. Alcohol
		N−H stretch	Primary amine,
			water impurities
	2500-2000	C≡N	benzo-nitrile
	1775-1650	C=O	carboxylic acid, ketones, aldehydes, esthers
	1650-1575	C−H bend	
		O−H bend	Alkanes, alcohols, phenols
	190-1325	O−H bend	
		C−O stretch	alcohols, phenols, alcohols
	1300-950	C=C strech	Alkenes
	640-600	≡C−H bend	Alkynes, aromatics

Figure 15. *FT-IR result for Gmelina arborea at 500°C.*

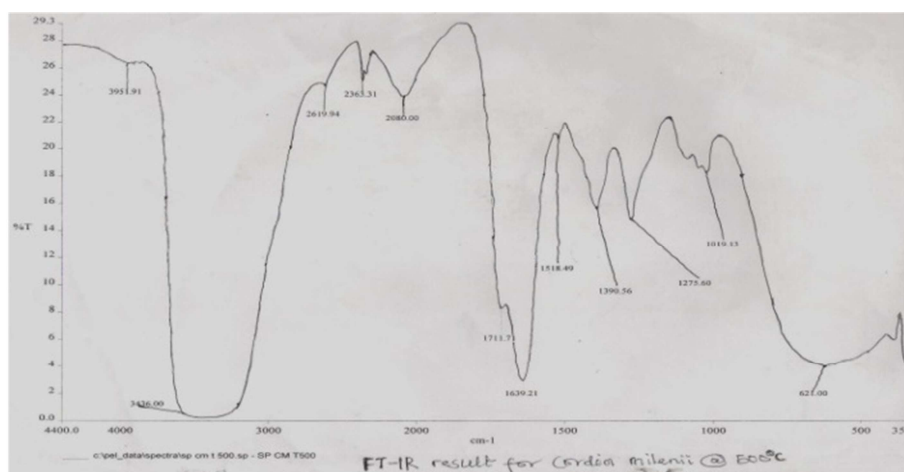***Figure 16.*** *FT-IR result for Gmelina arborea at 600°C.*

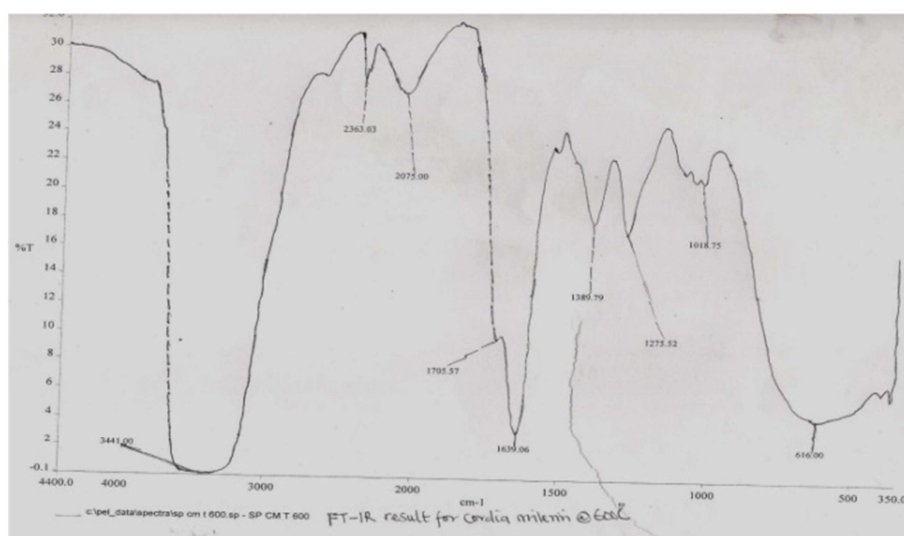**Figure 17.** *FT –IR result for Cordia milenii at 500°C.*

