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# Discovering the Macro-Elements Presence in Biochar Produced Indigenously

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***Abstract**: Biochar boosts soil fertility and helps plants to withstand drought. Its production locally has been a challenge and that is why an Indigenous Biochar Production Kiln (IBPK) was conceived, designed and fabricated at the Workshop of the Agricultural Technology Department, Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria. IBK convert biomass to carbon-rich organic material through thermal energy. The IBPK has two drums, the Internal Retort Drum (IRD) and External drum of diameters and heights of 350 mm x 600 mm and 500 mm x 800 mm respectively. The total weight of the IBPK was 82.50 kg. The IRD of 116 kg/m$^3$ volume was loaded with 55 kg biomass from wood waste, covered, and placed inside the external drum. The space between the outer wall of the IRD and the inner wall of the outer drum was 75 mm enough to contain firewood lighted and covered to produce the heat needed for the wood waste inside the IRD to convert it to Biochar. Smoke from the IBK escaped through the chimney attached to the external drum's lid. The operating time for the carbonization was 182 minutes and the conversion efficiency of the IBPK was 71 %. The average temperature of the IBPK during the conversion was 269 °C. The test carried out on the produced Biochar showed the presence of macro elements that included Nitrogen (2.95%), Phosphorus (21.79%), Potassium (4.95%) and Carbon (70.31%). The fabrication cost was Fifty-Two Thousand, Two Hundred Naira only (₦52,200:00). The IBPK is recommended for farmers to produce Biochar as needed for improved farm yield, and young graduates who want to go into Biochar production as a way out of unemployment.*

***Keywords:** Biochar, Kiln, NPK, Carbon, Agricultural Waste.*

## 1. INTRODUCTION

Biochar is a carbon-rich charcoal found as a black deposit obtained from organic residues in the soil [9]. It can also be produced by the pyrolysis of organic biomass or agricultural waste and plant materials such as grasses and forest residues with temperature ranges between 280 $^{o}$C and 500 $^{o}$C [11], [9], [12]. The term "Biochar" according to [5] is made up of two words, "Bio" which means organic materials and "char" which is thermally decomposed organic materials. Some of the elements found in Biochar include Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) and Ash in different proportions. It can also have the presence of Potassium (K), Phosphorus (P) and other elements depending on the biomass used for the char. Biochar is mainly used to improve soil nutrient content in other to increase crop yield and sequester carbon from the environment [5]. Based on the works of [5], [6], [3] and [9], Biochar can also be used as livestock feed. In this regard, Biochar is produced from different organic resources under varying conditions. Each type of Biochar has its unique properties, potential benefits, and considerations for production and application. The feedstock and production method choice depends on availability, local conditions, and intended applications. [3] and [9] observed that Biochar can be Wood-based, Paper-based or made from Crop Residue. It can also be Manure-based, Algae-based or made from Green Waste, Nutshell, Forest Residue, Poultry Litter and Sewage Sludge. In their study, [2] discovered that Biochar produced from coconut husk can retain the moisture content of the soil and the retention of carbon content. This was corroborated by [8] as they observed that Biochar is used in soil remediation through Biochar treatment. They also discovered that there was a large reduction in $CO_2$ emissions and retention of the soil carbon content. Biochar also serves as a tool for waste management and amendment of soil pH as well as soil sequestration [7] Biochar is also used for climate change mitigation and treatment of water among other benefits. Since we have more of this waste around us, it is wise to turn it into wealth through its conversion into Biochar as also observed by [10] who converted waste biomass to Biochar used in composites development for building constructions.

## 2. MATERIALS AND METHODS

This section presents the conception of the IBPK, the considerations for materials selected, the design of the kiln, the fabrication and the trial experiment carried out after the fabrication of IBPK.

### 2.1 The Conception

The conceptual design of IBPK as shown in Figure 1 has an outer drum of diameter 500 mm and a height of 800 mm, while the IRD is 350 mm in diameter and a height of 600 mm. The drums with lids were sourced locally from an oil depot in the Ile Oluji oil market. It was made of a galvanised metal sheet that could withstand severe heat up to 600$^o$C. There were eight air pots of diameter 20 mm each drilled around the upper part of the outer drum and a singular one at the bottom side to give partial entrance of air circulation in the drum which aids the burning of the wood. The IRD also have similar 6 airports at its bottom part to ease out gas emission from the heated biomass and to avoid condensation of the char during cooling. The exhaust pipe was made from hollow iron metal of 6 mm thickness and 600 mm height. There were handles made from 6 mm iron rods welded to the sides of the two drums to aid in easy transportation of the kiln and the removal of the IRD from the outer drum. The space between the outer wall of the IRD and the inner wall of the outer drum was 75 mm which is a sufficient space for the firewood needed to heat the biomass inside the IRD.

