FULLY BIODEGRADABLE POLYMERIC COMPOSITES FOR FDM 3D PRINTING – EFFECTS OF REINFORCING PARTICLE SIZE AND VOLUME ON FLOW AND PROPERTIES

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Abstract

Additive Manufacturing (AM) technology has emerged as a leading method for rapid prototyping in recent years. Its distinct advantages, such as low cost, high-speed fabrication, and also being a no mould technique, have facilitated the widespread adoption of 3D printing technology in producing lightweight structural components and high-precision products [1], positioning it as a critical driver of industry transformation [2]. However, the reliance on petroleum-based materials in current 3D printing practices has contributed to significant and irreversible environmental pollution. As a result, many researchers and industries are looking for sustainable and fully biodegradable 3D printing filaments as alternatives to traditional petroleum-based polymeric filaments [3]. This paper focuses on developing environmentally friendly polymeric composites for additive manufacturing that aims to produce sustainable, recyclable, and biodegradable filaments. Through this effort, it is expected that a meaningful contribution can be made toward reducing environmental burdens and promoting green manufacturing.

Polylactic acid (PLA) is used as the matrix material in this study, combined with several natural fillers such as sandalwood, barley grass, wool keratin, and squid ink powder through physical blending to produce fully green and sustainable filaments using FDM 3D printing, with the morphological images of composite pellets shown in Figure 1. The primary focus of this paper is to investigate the effects of reinforcing particle size and volume on the flowability and properties of these composites. By varying the particle sizes (ranging from less than 100 micrometers to larger sizes) and filler compositions, this research systematically examines how these parameters influence the rheological behavior during the printing process and the resultant mechanical and thermal properties of the printed samples [4]. It was observed that smaller particle sizes significantly improve the flowability of the composites, leading to smoother and more precise prints, as shown in Figure 2. In contrast, larger particle sizes may lead to uneven dispersion within the polymer matrix (Figure 3), increasing the risk of nozzle clogging and inducing flow instability during the printing process. This instability can result in reduced print quality and accuracy, particularly when printing complex geometries. Rheological results further support this finding presented in Figure 4, where the viscosity of composites containing 250-micron particle size is approximately 2.67 times higher than that of composites with 125-micron particle size under the same temperature condition. Additionally, within the same natural filler-reinforced composites, lower filler content resulted in better flowability during the printing process.

Furthermore, the study introduces an innovative approach by employing chemical modification methods to extract dyes from natural materials for colouring polymer matrix (i.e., PLA) [5], resulting in a variety of coloured 3D printing filaments. Dyeing PLA with natural dyes has proven to produce more durable and long-lasting colours. Additionally, exploring different natural filaments' colours addresses consumer demand for a variety of colour options in 3D printing, providing further potential for the development of commercially available natural filaments. Overall, this research emphasizes the critical role of reinforcing particle size and filler volume in optimizing the processing and performance of fully biodegradable 3D printing composites. The findings are expected to drive the development of greener, more sustainable alternatives in the 3D printing industry, contributing significantly to environmental conservation efforts.

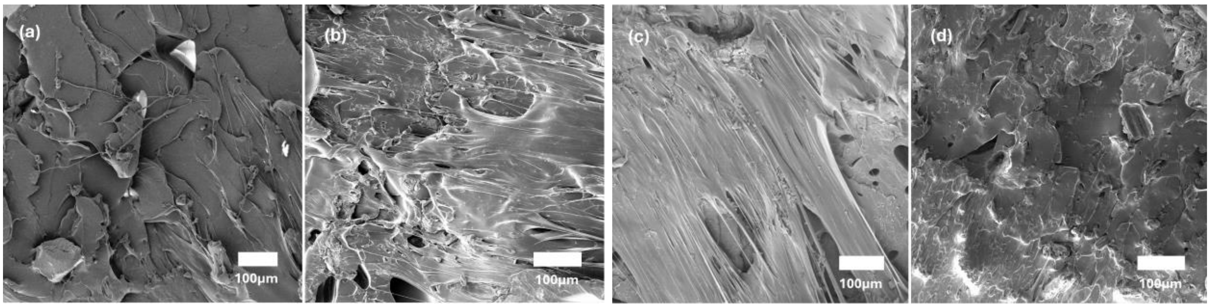

Figure 1: Surface morphology images of composite pellets made by physically blending PLA with 5% by weight of various natural fillers. (a) Wool keratin powder, (b) Barley grass powder, (c) Black squid ink powder, (d) Sandalwood powder.

