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# Production of Hybrid Biochar by Retort-Heating of Elephant Grass for Waste Management and Product Development

**Author A. G. 1 \*, AuthorJ. O. 1,2\*\*, Author D. V. 1, AuthorA. O. 1,\*\***

*1Department of Chemical Engineering, Faculty of Engineering and Technology, University of xxxx, Bity, P.M.B.1515, Country*

*2Department of Chemical Engineering, Jilali University, P. M. B. 5025, New Caty, Country*

*\*Corresponding author, Email address:* [*xhtopel@jmes.com*](mailto:xhtopel@jmes.com)

*\*\*Corresponding author, Email address:* [*yauthor2014@kamil.org*](mailto:yauthor2014@kamil.org)

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| **Received** xx xxx 2023, **Revised** xx xxx 2023, **Accepted** xx xxx 2023  **Keywords:**   * *Nanocomposite;* * *Hydroxypropyl methylcellulose;* * *Hydroxyapatite;* * *Methylene blue;* * *Adsorption*   ***Citation****: Author A. G., Author J. O., Author D. V. Author A. O. (2023) Production of Hybrid Biochar by Retort-Heating of Elephant Grass for Waste Management and Product Development, J. Mater. Environ. Sci., 14(X), xxx-xxx.* | **Abstract:** The aim of this study is to develop a new, efficient, and inexpensive natural based adsorbent with high efficacy for the cationic dye methylene blue (MB). Natural based nanocomposite based on hydroxyapatite (HAp) and hydroxypropyl methylcellulose (HPMC) was selected for this purpose, it was synthesized by the dissolution/reprecipitation method. A film with a homogeneous and smooth surface composed of nanoparticles was prepared from the nanocomposite. HPMC and hydroxyapatite biopolymers were selected due to their compatibility, biodegradability, and non-toxicity. The scanning electron microscopy (SEM) shows that a composite sheet with a homogenous and smooth surface indicates an excellent compatibility between HPMC and HAp in the composite. The nanocomposite was evaluated as an adsorbent for organic dyes from an aqueous solution. The effects of solution pH, initial MB concentration, composite concentration, and adsorption time on the adsorption efficiency were evaluated. The high-est adsorption rate was about 52.0 mg/g composite, the adsorption rate reached the equilibrium in about 20 min. The fittingness of the adsorption data to the adsorption models of Langmuir, Freundlich was investigated, results showed the adsorption process follows the Langmuir isotherm model. The kinetic study results revealed that the adsorption process is pseudo second order. The current composite could be an excellent alternative for current industrial scale adsorbents. |

# 1. Introduction

Solid waste management a major challenge of the 21st century due to increasing population, urbanisation and lifestyle changes due to technological development (Bouyanzer *et al.*, 2004). This problem is even more pronounced in developing countries such as Nigeria where solid waste management is a major concern (Benabdellah *et al.*, 2006), (Bouklah *et al.*, 2006). With increasing global change pressures coupled with existing un-sustainability factors, cities in developing countries are most likely to experience difficulties in efficiently managing municipal solid wastes. Municipal solid waste management constitutes one of the most crucial health and environmental problem facing African cities (Ouachikh *et al.*, 2009), (Bammou *et al.*, 2011), (Bouyanzer *et al.*, 2017). Most cities spend 20-50% of their annual budget on solid waste management (Lagrenee *et al.*, 2020), and only 20-80% of the waste is collected (Ahanotu *et al.*, 2023). The waste density ranged from 280 to 370 kg/m3 and the waste generation rates ranged from 0.44 to 0.66 kg/capita/day (Ebenso *et al.*, 2022). Pyrolysis is a way to utilise the carbon in plants before it can become a meal for eaters and return it to the soil as pure carbon biochar (Kaya *et al.*, 2022). Pyrolysis mimics the natural process that turned ancient plants into coal: When biomass is heated up with no oxygen supply it melts into carbon, syngas and bio-oil (Camara *et al.*, 2022). Almost the same solutions are proffered to management of LDPE which include biodegradation in a solid waste medium (Oguzie *et al.*, 2018), pyrolysis, gasification and carbonisation.

