Activation of Biochar for Different Applications

Project Report (Phase I)
In partial fulfillment of the requirements
For the degree of
Bachelor of Technology
by

Khushi Agrawal
(Roll No: 210107044)

Under the Guidance of
Dr Pankaj Tiwari

Department of Chemical Engineering
Indian Institute of Technology Guwahati

Nov – 2024

ABSTRACT

The pressing issues of environmental pollution and global warming pose a significant threat to ecosystems, ne
Biomass sources like agricultural residues, animal manure, and municipal waste can meet the growing deman
In this project, bamboo sawdust—a sustainable and abundant biomass material—will be used as the feedstoc
The biochar production process will involve both physical activation and chemical activation. Physical activatio

Table of Contents

Tables and Figures

Motivation

Producing biochar from biomass is a game-changer in the quest for sustainable solutions. When biomass, suc

The growing awareness of biochar's applications and benefits has driven significant market growth, with solid

2. Introduction

2.1 Biochar

Biochar is a form of highly stable charcoal produced by heating biomass in an oxygen-limited environment. Co

When biomass undergoes pyrolysis in an oxygen-limited environment, it forms a porous, carbonaceous solid w

2.2. Biochar Market

The biochar market is rapidly expanding, with India projected to achieve a compound annual growth rate of 15

The market segments into critical regions: North America, Europe, Asia-Pacific, South America, and the Middl

2.2.1 Biochar Market Analysis by Technology

Fig. 1. Biochar Market Analysis by Technology [3].

In 2023, pyrolysis remained the leading technology in the biochar market, accounting for approximately 62.5%

Gasification technology has seen moderate growth, primarily driven by the increasing demand for electricity ge

Additionally, small-scale producers are exploring alternative methods such as hydrothermal carbonization, aci

2.2.2 Biochar Market Analysis by Application

In 2023, the agriculture sector led the biochar market, accounting for over 76% of the revenue share, driven by

■Fig. 2. Biochar Market Analysis by Application [3].

2.2.3 Biochar Market Analysis by Region

North America is the largest biochar consumer, driven by high demand for organic food and sustainable livesto

Fig. 3. Biochar Market Analysis by Region [3].

2.3 Feedstock for Biochar

Depending on the source, biomass can be divided into five categories: woody, agricultural, aquatic, human an

Another class of biomass, known as aquatic biomass, is made up of many types of microalgae, plants, and mi

The next category of biomass is waste from animals and humans. This group includes various animal manure

3. Literature Review

3.1 Different Technique used for Biochar production:

Different feedstocks (forestry, agricultural and aquatic biomasses, livestock detritus, industrial and municipal w

3.1.1 Pyrolysis

A non-oxidative method of heat breakdown is pyrolysis. It produces three distinct product fractions: non-conde
Low heat (300–550 °C), slow heating rates (0.1–0.8 °C/s), and extended contact times (5–30 min or even 25–

3.1.2 Gasification

By transferring heat from carbonaceous materials to gasification agents like air, oxygen, or steam at temperatu

3.1.3 Hydrothermal Carbonization

The process known as hydrothermal carbonization (HTC) converts biomass into carbonaceous biofuel in the p

3.2 Activation of Biochar Produced

Activation is the process that converts biochar (BC) (or) biomass in to activated carbons (AC), which exhibits v

3.2.1 Chemical Activation

After the raw material has been crushed and ground to the required particle size, it is combined with a concent

Table 1. Recent studies on the chemical activation of biochar precursors [22].

3.2.2 Physical Activation

Through a dual-stage process, biomass is thermally treated at 600–900 °C in an inert atmosphere to form bioc

Table 2. Recent studies on the physical activation of biochar precursors [22].

3.2.3 Microwave Mediated Activation

Microwave-assisted chemical synthesis/process is getting significant importance in recent years and it has als

3.2.4 Physicochemical Activation

Along with physical and chemical activation processes, researchers also explored the integration of both the m

4. Objective

Biochar holds significant potential to become an essential resource in sustainable energy and environmental a

The main objectives of this report are:

Determination of Physical and Chemical Properties of Bamboo Sawdust

Synthesis of Biochar

2.1 Pyrolysis of the Prepared Bamboo Sawdust to Produce Biochar.

2.2 Activation of Biochar through Physical and Chemical Methods to Obtain Activated Biochar.

2.3 Characterization and Analysis of the Properties of Activated Biochar.

5. Materials and Methodology

In the forthcoming phase of this BTP, the focus will be on producing and activating biochar derived from bamb

5.1 Feedstock and Materials

Bamboo sawdust has been chosen as the feedstock for biochar synthesis. Bamboo is widely cultivated across

5.2 Methodolgy

5.2.1 Analytical Procedures

5.2.1.1 Proximate Analysis

Proximate analysis will be conducted to determine the moisture content, volatile matter, ash content, and fixed

Moisture Content: A 10 g sample of bamboo sawdust will be dried at 105°C for 24 hours to determine moisture

Volatile Matter: A 5 g sample will be heated in a muffle furnace at 900°C for 7 minutes with the crucible lid clos

Ash Content: A 5 g sample will be incinerated at 750°C for 6 hours in an open crucible. This procedure is in lin

Fixed Carbon: Calculated by subtracting the percentages of moisture, volatile matter, and ash from 100%.

