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FROM COLLOIDAL FORMULATION TO FUNCTIONAL FILM: PREDICTIVE DESIGN OF SUSTAINABLE PULLULAN-BASED ACTIVE COATINGS

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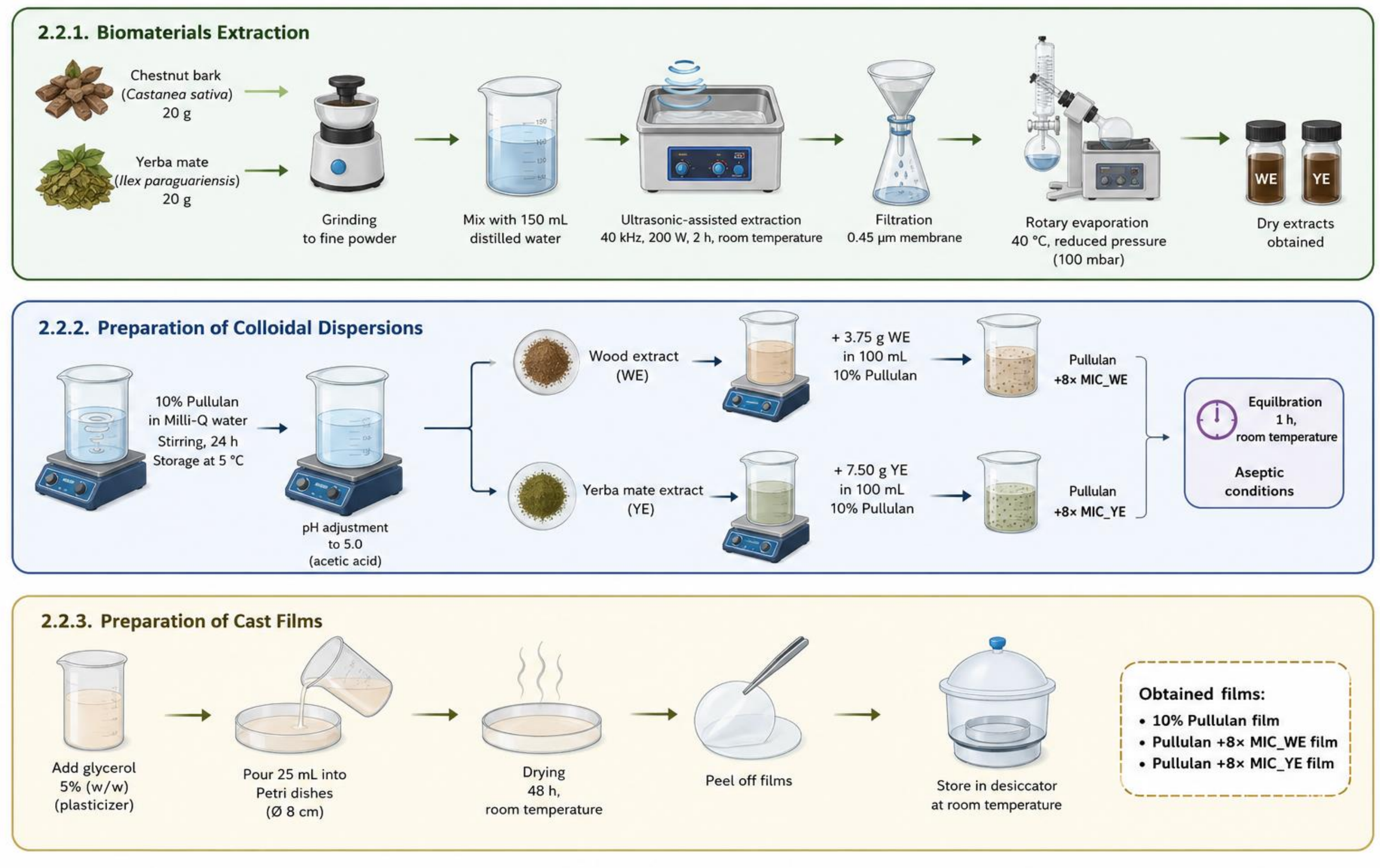
INTRODUCTION