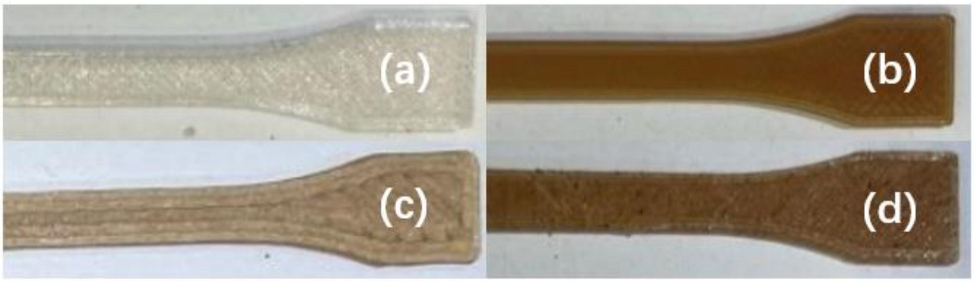

Figure 2 : 3D-printed tensile samples. (a) Pure PLA, (b) 125-micron particle size of 5% by weight bamboo-reinforced filament extuded by a 0.4 mm nozzle, (c) 125-micron particle size of 5% by weight bamboo-reinforced filament extuded by a 0.8 mm nozzle, (d) 250-micron particle size of 5% by weight bamboo-reinforced filament extuded by a 0.4 mm nozzle.

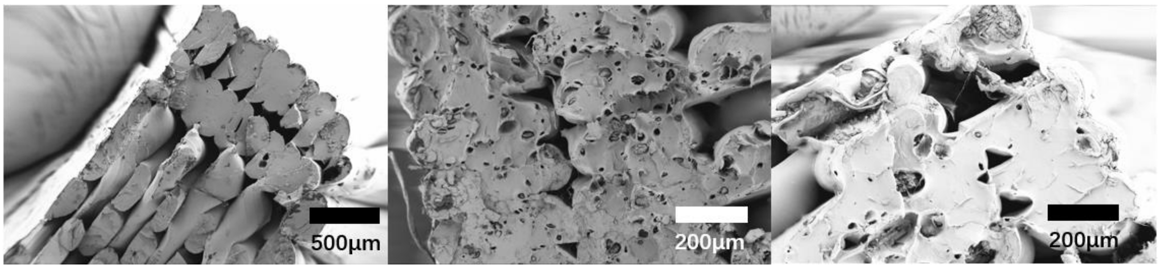

Figure 3: SEM images of 3D-printed samples.(a) Pure PLA (b) 125-micron particle size of 5% by weight bamboo-reinforced composite, (c) 250-micron particle size of 5% by weight bamboo-reinforced composite.

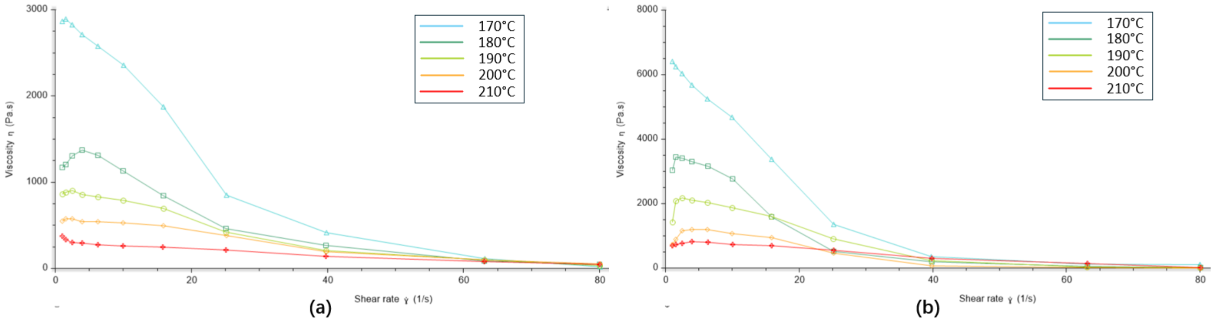

Figure 4 : 5% by weight bamboo-reinforced composites. (a) 125-micron particle size, (b) 250-micron particle size.

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