Enhanced Thermal and Mechanical Properties of Sapodilla/PLA Biocomposites Using Filament Extrusion 3D Printing

Nalaeram Sivaram R[1], Senthil Muthu Kumar Thiagamani[1,2,3*], Hossein Ebrahimnezhad-Khaljiri[4], Jeyanthi Subramaniam[5], Senthilkumar Krishnasamy[6], Chandrasekar Muthukumar[7], Mai Nguyen Tran Thanh[8], Anish Khan[9]

[1]Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Anand Nagar, Krishnankoil 626126, Tamil Nadu, India.

[2]Department of Mechanical Engineering, INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia.

[3]Centre for Advanced Composite Materials (CACM) Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Johor, Malaysia.

[4]Department of Materials Science and Engineering, Faculty of Engineering, University of Zanjan, Zanjan, Iran.

[5]School of Mechanical Engineering, Vellore Institute of Technology, Kelambakkam - Vandalur Rd, Rajan Nagar, Chennai 600127, Tamil Nadu, India

[6]Department of Mechanical Engineering, PSG Institute of Technology and Applied Research, Neelambur 641062, Coimbatore, Tamil Nadu, India

[7]Department of Aeronautical Engineering, Hindustan Institute of Science and Technology, Padur, Kelambakkam 603103, Chennai, Tamil Nadu, India

[8]Department of Transportation Construction, Faculty of Civil Engineering, Nha Trang University, 02 Nguyen Dinh Chieu St, Nha Trang City, Khanh Hoa Province, Vietnam

[9]Center of Excellence for Advanced Materials Research, King Abdulaziz University, Jeddah, Saudi Arabia

Corresponding Author Email ID: tsmkumar@klu.ac.in; Mobile Number: +91-9442394350

Abstract

The large-scale use of non-biodegradable materials, mainly comprising plastics, has raised serious environmental concerns for their viable alternatives. However, most of the biocomposites, including PLA-based matrix material, exhibit shortcomings in mechanical and thermal properties, thus posing serious barriers to their applications. Dealing with such challenges, the present work is related to the additive manufacture of biocomposites using Poly (lactic) acid (PLA) reinforced with sapodilla seed shell particulates through an FDM technique. PLA was mixed with different concentrations of SSS fillers such as 5, 10, 15, 20, and 25 wt.%. PLA and SSS were extruded into filaments used for 3D printing. The experimental results reported an improvement in tensile and flexural strength; in particular, the composites showed tensile and flexural strengths around 25.5 MPa and 49.46 MPa, respectively, which is an increase of about 51.25% and 27.6% as compared to the PLA matrix. However, the addition of SSS fillers did not have any significant influence on impact energy absorption. Thermal stability was checked using TGA, while its char residue increased from 1.15% to 2.59% in the composites, compared to pure PLA at 0.64%. These results clearly indicate that sapodilla seed shell fillers can overcome the inherent weaknesses of PLA, offering a promising solution toward lightweight and environmentally sustainable applications in additive manufacturing, such as biodegradable packaging materials and lightweight automotive interior components.

Keywords: Biopolymer; Natural filler; 3D Printing; Mechanical properties; thermal characterization

1. Introduction

Despite the fact that the collection of 3D printable materials has recently expanded dramatically, their number remains restricted, and their development continues to be one of the primary impediments to future improvements in 3D printing applications [1]. Amorphous polymers are the main materials used in the classic fused deposition method (FDM) of 3D printing. These materials include poly(lactic acid) (PLA), polyamide 6, polycarbonate, and acrylonitrile butadiene styrene (ABS) [2,3]. The field of composite product design and production is seeing a surge in interest due to recent developments in 3D printed composite materials. The addition of natural fillers to the printable polymer matrix gives the resultant materials unique physicochemical properties, enabling the production of 3D printed composites with improved properties and performances [4].

Due to the extensive use of non-biodegradable materials, notably plastics, the globe is currently experiencing a number of environmental problems [5]. In this regard, over the recent years, research on developing bio-composites has gained more attention owing to their lightweight, sturdy, and environmentally friendly nature. Further, there is a larger need to turn agricultural/crop residues and wastes into marketable commodities [6]. Many such waste materials from agricultural products such as banana [7,8], tamarind [9–12], rice [13], corn [14], egg, coffee [15–17], tea, beans [18], coconut [19], cashew [20] and other agricultural weeds [21,22] have been turned in to reinforcing fillers in composite applications. Other than agro-wastes animal wastes have also been used for instance sheep wool [23], fish scale [24] etc.

Table 4. The TGA/DTG data of SSS filler reinforced PLA biocomposites

Specimen	TGA/DTG			
	T_{onset} (◦C)	T_{max} (◦C)	D_W (%/min)	Y_C (%)
PLA	284.01	370.55	26.28	0.64
SSS5-PLA	284.13	370.58	27.31	1.15
SSS10-PLA	284.14	370.48	24.04	2.06
SSS15-PLA	284.12	369.02	25.23	2.08
SSS20-PLA	284.04	369.22	24.63	2.59
SSS25-PLA	284.00	370.77	22.94	2.22

4. Conclusions

With FDM 3D printing, there is a significant improvement in the properties of the obtained composites by incorporating SSS fillers into the PLA matrix. The important results obtained are:

- Tensile strength showed an increase of about 51% by addition of 15 wt.% SSS filler and reached 25.5 MPa against pure PLA.
- Its tensile modulus increased by 17.6% with the maximum value of 1.47 GPa at 10 wt.% SSS filler.
- The percentage improvement in flexural strength was 27.6%, thus giving a value of 49.46 MPa at 15 wt.% SSS filler.
- The tensile and flexural properties both improved with increasing filler content up to 15 wt.% and then decreased but still remained above the values for pure PLA.
- There is no impressive enhancement in absorption energy by the addition of SSS fillers.
- The thermal analysis showed different thermal stability, and the filled onset decomposition temperature and Tmax obtained with various filler contents.
- An increase in char residue from 0.64%, for pure PLA, up to 2.59% was recorded in the composites, indicating a better thermal stability for some composite filler concentrations.

The obtained results showed that with the addition of SSS fillers, PLA was able to improve some of its properties successfully, and because of this fact, they can be pursued as one of the potential ways for the development of lightweight and sustainable lighter-weight materials for additive manufacturing applications.

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Data Availability

Not applicable

Conflicts of Interest

The authors declare no conflicts of interest.

Author credit statement

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