The predictive design of sustainable coatings is often hindered by an insufficient understanding of how liquid coating formulations translate into functional films on solid substrates. In this work, biodegradable pullulan-based active coatings functionalized with polyphenol-rich yerba mate and chestnut wood extracts, obtained via green ultrasound-assisted aqueous extraction, are presented as a model system. Moving beyond conventional bulk-film approaches, the study adopts a liquid-to-solid-state framework, demonstrating that coating performance on solid carriers is governed by the combined understanding of colloidal stability, zeta potential, rheology, and surface tension in the liquid state, and wettability, surface free energy, and functional performance after film formation [1–2].

MATERIALS AND METHODOLOGY

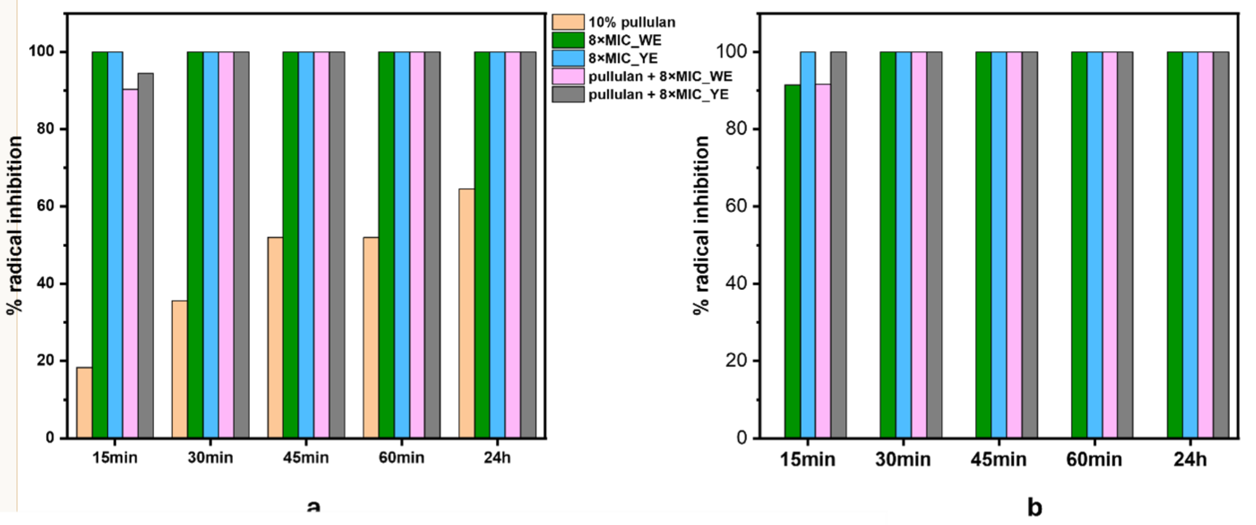


RESULTS

A. DISPERSION CHARACTERIZATION

B. FILM CHARACTERIZATION

Figure 1. Antioxidative activity of dispersions a) ABTS assay results b) DPPH assay results



