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Experimental Investigation for Humic Acid Extraction from Parthenium Derived Biochar

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Abstract

The study involved converting Parthenium biomass into biochar using a portable pyrolyzer at a temperature range of 450 °C to 600 °C. The study conducted a comprehensive proximate analysis of Parthenium biomass, including moisture content, volatile matter, ash content, and fixed carbon, with each trial conducted three times for precision. The results showed a remarkably low moisture level of 4.61%, along with an ash content of 7.63%, volatile matter content of 74.69%, and fixed carbon content of 13.7%. The ultimate analysis of biomass C, N, H, S, O contents of 37.96%, 3.83%, 5.83%, 0.35%, 43.95%.The study also focused on extracting humic acid (HA) from Parthenium-derived biochar using a hydrothermal (alkaline) method, with two repeated trials. The results, presented in Table 4.5, showed that the dried HA weight varied from 5.50 g to 5.96 g from a 50-gram biochar sample, yielding an average of 5.73 g and HA percentages ranging from 11.00% to 11.95%.

Keywords: Proximate, pyrolyzer, parthenium biomass, biochar, hydrothermal, HA(humic acid)

Introduction

Parthenium hysterophorus (*Asteraceae*) is a noxious plant that naturally grows in North and South America and the West Indies but has spread to many locations around the world. This invasive plant is considered one of the worst weeds ever discovered, causing serious problems for biodiversity and human/animal health such as dermatitis, asthma, and bronchitis. The seeds of this weed are believed to have been introduced to India from the United States through the "Food for Peace" program, which has caused it to spread rapidly across the country [8, 13].
Biochar is a valuable carbonaceous material that has been used for thousands of years. It is produced through pyrolysis, which involves heating organic biomass such as wood, crop residues, or plant waste in a controlled environment with limited oxygen. The process transforms the biomass into a stable, carbon-rich substance with a highly porous structure. Biochar is typically produced by slow pyrolysis of biomass at a temperature range of 300-700 °C [9, 10].

Humic acid is a complex mixture of organic molecules that ranges in color from dark brown to black. It plays a vital role in maintaining soil health and promoting plant growth. Microorganisms in the soil break down organic matter, forming humic substances, which include humic acid, fulvic acid, and humin. Humic acid has a high cation exchange capacity (CEC), which enables it to bind and retain essential mineral nutrients in the soil, making them available for plants while preventing their leaching [11, 12]. Additionally, it contributes to improving soil structure, enhancing soil porosity, aeration, and water retention. Humic acid's pH buffering capacity stabilizes soil acidity and alkalinity, while it also helps in stabilizing organic matter, lowering its decomposition rate, and promoting long-term carbon storage in soil. These qualities make humic acid an essential soil conditioner, fertilizer component, and a subject of extensive research in agriculture and environmental science for its role in enhancing soil fertility and overall ecosystem health [2, 12].

Material and Methods

Humic acids (HAs) were extracted from biochar derived from Parthenium by adding a solution of alkaline (KOH and distilled water). The hydrochloric acid and potassium hydroxide used were purchased from Jain Chemicals Industry Co. Ltd. and Reagent Factory, respectively. The biochar was obtained from Parthenium and collected from the Department of Renewable Energy and Engineering at MPUAT.

Production of biochar using slow type pyrolysis system

Biochar production was conducted using Parthenium (*Parthenium hysterophorus*) as the primary source of feedstock. The samples were gathered from the CTAE farm of MaharanaPratap University of Agriculture and Technology. Biomass usually contains three main components: hemi-cellulose, cellulose, and lignin. Additionally, it contains a significant amount of carbon, hydrogen, nitrogen, and oxygen. Cellulose and hemi-cellulose, which are made up of simple sugar monomers, tend to break down at temperatures below 450 °C, primarily releasing light molecular weight compounds as pyrolytic vapours. On the other hand, lignin is an amorphous and hydrophobic polymer with a significant molecular weight. It also has numerous functional groups, including aromatic substructures of carbon. During pyrolysis, lignin decomposes gradually over a wide temperature range, contributing more to the production of biochar Several studies [1, 3, 4] have shown that when the temperature exceeds 500 °C during the production of biochar from biomass, there is a significant change in both its production and physiochemical characteristics. As a result, biochar is considered an effective adsorbent due to the transformation of its properties when generated at temperatures over 500 °C. [5, 4].

Portable type Pyrolysis system

A pyrolysis system that is portable in nature was utilized to produce biochar. The system consists of an inlet, pyrolysis reactor, gas pipeline, flare, and outlet system, which can be seen in Figure. The capacity of this portable system is to produce 5-6 kg of biochar per day.

