POROUS CARBON MATERIALS DERIVED FROM SPENT COFFEE GROUNDS WITH POTENTIAL APPLICATION IN CO_2 CAPTURE

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INTRODUCTION

Anthropogenic CO_2 emissions continue to rise due to fossil fuel combustion and industrial activities, increasing the demand for efficient carbon capture technologies (Friedlingstein et al., 2024). Among the available approaches, porous carbon materials have attracted considerable attention because of their low cost, thermal stability, and tunable surface chemistry (Sadiq et al., 2024).

Spent coffee grounds (SCG), with an estimated global generation of approximately 6–10 million tons per year, represent an abundant carbon-rich residue with potential application in sustainable adsorbent production. In this context, hydrothermal carbonization (HTC) represents an attractive route for converting wet biomass into carbonaceous materials, while amine functionalization with TEPA can enhance CO_2 affinity through nitrogen-containing active sites (Li et al., 2024).

METHODOLOGY

Synthesis and characterization steps are summarized below.

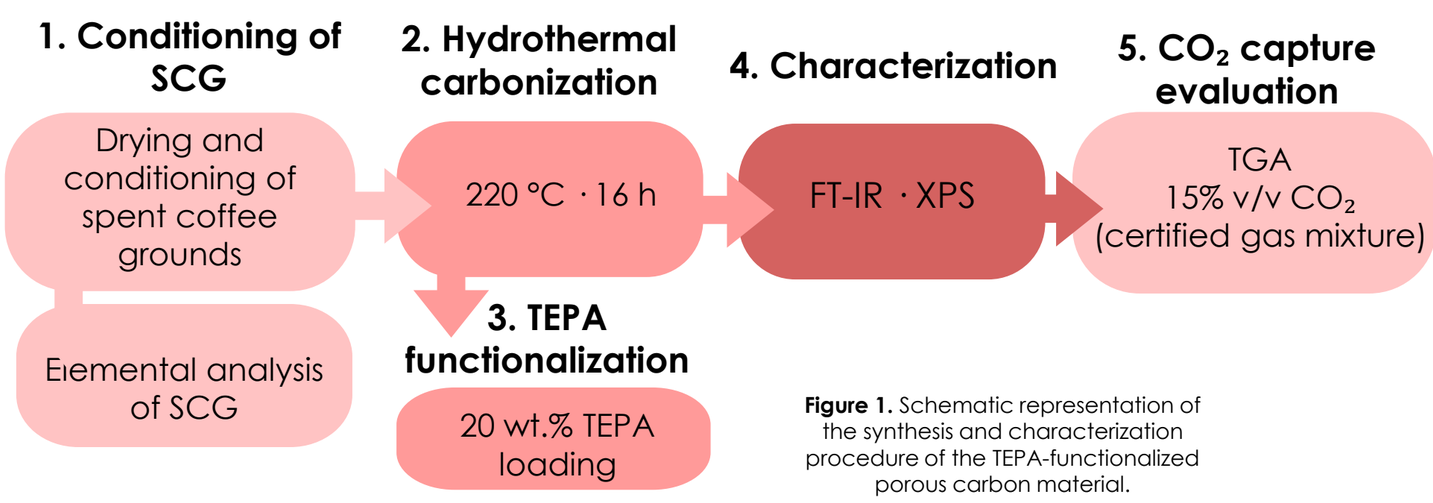

Figure 1. Schematic representation of the synthesis and characterization procedure of the TEPA-functionalized porous carbon material.

