

KCl/KOH-Activated Bakery Fly Ash as a First-Time Sorbent for Pharmaceutical Detoxification: Amitriptyline Adsorption in Simulated GI Fluids

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1 Background

Activated carbon (AC) is the gold standard for medical detoxification, but its efficiency depends on surface area, porosity, and functional chemistry.

Fly ash, a low-cost industrial waste, has potential as a carbon precursor, yet remains underutilized for pharmaceutical-grade sorbents.

Traditional activation methods often yield inconsistent quality for drug adsorption applications.

2 Problem

No reports so far on bakery fly ash as a precursor for medical-grade AC.

Existing fly ash AC suffers from low porosity, poor surface chemistry, and limited adsorption performance for emergency drug detoxification.

Gap: A sustainable, cost-efficient strategy to transform bakery waste into high-capacity sorbents for pharmaceutical detox is still missing.

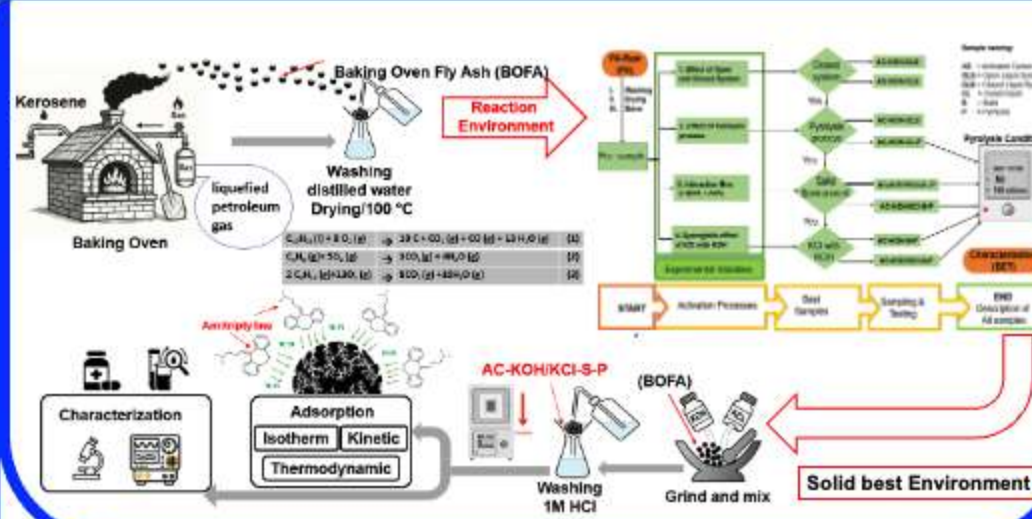
3 Aim

This study explores whether synergistic KCl/KOH co-activation can unlock the full potential of bakery fly ash.

Goal: To engineer high-surface area AC with enhanced affinity for amitriptyline in simulated gastric and intestinal fluids.

Innovation: First demonstration of bakery fly ash → medical detox sorbent, offering a waste-to-wealth route for pharmaceutical applications.