Parthenium was used as the feed material for the process. The reactor temperature varied from 450-650 °C. The biochar was produced using a slow pyrolysis process, which involved a prolonged residence time at high temperatures. Once the reactor cooled to room temperature, the biochar was retrieved. The biochar samples were then subjected to laboratory analysis to assess their various characteristics.

The performance of the portable pyrolysis system was evaluated by calculating the mass yield of the generated biochar.

Proximate analysis

The proximate analysis of biomass encompasses the measurement of moisture content, volatile matter, ash content, and fixed carbon. These individual measurements are comprehensively discussed in the following subsections.

Moisture content

The moisture content of the sample can be calculated using the following formula:

$$\mathrm{M.C}(\%) = \frac{w_1 - w_2}{w_1} \times 100$$

Where,

W_1 = weight of sample before drying, g;

W_2 = weight of sample after oven drying, g;

Volatile matter

$$\mathrm{V.M}(\%) = \frac{w_i - w_f}{w_i} \times 100$$

Where,

W_i = initial weight

W_f = final weight

Fixed carbon

The fixed carbon content is calculated by subtracting the moisture content, volatile matter, and ash content values from 100 percent.

$$\mathrm{F.C.}(\%) = 100 - (\mathrm{MC} + \mathrm{VM} + \mathrm{AC})$$

Ultimate analysis

The ultimate analysis of the selected biomass material will be conducted following established standards. This analysis will involve determining the percentage of carbon, nitrogen, hydrogen, and oxygen present in the sample.

Humic Acid

Procedure

- 500 ml of Alkaline solution was prepared using KOH and distilled water.
- Then, the 50 gm of biochar was mixed in the alkaline solution with the help of stirrer and placed into oven (130-190 °C). After the reaction was finished, the flask was naturally cooled at room temperature (12-24 hours).
- The supernatant was separated from residues by centrifugation (4000 rpm for 20 minutes). After centrifugation, the supernatant were filtered using filter paper and removed. This supernatant is called humin which is non-soluble in alkaline solution.
- The remaining liquid solution were acidized to pH < 2 with HCL. Further supernatant was separated from liquid solution by centrifugation and dried in an oven at 60 °C. The obtained dried materials were HA
- Remaining solution called fulvic acid.

Results

Proximate analysis of biomass

The moisture level in the parthenium biomass was found to be low, registering at only 4.61%. The biomass's proximate properties showed an ash content of 7.63%, a volatile matter content of 74.69%, and a fixed carbon content of 13.7%.

