

# POST-HARVESTED PLANTAIN BIOMASS AS POTENTIAL FEEDSTOCK FOR BIO-OIL

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**Abstract:**-This research work investigated the potential of Plantain biomass for bio-oil production. The fibre fraction of the biomass comprised: Extractive content of 26.56%, 22.04%, 33.71% for flower, stem and leaves respectively. Lignin content were recorded as 46.00%, 28.00%, and 27.00% for flower, stem and leaves. Holocellulose content were found to be 55.00%, 70.30%, 63.20% for flower, stem and leaves respectively.  $\alpha$  - Cellulose and hemicellulose contents were found to be 33.00%, 29.00%, 30.00% and 22.00%, 41.30%, 33.00% respectively. The flower, stem and leaves of the biomass were found to contain Moisture contents of 5.68%, 6.44%, 7.60% while the Ash content were recorded as 16.00%, 15.66%, 19.00% for flower, stem and leaves respectively. Pyrolysis of the Plantain biomass produced bio-oil and bio-char which were the two dominant products. The bio-oil derived from Plantain flower (PF), Plantain stem (PS) and Plantain (PL) were 2.73%, 2.63%, and 2.42% respectively. PF gave the highest bio-oil yield of 2.73%. While PS recorded as 82.93% of bio-char was the highest. The bio-char yield could be attributed to the part of the Plantain biomass and the moisture content. The GC-MS analysis revealed the presences of phenols, methyl esters and methyl stearate which are the major constituents of the oil-borne wood preservatives.

Therefore, the oil could serve as a potential remedy for wood infected by insects.

Keywords: Plantain biomass, Lignocellulosic contents, Bio-oil, Wood preservative.

## I. INTRODUCTION

Plantain is one of the most important crops of the tropical plants. It belongs to the family Musaceae and the genus Musa. Botanically known as *Musa paradisiaca*, it is called, 'Ogede agbagba' in Western Nigeria, 'Ayaba' in Northern Nigeria and 'Ogadejioko' in Eastern part of Nigeria [1]. Plantain biomass ranges from the leaves, stems, inflorescent flowers, peels and fruit bunch. It is estimated that plantain stem and leaves occupies 20% of the plant total biomass [2]. Plantain biomass are often dumped on road side or burnt resulting into environmental pollution. If these biomass is harnessed using conversion technology it will surely help in solving the problems of environmental pollution. Plantain inflorescent flower (hearts) is consumed as vegetable either fresh or steamed or cooked in soups, curries and fried foods in South Asia [3]. Plantain leaves are broad, elongated, flexible, and waterproof [4]. Direct combustion of pseudo-stems and leaves can also generate power [5]



Plantain Stem



Plantain Inflorescent Flower



Plantain Leaves



Lignocellulosic biomass is made up of very complex biopolymers non usable for food. The main components of lignocellulosic biomass are cellulose, hemicellulose, and lignin. In the pyrolysis of biomass, hemicellulose is readily pyrolysed follow by cellulose while Lignin is the least to pyrolysed [6]. Pyrolysis of organic matter is a very complex process and entails series of reactions when feedstock are heated in a non-reactive atmosphere. The thermal decomposition of organic components in biomass begins at 350 °C – 550 °C and goes up to 700 °C –800 °C in the absence of air or oxygen [7]. As this process begins, carbon, hydrogen and oxygen compounds in biomass break down into smaller molecules in the form of gases, condensable vapours (tars and oils) and solid charcoal (char) under pyrolysis conditions. The thermal decomposition of this organic matter depends on reaction conditions such as reactor (pyrolysis) temperature, reaction time and feedstock. For century now, Pyrolysis has been in used for the generation of bio-based fuels.

Wood is one of the most popular and fashionable construction materials to be found in our homes. It is no surprise then that we have the desire to take all measures to ensure a long life of wood and wood preservation are substances either natural or synthetic that provides protection to wood against fungi and insects that may damage and eventually destroy it. The primary purpose of wood preservatives is to increase wood service life, thereby avoiding the need for frequent replacements adding to deforestation.