4 Methodology



5 Results & Characterization

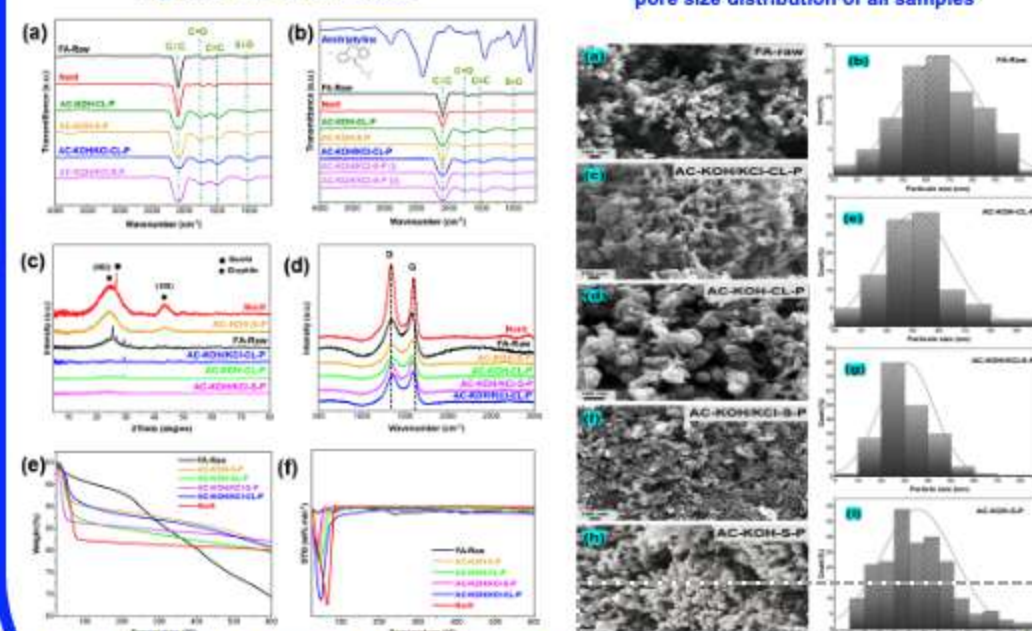
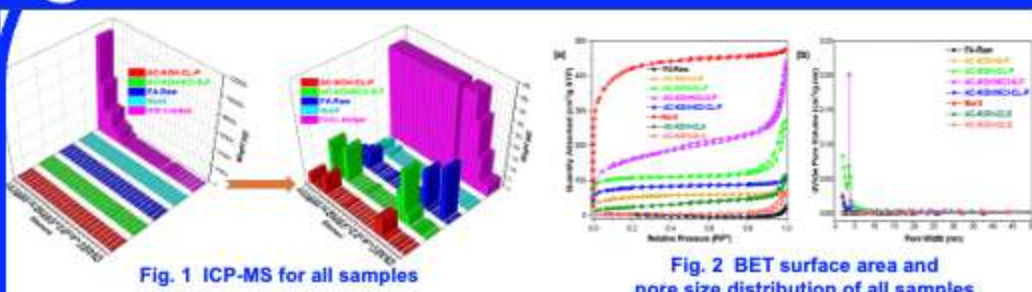


Fig. 3 (a, b) FTIR before and after Adsorption (c, d) XRD and Raman, (e, f) TGA and DTG for all samples

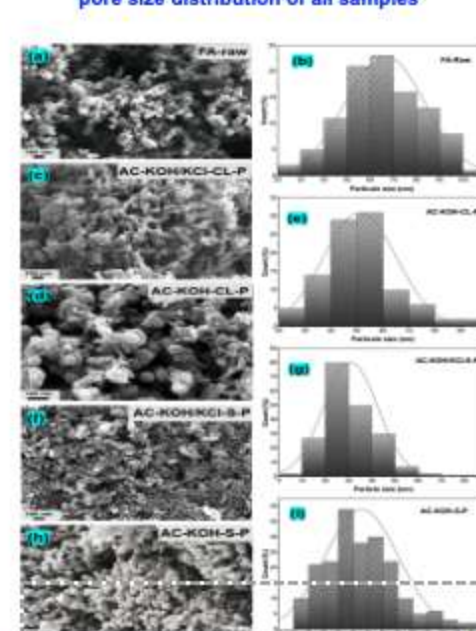


Fig. 4 FESEM and particle size distribution for all samples

6 Results & Adsorption Studies (Isotherm, Kinetics, Thermodynamics)

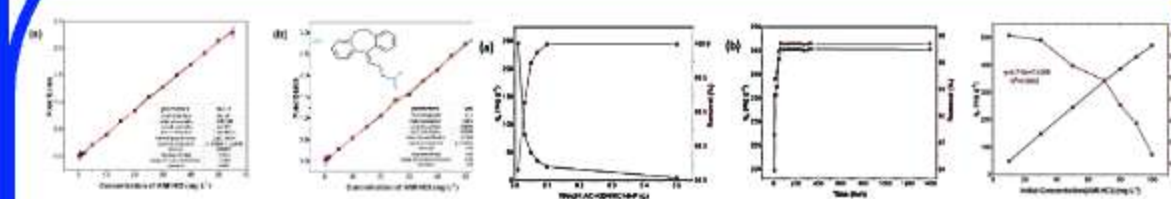


Fig. 5 Calibration curve of Amitriptyline HCl (AMI-HCl), (a) in SGF and (b) in SIF conditions

Table 1. Adsorption capacities at pH 1.2 and 7.5 for all samples.

