Amending PHB with Algal Biomass to Enhance Biodegradability

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Introduction

Pollution of the world's oceans has been taking place for over three centuries and is a growing problem all over the world. At least 60% of this pollution is made of petroleum-based plastic [1]. Plastic takes hundreds of years to degrade and, as a result, causes a number of environmental problems, including:

1. the death of marine mammals and sea birds
2. the release of toxic chemicals
3. disruption of the marine food web

To help reduce the amount of plastic that enters the oceans, scientists and engineers have started to develop biodegradable plastic alternatives. Many of these plastic alternatives are bioplastics, such as polyhydroxybutyrate (PHB) and polylactic acid (PLA).

http://www.cookiesound.com/2011/08/the-great-pacific-garbage-patch/

Problem

While bioplastics are a promising alternative to conventional plastics, many factors limit the large-scale production of these plastics. These factors are:

1. poor mechanical properties (ultimate tensile strength, Young's modulus)
2. slow degradation rates in aqueous environments

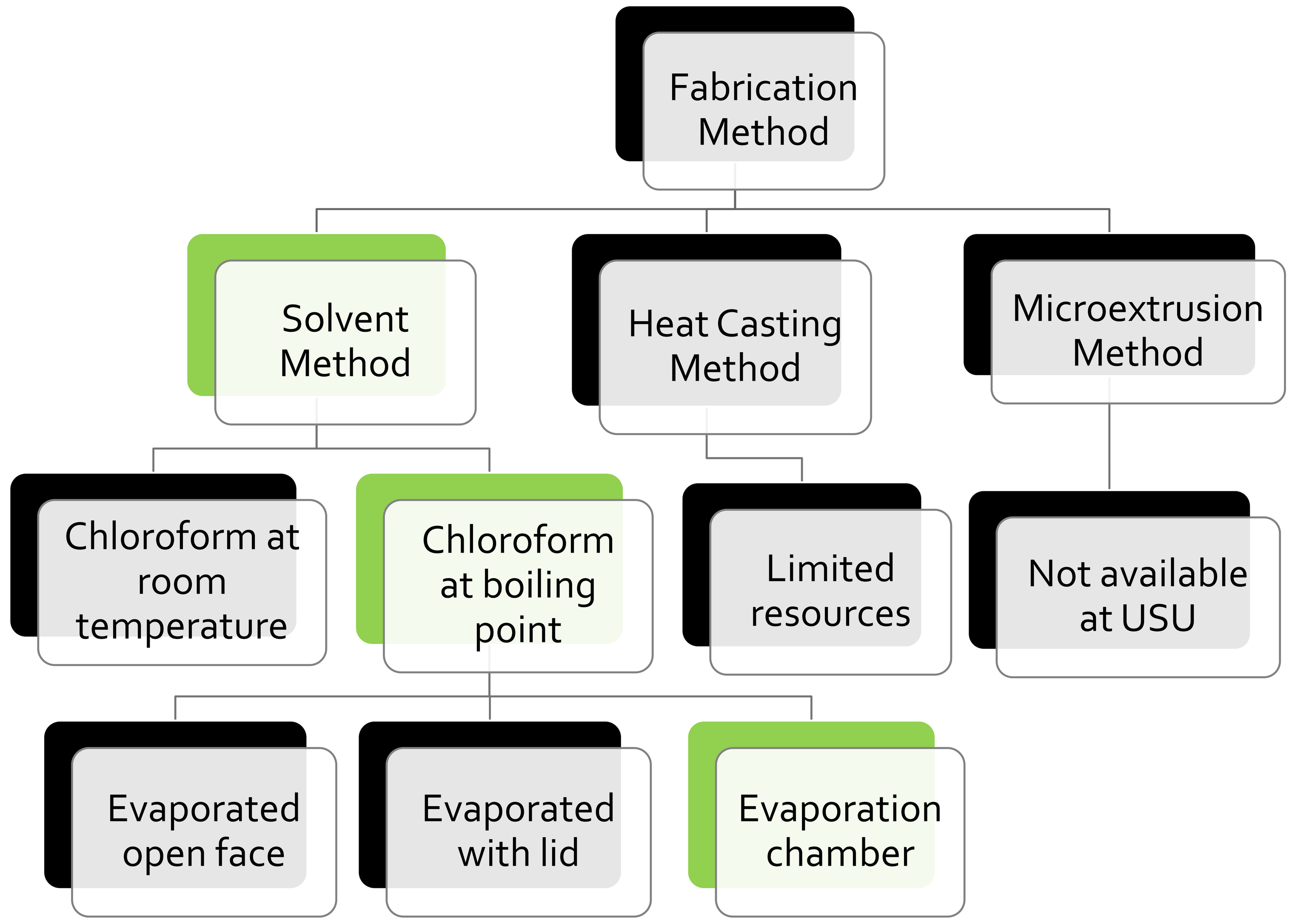
To help improve the mechanical properties and degradation rates, natural fibers or compounds can be added to the bioplastic during processing.