Creosote is a category of carbonaceous chemicals formed by the distillation of various tars and pyrolysis of plant-derived material, such as wood or fossil fuel. They are typically used as preservatives or antiseptics. The United States Environmental Protection Agency (EPA) considers creosote to mean a pesticide for use as a wood preservative meeting the American Wood Protection Association (AWPA) Standards P1/P13 and P2 [8].

## II. MATERIALS AND METHODS

### Sample Collection

Plantain (*Musa paradisiaca*.) post harvested biomass was collected from Plantain orchard of the Federal University of Technology, Akure (FUTA), Nigeria. Samples were separated into portions as stem, leaves and flower and washed with distilled water. The samples were sun dried for 5 D and ground into fine particle size using milling machine. The powdered sample was made to pass

through 1-5 mm size analytical sieve. Each samples were preserved in a black polyethylene bag prior to use.

### Determination of Fibre composition.

The extractive, lignin, holocellulose,  $\alpha$ -cellulose, hemicelluloses, moisture and ash content were determined using standard methods as described by TAPPI-204-cm-97, TAPPI-222om-02, ASTM D1104-56, ASTM D1103-60 and ASTM E871-82 respectively [9-14]. The hemi-cellulose was determined through the difference of holocellulose and alpha cellulose. All analyses were performed in triplicates.

### Pyrolysis of the Biomass

One thousand (1000) grams each of the prepared samples were fed into fixed bed reactor. The sample was subjected to a slow pyrolysis system in the absence of oxygen at 450 - 600 °C for 2 h. The pyrolyser was connected to an electric power source and a Liebig condenser linked to a water pump. A bucket filled with ice block was made available to cool the liquid pyrolytic fuel dispensing from the hot narrow tube attached on the reactor. At temperature between 450 - 600 °C the liquid fuel started dispensing until a temperature of 600 °C. At this temperature, the flow of pyrolytic fuel had stopped. The electric source was disconnected at the end of 2 h, the system was left to cool down for 24 h and thereafter dismantled. Solid black residue bio-fuel called char was left in the pyrolysis reactor. The char was weighed and recorded. The Pyrolytic liquid mixture which comprised two distinct layers after which the mixture distinctly separated into viscous and aqueous layers. The viscous layer was allowed to flow down the neck of the funnel and was collected as the bio-oil, weighed and stored in a labelled sample bottle.

## III. RESULTS AND DISCUSSION

Table 3.1 shows the fibre composition (dry wt %) of Plantain biomass flower, stem, and leaves. Extractive content were 26.56%, 22.04% and 33.71% for flower, stem and leaves. Lignin contents were 46.00%, 28.00% and 27.00% for flower, stem and leaves. This is similar to what was reported by (Bilba *et al.*, 2007) for banana leaves and (Abdullah *et al.*, 2014) for pseudo-stem [15-16]. Holocellulose content were 55.00%, 70.30% and 63.30% for flower, stem and leaves.  $\alpha$ -cellulose content were 33.00%, 29.00% and 30.00% for flower, stem and leaves respectively. High cellulose biomass will give more bio-oil



compare to low cellulose biomass [17]. Hemicellulose content were recorded as 22.00%, 41.30%, 33.00% which were consistent with the values reported by (Kabenge *et al.*, 2018) for Plantain pseudo-stem and leaves [17]. Moisture content were noted to be 5.68%, 6.44%, 7.60% for flower, stem and leaves. These were in agreement with the values reported by (Abdullah *et al.*, 2014)

for banana leaves [16, 18]. Ash content were 16.00%, 15.66% and 19.00% for flower, stem and leaves. The low yield of the ash content of the biomass contributed to the good yield observed during fermentation and pyrolysis products especially in the Plantain flower of the biomass as reported by (Fernandes *et al.*, 2012) .

Table 3.1: Proximate and Fibre Composition of Plantain Biomass.