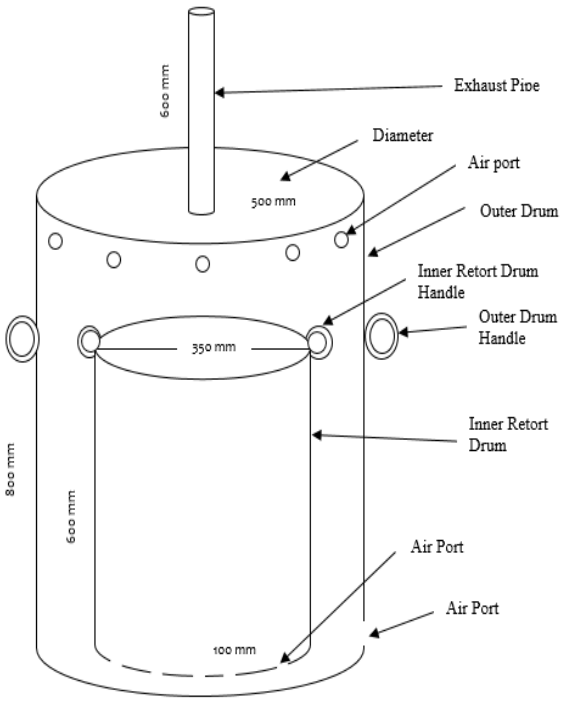



Figure 1: Conceived biochar kiln

### 2.2 Material Selection and Considerations

Materials were selected based on the safety of the operator and other people around, the machinability of the materials selected and the strength of the kilns to withstand heat up to 1500$^o$c. Other considerations include availability and cost which should be within the reach of peasant farmers in Nigeria. Ease of operations and maintenance were equally considered.

Mild steel of thickness 2 mm was selected for the kiln due to its availability, cheapness, heat resistance and ease of machination. Cast iron of diameter 20 mm was selected for the chimney because of its strength and ability to withstand heat.

### 2.3 Design Analysis

The volume of the IRD was calculated from the relationship in Equation 1

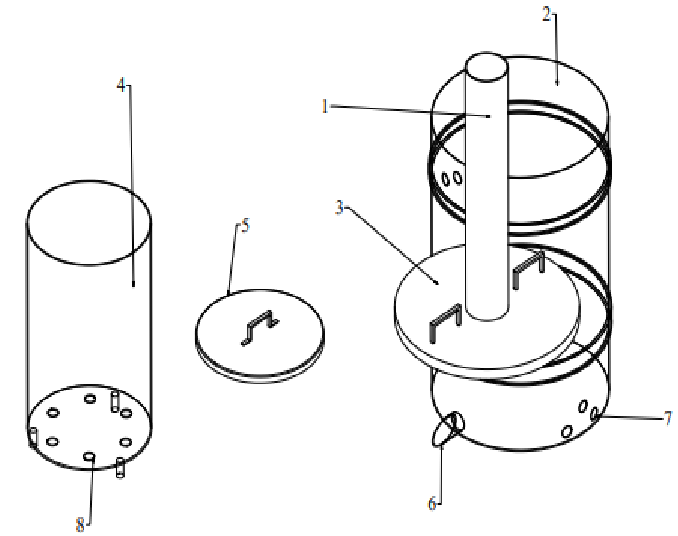
$$V = \pi r^2 h \tag{1}$$

Where $V$ is the volume of the IRD, $\pi$ is constant which is 3.142, $d$ is the diameter of the drum measured as 350 mm (35 cm), and $h$ is the height of the drum which was measured as 600 mm (60 cm). Therefore the volume of the IRD was calculated as follows;

