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Development of Nanopillar-Structured PLA Films Incorporating Grape Pomace-Derived Activated Carbon for Smart Food Packaging Applications

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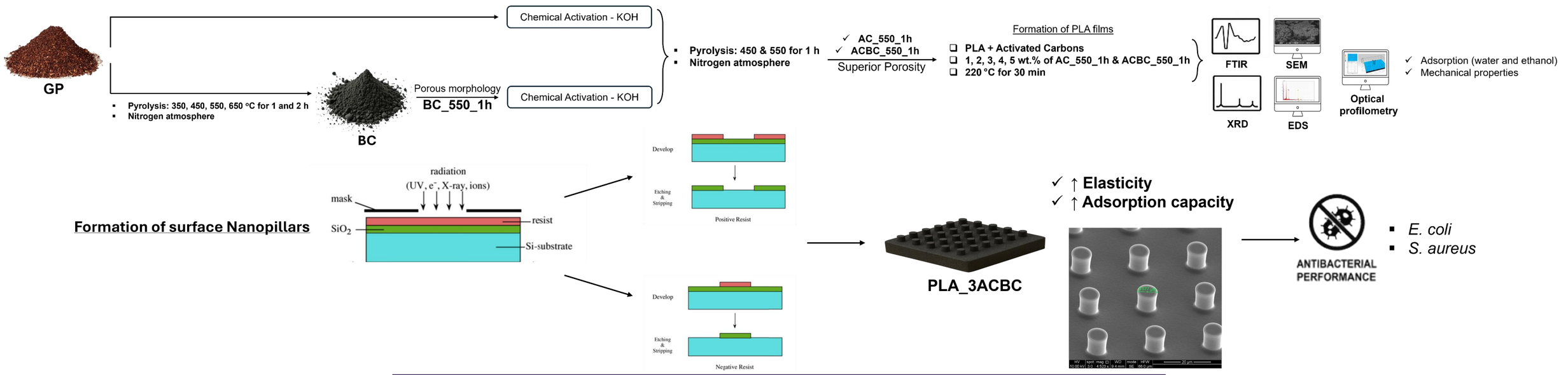
INTRODUCTION & AIM

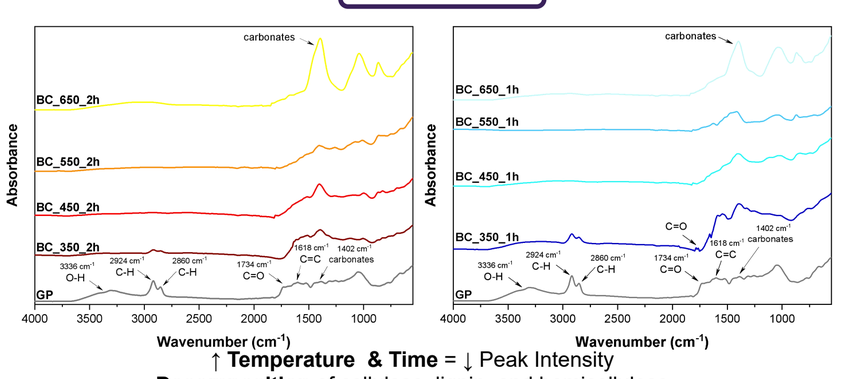
To reduce environmental pollution, food packaging should be biodegradable. [1] Poly(lactic acid) (PLA) is a biodegradable polymer for food packaging but has limited barrier, mechanical [2] and antibacterial properties. This study aims to enhance PLA with bio-additives from grape pomace (GP), a waste from wine production. Biochar (BC) and activated carbon (AC), produced through pyrolysis, improve mechanical properties and adsorption capacity of PLA due to their porosity, [3] while creating a nanostructure on the surface of the packaging enhances antibacterial activity. [4]

