

Plant-based calcium silicate from rice husk ash: A green adsorbent for free fatty acid recovery from waste frying oil

Abstract

Driven by the urgent need for a solution to tackle the surge of rice husk (RH) and waste frying oil (WFO) waste accumulation at a global scale, this report highlights the use of calcium silicates (CS) extracted from acid-pre-treated rice husk ash (RHA) for free fatty acid (FFA) removal from WFO as conventional RHA shows limited FFA adsorption performance. A novel alkaline earth silicate extraction method from acid-pre-treated RHA was outlined. The structural and behavioural attributes of the synthesised CS were identified through BET, SEM-EDS, and XRD analyses and compared to those of RHA. Notable morphology and structural modification were determined, including reducing specific surface areas, mitigating from amorphous to crystalline structure with regular geometric forms, and detecting Si–O–Ca functional groups exclusive to CS adsorbents. A comparison study showed superior lauric acid (LA) adsorption performance by CS adsorbents over acid-pre-treated RHA, with a significant increase from 0.0831 ± 0.0004 mmol LA/g to 2.5808 ± 0.0011 mmol LA/g after 60 min. Recognised as the best-performing CS adsorbent, CS-1.0 was used for further investigations on the effect of dosage, LA concentration, and temperature for efficient LA adsorption, with up to 100% LA removal and 5.6712 ± 0.0016 mmol LA/g adsorption capacity. The adsorption isotherm and kinetic studies showed LA adsorption onto CS-1.0 followed Freundlich isotherm with $K_F = 0.0598$ mmol^(1-1/n) L^(1/n) g⁻¹ & $Q_{e,cal} = 3.1696$ mmol g⁻¹ and intraparticle diffusion model with $k_{id} = 0.1250$ mmol g⁻¹ min^{0.5} & $C_i = 0.9625$ mmol g⁻¹, indicating rapid initial adsorption and involvement of carboxylate end of LA and the calcium ions on the CS-1.0 in the rate-limiting step. The high equilibrium adsorption capacity and LA adsorption rate indicated that the proposed CS-1.0 adsorbent has excellent potential to recover FFA from WFO effectively.

Keywords

Adsorption; Calcium silicate; Environmental remediation; Free fatty acids; Rice husk; Waste frying oil