Characterization of PLA-Shiitake Composite

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BACKGROUND

Fossil Fuel based plastics are cheap to manufacture but utilize non-renewable resources, such as natural gas, in their fabrication, contributing to environmental damage during their production and beyond as they do not degrade and persist within the environment.

Bioplastics and bioplastic composites could provide sustainable alternatives through utilizing renewable or regenerative materials in their fabrication and compilation.

PURPOSE

Broader Research Goal

- Research agro-waste such as rice straw, bamboo fiber, and mycelium among others, as potential fillers in plastic composites, to reduce amount of plastic used, potentially increase degradability and sustainability.

Summer Research Focus

- Shiitake (*Lentinula edodes, Shii*) and Polylactic Acid (*PLA*) chosen as composite focus.
- How does mycelium affect the material properties of PLA when compiled using twin-screw extrusion methods.

REQUIREMENTS AND MATERIALS

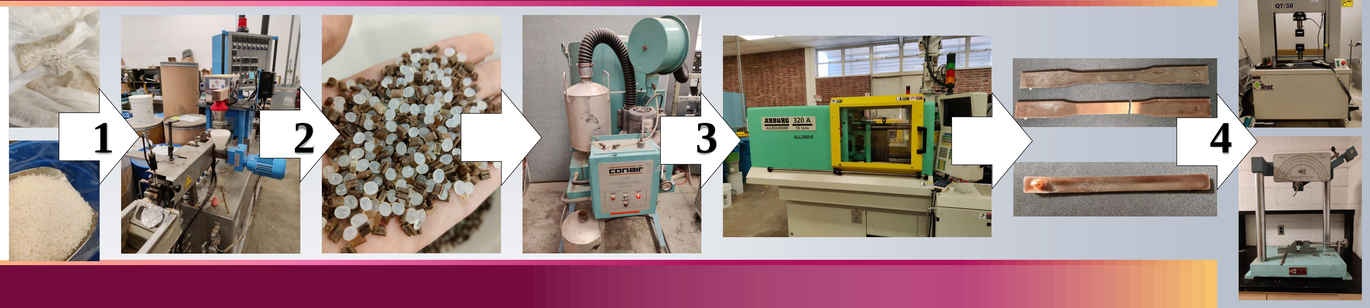
Requirements

- Produce PLA-Shiitake Composite (PLA/Shii) using a twin-screw compiler.
- Produce 5-10 samples with a percentage by volume of 5, 10, 15, and 20%.
- Characterize the mechanical properties.
  - Tensile testing using a QT/50 Universal Tester, following ISO 527-2 standards.
  - Impact testing using a TMI Impact Tester, following ASTM D-256 / ISO 179 standards.
  - Utilize SEM (Scanning Electron Microscopy) to study the physical structure of the PLA/Shii composite and the Shiitake powder additive.
  - Source Materials within the USA.

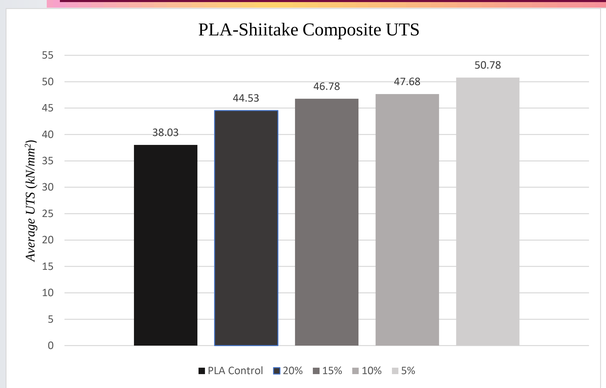
- PLA (Filabot Polylactic Acid, Extrusion grade)
  - Source material is renewable (Sugarcane, corn).
  - Industrially compostable and sustainable.
  - Society of Plastic Engineers (SPE) paper cites tuneable material properties through compounding.
- Shiitake Mushroom (Lentinula edodes)
  - Sourced within US (insert company name).
  - According to 2017 study, accounted for 22% of world mushroom supply.
  - "Wood rot" fungus grown primarily on sawdust.
  - Growing body of mycelium-based composite research.

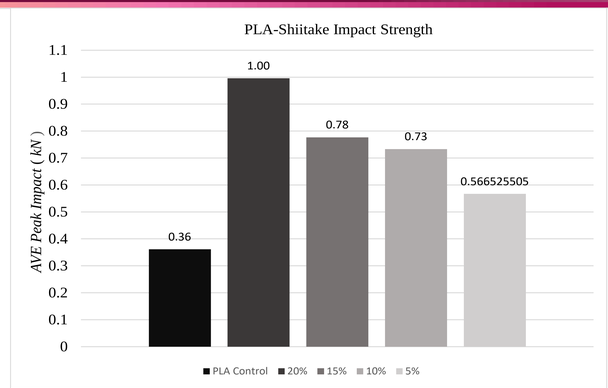
Methodology

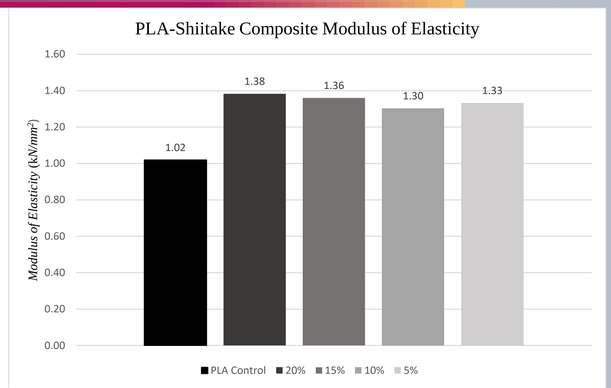
1. Shiitake Powder (above) and PLA Pellets (below) are added to Leistritz Compiler
2. PLA/Shii composite is extruded, pelletized and dried.
3. Samples are made using an Arburg 320A Injection Molder utilizing same machine settings as Pure PLA.
4. Tensile (above) and Impact (below) are loaded into respective testing machines.

