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Agro-Waste-Derived Biochar as a Low-Cost Adsorbent for Pharmaceutical Contaminant Removal

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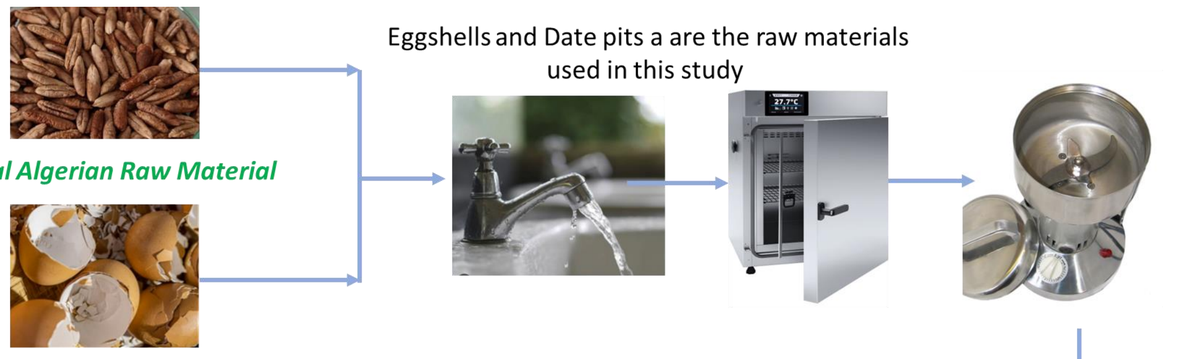
INTRODUCTION & AIM

The pollution caused by pharmaceutical contaminants has become a pressing environmental concern, as their persistent accumulation in ecosystems poses serious risks to water quality, food safety, and human health. The adsorption of pollutants onto activated carbon is a simple yet highly efficient method for water pre-treatment, widely applied at an industrial scale in both desalination and water treatment processes. The characterization of carbon adsorbents represents a broad area of research. While chemically synthesized adsorbents have predictable structural and chemical properties that are determined by their synthesis, activated carbons often exhibit considerable variability due to differences in raw materials and activation methods. The conversion of low-cost organic waste into high value-added materials without generating secondary pollutants remains a major challenge for sustainable and eco-friendly industrial development.

In this study, an inexpensive and readily available carbon precursor was selected and converted into a high-performance adsorbent. Activated carbon was synthesized at the laboratory scale from organic waste to produce a cost-effective adsorbent. The precursor material was characterized before and after treatment using XRD, SEM/EDS analyses. Adsorption experiments were carried out to investigate the removal of pharmaceutical contaminants, with a focus on paracetamol, using both the synthesized activated carbon and the raw precursor material. This study examines adsorption kinetics, equilibrium isotherms, and the effects of critical operating parameters.

