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Synthesis of Sugar Beet Pulp-Derived Activated Carbon for CO_2/CH_4 Separation from H_2-Rich Syngas

ABSTRACT

Türkiye is one of the top producers of sugar beets pulp (SBP) worldwide with a 7-8 million tons of fresh pulp produced every year. In order to advance waste biomass valorization aligned with "zero-waste" strategies. Activated carbons derived from SBP, an abundant agro-industrial waste, were synthesized via one-step and two-step KOH activation. The effects of activation strategy, biomass:KOH ratio (1:1, 1:2, and 1:3), and activation temperature (700-900 ºC) on structural properties and gas adsorption performance were systematically investigated. will be used to improve the separation efficiency, purity of hydrogen, and hydrogen-rich gas production by biomass gasification and steam reforming processes. The synthesized ACs were characterized using XRD, FT-IR, SEM, and BET analysis. As a result, the two-step activated carbons exhibited significantly higher CO_2 adsorption capacities than the one-step samples. The highest uptake was achieved by Two-AC-2-800 (5.2 mol/kg at 2 bar and 25 ºC), followed by Two-AC-1-800 (4.9 mol/kg), whereas the best one-step sample, One-AC-1-600, reached only 3.4 mol/kg, while excessive KOH loading significantly reduced adsorption performance, with One-AC-3-800 exhibiting only 0.8 mol/kg and Two-AC-3-800 only 2.5 mol/kg. CO_2 adsorption is observed to be very high compared to CH_4 and H2 adsorption levels from 0-6 bar at 25 ºC. The adsorption of CO_2 increases from 1.4 mol/kg at 1 bar to about 8.9 mol/kg at 6 bars while that of CH_4 is 4.6 mol/kg and H2 < 0.4 mol/kg.

Keywords: Sugar beet pulp, Activated carbon, CO_2 adsorption, Biomass valorization, Zero-waste strategy

BIOGRAPHY

Salahaldeen M. A. Aljafreh is a PhD Candidate in the Department of Chemical Engineering at Eskişehir Technical University, Türkiye. His research focuses on sustainable energy and environmental technologies, particularly biomass-derived activated carbons, adsorption-based gas separation, hydrogen purification, and carbon capture. His work includes Pressure Swing Adsorption (PSA) and Vacuum Pressure Swing Adsorption (VPSA) for hydrogen purification and methane upgrading, adsorption isotherms and kinetics, biomass gasification, biodiesel and green diesel production, and alkaline water electrolysis systems.