Fibre composition	Flower (dry wt%)	Stem (dry wt%)	Leaves (dry wt%)	Standard method
Extractive	26.56 ± 7.30	22.04 ± 0.08	33.71 ± 2.28	TAPPI-204cm-97
Lignin	46.00 ± 0.05	28.00 ± 0.05	27.00 ± 0.04	TAPPI-222om-02
Holocellulose	55.00 ± 0.03	70.30 ± 0.13	63.3 ± 0.16	ASTM D1104-56
α- cellulose	33.00 ± 0.0	29.00 ± 0.01	30.00 ± 0.18	ASTM D1103-60
Hemicellulose	22.00 ± 0.00	41.30 ± 0.00	33.00 ± 0.00	By difference
Moisture	5.68 ± 0.57	6.44 ± 0.75	7.60 ± 0.39	ASTM D1102-84
Ash	16.00 ± 6.00	15.66 ± 10.97	19.00 ± 9.80	ASTM E871-82

**Yield of Pyrolytic Products**

Table 3.2 shows the yields of Pyrolytic products of the Plantain biomass.

The Percentage (%) yield of the derived Bio-oil was calculated as follows:

$$(\%) Yield = \frac{W}{M} \times 100\% \quad (1)$$

W is the weight of the bio-oil,

M is the weight of the biomass used.

The bio-oil derived from Plantain flower (PF), Plantain stem (PS) and Plantain leaves (PL) were

2.73%, 2.63%, and 2.42% respectively. The PF gave the highest bio-oil yield of 2.73%. This observation was due to its high lignin content and high cellulose content. Biomass with high cellulose content will give more bio-oil compare to low cellulose content biomass [17]. The PS gave the highest bio-char yield of 82.93%. This observation is consistent with the findings of (Bridgwater *et al.*, 2007) that biomass with high lignin content will give more char than oil in slow pyrolysis process [19]. The bio-char yield could be attributed to the part of the Plantain biomass and the moisture contents.

Table 3.2: Percentage (%) Yield of Pyrolysis Products

S/no	Samples	Derived Bio-char Yield (%)	Derived Bio-oil Yield (%)
1	PF	58.40	2.73
2	PS	82.93	2.63
3	PL	58.80	2.42



PS = Plantain stem

PF = Plantain flower

PL = Plantain leaves

**Characterization of the Derived Bio-oil using GC-MS**

The various chemical compounds present in the derived bio-oil were characterized using GC-MS. GC-MS spectrometer (Agilent 7890A) was equipped with 5975, HP-5m intermediate polar capillary column 30 m length, 0.33 mm internal diameter, 0.25µm thickness. Helium gas was used as carrier gas at constant flow rate of 1ml/min. Injection was done in split less mode, injector temperature was 250°C. The oven temperature was programmed from 90°C per min then at 3°C per min to 180°C for 10 min. Identification was done by comparing their mass spectra with a GC-MS spectral NIST and WIELY library.

Table 3.3 - 3.5 show the various chemical compounds present in the Plantain flower, Plantain stem and Plantain leave derived bio-oil. Table 3.3 shows the presence of straight chain alkane compounds, aromatic phenol compounds, fatty acid and Ester compounds. Hexadecanoic acid, methylester and Heneicosane were the most abundant compound in the Plantain flower derived

bio-oil at peak area 7.06% and 8.26. Table 3.4 shows the presence of aromatic phenol compounds, double chain alkene compounds and fatty acid and ester compounds. Aromatic phenol compounds were the most abundant compound found in the Plantain stem derived bio-oil at peak area 12.10%. Table 3.5 shows the absence of aromatic phenol compounds, the presence of double chain alkene compounds, fatty acid and Ester compounds. Ester compounds were the abundant compound found in the Plantain leave derived bio-oil at peak area 32.42%. Similarly aromatic phenol compounds were noticeably in Plantain flower and stem derived bio-oil but completely absent in Plantain leaves derived bio-oil. Fatty acid and Methyl ester were found in all the three derived bio-oil. This is therefore an indication that the derived bio-oil could serve as preservatives due to the presence and abundant chemical compounds like phenols methyl ester also share characteristic with cresote having a Distinguish smoky flavor and burned taste [20].

