Improving Strength Properties of Paper Utilizing Mycelia Fungus

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Objective

- Investigate the use of mycelium with wood-based pulps to produce paper and evaluate changes in strength
- Other Aims:
  - Test different mycelium types in relation to different wood-based pulp
  - Develop new materials by creating handsheets with mycelia

Introduction

- Johnson and Carlson reported that small amounts of mycelia might be incorporated into wood fiber paper without effects on paper strength. [2]
  - Different quantities of mycelia might be used to impart specific properties. [2]
  - Their research indicated that fungus (mycelium) could improve strength properties of paper.
  - Mycelia could be utilized as a fiber extender in low concentration mixtures with wood fibers. [2]
- Mycelium:
  - The vegetative part of a fungus
  - Branching and thread-like

Three Types of Fungus Investigated

Common Name	Scientific Name	Growth Pattern
Reishi	*Ganoderma Lucidum*	longitudinally radial non-arterial format
Pearl	*Pleurotus Ostreatus var. Columbus*	longitudinally radial pattern and forms a think mat after time passes
Enoki	*Flammulina Velutipes*	longitudinally linear

- Sheets made of mycelia alone and dried in the air or by dry heat tend to be brittle. However, adding small amounts of cellulose fiber permitted the manufacture of a "satisfactory sheet". [3]
- A startup company, Ecovative, is currently using mycelium to make biologically inert Styrofoam as well as home-insulation. [1]
- The "mycopackaging" industry is still in its infancy, with many of its methods and procedures protected as intellectual property under trade secrets.

Oyster Mushroom (Pleurotus ostreatus) mycelium growing in a petri dish on coffee grounds. 2/10/12.
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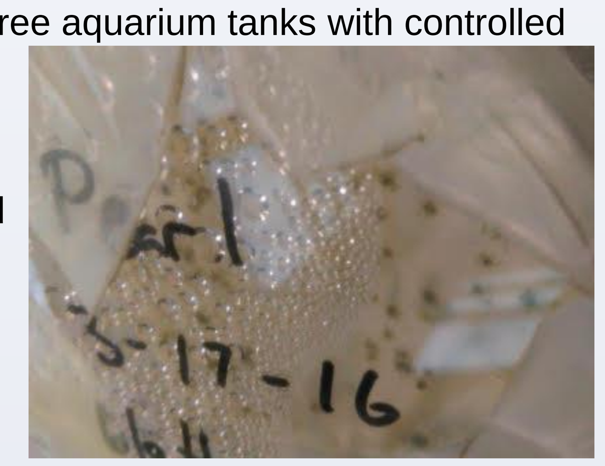
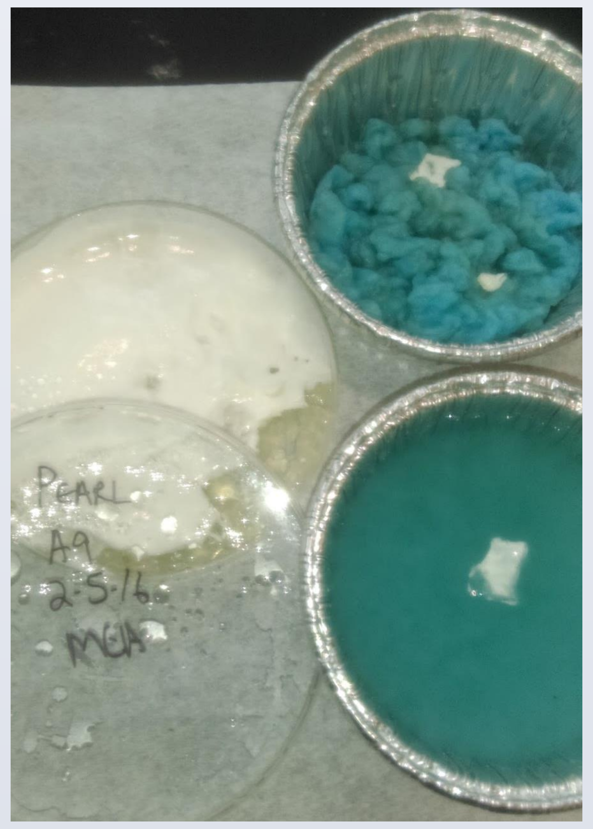
Methods

- The development of a mycelium-based sheet from a wood pulp food source began with obtaining the samples of Reishi, Pearl, and Enoki mycelium.
- The mycelium was grown in three aquarium tanks with controlled temperature and humidity.