MATERIALS & METHOD

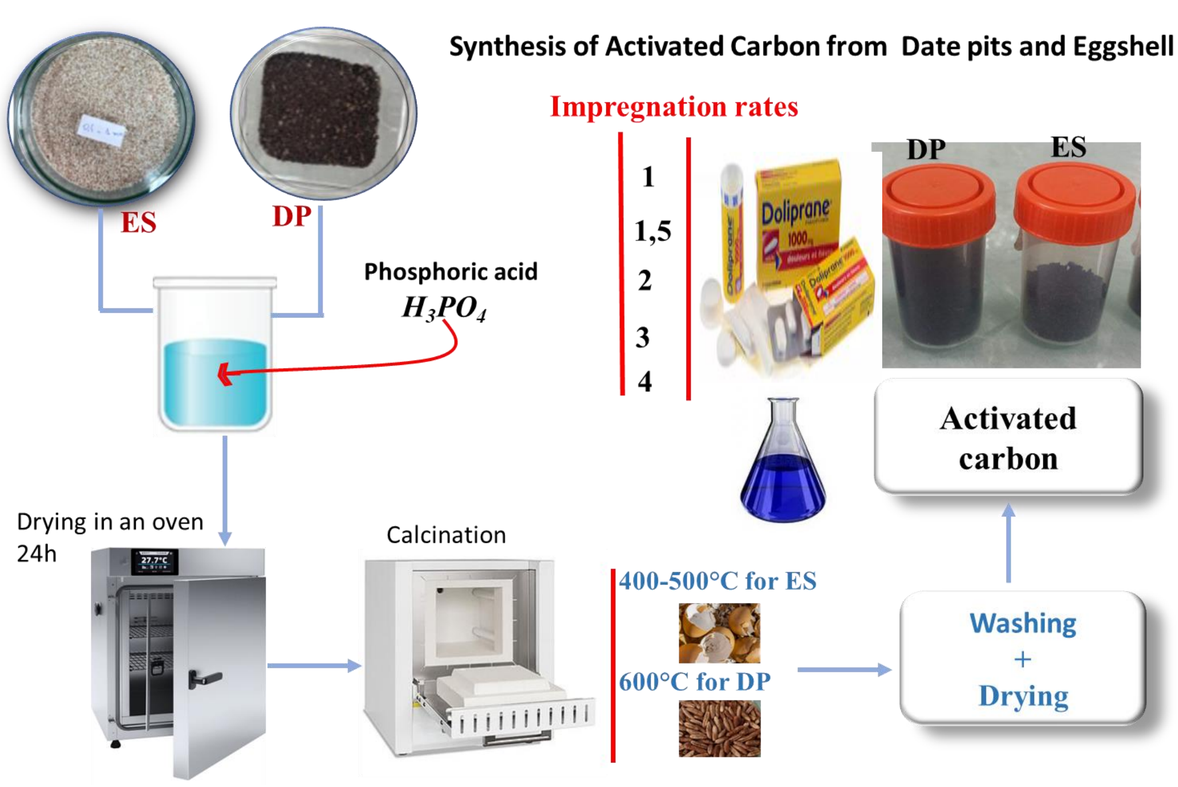
❖ Steps for the Preparation of Raw Material



The preparation of these raw materials includes the following steps:

- Collection of eggshells and date pits
- Washing of the raw material with water water heated to 50-80 °C
- Drying of the raw material in an oven at 110 °C for 5 hours
- Grinding and sieving to obtain fine particles (0.5-1 mm)

❖ Preparation of activated carbon (PAC)



1.Impregnation with phosphoric acid (various ratios)
2.Contact time: 24 h
3.Drying in an oven to remove moisture (24 h)
4.Calcination:400–500 °C (*ES),* 600 °C (DP*)*
6.Washing with distilled water until neutral pH
7.Final drying at 110 °C for 24 h

RESULTS & DISCUSSION

❖ Selection of prepared carbon samples

BM concentration (10 mg/L), Adsorbent dose used (0.3 g),Agitation speed (250 rpm), Contact time (30 min)

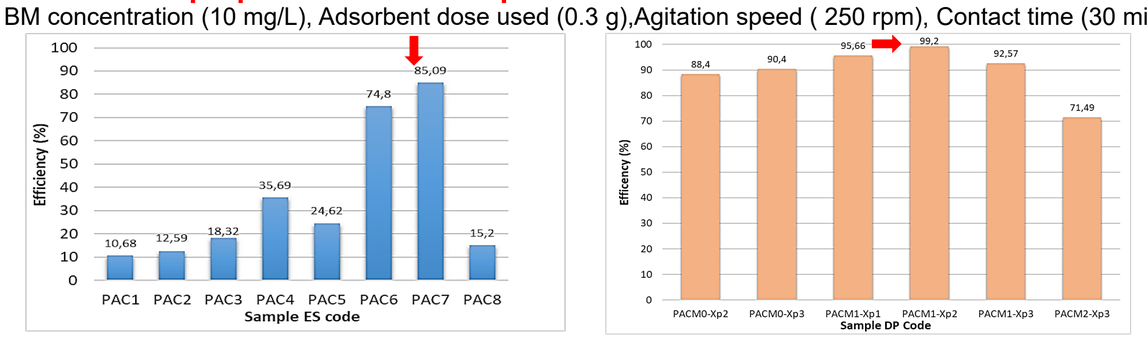


Fig 1. Histogram comparing MB removal efficiencies for different activated carbons prepared from ES and DP)

