The Development of Fermentation-Assisted Porous Gelatin/Sodium Alginate Hydrogel Material and Enhancing Photocatalytic Properties with Zinc Oxide

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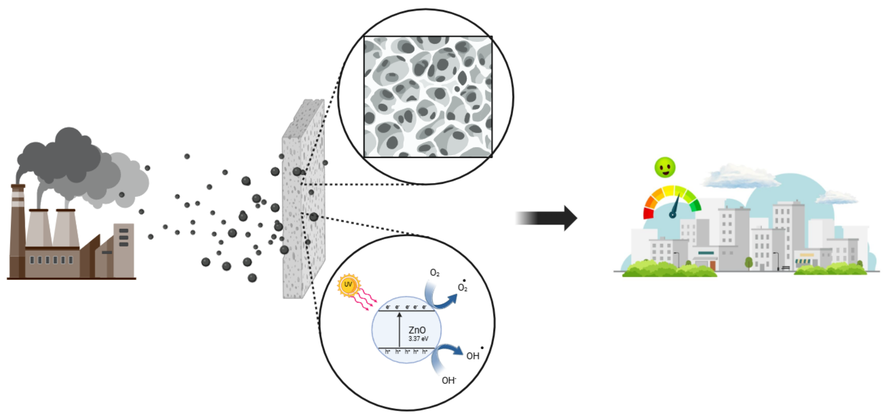
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Abstract

A porous hydrogel based on sodium alginate and gelatin was developed using a microbial fermentation approach, in which carbon dioxide generated from yeast and glucose acted as an internal pore-forming agent. The material was designed for environmental applications, particularly particulate filtration for air pollution control. The optimal gelatin-to-sodium alginate ratio was determined based on morphology observed by scanning electron microscopy (SEM), physical appearance, and pore size analysis using ImageJ. Among the formulations, a ratio of 3:5 showed the optimal structure, with an average pore size of 54.86 ± 2.26 μm and an interconnected porous network. The optimized hydrogel was further functionalized by incorporating zinc oxide (ZnO) at different loadings. The presence and distribution of ZnO were confirmed by X-ray diffraction (XRD) and energy-dispersive X-ray spectroscopy (EDS) mapping, while Fourier-transform infrared spectroscopy (FTIR) verified the polymer functional groups. Photocatalytic activity under ultraviolet irradiation showed that the hydrogel with the highest ZnO loading achieved 64% degradation of Rhodamine B after 8 h. In addition, PM2.5 filtration tests showed that the sample with the highest ZnO loding (35-GAZ3) was the most efficient at filtering particles. These results suggest that the fermentation-assisted porous hydrogel has potential for particulate matter removal and air pollution control.

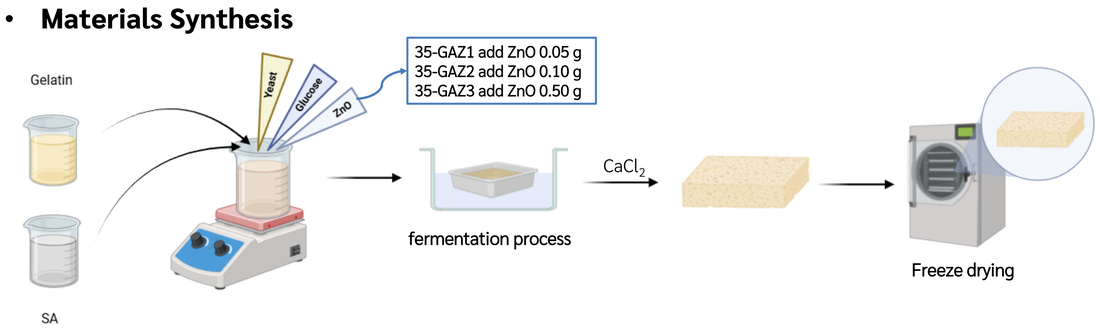
Introduction

Fine particulate matter (PM2.5) is a serious air pollutant that can penetrate deep into the respiratory system and bloodstream, posing significant health risks. Therefore, the development of environmentally friendly porous materials capable of both filtering and degrading particulate pollutants has attracted considerable interest. Bio-based hydrogels formed from gelatin and sodium alginate can create porous structures that enhance particle capture, while yeast fermentation creates internal pores. The incorporation of ZnO provides photocatalytic activity for pollutant degradation under light, thereby enhancing the air purification capability of the material.