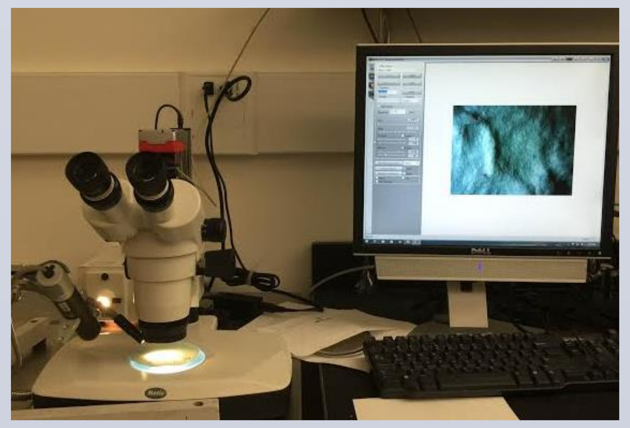


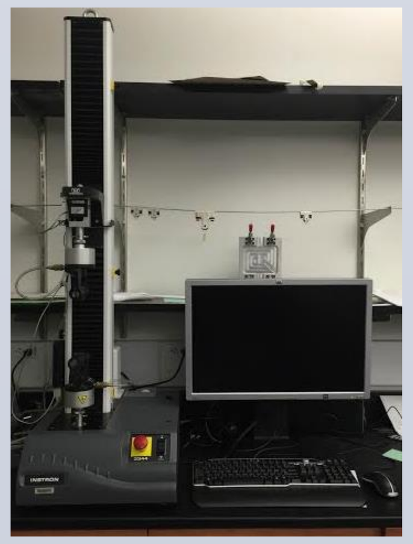
- Each mycelium was inoculated onto a damp TAPPI Standard blotting sheet and onto filter paper.
- Bleached and unbleached pulp slurries were prepared and inoculated with each of the three types of mycelium.



- The pulp slurry and moist pulp were used to create a handsheet using filter paper as a forming wire.

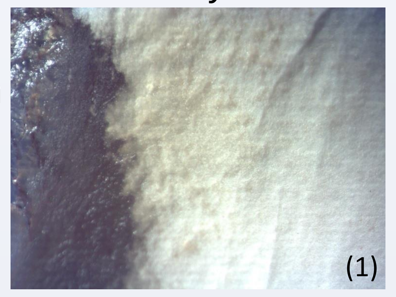
- The mycelium was studied using the Motic SMZ-168 Imaging Microscope with low angle light.
- Grammage and tensile strength were determined for the produced sheets.



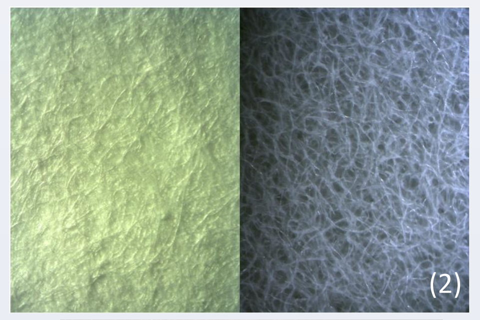


Results

- Samples were successfully inoculated and visible mycelium was present before testing occurred
  - Pearl tended to have the best growth
  - Mold growth was a persistent issue

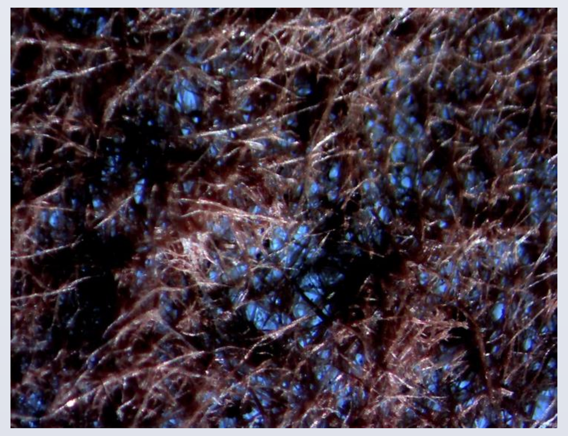


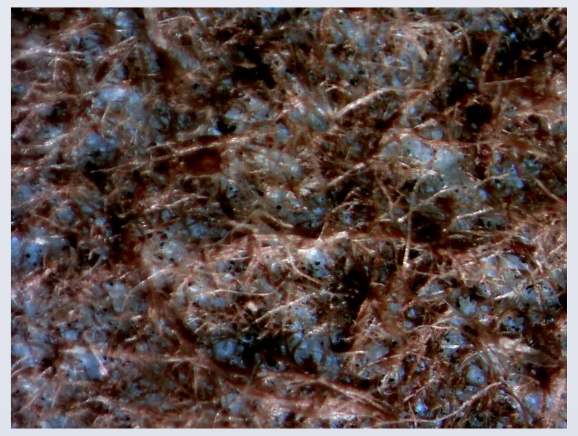
- A sample of freshly inoculated pearl shows the fully developed mycelium structure over agar (1)
- The blotter sheet and filter paper under inoculated sample provides a comparative visual (2)