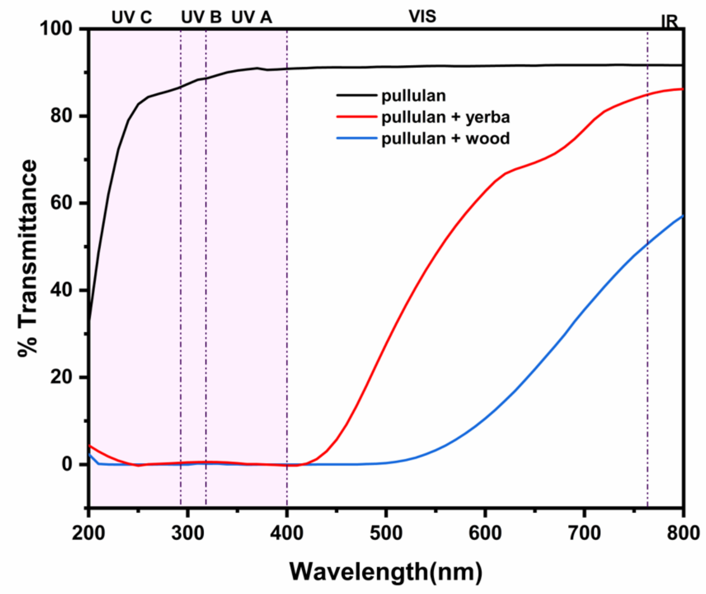


Figure 3. UV–Vis transmittance spectra of films

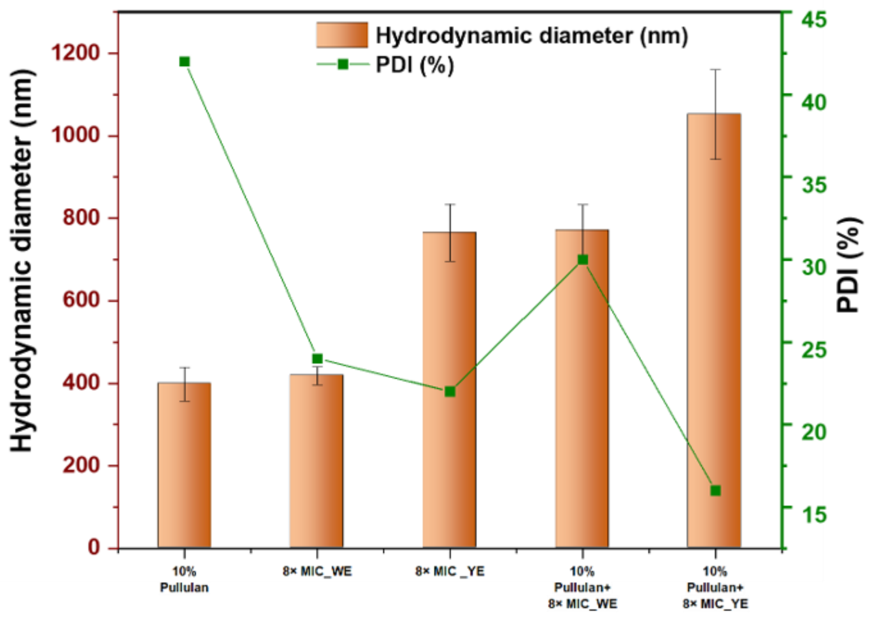
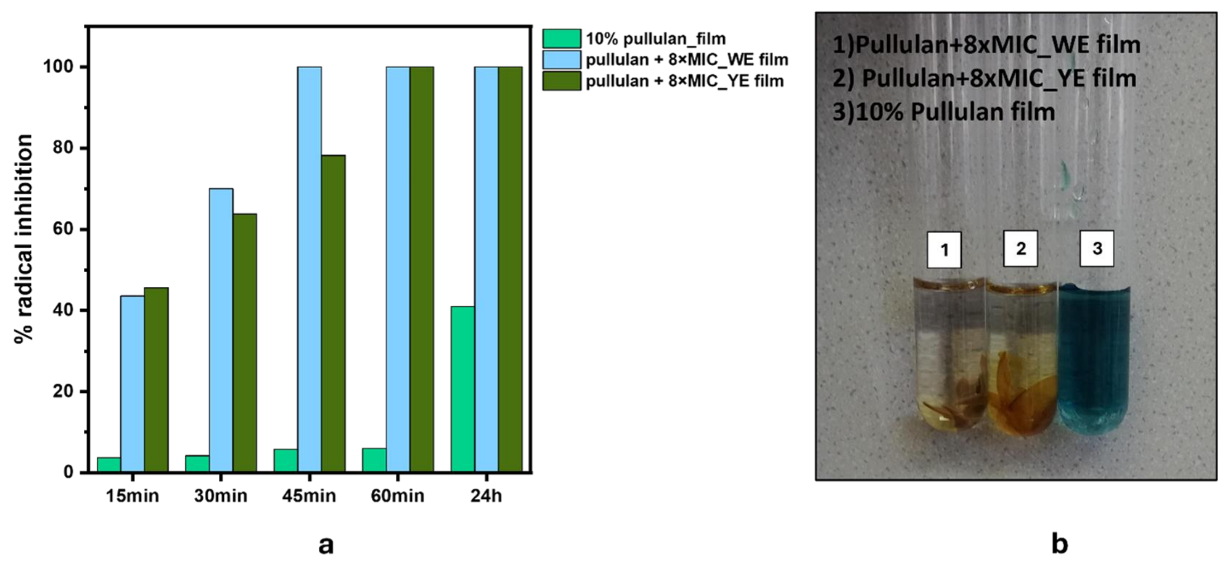
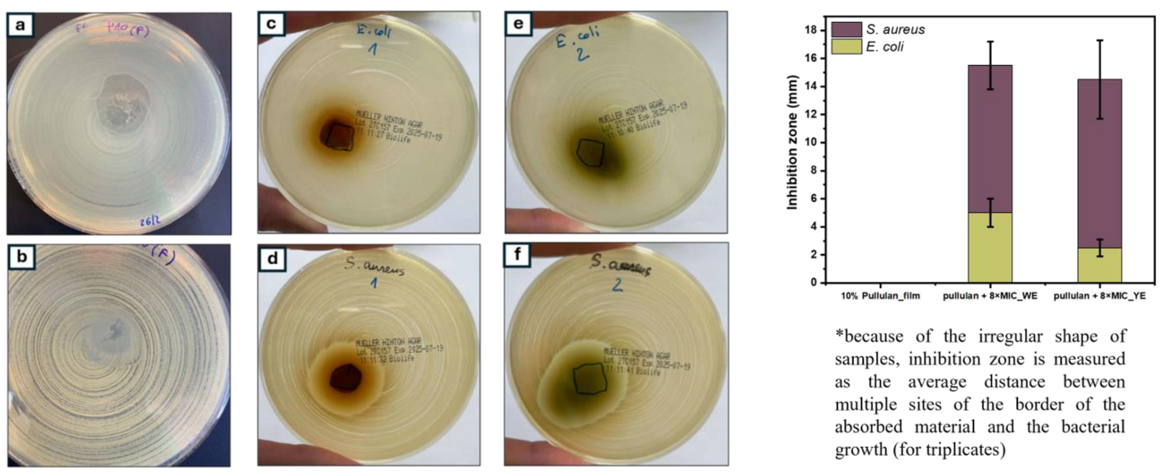


