RESEARCH ARTICLE OPEN ACCESS

Adsorption Characteristics of Activated Carbon Produced from Slow Pyrolysis of Cajanus Cajan Stalk

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Abstract:

The models produced from the calibrations were used to predict these physical properties in a test set of activated carbon samples made from diverse source sources. A sample was heated to different temperatures (200°C, 300°C, 400°C, and activated carbon) to track changes in the adsorption's properties. The predicted values and projected values often agree well and give good results for the agricultural waste of Cajanus Cajan. Our experiment yielded entirely satisfactory IV and MB values of 726 mg/g and 175 mg/g, respectively. MB and IV adsorption tests may yield more information with this method than is generally achievable with this material.

Key Words: Pore volume, MB dye adsorption, Iodine adsorption, specific surface area, and AC.

I. INTRODUCTION

Narsinghpur grows Cajanus Cajan stalks (Madhya Pradesh). Other studies used liquid-phase iodine adsorption to assess sludge-based activated carbons [4]. The adsorption of aqueous I2 may quickly determine the surface area of activated carbons with pores bigger than 1 nm. [4] The American Society for Testing and Materials' standard method was used to compute the iodine value, the quantity of iodine absorbed per gram of activated carbon at 0.02 N. (ASTM 2006). Experiment means were shown. Three identical samples determined standard deviation. The iodine value best describes activated carbon performance. Activity level (a higher number indicates a higher degree of activation). Displays micropore content (0–20 A).

Methylene number is a characteristic of activated carbon (AC) that may be used to determine the material's capacity to remove color (adsorption properties in solutions). With the molecular formula C16H18N3SCl, methylene blue is a heterocyclic aromatic chemical substance. [1] It may be used in various disciplines, including biology and chemistry. When dissolved in water, it transforms from a solid, flavorless, dark green powder to a blue solution. Each methylene blue molecule in the hydrated state is paired with three water molecules. [10]

II. Materials and Procedures

2.1 Preparation of Biomass Sample-

The Cajanus Cajan stalk was dried in the sun before being divided into little pieces by the cutter. For thermal treatment of the Cajanus Cajan biomass, the tiny Cajanus Cajan stalks were placed in the semi-batch pyrolysis reactor. At three different temperatures, pyrolysis was performed, 200, 300, and 400 °C, to treat Cajanus Cajan biomass. After the heat treatment, allow the sample to be removed from the reactor and cool before storage. The sample was crushed into an extremely fine powder using a mortal pestle. The biochar samples were then dried in an overnight hot, air-dry oven and cooled in a desiccator to make them moisture free before being used for iodine and methylene blue measurements.

2.2 Pyrolysis:

Slow pyrolysis is used to increase the yield of solid products from the thermal treatment of biomass to produce new materials like biochar and energy.

Organic material is slowly heated without oxygen to undergo slow pyrolysis. Some of the organic material's volatile components evaporate rather than burn, leaving behind charcoal, generally made up of 80-85% carbon compound and gases such as CO2, CO, CH4, H2, and bio-oil.

2.3 The biomass of Cajanus Cajan stalks is pyrolyzed:

First, we remove the stalk from the Cajanus Cajan plant and dry it in the open air with sunshine to remove any moisture. Cut the Cajanus Cajan stalk into small pieces (cut it into small pieces, so the heat flows into the stalk easily, and we get the product as we want it), then place it in the reactor and do its thermal treatment at independent temperatures, such as 200°C, 300°C, and 400 °C, after which when this pyrolysis process is complete if this occurs, let the system cool down, and after cooling, remove the bio-char sample from the reactor.

Chemical Activation for the Production of Activated Carbon

After being reduced to a powder with a particle size of 0.20-0.70 mm, the leftover material from the supercritical extraction of strawberry seeds was dried before being impregnated with acetic vinegar to activate the chemicals. The sample was dried after 24 hours to ensure full acid evaporation. Following that, the sample was pyrolyzed in a quartz reactor heated by a vertical furnace using argon at a flow rate of 150 mL/min at 600 °C at a heating rate of 10 °C/min. The sample was held at the desired temperature for two hours before being cooled in an inert gas. The activated carbon that was obtained was designated as AC.