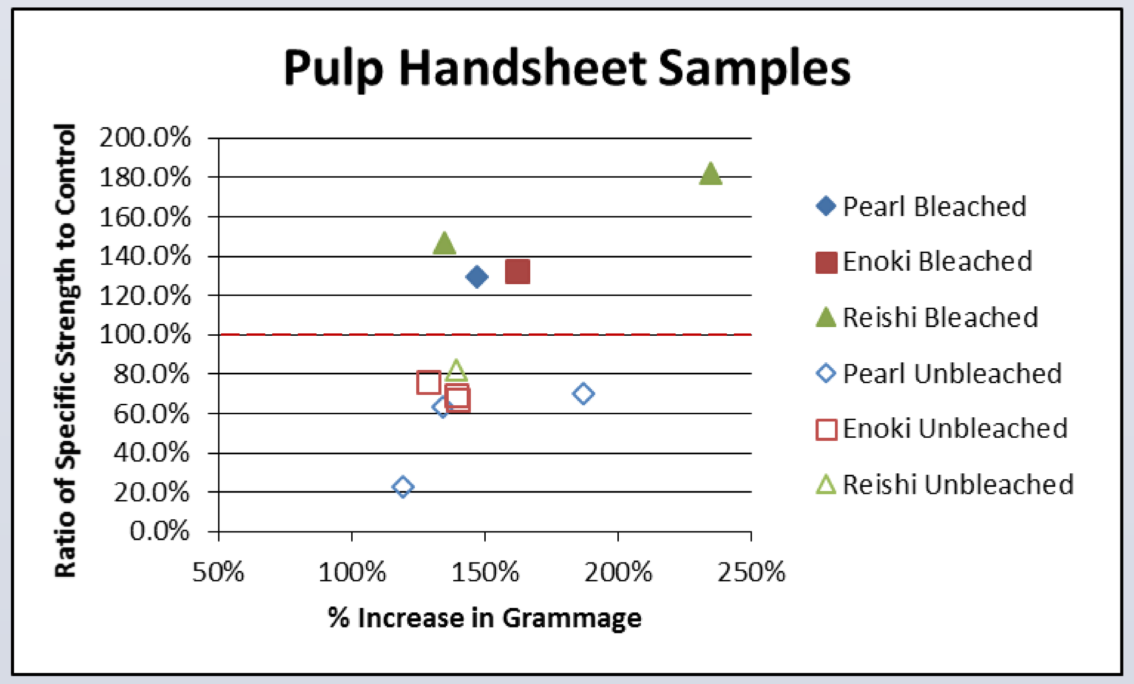


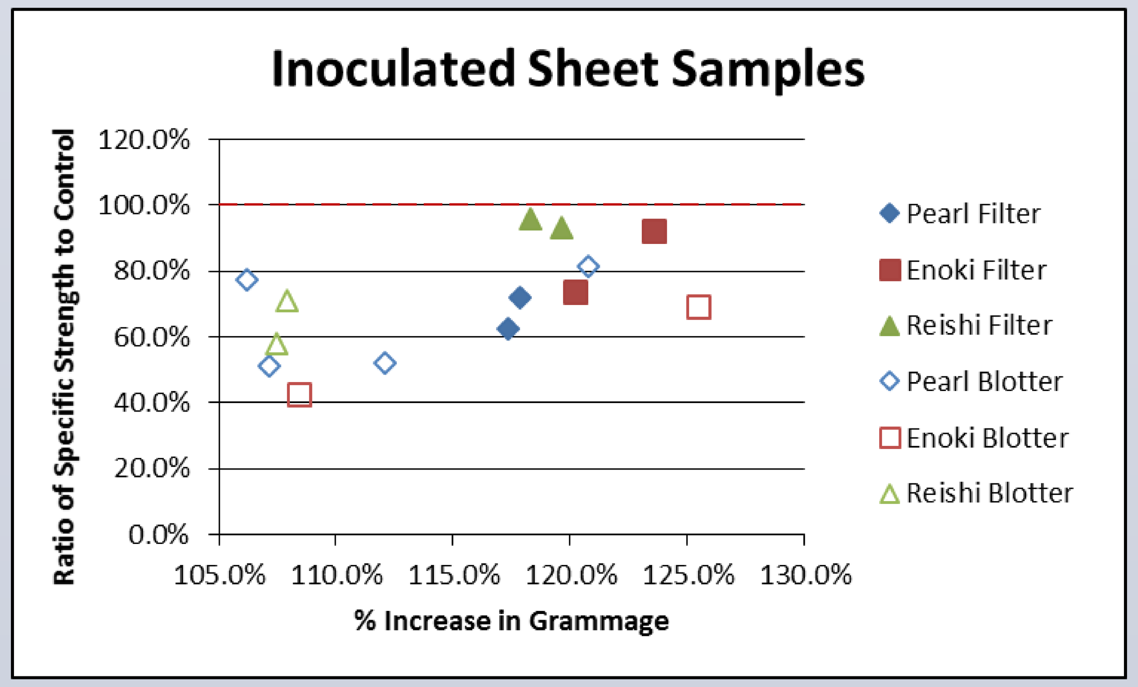
- Pearl provided some of the best results from straight inoculation
- This picture (right) shows the tendrils of mycelium stretching off the inoculation piece (3)

