Design and Evaluation of Sustainable PLA-Based Composite Filaments Using Local Bio-Waste for 3D Printing

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The global demand for sustainable materials in additive manufacturing has increased due to growing environmental concerns and the overreliance on petroleum-based polymers. Polylactic acid (PLA) is a widely used biodegradable material in fused deposition modeling (FDM) and exhibits limitations such as brittleness and moderate mechanical strength. This study investigates the development of sustainable PLA-based composite biodegradable filaments reinforced with locally available waste materials, including eggshells, rice husks, spent tea grounds and Ceylon olive seeds. The primary objective is to evaluate the feasibility, printability, and mechanical performance of these composites for 3D printing applications while promoting the utilization of Sri Lankan agricultural and food waste. The selected bio-waste materials were first crushed into fine powder, followed by sieve analysis to achieve controlled particle sizes below 200µm and then oven-dried at 60ºC to remove moisture before extrusion. Proper moisture removal was critical to prevent defects such as air bubble formation and poor interlayer bonding during printing. The dried fillers were blended with PLA with 1-5 wt% and extruded using the Filabot EX2 single screw extruder at 165.5ºC to produce filaments of 1.75 mm diameter. Standard test specimens were fabricated using Crealty Ender 3V2 FDM 3D printer under controlled process parameters and mechanically tested, according to ASTM D638 and ASTM D256 for tensile and impact properties, respectively. The results indicate that only 1-3 wt% filler compositions produced printable and stable filaments, while 4-5 wt% filler compositions resulted in extrusion instability, nozzle clogging, and poor print quality. Mechanical testing revealed that filler addition increased Young's modulus across all materials, with eggshell and Ceylon olive seed fillers showing the most significant stiffness improvement. Impact strength improved with tea waste fillers, indicating enhanced energy absorption. Tensile strength decreased by approximately 40-50% compared to pure PLA, limiting structural applications. This study demonstrates that locally sourced biodegradable waste can be effectively utilized to develop sustainable, low-cost PLA composites, suitable for non-load-bearing 3D printing applications, promoting circular economy practices and environmentally responsible manufacturing.

Keywords: PLA composites, FDM 3D printing, sustainable materials, biodegradable filaments, circular economy