Sample	Q _s at pH 1.2 (mg/g)	Q _s at pH 7.5 (mg/g)
AC-KOH-CL-P	341	351
AC-KOH-S-P	112	182
AC-KOH/KCl-CL-P	74	151
AC-KOH/KCl-S-P	204	245
AC-KOH-CLS	45	101
AC-KOH-CLS	66	155
NCB	250	250
FA-RAW	37	77

Fig. 6 Effect of (a) adsorbent mass, (b) contact time, (c) pH solution, and (d) Initial Concentration at SGF adsorption of AMI-HCl onto AC-KOH/KCl-S-P

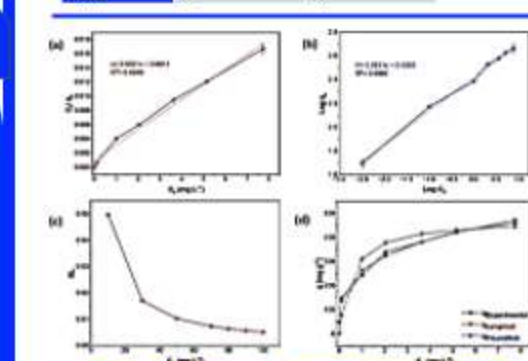


Fig. 8. Adsorption isotherm models in SGF.

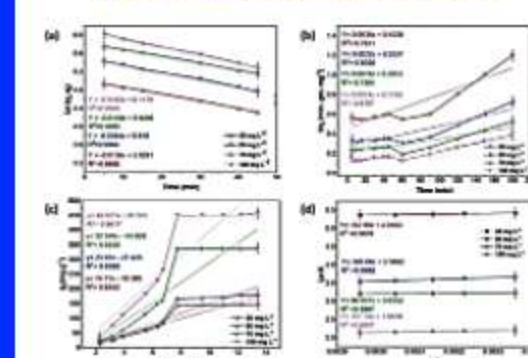


Fig. 9. (a) PFO kinetic plot, (b) PSO kinetic plot, (c) Intraparticle diffusion, (d) van't Hoff plot for AMI-HCl adsorption on AC-KOH/KCl-S-P in SGF conditions.

Table 3. Freundlich, Langmuir, and Dubinin-Radushkevich isotherm models in.

Models	Equation	Model parameters	Models	Equation	Model parameters
Langmuir	$Y = 0.0021x + 0.0011$	$K_L = 5.509 \text{ L mg}^{-1}$ $Q_{max} = 476.190 \text{ mg g}^{-1}$ $R^2 = 0.9849$	Langmuir	$Y = 0.0021x + 0.0008$	$K_L = 2.625 \text{ L mg}^{-1}$ $Q_{max} = 476.190 \text{ mg g}^{-1}$ $R^2 = 0.9849$
Freundlich	$Y = 0.2772x + 2.4252$	$n = 3.6075$ $K_F = 266.195 \text{ L g}^{-1}$ $R^2 = 0.9967$	Freundlich	$Y = 0.2798x + 2.4697$	$n = 3.5739$ $K_F = 294.9171 \text{ L g}^{-1}$ $R^2 = 0.9968$
Dubinin-Radushkevich	$Y = 0.0084x + 5.8175$	$\alpha = 336.6 \text{ mg g}^{-1}$ $\beta = -0.0084 \text{ mol}^2 \text{ K}^{-1}$ $E = 2.73 \text{ kJ mol}^{-1}$ $R^2 = 0.8652$	Dubinin-Radushkevich	$Y = 0.0077x + 5.842$	$\alpha = 336.6 \text{ mg g}^{-1}$ $\beta = -0.0077 \text{ mol}^2 \text{ K}^{-1}$ $E = 2.73 \text{ kJ mol}^{-1}$ $R^2 = 0.8744$

SGF

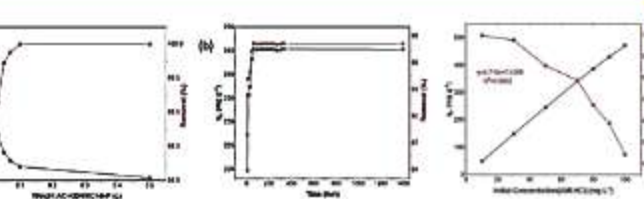


Fig. 7 Effect of initial concentration with SIF.

Table 2. RMSE values/kinetic models in SGF and SIF

Model	RMSE (mg/g)
SGF	4.8814
SIF	245.49
SGF	12.147
SIF	103.18

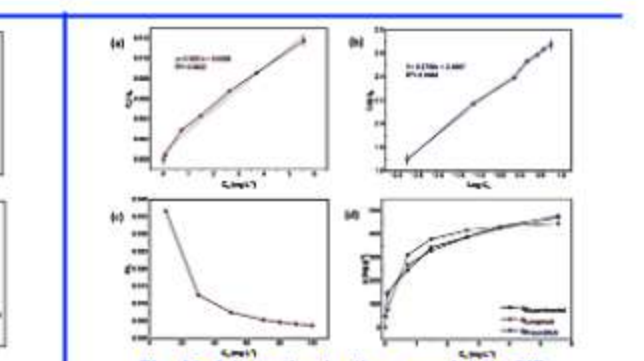


Fig. 10. Adsorption isotherm models in SIF.