In this study, elephant grass (*Pennisetum Purpureum*) was co-carbonised with low density polyethylene (LDPE) to produce hybrid biochar in a top-lit updraft biomass conversion reactor using the method described by ... In the method, an updraft gasifier with retort heating was used. The goal of the process is two-pronged. Firstly, the management of plastic wastes. Secondly is the energy conservation from the plastic and the readily available biomass to produce valuable products.

# 2. Methodology

## 2.1 Sourcing and preparation of

Dried sample of … These were also locally sourced.

## 2.2 Experiments

Details of experiments are exactly as those described in previous reports (Juan *et al.* 2018, Ebenso *et al.*, 2022, Raberto *et al.*, 2023). The biomass conversion was conducted in the 48.5 cm high reactor with full dimensions and schematics provided elsewhere. The hybrid co-conversion of biomass and plastic was conducted in the 53 cm high reactor with full dimensions and schematics provided elsewhere (Hatem and Shamran, 2020). The reactors consist of a centrally oriented conversion chamber within its’ set-up and possessing several small air holes at the base. The chamber houses the feed to be converted while the combustion fuel for heat generation occupies the ‘heating gap’ between the chamber and the reactor itself.

## 2.3 Product characterisation

The products (biomass biochar and hybrid biochar) recovered from the process were characterised to ascertain some of their properties using Scanning Electron Microscope with energy Dispersive X-ray Spectroscopy (SEM-EDS), Fourier Transform Infra-Red Spectroscopy (FTIR) and Brunauer-Emmet-Teller (BET) analysis. Scanning Electron Microscopy (SEM, Phenom proX, Phenom-World BV, Netherlands) was used to study the surface morphology of the particles of the biochar. A double adhesive was placed on a sample stub. The sample was sprinkled on the sample stub and subsequently taken to a sputter coater (quorum-Q150R Plus E) and coated with 5 nm of gold. The sample was placed on a charge reduction sample holder and introduced into the column of the SEM machine. It was firstly viewed with a NavCam before being sent to SEM mode. The acceleration voltage of the microscope was set to 15 kV and magnification at 1000 – 1500×. FTIR (Shimadzu, FTIR-8400S, Japan) was used to determine the functional groups and complexes present in both biochar samples. The surface area, pore volume and size of the chars were measured. The surface properties of the char samples were studied using a Multipoint BET surface area and the DR (Dubinin–Radushkevic) method for the pore volume and width (diameter). Adsorbate was introduced to give the lowest desired relative pressure, and then the volume adsorbed was measured.

# 3. Results and Discussion

## 3.1 Temperature profile

Temperature readings were taken at the various points Tb, Tm, Tt, and Ti for each of the reactor at a time interval of 10 minutes to generate a temperature profile along the time of carbonisation. Tb, Tm, Tt, and Ti represents temperatures at the bottom (side), middle (side), top (side) and within the reactors respectively. The initial set of temperature measurements was done before ignition and the final set was done when the system had come into equilibrium with atmospheric conditions.



**Figure 1a.** Temperature profile for biomass conversion



**Figure 1b.** Temperature profile for hybrid co-conversion

## 3.2 Product yield

The bio-char yield for both processes was computed using the system of equations in **Eqn. 3** (Sharma and Kaur, 2019 & 2022).

**Eqn. 1**

**Eqn. 3**

Where M1 = mass of conversion chamber + Feed (in grams), M2 = mass of conversion chamber (in grams), M3 = ….summarised in **Table 1**.

**Table 1.** Summary of reactor performance

|  |  |  |
| --- | --- | --- |
| **Index** | **Biomass conversion** | **Hybrid co-conversion** |
|  |  |  |

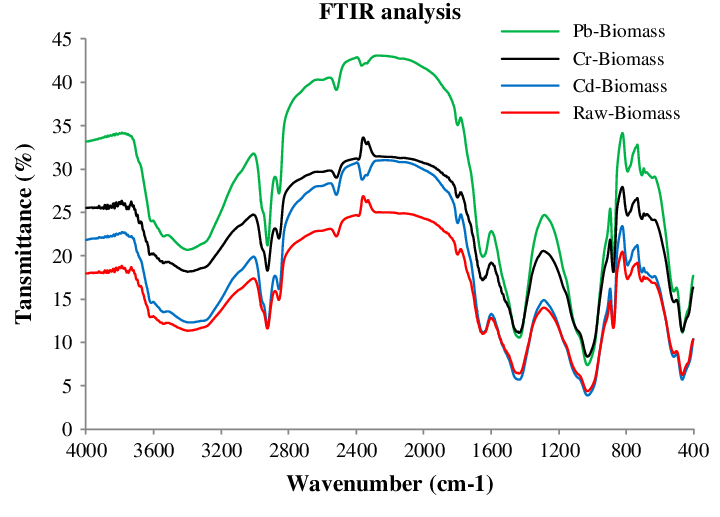
The biomass biochar yield of 13.8 wt% (at 371oC peak temperature) in this study is similar to the 14.29 wt% (at 300oC peak temperature) obtained for the same feedstock in a previous investigation (Marchant *et al.*, 2008). This was confirmed by the EDS results.