RESULTS

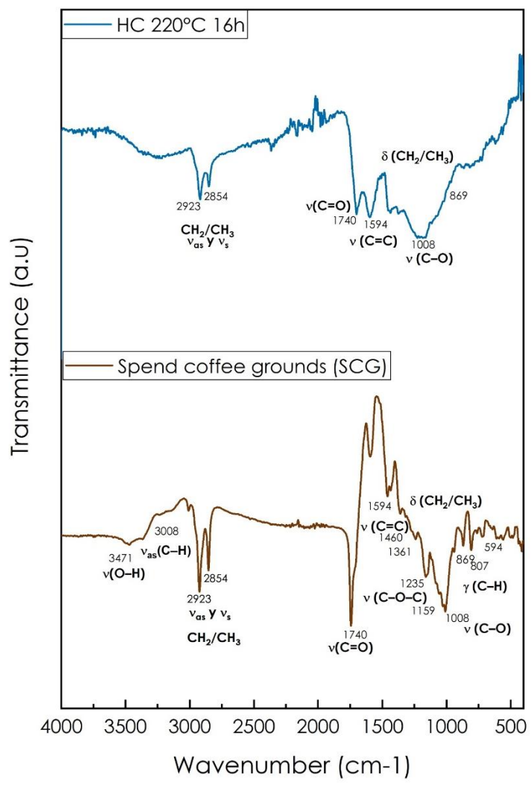

Figure 2. FTIR spectra of spent coffee grounds before and after hydrothermal carbonization at 220 °C for 16 h.

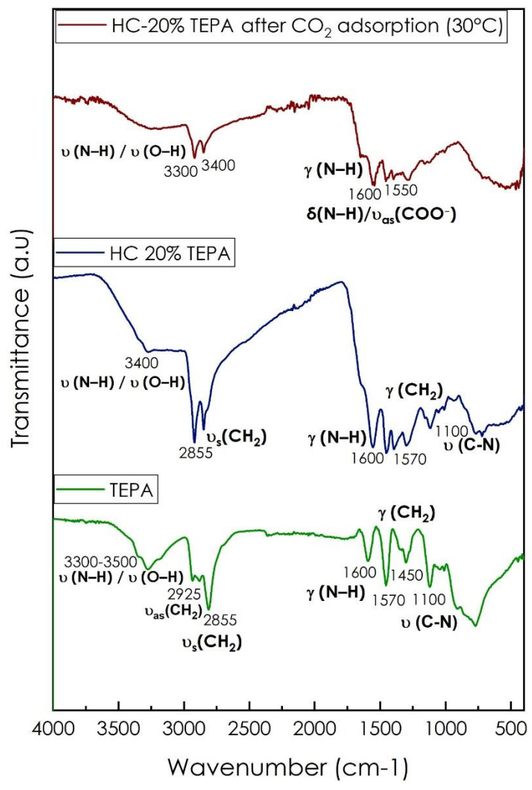

Figure 3. FTIR spectra of TEPA, TEPA-functionalized hydrochar before CO_2 adsorption, and post-adsorption material at 30 °C

FTIR and XPS analyses showed that hydrothermal carbonization at 220 °C for 16 h promoted the development of aromatic carbon structures and oxygen-containing functional groups in the obtained hydrochar. XPS deconvolution revealed the presence of C–C/C=C, C–O/C–N, pyrrolic nitrogen, and oxygenated surface functionalities after TEPA incorporation.

Thermogravimetric CO_2 adsorption experiments performed under a 15% v/v CO_2 (certified gas mixture) showed the best adsorption performance at 30 °C. Additionally, FTIR analysis after adsorption suggested the formation of carbamate species, confirming the interaction between CO_2 molecules and amine groups on the hydrochar surface.

The main results obtained in this work are presented below.

Table 1. Elemental analysis of spent coffee grounds

CARBON (C) %	HYDROGEN (H) %	NITROGEN (N) %	SULFUR (S) %	OXYGEN (O) %
52.29	6.81	2.76	0	38.06

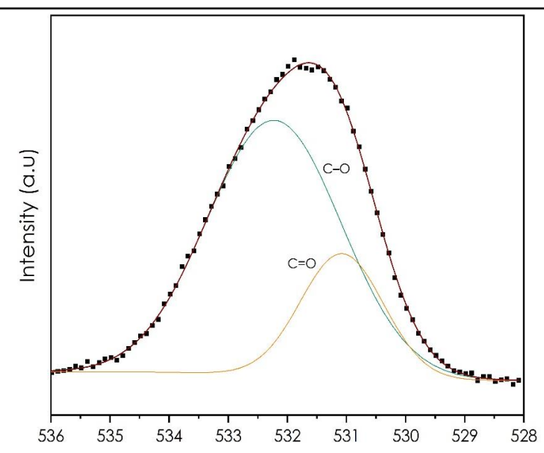

Figure 4. High-resolution XPS spectrum of the O1s region of the hydrochar obtained by hydrothermal carbonization at 220 °C for 16 h.