Objectives

The primary objectives of this project were to:

1. design a composite bioplastic using PHB and algal biomass
2. determine the ideal ratio of PHB and algal biomass that at least matches, ideally improves, the mechanical properties (Young's modulus, ultimate tensile strength, and percent elongation) and degradation rate of neat PHB

Design Process



For the composite, PHB was chosen as the bioplastic and algae was selected to be the additive.

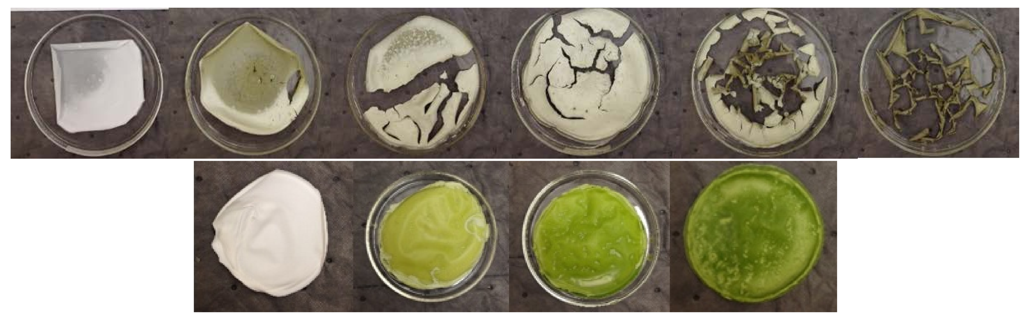
PHB was chosen because:

- it is readily degradable in seawater
- it is not synthetically produced

Algae was chosen because:

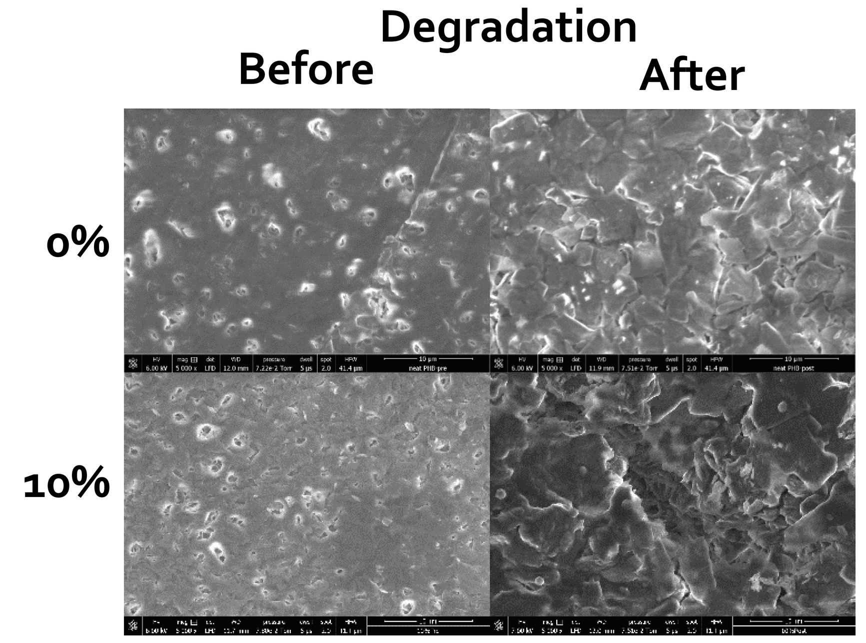
- it increased the rate of degradation in petroleum-based plastics [2]
- it is readily available

In order to determine the ideal ratio of PHB and algae that enhances the biodegradation and mechanical properties of PHB, the composites were fabricated using 0, 5, 10, and 20% algae.