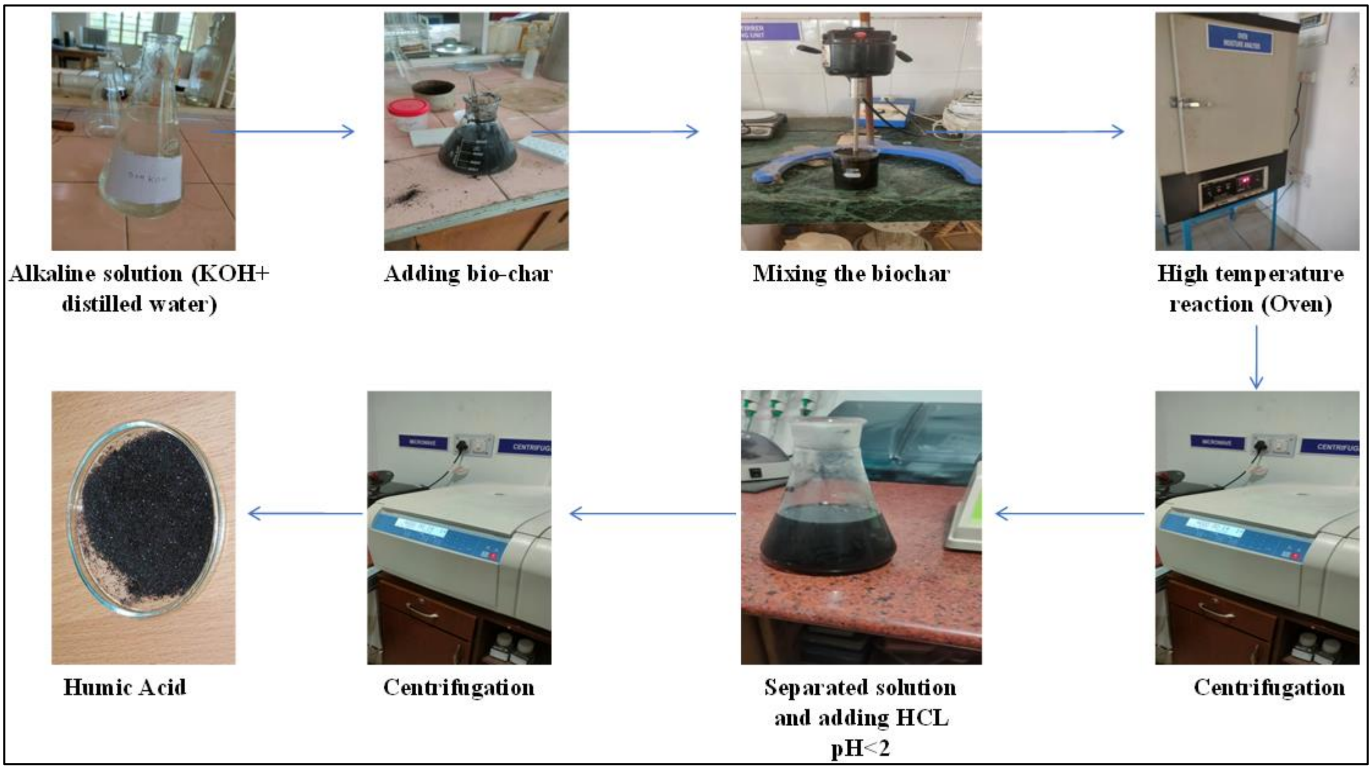

Fig1: Flow Chart ofHumic Acid (HA) Extraction process

Table1: Proximate analysis of biomass

Properties	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
Values	4.61	74.69	7.63	13.07

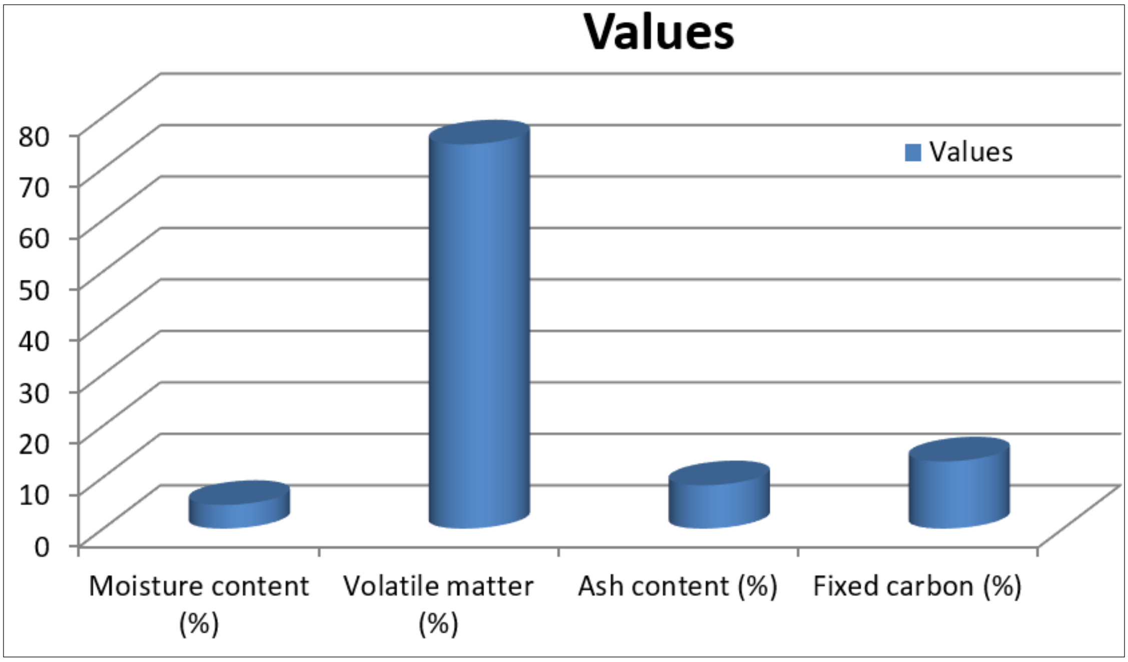

Fig2: Proximate analysis of biomass

Ultimate Analysis

Table 2 shows the total content of carbon (C), hydrogen (H), nitrogen (N), sulphur (S) and oxygen (O) of the selected biomass parthenium.