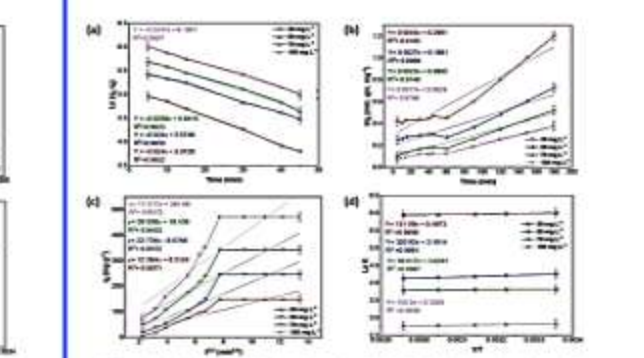


Fig. 11. (a) PFO kinetic plot, (b) PSO kinetic plot, (c) Intraparticle diffusion, (d) van't Hoff plot for AMI-HCl adsorption on AC-KOH/KCl-S-P in SIF conditions.

Table 3. Freundlich, Langmuir, and Dubinin-Radushkevich isotherm models in.

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SIF

7 Mechanism of Adsorption

- Adsorption: PFO kinetics, Freundlich isotherm → multilayer on heterogeneous surface.
- Interactions: π - π stacking + H-bonding.
- pH (PZC $\approx$ 6):
- pH < 6 → weaker adsorption.
- pH > 6 → stronger adsorption.
- Diffusion: Film → intraparticle → equilibrium.
- Activation (KCl/KOH):
- KOH → micropores.
- KCl → mesopores, stability.
- Result: Hierarchical porous carbon, high surface area.

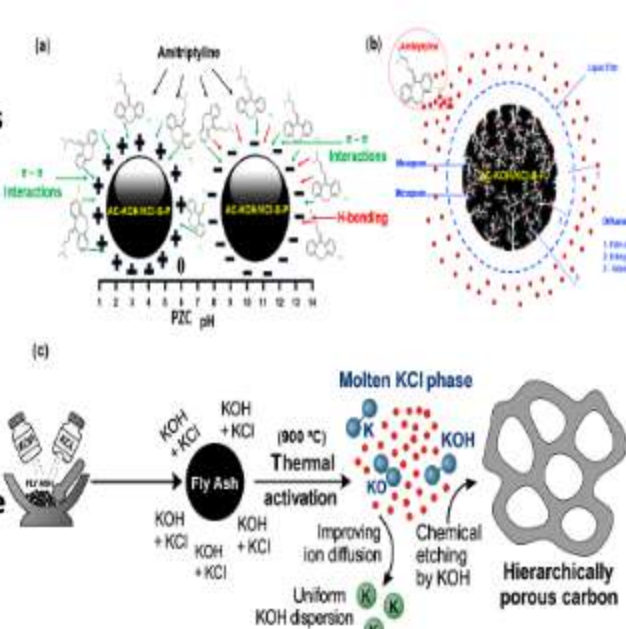


Fig. 12. Schematic illustration of the adsorption mechanism of (AMI-HCl) onto AC-KOH/KCl-S-P: (a) pH-dependent π - π and H-bonding interactions, (b) diffusion pathways including film and intra-particle diffusion, and (c) synthesis and hierarchical porosity development of AC-KOH/KCl-S-P contributing to superior adsorptive performance.

8 Conclusion & Highlights

- First-time use of bakery fly ash as a detox sorbent
- KCl/KOH activation gave highest surface area ($541 \text{ m}^2 \text{ g}^{-1}$)
- Superior amitriptyline adsorption: 200 mg g^{-1} (gastric), 240 mg g^{-1} (intestinal)
- Adsorption fit pseudo-first-order kinetics & Freundlich isotherm
- Spontaneous, exothermic physisorption confirmed ($\Delta H^\circ < -40 \text{ kJ mol}^{-1}$)
- Sustainable, cost-efficient route: bakery waste → medical-grade activated carbon

9 Acknowledgment

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