METHOD

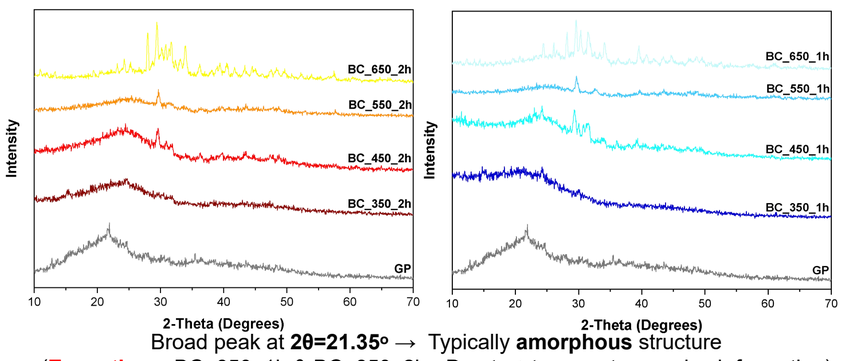


RESULTS & DISCUSSION

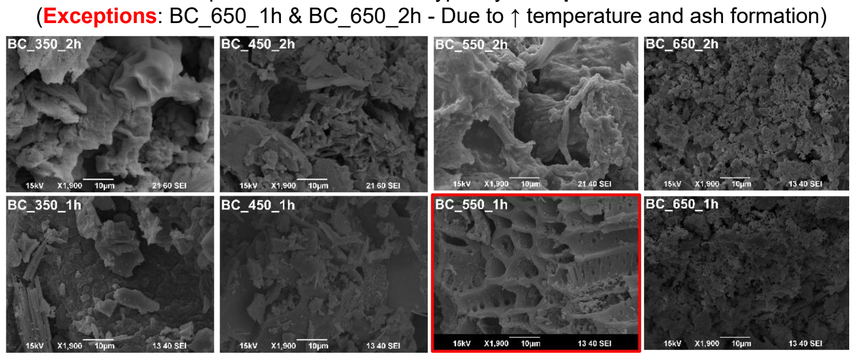
Biochars



↑ **Temperature & Time** = ↓ Peak Intensity
Decomposition of cellulose, lignin, and hemicellulose

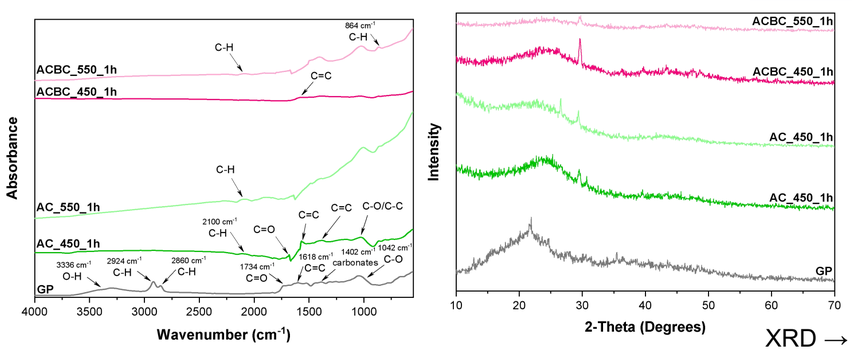


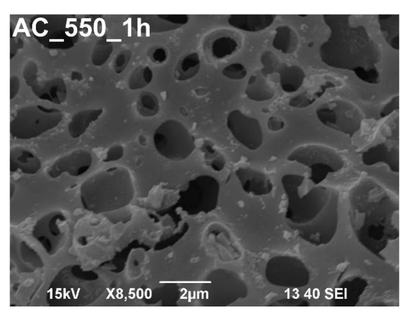
Broad peak at **2θ=21.35°** → Typically **amorphous** structure
(**Exceptions**: BC_650_1h & BC_650_2h - Due to ↑ temperature and ash formation)

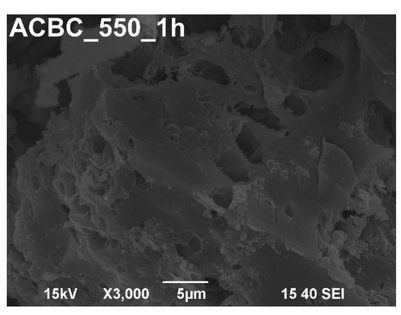


BC_550_1h → Porous structure → Symmetrically arranged micropores of various sizes