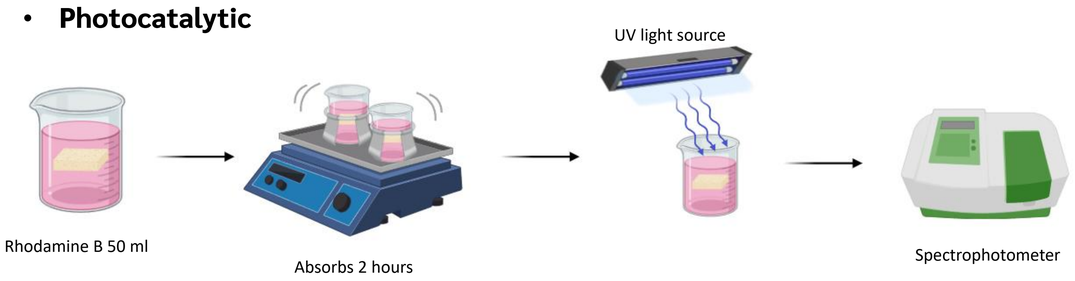


Methodology

- **Materials Synthesis**



- **Photocatalytic**



Conclusion

Porous hydrogels were successfully synthesized via a yeast fermentation process. The gelatin/SA ratio of 3:5 provided the most suitable structure with interconnected pores and good formability. The incorporation of ZnO was confirmed by XRD and EDS mapping, while FTIR verified the polymer structure. The photocatalytic test showed that the sample with the highest ZnO content achieved the best performance, with 64% degradation of Rhodamine B after 8 hours. PM2.5 filtration results indicated that 35-GAZ3 exhibited the fastest filtration performance. These results suggest that the developed material has potential for future applications in air filtration and pollutant degradation.

References

[1] Cheng J. et al. (2024). Fermentation-inspired macroporous and tough gelatin/sodium alginate hydrogel for accelerated infected wound healing. International Journal of Biological Macromolecules, 268, 131905.
[2] Rahman Q. I. et al. (2013). Effective photocatalytic degradation of rhodamine B dye by ZnO nanoparticles. Materials Letters, 91, 170–174.

Results and Discussion

- Morphology

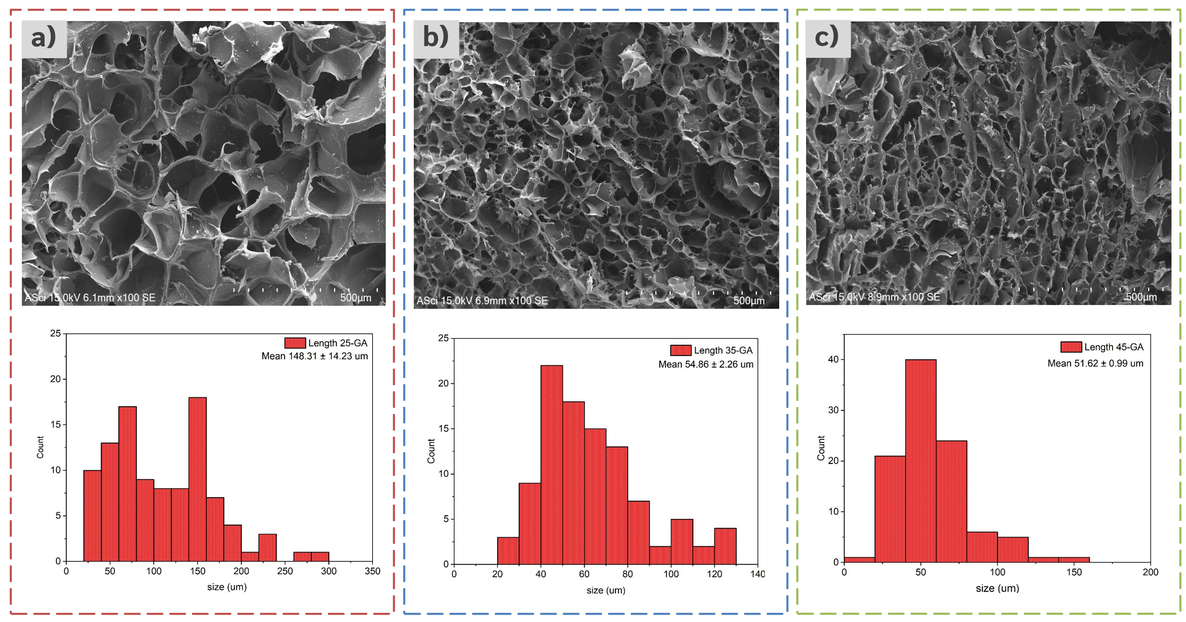


Fig. 1. SEM images and Pore size distribution of sample a) 25-GA b) 35-GA c) 45-GA