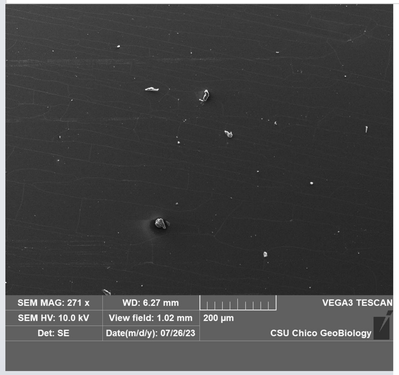


RESULTS

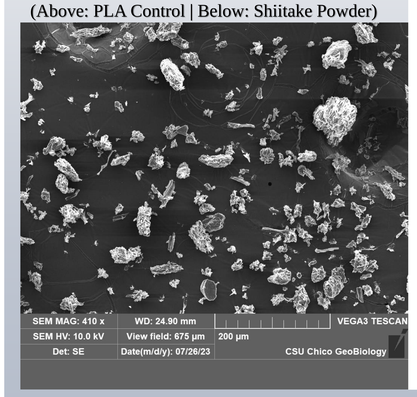








(Above: PLA Control | Below: Shiitake Powder)

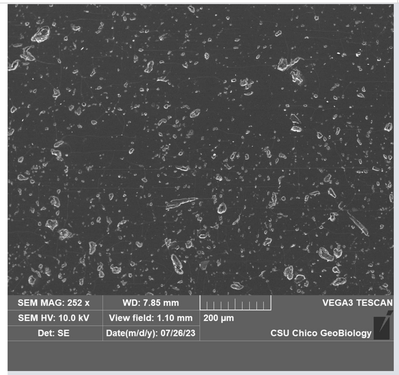


Mechanical Properties

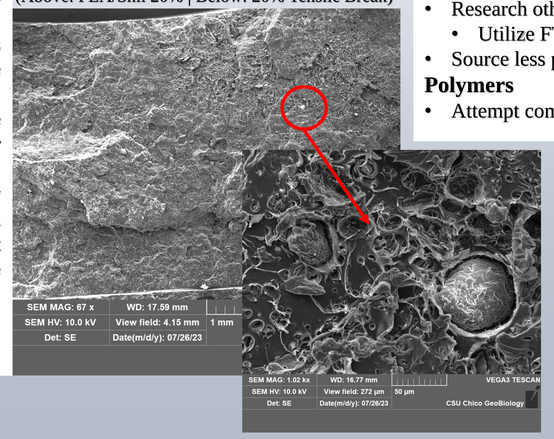
- PLA/Shii Composite showed higher ultimate tensile (UTS), impact strength and modulus of elasticity than that of Pure PLA control.
- A downward trend is seen in the AVG UTS of PLA/Shii as the % additive by volume increases, while the opposite is seen in the AVG Peak Impact.
- Modulus of Elasticity for PLA/Shii Composite higher than PLA Control, but relatively similar across percentages.

SEM Characterization

- Tensile breaks and polished samples used for characterization.
- SEM shows that the Shiitake additive was distributed uniformly in PLA using the twin-screw method.
- Shiitake powder additive revealed to be granular instead of fibrous, with irregular grain shapes and sizes.
- The granular shape of the additive may contribute to observed trends in UTS and Peak Impact, where the granules resist shearing force of impact, but slide past one another when pulled apart.



(Above: PLA/Shii 20% | Below: 20% Tensile Break)



CONCLUSIONS

- PLA/Shii Composite provides an all-around stronger alternative to PLA alone.
  - Reduces the amount of plastic used.
  - Utilizes renewable materials.
  - Shiitake granules increase strength, but overall composite remains brittle.

Further Research

- Preform degradation study to observe how shiitake as an additive affects how PLA breaks down.
- Produce an appropriately sized filament for 3d printing and test how performance in FDM printing.

Mycelium

- Research other potential species of mushroom.
  - Utilize FTIR to identify functional compounds in species.
- Source less processed shiitake or grow shiitake onsite.

Polymers

- Attempt compiling with PHA (Polyhydroxyalkanoate).

REFERENCES

1) Ramezani Dana, Hossein, and Farnoosh Ebrahimi. "Synthesis, Properties, and Applications of Polylactic Acid-based Polymers." *Polymer Engineering & Science*, vol. 63, no. 1, 2022, pp. 22–43, https://doi.org/10.1002/pen.26193.
2) Yang, Libin, et al. "Material Function of Mycelium-Based Bio-Composite: A Review." *Frontiers in Materials*, vol. 8, 2021, https://doi.org/10.3389/fmats.2021.737377.
3) Zin, M I, et al. "Chitin Fiber from Mushroom as Reinforcement for Biobased Polymer." IOP Conference Series: Materials Science and Engineering, vol. 1192, no. 1, 2021, p. 012016, https://doi.org/10.1088/1757-899x/1192/1/012016.

For a full list of references, please scan the QR code.

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