❖ Morphological Characterization of the Prepared Adsorbents

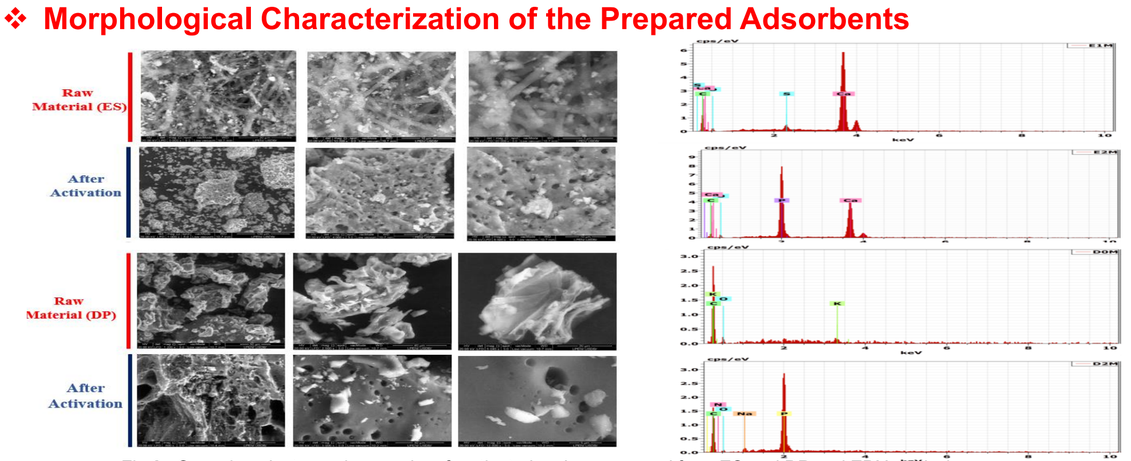


Fig 2 . Scanning electron micrographs of activated carbon prepared from ES and DP and EDX analysis

❖ Comparison of the Effectiveness of Eggshells and Date Pits as Adsorbents

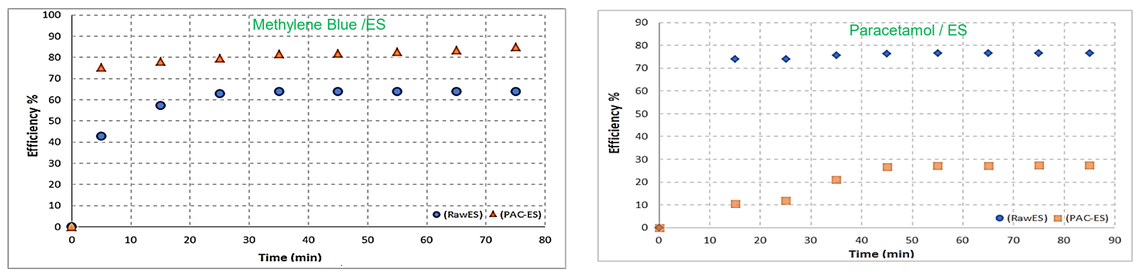


Fig 3. Paracetamol and MB adsorption efficiency versus time for different adsorbents (Raw ES and PAC) (C_0=10 ppm, m=1.2 g)

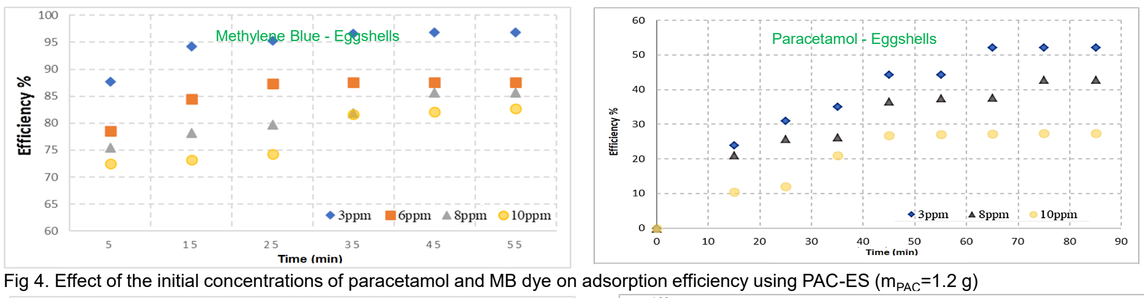


Fig 4. Effect of the initial concentrations of paracetamol and MB dye on adsorption efficiency using PAC-ES (m_{PAC}=1.2 g)