2.4 Activated carbon and biochar have distinct characteristics:

Thermal degradation of the Cajanus Cajan stalk biomass occurs between 200 and 400 °C, with a recovery rate of 35 to 40% for biochar and 50 to 70% for carbon. We subjected the biomass to treatments for 15 minutes at residual temperatures of 200, 300, and 400 °C. We observed changes in the biomass's characteristics and adsorption using chemical titration methods such as IV and MB adsorption.

First, the IV and methylene blue (MB) dye adsorption tests are used to gauge the effectiveness of the activated carbon. This study's primary goal is to determine the ideal activation factor mixture (precursor, temperature, activation agent, and degree of heat treatment) to produce the best result from Cajanus Cajan stalk. Several procedures and actions are sequentially carried out to accomplish the final aim.

The impact of temperature on Cajanus Cajan char activation was investigated. After an hour of heating in the presence of nitrogen (N_2) and carbon dioxide (CO_2) or without oxygen (O_2), three temperature levels—200, 300, and 400 °C—are used, with 900 °C for each level. After that, MB adsorption is used to assess the heat-treated Cajanus Cajan chars.

2.5 Iodine number or value:

Procedure–

The American Society for Testing and Materials' standard technique calculated the amount of iodine absorbed per gram of activated carbon at 0.02 N equilibrium (ASTM 2006). 2 drops of starch solution in a conical flask with 10 ml of 0.1 N iodine solution standardized it. Light-yellow iodine solution became blue. The solution was titrated with 0.05 N sodium thiosulphate until colorless. Burette readings are blank (B). Activated carbon weighed exactly 0.2 g. It filled the dry iodine flask. 40 cc of 0.1 N iodine solution followed. A 4-minute shaking of the flask followed by filtering. In a dry flask, 10 cc of the filtrate was titrated against a standard sodium thiosulphate solution with starch as an indicator. [6]

The following formulas estimate the iodine value:

Iodine Value = C * Conversion factor,

Conversion factor = 127 * normality of iodine * 40 / Wt. of Sample blank reading,

C = (B–A).

2.6 Methylene Blue Number / Methylene Value:

0.05 g of activated carbon was agitated with 100 ml of 100 ppm MB solution at 200 rpm for three hours to calculate its methylene blue number. After filtering the solution using Whatman 41 filter paper, a UV/visible spectrophotometer assessed absorbance at 664 nm to determine the remaining methylene blue content.

$$MB_N\,(mg/g) = \frac{(C_o - C_e) \times V}{M}$$

Calculations-

Co is the initial concentration of MB (mg/L),

Ce is the equilibrium concentration of MB (mg/L),

M is the mass of the adsorbent (in grams),

V is the volume of the solution (in Liter),

MBN is the Methylene Blue Number.[12]

Here, we have looked at the kinetics of adsorption and the isotherm of adsorption for biomass, biochar, and activated carbon.

2.7 Study of adsorption kinetics

The adsorption kinetics of activated carbon is investigated using three distinct models. There are three models: a pseudo-first order kinetic model, a pseudo-second order kinetic model, and an intra-specific diffusion model [8].

2.8 Adsorption isotherm model investigation

This section investigates two alternative models to research the adsorption isotherm models. The models are the Langmuir isotherm model and the Freundlich isotherm model [5].

Adsorption isotherms

The design of adsorption systems depends critically on understanding adsorption isotherms. Equilibrium between the concentrations of the liquid phase (free solution) and the solid phase (solutes linked to adsorbents) is achieved in a batch system. Adsorption isotherms established at a set temperature can be used to characterize it. Adsorption equilibrium descriptions are often well provided by Langmuir and Freundlich isotherms. The Langmuir isotherm, stated in its linearized form as Ceq/(X/m) = 1/ Kb + Ceq, is the pertinent model to describe the adsorption process.