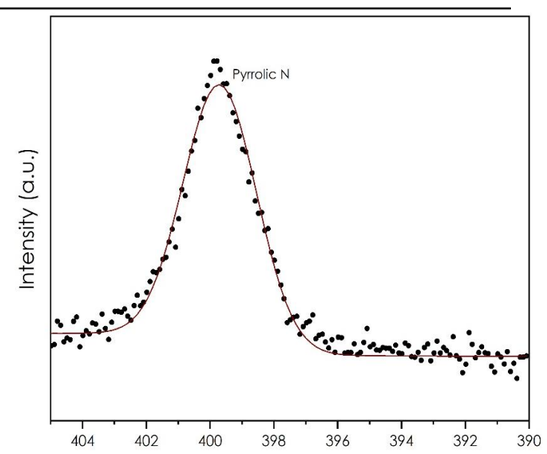

Figure 5. High-resolution XPS spectrum of the N1s region of the hydrochar obtained by hydrothermal carbonization at 220 °C for 16 h.

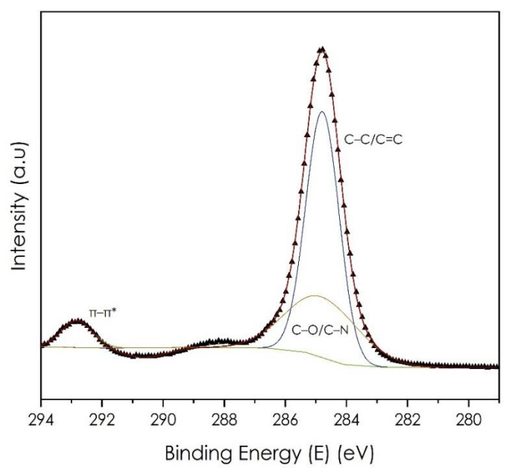

Figure 6. High-resolution XPS spectrum of the C1s region of the hydrochar obtained by hydrothermal carbonization at 220 °C for 16 h.

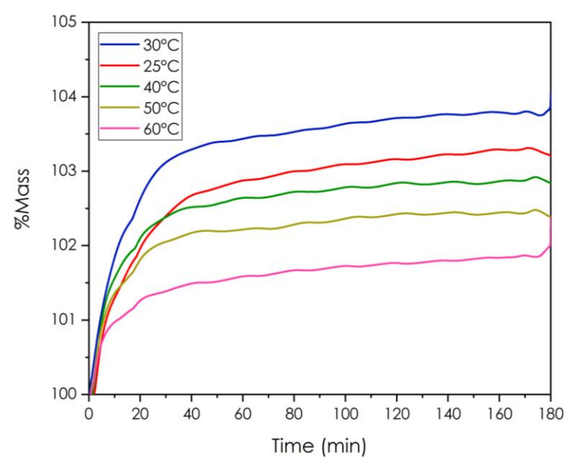

Figure 7. Thermogravimetric CO_2 adsorption profiles of HC-20% TEPA under a 15% v/v CO_2 certified gas mixture at different adsorption temperatures.

CONCLUSION

Spent coffee grounds have potential application in CO_2 capture when subjected to surface modification processes such as hydrothermal carbonization and functionalization with amine species. In this work, TEPA functionalization promoted the incorporation of nitrogen-containing surface groups, enhancing the interaction between the material surface and CO_2 molecules. The best adsorption performance was observed at 30 °C, likely due to a favorable balance between CO_2 diffusion and the stability of amine–CO_2 interactions, whereas lower temperatures may limit mass transfer and higher temperatures can reduce adsorption efficiency due to the exothermic nature of the adsorption process.

ACKNOWLEDGEMENTS

C. García González thanks to SECIHTI for her personal scholarship support. This work was financially supported by the SECIHTI CF-2023-I-109 project and DGAPA Grant IN114526.

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