Figure 18. *FT-IR result for Cordia milenii at 600°C.*

4. Discussions

4.1. Physical Properties of Pyrolytic Oil

The study revealed that the bio-oil yield was higher at 600 °C for *Cordia milenii* pyrolysis. At this condition the mean yield of *Cordia milenii* was 72.33g/cm^3 compare to the yield of Gmelina arborea (49.33g/cm^3). There was general increase within the volume of oil yield because the temperature increases. per [9] the bio-oil derived weren't standardized products and may exhibit a good range of properties and compostion consistent with the feedstock and pyrolysis technique employed. Considerable experimental evidence suggested that there's increase in yield between liquid and gas and reduction in carbon solids (char) during wood pyrolysis which depends on the heating conditions [10]. Keown et al. [11] reported that the cell structure may affect the pyrolysis behaviour of biomass, The liquid yield were high showing the potential of reconversion liquid hydrocabon from the fast pyrolysis of biomass. The liquid appeared brownish dark with a powerful acidic smell. Heavy condensate or tar was also formed and adhered to the inner wall

of condenser, liquid collectors and connecting pipes. At the initial stage, biomass is decomposed and depolymerized to small compounds by dehydration, dehydrogenation, deoxygenation and decarboxylation and these compounds may rearrange through condensation, cyclization and polymerization to make new compounds. These commensurate with the study of Adegoke and Rotowa [1] on *Nesogodonia papaverifera* and *Gmelina arborea* within the preparation and characterization of bio-oil produced from sawdust of those wood species.

The characteristics of the oils derived from these studied species were very the same as the characteristics of other biomass pyrolytic oils. the foremost prominent characteristic is that the nature of the oil because of high oxygen content as agreed with [12]. an occasional pH range value of 3.52 - 3.73 may be a common feature within the sampled species derived liquid and that they are therefore very corrosive. The results of the density presented in figure 5 revealed that there's significant difference within the values obtained for *G. arborea* and *C. milenii*, with *C. milenii*, having the very best density value of 1.00 g/cm^3 which was lower compared with report of [12] with approximated value of 1.2 g/cm^3 bur accurate (1.00 g/cm^3) with the worth of [13]. Upon pyrolysis within the temperature range

of 500°C - 600°C, the bio-oil yield of wood samples was higher. Its maximum value was reached at the next temperature. Upon pyrolysis at 600°C, the formation of latest, thermally more stable bonds occurs. This results agrees with previous studies [1, 13] their results also reported higher yield of the char residue and increase within the amount of non-condensing gases upon pyrolysis of the samples. The results of the pour point revealed that Cordia milenii has the very best pour point value of -0.90 at temperature of 600°C which can not cause any trouble in most of the tropical regions but in colder regions with sub zero climate it should have freezing problems.

4.2. Proximate Analysis of Bio-char produced from Selected Sawmill Wood Residues

Proximate analysis is that the quickest and easiest method of investigating the fuel quality of solid materials. After pyrolysis the volatile matter content of the chosen sawmill wood species reduces between the various samples at different temperature with *Cordial milenii* having the best volatile matter content of 45%, which indicates higher biomass to liquid fuels from this species. The results of the share ash content presented in Figure 7 indicated that G. arborea had an higher ash content (25.000) compared with (21.67) recorded in *Cordia milenii* at a lower temperature of 500°C, higher values of 40.00 and 31.67 were respectively recorded at an higher temperature of 600°C these is also because of its chemical composition and presence of high extraneous materials within the species [14] Percentage ash content, fixed carbon and volatile matter were the desired prerequisite for the determination of heating value of the samples. it absolutely was observed that there's no significant difference within the percentage fixed carbon between the species and differed significantly for percentage ash content and volatile matter between the species. Ash is an impurity that may not burn, it reduces handling and burning capacity, it increases cost and affects combustion efficency causes clinkering and slagging. The heating value range for the bio-char produced from *Cordia milenii* and *Gmelina arborea* were obtained as 23083.22 - 26725.74, and 20305.98 - 25637.17 (Kj/kg) respectively. it's further shown that significant variations don't seem to be found among selected sawmill residues. This denotes high heating values nearly as good combustion characteristics for energy generation and to amass alternative source of bio-briquette for domestic and industrial application [1, 13, 15] Hence, any of those species are often use for industrial combustion needs.

4.3. Compositional Analysis of the Bio-oil

The basic analysis of the oil may be a significant criterion for the look of a combustion plant utilizing the oil. the last word word analysis showed the variations within the fundamental composition of the chosen sawmill wood residues (Figure 1). The analysis showed significant variation in carbon and oxygen content whereas there are slight variations in hydrogen, nitrogen and sulphur content form of the oxygen within the initial feedstock is believed to possess became H_2O, CO and CO_2. The high oxygen content ends up in an occasional energy density of

the bio oils. it absolutely was observed that changing the temperature causes atiny low variation within the fundamental content of the bio-oil samples. However, no particular trends within the essential composition were found within the range of reaction temperatures used.

