Circular Solutions for Additive Manufacturing: Bio-Based Composites with Catalytic Potential

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INTRODUCTION: Additive manufacturing (AM) is an advanced fabrication technique that enables the creation of complex polymeric, ceramic, metallic, and composite structures through a layer-by-layer deposition process [1]. By building components directly from CAD data, AM offers significant advantages in terms of design flexibility, material efficiency, and rapid prototyping, making it a transformative approach across various engineering and biomedical applications. The development of bio-derived materials as alternatives to conventional petroleum-based feedstocks for various 3D printing technologies opens new avenues toward achieving a truly sustainable and circular economy. This shift not only reduces environmental impact but also promotes material recyclability, biodegradability, and resource efficiency in additive manufacturing processes [1-2]. In this study, we present the preparation of chitosan–polylactic composite blends utilizing two chitosan samples extracted in-house from shrimp waste and compare their performance with that of commercially available low and medium molecular weight chitosan.

EXPERIMENTAL METHODS: Composite blends of chitosan including commercial sorts of low and medium molecular weight, as well as laboratory-extracted chitosan derived from shrimp head and shell waste were prepared with polylactic acid (PLA) using extrusion molding. Comprehensive characterization of the extruded filaments was performed to assess the influence of chitosan molecular weight and loading on their physico-mechanical and thermal properties. Melt flow index measurements, tensile testing, dynamic mechanical analysis, and differential scanning calorimetry were employed to evaluate flow behavior, mechanical performance, and thermal transitions. The filament morphology was examined using scanning electron microscopy (SEM) to investigate the dispersion and interfacial compatibility of the chitosan phase within the PLA matrix. Furthermore, the potential for incorporating high metal content (Nickel) into the composite filaments was explored, with particular attention to maintaining adequate printability and structural integrity for additive manufacturing applications

RESULTS AND DISCUSSION: The findings revealed that specific formulations of chitosan-PLA composite filaments allow for the successful incorporation and retention of nickel particles, thereby demonstrating their suitability as novel catalyst support materials. The composite filaments were processed via fused deposition modelling (FDM), a thermoplastic extrusion-based 3D printing technique, to fabricate test specimens with controlled geometries. Composite filaments were 3D-printed into geometries with a high surface area-to-volume ratio, tailored to enhance mass transfer and active site accessibility, thereby targeting potential applications as catalytic supports in heterogeneous reaction systems. Post-printing, the internal architecture, homogeneity, and potential porosity of the specimens were analyzed using micro-computed tomography (micro-CT), enabling non-destructive evaluation of the structural integrity and distribution of the embedded metal phase.

CONCLUSION: This study shows the innovative use of FDM for the fabrication of catalytic supports, offering enhanced design flexibility, high geometric precision, and the ability to tailor surface architecture for improved catalytic performance. It exemplifies a sustainable approach to material design by valorizing seafood industry wastes specifically chitosan extracted from shrimp shells and heads as a functional component in advanced composite systems. It contributes to the development of circular economy strategies by converting biowaste into high-performance materials with potential applications in heterogeneous catalysis and other environmentally relevant technologies.

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