Figure 2. Hydrodynamic diameter and Poly dispersity index (PDI) of the dispersions

Figure 4. Antioxidative activity of dispersions a) ABTS assay results b) DPPH assay results





*because of the irregular shape of samples, inhibition zone is measured as the average distance between multiple sites of the border of the absorbed material and the bacterial growth (for triplicates)

Figure 5. Antibacterial activity results of the cast films against E. coli (on the top) and S. aureus (on the bottom) respectively a), and b) 10% Pullulan film c) and d) pullulan + 8×MIC_WE film e) and f) pullulan + 8×MIC_YE film and the measured inhibition zone in mm. (on the left)

REFERENCES

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[2] Pieters, K.; Mekonnen, T. *Progress in waterborne polymer dispersions for coating applications: commercialized systems and new trends.*, RSC Sustainability, 2024, 2, 3704–3729. https://doi.org/10.1039/D4SU00267A

CONCLUSIONS

Negative zeta potential values (~−25 mV) ensured colloidal stability and homogeneous coating dispersions, while reduced surface tension promoted efficient spreading during deposition. The resulting pullulan-based films exhibited improved wettability, UV-shielding, antioxidant activity and antibacterial performance. The study demonstrates that combining liquid-state and solid-state characterization enables predictive design of sustainable bio-based coatings for advanced food-packaging applications.

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