Table 3.3: Major Chemical Compounds Identified from Plantain Flower derived Bio-Oil

RETENTION TIME (min)	IDENTIFIED COMPOUNDS	PEAK AREA (%)
3.268	Paradrine, S-[Tri-t-butoxysilyl]-2mercaptoethylamine	0.97
4.139	2,3-dimethyl-phenol, 3,4-dimethy-phenol, and 3-ethyl-phenol.	1.05
10.944	Tetradecane, Tridecane, Heptadecane.	3.63
13.425	Hexadecanoic acid, Methylester	7.06
14.111	Eicone, Hexadecane.	4.30
15.073	Heneicosane, Pentadecane	8.26
15.373	Methylstearate	2.62
18.554	Phenylephrine, 1,2-Hydrazinedicarboxamide	0.55
18.768	N.omega-Nitro-L-arginine, Imidazole, 2-amino-5-[(2-carboxy)vinyl].	2.23



22.397	n-hexylmethylamine, Octodrine, Acetaldehyde.	0.27
15.125	Cis-Vaccenic acid	3.46
10.868	9-Octadecenoic acid, (E)-oleic acid Hexadecen-1-ol,trans-9-n-pentadecanol Dichloroacetic acid, tridecylester	2.31

Table 3.4: Major Chemical Compounds Identified from Plantain Stem Derived Bio-Oil

<b>RETENTION TIME (min)</b>	<b>IDENTIFIED COMPOUNDS</b>	<b>PEAK AREA (%)</b>
3.996	2,4-dimethyl-phenol, 3,5-dimethyl-phenol.	7.35
4.320	3-ethyl-phenol, 4-ethyl-phenol.	6.56
9.77	Hexadecane, Tridecane	2.81
10.944	Tetradecane, Heptadecane	2.83
11.977	Cyclotetradecane, 1-Nonadecene, Heptadecyltrifluoroacetate.	1.90
12.049	Pentadecane, Octadecane	2.79
13.406	Hexadecanoic acid, methyl ester	6.03
14.111	Eicosane, Octadecane	4.20
15.106	9-Octadecenoic acid, methyl ester-(E), 11- Octadecenoic acid, methyl ester, Cis-13- Octadecenoic acid, methyl ester.	5.09
15.358	Methylstearate	2.54
19.111	Bis(2-ethyl hexyl)phthalate, Diisooctylphthalate, Di (Oct-3-yl)ester phthalic acid.	





Table 3.5: Chemical Compounds Identified from Plantain Leaves Derived Bio-Oil

RETENTION TIME (min)	IDENTIFIED COMPOUNDS	PEAK AREA (%)
11.301	7-Tetradecene, 3-Tetradecene, (Z), 3-Tetradecene	23.95
13.435	Hexadecanoic acid, methyl ester Pentadecanoic acid,14-methyl ester	32.42
15.082	Ethyl - N-Isopropylureidoacetate, Phenylephrine, Benzene ethanamine,4- methoxy-alpha-methyl.	8.63
15.130	Cis-13-Octadecenoic acid, methyl ester, 9- Octadecenoic acid (Z), methyl ester, 11- Octadecenoic acid, methyl ester.	16.37
15.382	Methyl stearate.	18.62

#### IV. CONCLUSION

The Plantain derived bio-oil is an attractive wood preservatives. The fibre composition of the various part of the Plantain biomass revealed they contain extractives, lignin, holocellulose, cellulose, hemicellulose, moisture and ash contents in various proportion. The result of the GC-MS analysis revealed that derived bio-oil has and share similar chemical compound with the conventional creosote oil-borne preservative. The smoky flavor and burned taste is another added advantage that suggests the potentiality of the derived bio-oil as a good wood preservative.