4.4. Chemical Properties of Pyrolytic Liquid (FT-IR Analysis)

The FT-IR analysis suggested that the functional groups like alcohols, ketones, carboxylic acids, esters, alkanes, alkenes, alkynes, amide, nitriles, nitro compounds, ethers, aromatic rings were present within the bio-oil from *G. arborea* and *C. milenii*. The FT-IR spectra of bio-oil samples obtained from different temperatures exhibited the identical peaks but these spectra differed within the relative intensity of some bands. it's to be confirmed with gas chromatography results. The functional groups of the three and various class of compounds that were identified from the FT-IR spectrum are presented in Tables 1 and 2. The FT-IR spectra were recorded within the transmission mode between 3600 and 600 cm^{-1} for the samples. both residues have similar aromatic and aliphatic functional groups but with different vibrating frequencies (cm^{-1}). At 500°C, the O−H stretching vibrating frequency between 3600 and 3200 indicated the presence of phenols and alcohols (−OH in alcohols and phenols). The group and sophistication −NH2 in aromatic amines, primary amines and amides indicate the NH stretching vibrations. The absorbance between 2500 and 2000 represent the presence of benzo-nitrile with C≡H. The C=O deformation vibration between 1775 and 1650 cm^{-1} indicates the presence of acid, ketones, aldehyde, esters and benzene derivatives. The absorption between 1680 and 1575 cm^{-1} indicated the presence of alkanes. The absorbance peaks between 1575 and 650 represent N−H bend, C−H bend, ≡C−H bend and C=C which further indicated the presence of alkanes, aromatic compounds and alkynes. the increase in these bands suggests a rise in aromatic structures, nitrogeous compounds and alkanes. The weaker bands suggest a decrease in carbonly groups (COOH, Ketones and aldehydes) furthermore as aliphatic groups.

Russell *et. al.* [16] recognized the formation of aromatic compounds, whe cellulose was thermo-chemically converted in an alkali solution. They suggested that these aromtic were formed by condensation or cycliation of unstable intermediate fragments, which were generated by degradation of the cellulose. These changes observed by FT-IR indicate that bio oil possess both the aliphatic structures and aromatic components. The changes of intensity of the bands indicated the decrease in aliphatic structure and increase in aromatic components with increaseing reaction temperature. At 600°C similar functional groups were observed within the FT-IR spectrum altogether the chosen wood species with none effect of temperature regimes used during pyrolysis. Meier *et. al.* [17] and Bramer *et. al.,* [18] reported that top oxygenated compounds present in biomass pyrolysis oil is accountable for differences within the properties and behavior of bio-oil. Hence, it's vital to

deoxygenate the liquid by some upgrading technology.

5. Conclusion

Pyrolysis is an efficient due to produce liquid fuels from biomass. the standard of bio-oil needs to be improved before it'll be used as a traffic fuel or combusted in boilers. During pyrolysis process the solid content within the bio-oil is reduced by efficient char removal. The bio-oil obtained showed comparable fuel properties and will be treated as moderate grade commercial fuels. So on utilize it as commercial transportation fuel certain enhancement in properties like density and corrosiveness need to be normalize. The bio-oil obtained contains chemical compounds of varying carbon chain length from C4 - C27 and functional groups like alkanes, alkenes, alkynes, alcohols, ketones, aldehyde, aromatic rings, amides and nitrile compounds. Bio-char (charcoal) obtained has good calorific value, thus is additionally used as alternative fuel (briquette production) but it can't be used as adsorbent as its expanse was quite low. The physical properties of the bio-oil obtained from sawmill wood residues falls within the appropriate range for fuel production. The chosen wood species are therefore suitable for production of bio-oil with acceptable physical and chemical properties. The thermal degradation processes (pyrolysis), may help to chop back environmental pollution, deforestation at the identical time providing greater amounts of desirable, renewable fuel and chemical source. Based on the result of the study, it is recommended that:

1) Residence time taken for every temperature range to convert the feedstock to grease, and quantity of oil yield per specie.
2) Determination of the chemical components within the pyrolytic oil using Gas Chromatography-Mass Spectroscopy (GC-MS).
3) Upgrading of the bio-oil produced to high grade liquid fuel for further use in combustion engines and other applications.
4) Research should be directed to grasp the effect of particle (feedstock's) size on the yield of bio-oil.

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