$$V = 3.142 \times 350^2 \times 600 = 3.142 \text{ x } 122500 \text{ x } 600$$

$$V = 230{,}937{,}000 \text{ mm}^3 = 0.231 \text{ m}^3 = 231 \text{ litres.}$$

The explosive view, the isometric view and the 4D of the designed IBPK are shown in Figures 2, 3 and 4 while the fabricated Indigenous Biochar Production Kiln is shown in Figure 5




| PART LIST | | |
|---|---|---|
| SN | DESCRIPTION | QTY |
| 1 | CHIMNEY | 1 |
| 2 | OUTER KILN | 1 |
| 3 | OUTTER KILN LID | 1 |
| 4 | INNER RETORT | 1 |
| 5 | INNER RETORT LID | 1 |
| 6 | BIGGER AIR INLET | 1 |
| 7 | SMALLER AIR INLET | 9 |
| 8 | PRODUCE-GAS OUTLET | 8 |

Figure 2: Explosive view of biochar kiln

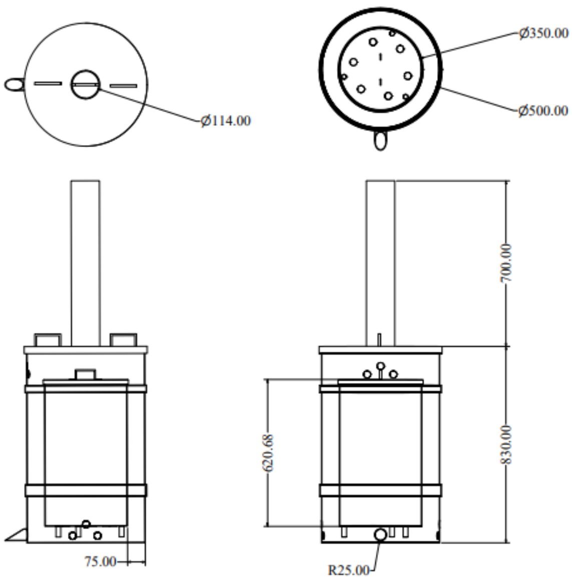



Figure 3: Isometric view of biochar kiln

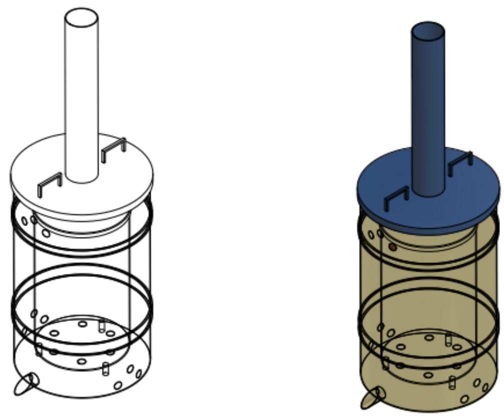


Figure 4: 4D view of the biochar kiln


Figure 5: Fabricated biochar kiln

### 2.4 Trial Experiment

Wood waste was gathered from the Federal Polytechnic Demonstration Farm for a trial test. They were sun-dried to a moisture content of 11 % using Wood Moisture Meter TESMEN, TWM-186. The dried wood (biomass) is then weighed to 55 kg in three places through a Camry Digital Weighing Scale of 300 kg capacity. The first 55 kg biomass was loaded into the IRD already placed inside the outer drum and covered. The space between the outer wall of the IRD and the inner wall of the outer drum was filled with firewood which was ignited at the top of the drum and the burning fire was allowed to catch other wood before closing the outer drum. This drum has an air inlet of 25 mm diameter at its bottom end to aid the burning and the smoke escapes through the chimney attached to the lid. The burning process took 182 minutes for the carbonization of the biomass with a maximum heat of 269$^{o}$C measured with a Casio W-800H-1AVDF digital stopwatch and HEIMANN Non-contact Infrared Laser Thermometer respectively.

On cooling down, the biomass inside the IRD was removed as Biochar as shown in Figure 6. This process was replicated thrice while keeping the weight and moisture content constant, and the average data was taken for our results analysis. The conversion efficiency of the IBPK was calculated from the relationship in Equation (2) according to [4]. The mineral elements of the Biochar produced were determined using the dry ash method as described in the Association of Official Analytical Collaboration [1].

$$Conversion\ Efficiency\ (\%) = \frac{Biomass\ Initial\ Weight}{Biochar\ Weight} \times 100 \qquad (2)$$

Figure 6: Biochar produced from wood waste

## 3. RESULTS AND DISCUSSION

The results of the fabrication and trial experiment carried out using the IBPK developed are reported in this section.