5.2.1.2 Thermogravimetric Analysis (TGA)

Thermogravimetric Analysis (TGA) will be utilized to assess the thermal stability and decomposition behavior o

Procedure: Approximately 10 mg of the sample will be heated from room temperature to 800°C at a rate of 10

5.2.2 Pyrolysis

Pyrolysis will be performed to convert bamboo sawdust into biochar under controlled conditions. The process

Procedure: Approximately 50 g of dried bamboo sawdust will be placed in a stainless steel reactor. The reacto

Expected Yield: Biochar yields from bamboo pyrolysis are typically around 30–40%, depending on the specific

5.2.3 Chemical Activation

Chemical activation will be conducted using potassium hydroxide (KOH) to enhance the porosity and surface a

Procedure: The char will be impregnated with KOH at weight ratios of 1:1, 1:2, and 1:3, stirred at 100 rpm for 2

5.2.4 Physical Activation

Physical activation will be performed to further develop the pore structure of the biochar. This method involves

Procedure: The activation of pyrolyzed bamboo char will be conducted at varying temperatures (850°C, 900°C

5.2.5 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis will be conducted to identify the functional groups present on the surface of the activated biocha

Procedure: FTIR spectra will be obtained in the range of 4000–400 cm^{-1} using a Shimadzu IRAffinity-1 spectr

Expected Results: Functional groups such as hydroxyl, carboxyl, and carbonyl are expected to be present, wh

5.2.6 Brunauer–Emmett–Teller (BET) Surface Area and Porosity Analysis

BET analysis will be conducted to measure the surface area, pore volume, and pore size distribution of the act

Procedure: The BET surface area and pore characteristics will be measured under nitrogen adsorption conditi

Expected Results: Activation is anticipated to increase the surface area and porosity of the biochar, enhancing

5.2.7 Scanning Electron Microscopy (SEM)

SEM will be employed to analyze the surface morphology and pore structure of the activated biochar. Visual c

Procedure: The sample will be prepared on a carbon-coated grid and observed under high-vacuum conditions

Expected Results: SEM images are expected to reveal an enhanced porous structure and rougher surface on

5.2.8 X-Ray Diffraction (XRD)

XRD will be used to determine the crystallinity and phase composition of the biochar, which influence its chem

Procedure: XRD patterns will be obtained using Cu Kα radiation across a 2θ range of 10–80° [27].

Expected Results: The biochar is anticipated to exhibit an amorphous structure with minimal crystallinity, indica

5.2.9 Thermogravimetric Analysis (TGA)

TGA will be performed to assess the thermal stability and decomposition profile of the biochar. This analysis p

Procedure: Approximately 10 mg of biochar will be heated from room temperature to 800°C at a rate of 10°C/r
Expected Results: The TGA curve is expected to show distinct weight-loss phases for moisture, volatiles, and

6. Results and Discussions

6.1 Proximate Analysis

Based on reference studies, the proximate analysis of bamboo prior to carbonization revealed:

Moisture Content: 6.97%, determined by drying a 10 g sample at 105°C for 24 hours.

Volatile Matter: 73.02%, measured by heating a 5 g sample at 900°C for 7 minutes in a muffle furnace.

Ash Content: 0.10%, calculated by incinerating a 5 g sample at 750°C for 6 hours.

Fixed Carbon: 19.91%, estimated by subtracting moisture, volatile matter, and ash content from 100%.

Table 3. Proximate analysis of bamboo [32].

6.2 Thermogravimetric Analysis (TGA)

The TGA curve is anticipated to show weight loss stages [32]:

Table 4. Thermogravimetric analysis of bamboo [32].

Fig.7. TG and DTG curve of bamboo biomass [32].

6.3 Physical Activation

Table 5. Effect of physical activation on bamboo [32].

Optimal Activation Temperature: 900°C–950°C is ideal for achieving a balance between high surface area, mi

High Temperatures Impact: At 1000°C, pore coalescence leads to a reduction in micropore volume, emphasiz

6.4 Chemical Activation

Table 6. Effect of chemical activation on bamboo [33].