- Below are pictures of two samples of Pearl from a slurry inoculation.
  Left: Sheet formed, then heated.
  Right: Sheet formed, fed, grown for 1 week, and then heated.



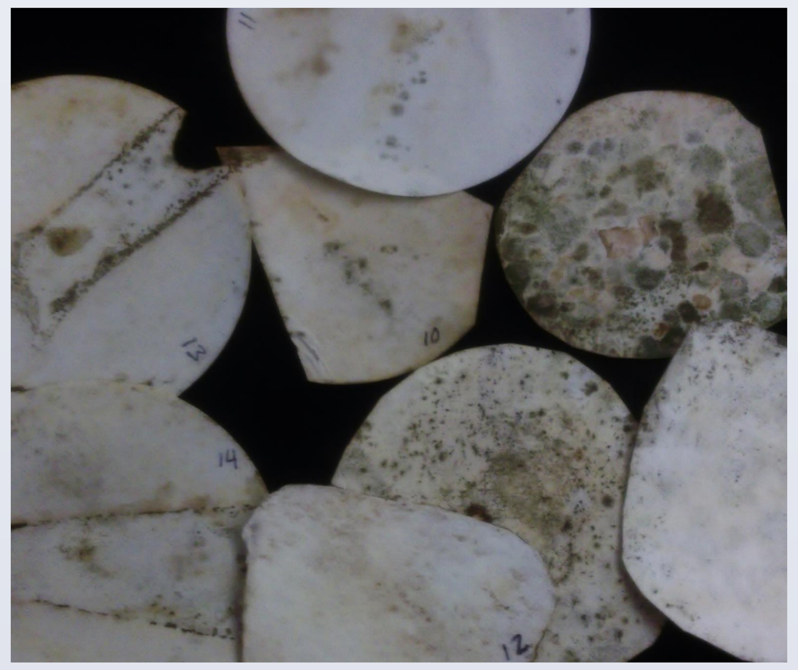






Conclusion

- Mycelium can grow with wood-based pulp as food source, but added malt was more effective.
- Reishi performed best in terms of strength, but more investigation is required to draw definitive conclusions
- Inoculating preformed sheets resulted in a loss of specific tensile strength
- Inoculating pulp and then forming sheets resulted in:
  - Beached Pulp: Increased strength with mycelium
  - Unbleached Pulp: Decreased strength with mycelium
- Environmental conditions and sterilization are essential factors
- The major unwanted outcome was mold growth.
- The rate of mycelium growth was slower than anticipated.



Recommendations for Further Study

- Improve sterilization of growth environment
- Improve environmental control for temperature and humidity
- Develop different methods for growing the mycelium
- Utilize different types and concentrations of mycelium
- Standardize how much malt is fed to the mycelium and investigate different food sources to speed up growth

References

[1] Fisher, Adam. "Industrial-Strength Fungus." Time. Time Inc., 8 Feb. 2010. Web. 12 Oct. 2015.

[2] Johnson, Morris A., and John A. Carlson. "Mycelial Paper: A Potential Resource Recovery Process?" The Institute of Paper Chemistry (1977): n. pag. Web. 26 Sept. 2015.

[3] Van Horn, W., Shema, B., 1954. Sheets Comprising Filaments of Fungi. United States patent 2811442

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