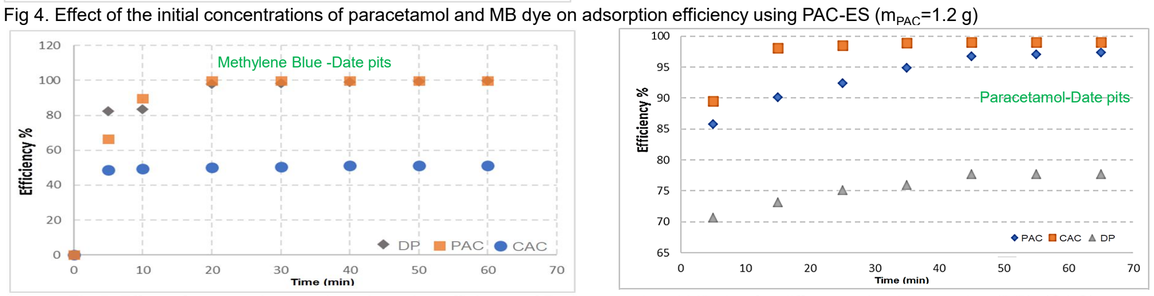


Fig 5. Effect of contact time on the adsorption efficiency of Paracetamol and MB dye for different adsorbents using (DP), (CAC), and (PAC) (C_0 = 10 ppm, m = 0.25 g).

Tab 1. Comparison of Langmuir and Freundlich adsorption isotherm parameters for the adsorption of methylene blue (MB) and paracetamol onto PAC prepared from eggshells and date pits

Methylene Blue			Paracetamol		
Type of Isotherm	Constants		Type of Isotherm	Constants	
Langmuir	Q_m (mg.g^{-1})	1,654	Langmuir	Q_m (mg.g^{-1})	0,6748
	K_L(L.mg^{-1})	3,4391		K_L(L.mg^{-1})	0,9476
	R^2	0,9622		R^2	0,966
Freundlich	K_f(mg/g)(L/mg)$^{1/n}$	1,2235	Freundlich	K_f(mg/g)(L/mg)$^{1/n}$	0,3497
	n	2,4408		n	3,7
	R^2	0,9798		R^2	0,8978

PAC prepared from Eggshells

Methylene Blue			Paracetamol		
Type of Isotherm	Constantes		Type of Isotherm	Constantes	
Langmuir	Q_m (mg.g^{-1})	36,63	Langmuir	Q_m (mg.g^{-1})	66,67
	K_L(L.mg^{-1})	6,0667		K_L(L.mg^{-1})	0,5281
	R^2	0,9865		R^2	0,9998
Freundlich	K_f(mg/g)(L/mg)$^{1/n}$	33,5354	Freundlich	K_f(mg/g)(L/mg)$^{1/n}$	21,728
	n	2,392		n	1,4821
	R^2	0,9789		R^2	0,9897

PAC prepared from Date pits

CONCLUSION

- Raw eggshell, without chemical activation, was found to be an effective adsorbent for pharmaceutical contaminant "Paracetamol", highlighting its potential as a low-cost alternative (80%). Eggshell-derived activated carbon was highly effective for BM removal, achieving 82.69% efficiency (55 min, C_0=10 ppm).
- Activated carbon derived from date pits has proven to be highly effective (> 95%) in removing paracetamol and dyes, regardless of the initial concentration of pollutants.

FUTURE WORK / REFERENCES

- Examine the recyclability of eggshells and date pits using innovative and emerging adsorption methods.

References

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2. Joseph Merillyn Vonnie, Chua Shek Li, Kana Husna Erna , Koh Wee Yin, Wen Xia Ling Felicia, Md Nasir Nur' Aqilah and Kobun Rovina.Development of Eggshell-Based Orange Peel Activated Carbon Film for Synergetic Adsorption of Cadmium (II) Ion.Nanomaterials 2022, 12, 2750. https://doi.org/10.3390/nano12162750