Where X/m (mg/g) denotes the adsorption density, Ceq (mg/L) is the equilibrium adsorbate concentration in solution, b (mg/g) denotes the adsorption capacity corresponding to full monolayer coverage, and K (L/mg) denotes the Langmuir constant linked to the energy of adsorption. The Langmuir constants b and K result from the linear behavior of Ceq/(X/m) vs. Ceq. Methylene blue's adsorption isotherms were investigated on the samples made (200, 300, 400, and activated carbon), and they were compared to purchased Merck's powdered activated carbon of MB 180 (mg/g). You can see that the Merck-activated carbon and the chemically activated biochar had the most significant values for the adsorbed concentrations. In contrast, the untreated natural biochar had the lowest values. The Langmuir constants were derived from the fitting straight-line equations with strong correlation coefficients (R2 = 0.99). The highest values from the adsorption capacity (b) measurements for the activated sample (AC) are unmistakable proof that the chemical activation process significantly improves the absorptive ability of the Bio-char, going from 4.19 mg/g for the untreated plant up to 175 mg/g for the chemically activated plant, which represents a six-fold increase in adsorption capacity.

3. Findings and Discussion

We have observed alterations in the biomass and increased adsorption in pre-treated biomass by the adsorption capacity of mg of iodine per gram of carbon.

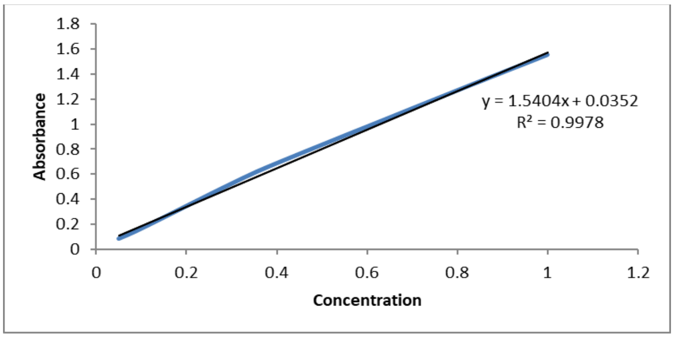
3.1 Iodine value for biomass processed at various temperatures-

Table -1: IV and MB Value of bio-char.

IV and MB Value for bio-char processed at various temperatures			
S.No.	Temperature (°C)	IV Value (mg/g)	MB value (mg/g)
1.	200	378.48	4.194
2.	300	449.79	8.92
3.	400	578.99	12.89
4.	Activated Charcoal	726.53	175.50

A. Increase the surface area of biochar according to biomass. The micropores of the treated biomass increase the adsorption capacity of iodine and methylene blue dye according to increasing order like this-

B. AC>400>300>200



C.

Chart -1: Methylene Blue at different temperature treated biomass-Calibration Curve

3.3 Comparative of Rice Husk Activated Charcoal:-

We have seen that the adsorption (Iodine and Methylene blue values) in Cajanus Cajan stalk biomass, bio-char, and activated carbons are more satisfactory than the other rice husk bio- and activated biochar.

Sr. No.	**Rice Husk**	**Temp.**	**IV Value, (mg/g)**	**MB Value, (mg/g)**
1	Rice Husk Activated Carbon	420	244.5	-
2	Rice Husk Activated Carbon	520	265.5	-
3	Rice Husk Activated Carbon	900	205.5	-

4	Rice Husk Carbon	900	228	80
5	Rice Husk Carbon (NaOH, treated)	-	254	-
6	Rice Husk Activated Carbon	700	510.82	61.1
7	Rice Husk	-	178	52.7

IV. Conclusion

Iodine and methylene blue levels are determined using inexpensive, straightforward processes that don't require expensive machinery. Also, compared to what is typically achieved with this material, the suggested approach enables more significant information to be extracted from methylene blue and iodine adsorption experiments. In the absence of oxygen, increasing the penetration temperature causes the biochar's porosity to rise and the adsorption of iodine and methylene blue dye to rise directly proportionate to the temperature. The IV and MB values of activated carbon are 726 mg/g and 175 mg/g, respectively. The considerable methylene blue dye adsorption demonstrated that this extraordinary powdered species is suited for waste water treatment and the adsorption of reasonably big molecules like dyes.

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