Development of 3D Printing Filament from Carboxymethyl Cellulose Synthesized from Sugarcane Bagasse

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Abstract

This study aimed to develop a sustainable 3D-printing filament using carboxymethyl cellulose (CMC) synthesized from sugarcane bagasse and to evaluate its mechanical, thermal, and printability properties. The experimental procedure consisted of five main stages: (1) preparation and purification of sugarcane bagasse, (2) cellulose extraction, (3) CMC synthesis through alkalization and carboxymethylation, (4) blending of the synthesized CMC with polylactic acid (PLA) and maleic anhydride-grafted PLA (MA-g-PLA) as a compatibilizer, and (5) filament extrusion using a mini twin-screw extruder. The synthesized CMC was characterized by Fourier Transform Infrared Spectroscopy (FTIR) in the mid-infrared region (4,000–400 cm^{-1}). FTIR analysis confirmed the successful synthesis of CMC, with a prominent absorption peak at 3270.36 cm^{-1} corresponding to hydroxyl (–OH) stretching vibrations characteristic of cellulose derivatives. The fabricated filament exhibited a uniform average diameter of 2.15 ± 0.05 mm. Mechanical testing conducted according to ASTM D885-03 revealed a maximum tensile strength of 21.402 MPa and an elongation at break of 1.4%. Differential Scanning Calorimetry (DSC) analysis showed a glass transition temperature (Tg) between 50 and 55 °C, a recrystallization temperature (Tcc) between 90 and 110 °C, and a melting temperature (Tm) in the range of 150–170 °C. The incorporation of bagasse-derived CMC enhanced the thermal behavior and printability of the filament while maintaining compatibility with conventional FDM 3D printers. These findings demonstrate the potential of sugarcane bagasse as a renewable feedstock for producing value-added bio-based 3D-printing materials and contribute to the sustainable utilization of agricultural waste.

Keywords: Sugarcane Bagasse, Carboxymethyl Cellulose, 3D Printing Filament