### 3.1 Weight and Conversion Efficiency of IBPK

The average weight of Biochar produced and the conversion efficiency of the IBK were 39.17 kg and 71 % respectively as shown in Table 1 while the moisture content and Biomass weight were kept at 11 % and 55 kg respectively. Further study is ongoing to vary the moisture contents while retaining a constant weight to see the impact on the conversion efficiency of the IBPK.

Table 1: Biochar parameters measured and calculated

| Biomass | Moisture Content (%) | Biomass Weight (kg) | Biochar Weight (kg) | Conversion Efficiency (%) |
|---|---|---|---|---|
| Wood 1 | 11% | 55 | 38.6 | 70.18 |
| Wood 2 | 11% | 55 | 37.7 | 68.55 |
| Wood 3 | 11% | 55 | 41.2 | 74.91 |
| **Average** | **0.11** | **55.00** | **39.17** | **71.21** |

### 3.2 Biochar Elements

From Table 2, it was seen that the average percentage presence of Nitrogen (N), Phosphorus (P) and Potassium (K) for the three sets of experiments conducted were 3.31 %, 22 %, and 5.05 % respectively. Whereas that of Carbon was about 70 %

Table 2: Elements presence of biomass

| Elements | Biomass 1 | Biomass 2 | Biomass 3 | Average (%) |
|---|---|---|---|---|
| Nitrogen (N) | 2.95 | 3.55 | 3.42 | 3.31 |
| Phosphorus (P) | 21.79 | 21.8 | 21.5 | 21.70 |

| | | | | |
|---|---|---|---|---|
| Potassium (K) | 4.95 | 5.21 | 4.98 | 5.05 |
| Carbon (C) | 70.31 | 69.44 | 70.1 | 69.95 |

As shown in Figure 7, it was discovered that the Biochar produced have the presence of the major macro-elements (N, P, K) and is high in Carbon content. This observation corroborates the study of [6] who observed that for wood-based Biochar, carbon content is the highest when compared to other elements present in it. This also shows that the desired elements needed for soil amendment should influence the farmer in choosing the right biomass to turn to Biochar.

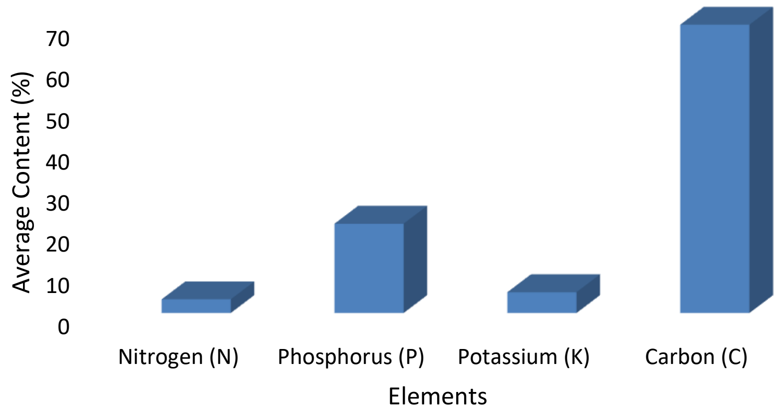



Figure 7: Elements in the produced Biochar

## 4. CONCLUSION AND RECOMMENDATION

Indigenous Biochar Production Kiln (IBPK) was successfully designed and fabricated at the Department of Agricultural Technology, Federal Polytechnic, Ile Oluji, Ondo State, Nigeria. A trial experiment carried out using the IBPK to turn wood waste into Biochar was successful. The Biochar kiln can easily be operated by peasant farmers since it doesn't have any special skill to handle. However, the heat coming from the firewood cannot be regulated since firewood is used to fire up the biomass inside the retort chamber.

It is recommended that the Biochar Kiln should be used to produce Biochar from various biomass and waste farm products. The produced Biochar should be tested for the presence of micro and macro elements needed for soil amendment for improved crop yields. Further study is expected to automate the process so that the heat needed for the conversion of biomass to Biochar can be regulated.

## ACKNOWLEDGMENT

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