Optimal Conditions: Activation at 800°C with a char-to-KOH ratio of 1:3 provides the highest BET surface area

Pore Structure: Higher activation temperatures and KOH ratios result in increased microporosity and pore volu

7. Future Work

In the next phase of my BTP, all the experiments and analyses outlined in the methodology and results sectio
Additionally, chemical activation will be performed using KOH at different impregnation ratios and activation te
Finally, the prepared activated carbon will be tested for adsorption applications, such as removing heavy meta

8. Conclusion

This study outlines a structured approach for investigating bamboo sawdust as a sustainable feedstock for bio
In the next phase of this BTP, the biochar will undergo activation and detailed characterization to enhance its s

9. References

[1] Lehmann, J.; Joseph, S. Biochar for Environmental Management: Science, Technology and Implementatio
[2] Wang, J.; Xiong, Z.; Kuzyakov, Y. Biochar Stability in Soil: Meta-Analysis of Decomposition and Priming Ef
[3] Gabhane, J.; Tripathi, A.; Athar, S.; William, S. P. M. P.; Vaidya, A. N.; Wate, S. R. Assessment of Bioener
[4] Pappu, A.; Saxena, M.; Asolekar, S. R. Solid Wastes Generation in India and Their Recycling Potential in B
[5] GVR Report. Biochar Market Size, Share & Trends Analysis Report By Technology (Gasification, Pyrolysis
[6] Kumar, S.; Kumar, G.; Avasthe, R. Applications of Biomass Derived Biochar in Modern Science and Techn
[7] Sakhiya, A. K.; Anand, A.; Kaushal, P. Production, Activation, and Application of Biochar in Recent Time. R
[8] Xu, X.; Zhang, H.; Zheng, J. Characterization and Functional Applications of Enriched Biochar. Environme
[9] GVR Report. Biochar Market Size, Share & Trends Analysis Report By Technology (Gasification, Pyrolysis
[10] Proximate Analysis and Moisture Content Determination. ScienceDirect.
[11] Volatile Matter and TGA Heating Process. ResearchGate.
[12] Ash Content Analysis. ScienceDirect.
[13] TGA Procedure Specifics for Bamboo. Springer.
[14] Cheng, C. H.; Sun, H.; Chen, T.; Wang, C. Effect of Pyrolysis Temperature on the Properties of Biochar D
[15] Wang, L.; Li, J.; Zheng, X. Production, Activation, and Applications of Bamboo-Derived Biochar. Renewab
[16] Liu, Z.; Ma, X.; Cheng, L. Chemical Activation of Biomass-Derived Biochar Using Potassium Hydroxide (K
[17] Xu, X.; Chen, X.; Liu, Z. Physical and Chemical Activation of Biochar for Enhanced Adsorption Capabilitie
[18] Zhang, H.; Zhu, H.; Liu, Y. Characterization and Adsorption Properties of Bamboo Biochar Activated with
[19] Phansiri, M.; Anuwongcharoen, N. Characterization and Properties of Activated Carbon from Tamarind Se

[20] Environmental Technology & Innovation. ScienceDirect.
[21] Patra, B. R.; Mukherjee, A.; Nanda, S.; Dalai, A. K. Biochar Production, Activation, and Adsorptive Applica
[22] Characterization of Biochar and Activated Carbon: Methods and Applications. Journal of Environmental M
[23] BET Surface Area Analysis in Biochar Characterization. Applied Surface Science 2019, 476, 925–934.
[24] SEM Analysis of Activated Biochar Derived from Agricultural Biomass. Microscopy and Microanalysis 201
[25] Microscopic and Structural Analysis of Biochar Surface Morphology. Carbon 2021, 178, 591–600.
[26] XRD Characterization of Amorphous Carbon Materials. Materials Science Forum 2022, 1056, 1–15.
[27] Crystallinity in Activated Biochar and Its Impact on Adsorption Efficiency. Journal of Carbon Research 202
[28] Thermogravimetric Analysis in Biochar Production and Stability Assessment. Thermochimica Acta 2019, 6
[29] Thermal Decomposition Profiles of Biochar from Various Feedstocks. Renewable and Sustainable Energy
[30] Biocarbons as Emerging and Sustainable Hydrophobic/Oleophilic Sorbent Materials for Oil/Water Separat
[31] Phothong, K.; Tangsathitkulchai, C.; Lawtae, P. The Analysis of Pore Development and Formation of Surf
[32] Mistara, E. M.; Alfatah, T.; Supardan, M. D. Synthesis and Characterization of Activated Carbon from Ba
[33] Environmental Technology and Innovations. Applications of Advanced Biochar Materials. Materials Today