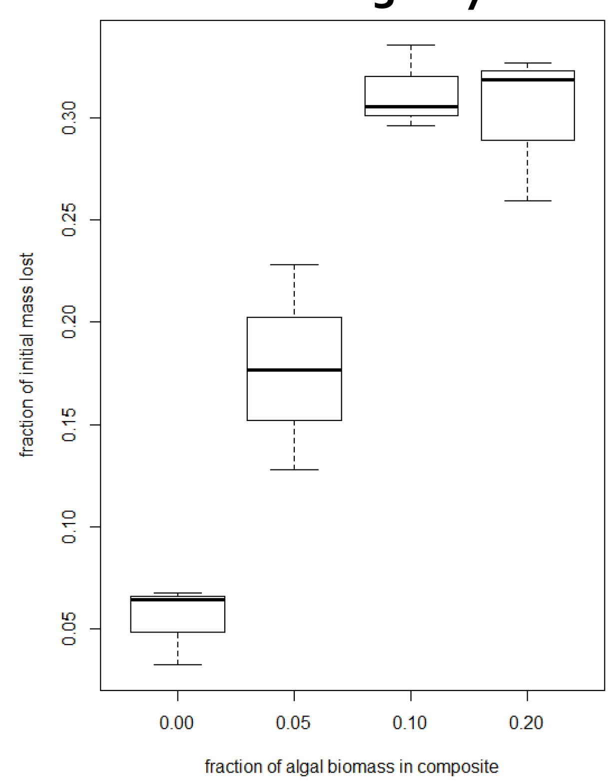


Results

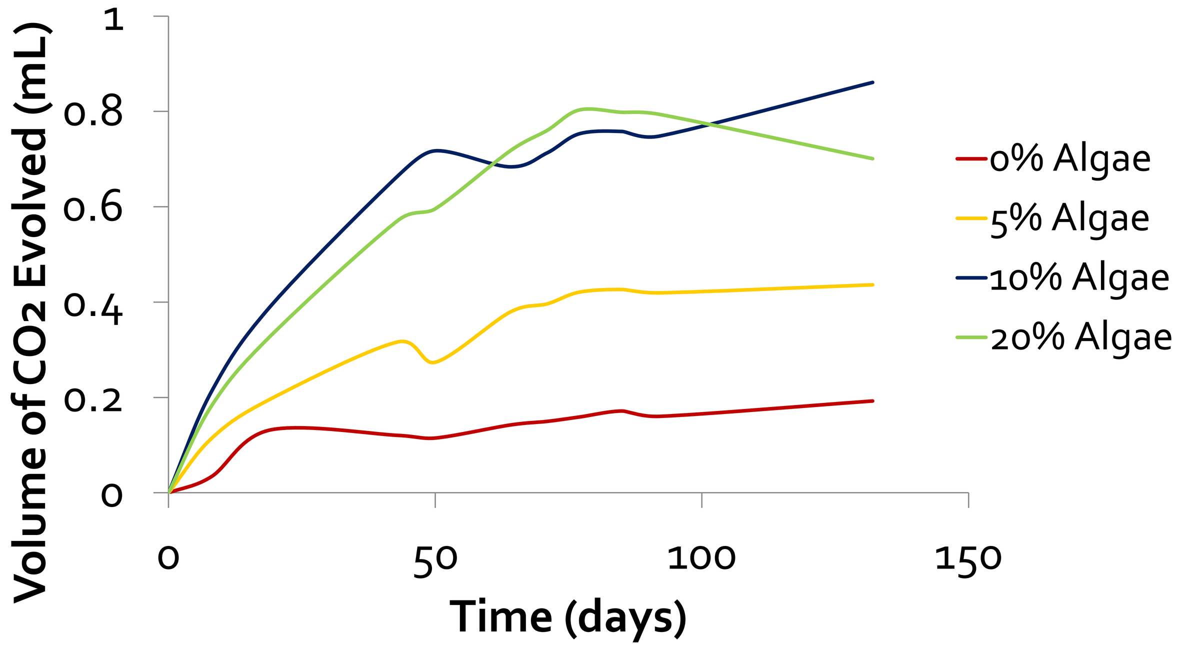
SEM Images Before and After Degradation



Residual Weight Tests After 83 Days



Volume of CO_2 Evolved by PHB-Algae Composites in Seawater



% Biodegradation of PHB-Algae Composites

Sample	% Biodegradation
0% Algae	2.682 ± 0.41
5% Algae	2.986 ± 0.62
10% Algae	8.756 ± 0.93
20% Algae	4.938 ± 1.70

