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Pressurized CO_2 activation of waste jute stick for enhanced CO_2 capture applications

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1. ABSTRACT

Activated carbon could be used for CO_2 capture, although its effectiveness depends on several factors, including pore structure, surface area, and the presence of certain functional groups. In this study, several activated carbons were synthesized from novel waste biomass (i.e. jute stick) by utilizing CO_2 with a novel pressure varying method. Remarkably, elevated CO_2 pressures during the activation process resulted in increased activation yields and improved porosity in the synthesized activated carbons. Additionally, these activated carbons exhibit exceptional CO_2 adsorption capacities, rendering them viable candidates for utilization in the major CO_2 emission sources, notably industrial exhaust streams.

2. INTRODUCTION

The escalating levels of carbon dioxide (CO_2) in the atmosphere, stemming from human activities such as the combustion of fossil fuels, represent a significant catalyst for global climate perturbations [1,2]. Thus, the imperative to address CO_2 emissions through efficacious capture and storage methodologies is pivotal for the sustenance of environmental equilibrium. Among these methodologies, adsorption-based CO_2 capture utilizing porous solid sorbents has emerged as a promising solution due to its potential for excellent efficiency, lower energy consumption, and simplified operational modalities compared to alternative capture techniques [3,4].

Within the spectrum of investigated sorbent materials, activated carbon has commanded considerable attention owing to its extraordinary porosity, excellent surface area, customizable pore structure, and relatively economical procurement. Activated carbons can be derived from diverse carbonaceous precursors, including agricultural residues, coal, and biomass, rendering them appealing from both fiscal and environmental perspectives [5]. Moreover, the intrinsic chemical robustness and thermal resilience of activated carbons augment their suitability for CO_2 capture endeavors.

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In this study, several activated carbon (AC) samples were synthesized from waste jute stick which is abundandly available in Indian subcontitent. These AC samples were characterized for viability to be employed in CO_2 capture applications. Activation parameters such as temperature, duration, CO_2 pressure, and flow rate were varied to optimize the porous properties.

3. METHODOLOGY

The activation chamber was thoroughly designed using corrosion-resistant Inconel material to ensure both the safety and the purity of the resulting activated carbon. The activation temperature and pressure were varied between 700 to 1000°C and 1 to 10 bar, respectively. The optimum condition for highest porosity and yield was observed at 800°C temperature, 10 bar pressure, 1 hour duration, and 50 ml/min exhaust gas flow rate.

The CO_2 adsorption capacity of the synthesized sample was then investigated using a 3Flex apparatus at 0°C from zero to 110 kPa pressure range.

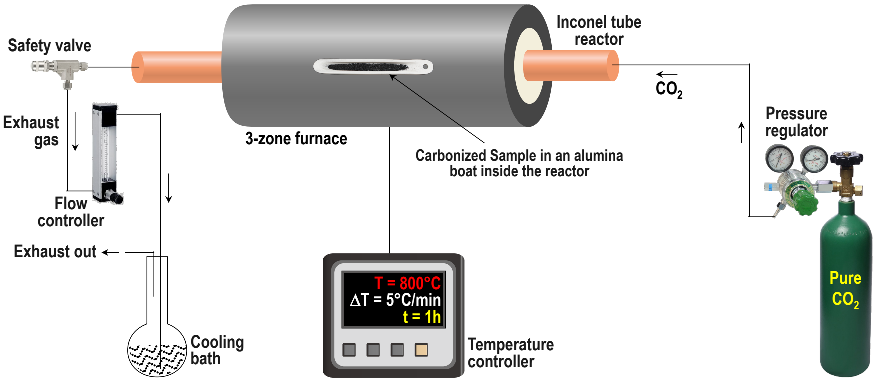

Figure 1. Schematic of the pressure regulated CO_2 activation system to for activated carbon synthesis from Bangladeshi Jute Stick (BJS).

4. RESULTS

The porous properties of the synthesized activated carbon were determined from N_2 adsorption isotherm obtained from at 77 K. The characterization results are shown in Table 1.

Table 1. Porous Properties of BJS–C600–A800–10.0bar–1h activated carbon.

Parameters	Values
Total surface area, S_{total} [$m^2\ g^{-1}$]	844
Micropore volume, $\upsilon_{\mu p}$ [$cm^3\ g^{-1}$]	0.414
Activation yield, Y [%]	57.40

The synthesis parameters, including activation time, temperature, flow rate, and CO_2 pressure during activation, were methodically varied to optimize the porous properties and enhance the activation yield. As illustrated in Table 1, the results exhibit considerable porous characteristics of the synthesized activated carbon, coupled with an impressive activation yield of 57.4%. The refined parameters for the preparation of the activated carbon are as follows: Activation temperature (T_{act}) set at 800°C, activation time (t_{act}) maintained at 1 hour, and CO_2 pressure (P) regulated at 10 bar. These optimized conditions represent a significant advancement in tailoring the activated carbon for various applications. Besides, few researchers have explored the activation of pressurized waste biomass. The results of our study are superior to the studies reported by Yi et al. [6], Liu et al. [7], and Bai et al. [8].

The CO_2 adsorption capacity of the synthesized sample was experimentally investigated, the results of which are graphically depicted in Figure 2. The data obtained from the measurements reveal an exceptionally high adsorption capacity of 141 mg of CO_2 per gram of activated carbon. Additionally, the desorption curve exhibits minimal hysteresis, indicating that all adsorbed CO_2 can be efficiently recovered for utilization whenever necessary. This remarkable performance underscores the potential of the synthesized activated carbon in various environmental and industrial applications.

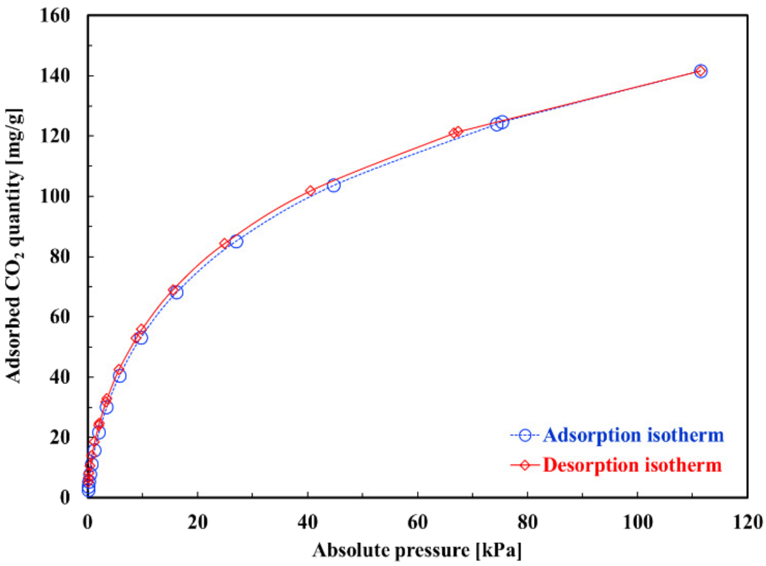

Figure 2. CO_2 adsorption/desorption isotherms at 273K of BJS–C600–A800–10.0bar–1h activated carbon.

5. CONCLUSIONS

The physical activation of waste jute sticks was carried out within a novel high-pressure CO_2 environment. The synthesized activation carbon showed an impressive surface area of 844 m^2 g^{-1} accompanied by a remarkable activation yield of 57.4%. Further exploration revealed an exceptional CO_2 adsorption capacity of 141 mg per gram of activated carbon, a figure that holds significant promise for industrial CO_2 capture and a multitude of environmental applications.

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