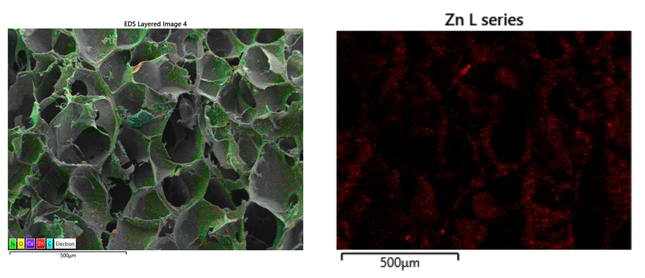


Fig. 2. Elemental mapping of Zn .

Element	Wt%	Atomic%
C	46.32	60.10
N	9.51	10.58
O	25.23	24.58
Ca	1.53	0.60
Zn	17.41	4.15
Total	100.00	100.00

Table. 1. The atomic and weight percentage of various elements.

- Characterization

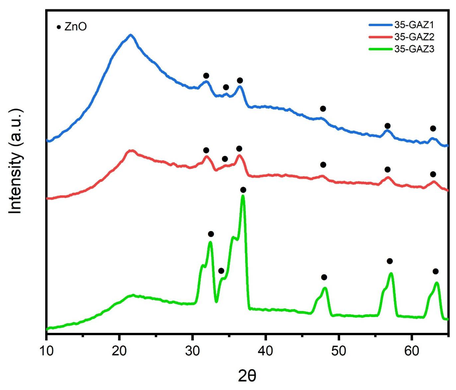


Fig. 4. XRD patterns of materials with different ZnO concentrations confirms the presence of ZnO.

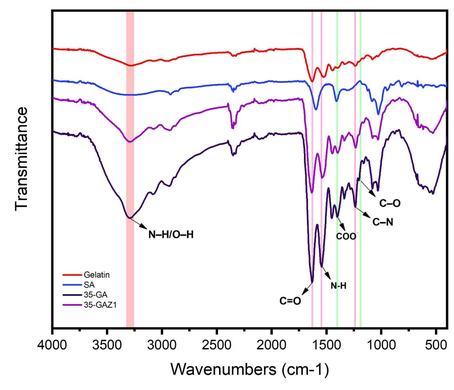


Fig. 5. FTIR spectra confirms the functional groups and structural characteristics of the material.

- Photocatalytic activity investigation

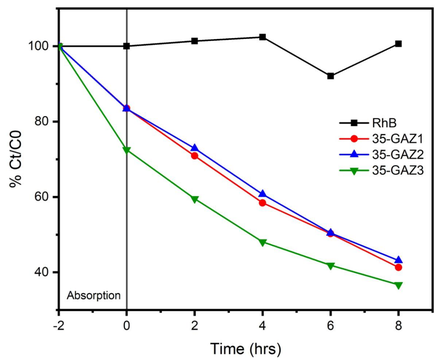


Fig. 6. Photocatalytic degradation of Rhodamine B by ZnO shown as $\%C_t/C_0$.

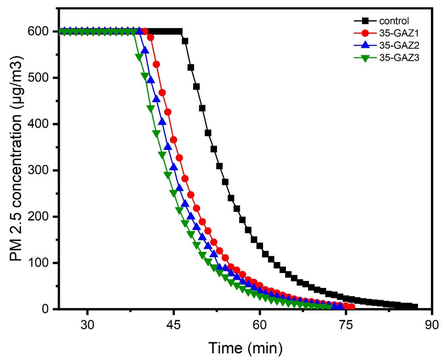
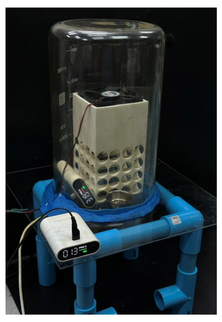


Fig. 7. PM2.5 filtration test and experimental setup.



Acknowlegements

The authors would like to thank Assoc. Prof. Dr. Chamnan Randorn for his guidance on this research. Also, thank the members of the SFM Laboratory and the Department of Chemistry, Faculty of Science, Chiang Mai University, for their support in this research.