Table2: Ultimate analysis of biomass

Ultimate Analysis(%)	C	N	H	S	O
Value	37.96	3.83	5.83	0.35	43.95

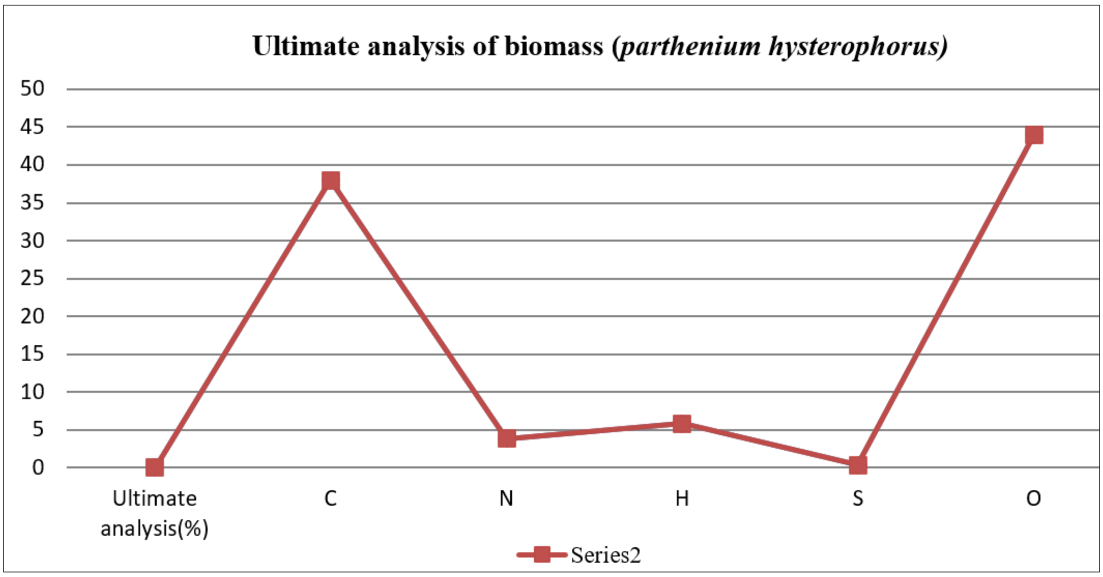

Fig3: Ultimate analysis of biomass

Humic Acid

Humic acid (HA) was extracted from Parthenium-derived biochar using an alkaline method. The experiment was repeated twice to ensure accuracy. The data collected included the wet weight of HA, the dried weight of humic acid, and the yield percentage, which is presented in table3.

Table 3: Humic acid yield

Experiments	First Experiment	Second Experiment	Average yield
Weight (%)	5.50	5.95	5.73

The yield results indicated that the dried weight of humic acid varied between 5.50 g and 5.96 g when extracted from a 50-gram sample of Parthenium-derived biochar. The average dried weight was 5.73 g, and the yield percentages of HA ranged from 11.00% to 11.95%.

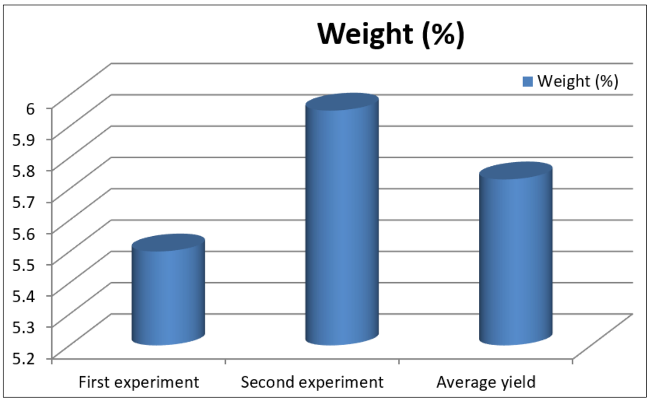

Fig4: Humic acid yield

Conclusion

In this study, important parameters including moisture content, volatile matter, ash content, and fixed carbon were evaluated through proximate analysis of parthenium biomass. The testing was conducted with great accuracy, and the results showed notably low moisture levels at 4.61%, with 7.63% ash content, 74.69% volatile matter, and 13.7% fixed carbon. These findings are consistent with previous research by Shafiq *et al.* [7, 8]. The high ash content indicates the need for careful consideration and optimization of biomass properties to enhance the efficiency and cost-effectiveness of conversion processes, particularly at higher pyrolysis temperatures.

The ultimate analysis of the biomass C,N,H,S,O content showed values of 37.96%, 3.83%, 5.83%, 0.35%, 43.95%.

In this study, humic acid (HA) was successfully extracted from Parthenium-derived biochar using a hydrothermal (alkaline) method. Two trials were conducted for precision, and the data encompassing wet and dried weights of HA, along with yield percentages, was systematically collected and presented in Table 3. The results demonstrated consistent dried HA weights ranging from 5.50 g to 5.96 g, with an average of 5.73 g, and corresponding yield percentages between 11.00% and 11.95%.

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