- The 10% algae blend had the highest percent of biodegradation and the percent of biodegradation was statistically significantly different (SSD) (p-value < 0.05) from the other blends.
- The 10% and 20% algae blends ranked the highest for the residual weight test and were not SSD from each other.
- For ultimate tensile strength, the 0, 5, and 10% blends were not SSD. The ultimate tensile strength of the 20% composite was lower than the other blends.
- None of the blends were SDD in percent elongation.

Mechanical Properties of PHB-Algae Composites

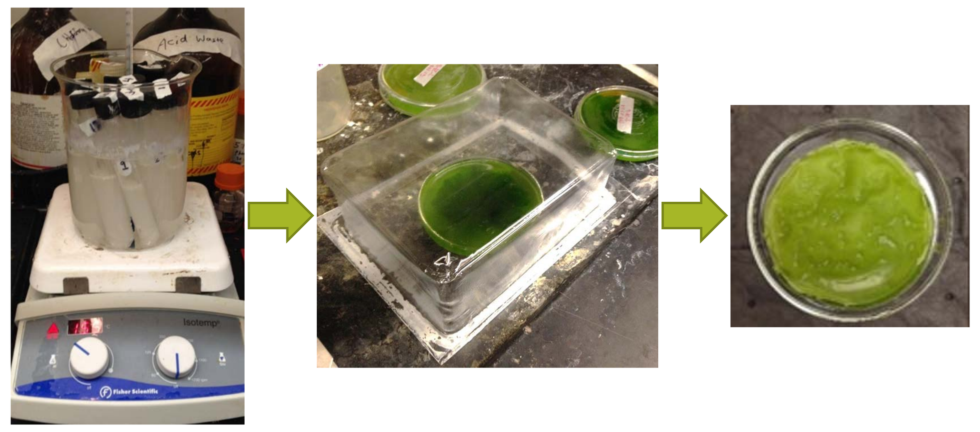
Sample	0% Algae	5% Algae	10% Algae	20% Algae
Modulus (MPa)	2337.048 ± 325.402	1900.310 ± 403.943	2024.833 ± 334.410	833.009 ± 184.935
Ultimate Tensile Strength (MPa)	10.676 ± 1.174	8.648 ± 1.045	8.343 ± 1.395	3.216 ± 0.908
% Elongation	1.583 ± 0.460	1.356 ± 0.352	1.058 ± 0.145	0.906 ± 0.199

Final Design

Using the solvent casting and evaporation chamber method, homogenous PHB and algal biomass composite films were successfully fabricated, meeting objective 1.

Based on the results of the degradation testing, the 10% algae composite was selected because it demonstrated a higher percent of biodegradation compared to the other composites, meeting objective 2.

The 10% algae composite could not be considered SSD from the 0% algae composite for modulus of elasticity, ultimate tensile strength, or percent elongation, meeting objective 2.



Future Work

Despite the success of this design, many improvements could be made. Some parameters that could be changed and evaluated include:

- the use of a different casting method (micro-extrusion, pelleter, etc.)
- using different additives
- testing CO_2 evolution with sediment as well as seawater to more accurately account for the microbial activity in seawater
- using agitated conditions when testing CO_2 evolution and residual weight to better replicate oceanic conditions
- using PLA as the base bioplastic

References

[1] Le Guern Lytle, Claire. "When The Mermaids Cry: The Great Plastic Tide." *Plastic Pollution*. N.p., n.d. Web. 10 Dec. 2016.

[2] Zeller, Mark Ashton, Ryan Hunt, Alexander Jones, and Suraj Sharma. "Bioplastics and Their Thermoplastic Blends from Spirulina and Chlorella Microalgae." Journal of Applied Polymer Science 130.5 (2013): 3263-275.

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