Proceedings of the 8th International Conference on Theoretical and Applied Nanoscience and Nanotechnology (TANN 2024)
Chestnut Conference Centre - University of Toronto, Toronto, Canada – June 10-12, 2024
Paper No. 121
DOI: 10.11159/tann24.121

Preparation of 3D Printable Filament Using Brewer's Spent Grain Derived Poly-Lactic Acid Nanocomposites

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Abstract

Additive manufacturing (AM), best known as three-dimensional (3D) printing technology, has originated from layer-by-layer fabrication technology based on 3D structures created from computer-aided design (CAD). Fused deposition modeling (FDM) 3D printing processes are among the most widely used forms of 3D printing at the consumer level due to their quick and low-cost prototyping of simple parts. In a typical FDM 3D printing process, thermoplastic filaments, such as polylactic acid (PLA) or acrylonitrile butadiene styrene (ABS), are extruded through a heated nozzle to melt and further deposit layer-by-layer to build a desired 3D structural object. Compared to ABS, PLA is a superior raw material for FDM-based 3D printing, owing to its biodegradability and environmentally friendly properties.

PLA is a flexible and biodegradable aliphatic polyester. The polymer is made of repeating lactate monomers of lactic acid through the condensation of water. Traditionally highly-purity lactic acid can be produced through biological fermentation involving numerous *Lactobacillus spp*., *Lactococcus lactis*, *Bacillus amyloliquefaciens*, and *Streptococcus salivarius* [1]. The production of lactic acid however varies on each microbial growth parameter and nutritional requirement. In our recent study, lactic acid with moderate quality was obtained via the fermentation of *Lacticaseibacillus rhamnosus* in the recycled brewer's spent grain (BSG) medium and further to produce PLA through a simple ring open polymerization [1]. The as-made PLA pellets exhibit a unique antibacterial property due to the absorbance of Zn^{2+} which is the catalyst during the ring open polymerization. BSG is the major byproduct of beer production, accounting for 36.4 million tons per year [2]. BSG is a lignocellulosic material composed of the husk pericarp and seed coating that predominantly consists of lignin (28%), arabinoxylans (28%), and around 17% to 28% non-cellulosic polysaccharides [3]. Despite its use in livestock feeding on a small scale, BSG remains a huge biowaste in the beer industry.

In this study, 3D printable PLA-BSG composites are prepared via the blending of the above BSG-derived PLA fine powders and BSG particles with an average particle size of 50 microns. The PLA-BSG composites are further extruded through Filabot's EX2 Filament Extruder to prepare polymer filament. The extruding conditions, including extruding speed, nozzle temperature, and weight ratios of PLA and BSG, are examined by measuring the filament surface roughness and diameter, as well as the mechanical strength. The optimized extruding temperature is found at 145 °C which is relatively lower than bulk PLA melting temperature around 173 °C. To overcome the weak mechanical strength [4], the composite is further strengthened by blending with nanocellulose fiber (CNF). Initial results show that the elastic modulus is significantly improved. The resultant filament is subjected to further thermal stability analysis, antibacterial analysis, and biodegradable analysis. Overall, this fully bio-based filament has the potential to be used as a cost-effective and environmentally friendly 3D printable material in biomedical applications, including drug-eluting stents and medical simulators such as joint-dislocation models.

References

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