#### V. REFERENCES

- [1]. Oladeji, A.T., Idoko A.S., Abodunrin T.P., Yakubu M.T. (2010). 'Studies on the physicochemical properties and fatty acid composition of the oil from ripe plantain peel (*Musa paradisiaca*).' *African Scientist*. Vol.11, Issues 1,pp 73-78.
- [2].Ratnaprasad, A.V., Rao, K.M., Nagasrinivasulu, G. (2009). 'Mechanical properties of banana empty fruit bunch fibre reinforced polyester composites'. *Indian journal of fiber and textile research*. Vol.34: pp162-16.
- [3].Solomon, C. (2008). *Encyclopedia of Asian Food* (Periplus Ed.). Australia: *New Holland Publishers*.
- [4]. Molly Watson. (2014) "Banana inflorescent Flowers".
- [5]. Tock, J. Y., Lai, C. L., Lee, K. T., Tan, K. T., Bhatia, S. (2010). 'Banana biomass as potential renewable energy resource': A Malaysian case study,"and *Sustainable Energy Reviews*. 14 (2) 798-805.
- [6]. Cardona, C.A., Sánchez, Ó.J., Gutiérrez, L.F. (2010b). 'Process synthesis for fuel ethanol production'. *Biotechnology and bioprocessing*, 1st edition. CRC Press, Boca Raton.
- [7].Fisher, T., Hajaligol, M., Waymack, B., Kellogg, D. (2002). 'Pyrolysis behavior and kinetics of biomass derived materials.'*Journal of Applied Pyrolysis*. Vol. 62, pp 331- 349.
- [8].Price, Overton W., Kellogg, R.S., Cox, W.T. (1909). *Forest of the United State*
- [9]. Technical Association of the Pulp and Paper Industry. (TAPPI-204-cm-97), Solvent extractive of wood and pulp.
- [10]. Acid insoluble lignin in wood and pulp. Technical Association of the Pulp and Paper Industry. (TAPPI-222om-02)
- [11]."*Standards Test Method for Holocellulose in Wood*," (ASTMD1104-56), ASTM International, (1978).



[12]. "Standards Test Method for Alpha-Cellulose," (ASTMD1103-60), ASTM International, (1978).

[13]. "Standards Test Method for Moisture Analysis of Particulate Wood Fuels," (ASTM E871-82), ASTM International, (1998).

[14]. "Standards Test Method for Ash in Wood," (ASTMD1102-84), ASTM International (2001).

[15]. Bilba, K., Arsene, M.A.; Ouensanga, A. (2007). 'A Study of banana and coconut fibers': Botanical composition, thermal degradation and textural observations. *Bioresource Technology*. Vol. 98: pp58-68.

[16]. Abdullah, N., Sulaiman, F., Miskam, M.A. (2014). 'Characterization of banana (*Musa spp.*) pseudo-stem and fruit-bunch-stem as a potential renewable energy resource'. *International Journal of Biology and Veterinary Agricultural Food Engineering*. Vol. 8: pp712.

[17]. Kabenge, I., Omulo, G., Banadda, N. (2018). 'Characterization of banana peels wastes as potential slow pyrolysis feedstock'. *JSD*. Vol. 11:pp14.

[18]. Fernandes, E., Marangoni, C., Medeiros S. (2012). 'Slow pyrolysis of banana culture waste': Leaves and pseudo stem. Paper presented at the 3rd International conference on industrial and hazardous waste management.

[19]. Bridgwater, T. (2007). 'Pyrolysis of Biomass'. *IEA Bioenergy: Task Bioenergy Research Group*, Aston University: Birmingham, UK.

[20]. Roscoe, Henry Enfield., and Schorlemmer, Carl. (1888). "Creosote and Creosote oils". *A Treatise on Chemistry: The Hydrocarbons and Their Derivatives or Organic Chemistry*. Vol. 3, Issues 4: pp32-37.