Activated Carbons

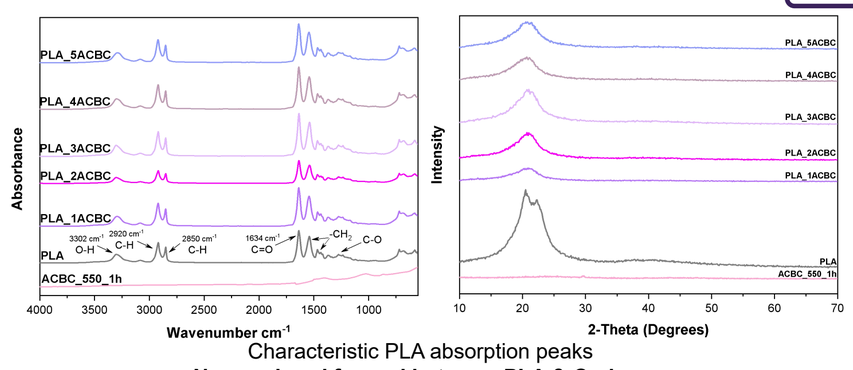




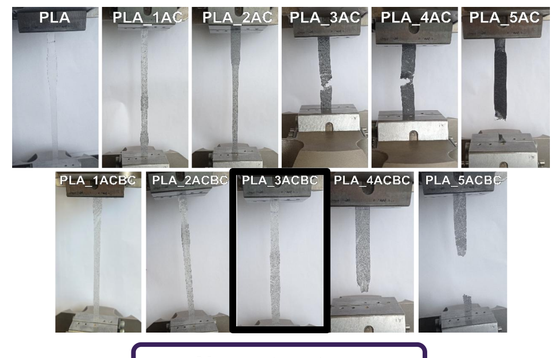


XRD → **2θ=24.35°**
Broad peak = Amorphous nature of materials & confirmation of **porous structure**

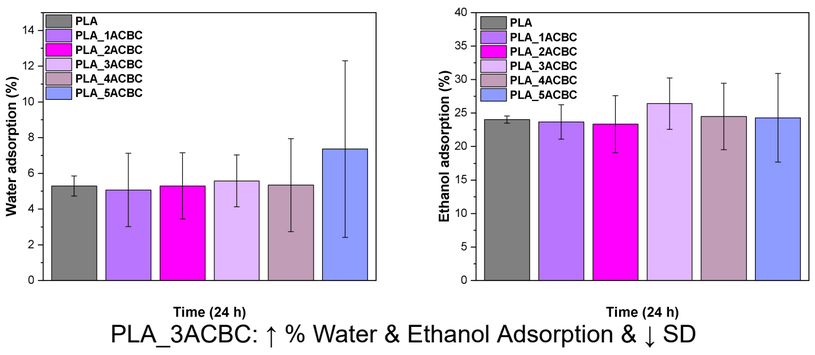
Films



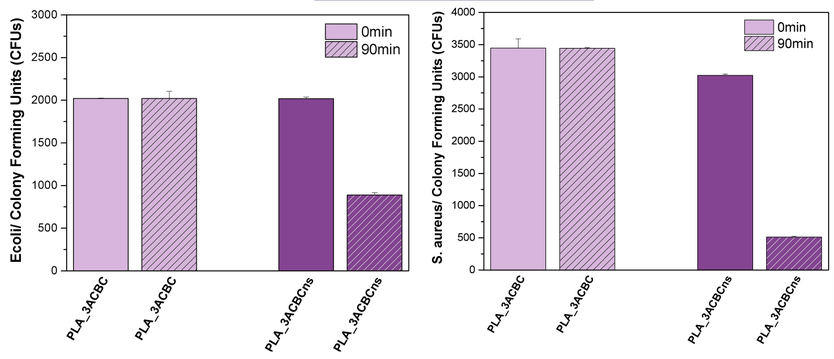
Characteristic PLA absorption peaks
No new bond formed between PLA & Carbon



Nanostructure



PLA_3ACBC: ↑ % Water & Ethanol Adsorption & ↓ SD



CONCLUSION

Collectively, in this study the sorption and mechanical behavior of PLA films are improved by AC addition up to a threshold (3wt.%). Film performance is decreased by particle aggregation and microcrack development above this concentration. Compared to films using AC from raw GP, those containing AC from BC maintained their mechanical integrity better at greater loadings. This study demonstrates a sustainable strategy for valorizing GP into high-performance AC additives for biodegradable food packaging.

REFERENCES

[1] J. H. Park, *et al.*, *Macromolecular Research* 25(11):1135–44, (2017)
[2] P. Chaudhary, *et al.*, *Journal of Inorganic and Organometallic Polymers and Materials* 30(12):5180–92, (2020)
[3] T. Bhattacharya, *et al.*, *Sustainable Materials and Technologies* 39:e00831, (2024)
[4] H.-K. Kim, *et al.*, *ACS Applied Polymer Materials* 6(5):2836–48, (2024)