## 3.3 Product composition

The composition of the products was determined using Energy Dispersive X-ray spectroscopy (EDS). The spectrums are shown in **Figures 2** and the results summarised in **Table 2**. The only major component missing is Hydrogen. From the results in **Table 2**, it can be observed that the hybrid

**Table 2.** Major elemental composition of the biomass and hybrid biochar

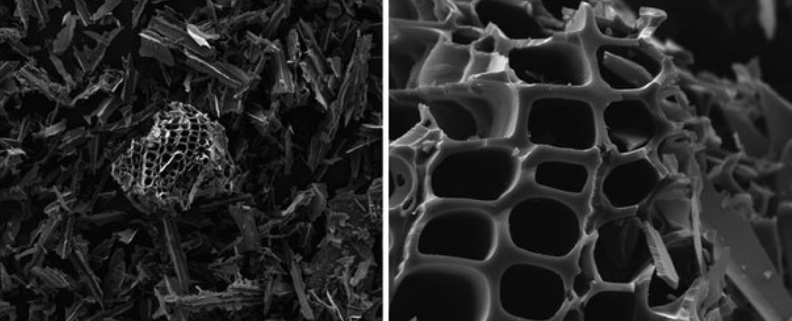
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| --- | --- | --- | --- | --- | --- |
| **S/N** | **Element** | **Biomass Biochar** | | **Hybrid Biochar** | |
| **Atomic Conc.** | **Weight Conc.** | **Atomic Conc.** | **Weight Conc.** |
| 1 | Carbon | 74.13 | 57.79 | 86.89 | 75.46 |
| 2 | Silicon | 9.63 | 17.55 | 1.95 | 3.95 |
| 3 | Potassium | 4.17 | 10.57 | 3.46 | 9.79 |
| 4 | Oxygen | 9.57 | 9.94 | 4.59 | 5.31 |
| 5 | Nitrogen | 0.85 | 0.78 | 1.26 | 1.27 |
| 6 | Chlorine | 0.38 | 0.89 | 0.50 | 1.29 |
| 7 | Calcium | 0.26 | 0.67 | 0.25 | 0.72 |
| 8 | Aluminum | 0.33 | 0.57 | 0.26 | 0.50 |
| 9 | Phosphorus | 0.26 | 0.52 | 0.26 | 0.58 |
| 10 | Magnesium | 0.26 | 0.40 | 0.28 | 0.50 |
| 11 | Sulfur | 0.12 | 0.24 | 0.19 | 0.44 |
| 12 | Sodium | 0.06 | 0.08 | 0.11 | 0.18 |



**Figure 2.** FTIR spectrum for biomass ….

## 3.4 Biochar surface morphology

The surface morphology of the products was determined using SEM. **Figure 3a-b** shows the SEM micrographs of the (see **Table 2**).



**Figure 3.** SEM micrograph of biochar, at (a) 1000× and (c) 1500×

## 3.5 Biochar functional groups

**Table 3** shows the functional groups of raw ….correspond to the alkoxyl (C-OH) group (Azizi, *et al.*, 2021). The peak 1635 cm-1 observed in the biomass spectra which shifted to 1620 cm-1 and 1573 cm-1 in biomass. Retort heating also underlines the usability of the process even in remote locations or in on-site applications (Zhong and Shahidi, (2015).

# Conclusion

The co-conversion cost, high biochar yield and no electrical power requirement. The study has been able to successfully achieve the co-conversion of biomass and plastics (as typologies of MSW major components valuable products with a twin goal of waste management and product development.

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# Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest.

*Compliance with Ethical Standards:* This article does not contain any studies involving human or animal subjects.

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