

Sustainable 3D Printing in a Nutshell

Improving Print Quality in Ambient 3D Printing Using Pecan Shell-Based Biomaterials



With growing concern over our reliance on non-renewable resources and the environmental impact of conventional manufacturing, the quest for sustainable materials and eco-friendly production processes has intensified. This pursuit has extended to the field of additive manufacturing, where bio-materials have emerged as promising alternatives, aiming to reduce energy consumption and utilise material waste streams. While biopolymers like PLA are a good step forward, they still pose sustainability challenges, primarily related to energy-intensive melting processes, competition with food sources for production, slow biodegradability, and inadequate waste disposal systems. Consequently, researchers have turned to utilizing biomass waste streams to create 3D printable materials that solidify at ambient temperatures, offering potential solutions to reduce waste, energy consumption, and promote a circular economy. However, the currently existing bio-based materials for ambient printing exhibit inconsistencies in quality. To allow for commercial adoption of these materials, enhancements in print quality are necessary.

Research Objectives

This thesis addressed the core issue of lower print quality in room-temperature printing of biomaterials. The primary aim was to develop and optimize the print quality of these materials, fostering a deeper understanding of the key factors that influence their printing performance. Within the context of print quality, the study examined parameters such as dimensional accuracy, bridging, overhang performance, warpage, corner sharpness, surface finish, and precision. Furthermore, the research investigated the feasibility of reprinting these materials and its impact on their print quality. Extra attention was dedicated to investigating the influence of the rheology characteristics of the materials on the resulting print quality.

Print Quality of Pecan Shell-Based Materials

The research led to the creation of two materials, AB1 and CLAB4, utilizing an underutilized waste source—Pecan shells—and the optimization of print parameters to enhance their print quality.

AB1 demonstrated exceptional bridging capabilities, achieving distances of up to 15 mm, minimal shrinkage (averaging 6% in the xy-directions and 4% in the z-direction), and good result precision. In contrast, CLAB4 excelled in surface finish, printing overhangs up to 40 degrees, and showcased higher efficiency in material preparation. Most noteworthy of both materials is their reprintability without evident degradation

in print quality, a crucial feature for sustainable printing methodologies. Though these materials are not yet close to the quality standard of conventional 3D print materials such as PLA, they do show potential for further development. Their development and analyses pave the way for further advancements in sustainable 3D printing materials, offering potential alternatives to traditional plastics.

Rheology Importance

In this Research, rheology characteristics have proven to be pivotal in room temperature printing due to their direct influence on material flow and behaviour. Unlike conventional melting-based printing, where materials flows upon heating and solidify ones they are extruded, ambient printing requires inks to have specific rheology behaviours caused by changes in Shear.

Rheology governs how easily the ink flows when extruded and its ability to retain shape once extruded. For ambient printing, achieving the right balance of shear-thinning behavior—where viscosity decreases under shear stress—and elastic recovery—ensuring the viscosity increases sufficiently after extrusion—is crucial. These characteristics dictate how well the ink adheres to the desired structure during printing, directly impacting the final print quality and precision achievable with sustainable materials.

Rheometer tests can serve as a tool to further advance materials recipes and preparation procedures. In this research, for example, Mixing the material before extrusion showed to significantly increase the reaction to shear leading to more precise extrusion.

Challenges and Future Avenues in Sustainable 3D Printing

The research opens doors for future work, but ongoing challenges mean there's more to explore. The sensitivity of biowaste-derived materials to environmental factors, affecting print quality, remains a crucial challenge. Recommendations for further research encompass critical facets such as environmental condition control, in-situ solidification techniques, further rheology optimization, durability enhancement, and nozzle clogging prevention. Addressing these aspects holds the key to further advancing sustainable materials and methods for 3D-printing.

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Integrated Product Design

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