Analyzing the Effect of Surface Energy on Algae with Specialized Attachment Mechanisms in Static and Flow Environments

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Abstract

The goal of this research is to observe the effects of surface energy on the attachment of algae with specialized attachment mechanisms to substrata in stationary environments and small, controlled flow environments. The substrate materials tested are glass and polylactic acid (PLA). The algae species in focus for this experiment are two types of filamentous green algae, Oedogonium and Stigeoclonium.

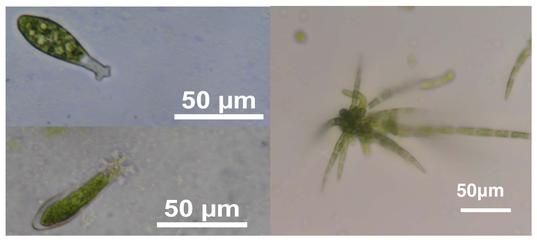


Figure 1. Specialized attachment mechanisms of each filamentous algae. Left-Oedogonium, holdfast and mucilage basal pads. Right-Stigeoclonium, "star-like" basal rhizoids.

In nature, multiple algae types grow together on rocks and surfaces, but the factors affecting algal attachment are not fully understood. Different types of algae are preferred for different commercial applications, such as pollutant removal, nutrient supplements, and biofuel production. The economic viability of algae cultivation could be improved if the details governing algal attachment were better understood.

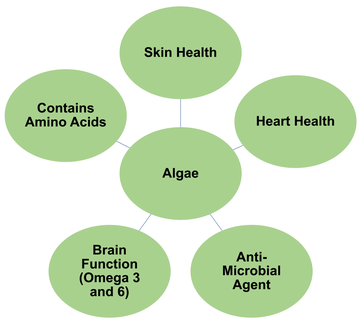


Figure 2. Chart displaying some of the many applications of algae.

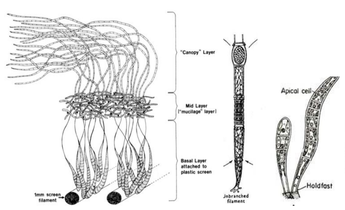


Figure 4[2]. Filamentous algae attachment, which more closely resembles the growth of terrestrial plants.

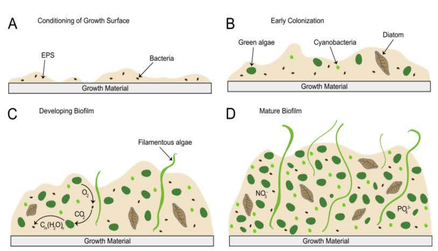
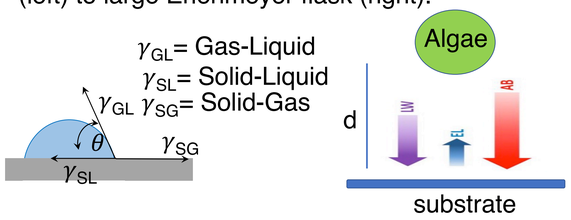


Figure 3[1]. Microalgae attach to a surface conditioned by bacteria and extracellular polymeric substance (EPS). As algae attach a biofilm is formed on the surface.

Methods

Figure 5. Stigeoclonium and Oedogonium culture set up, from vial (left) to large Erlenmeyer flask (right).

Cultures were started from pure strains of Stigeoclonium purchased from University of Texas. Growth began in a vial, the algae were fed Bold 3N Medium and sized up as concentration increased. Stigeoclonium was kept under a growth lamp 24/7.



Total Interaction Energy[3]

$$G^{TOT}(d) = G^{AB}(d) + G^{LW}(d) + G^{EL}(d)$$

- G^{AB} Acid-base Interactions
- G^{LW} Lifshitz-van der Waals Interactions
- G^{EL} Electrostatic Interactions

The van Oss[4] contact angle method was used to obtain surface energy parameter values to fit in the modified Young's Equation.
Three probe fluids used: water, hexadecane, and ethylene glycol.

Modified Young's Equation

$$cos\theta = -1 + \frac{2\left(\gamma_{sr}^{LW}\gamma_{l}^{LW}\right)^{1/2}}{\gamma_l} + \frac{2\left(\gamma_{sr}^{+}\gamma_{l}^{-}\right)^{1/2}}{\gamma_l} + \frac{2\left(\gamma_{sr}^{+}\gamma_{l}^{-}\right)^{1/2}}{\gamma_l}$$

- Accounts for Lifshitz van der Waals forces (VdW).
- VdW: dipole-dipole (polar), dispersion (nonpolar), and hydrogen bonding.
- Lifshitz: no pairwise additivity, looks at bulk whole bodies.

- Accounts for acid-base/polar interactions.
- Attraction or repulsion based on polarity.

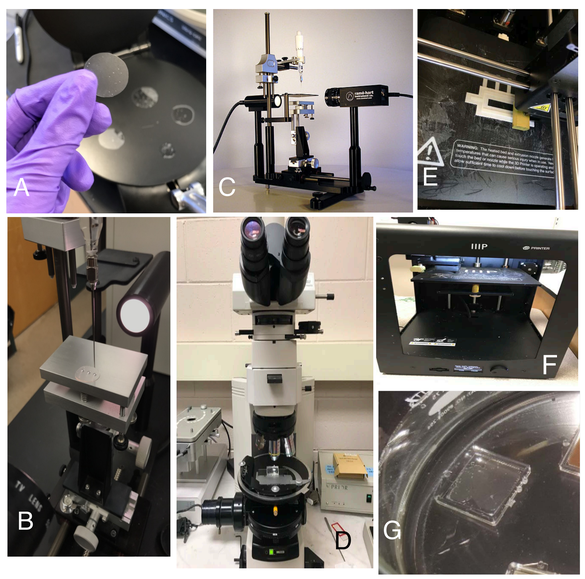


Figure 6. Pressed PLA disks (A), Goniometer to measure contact angles (B,C), Nikon 90i Microscope (D), and 3D printer (E,F). static attachment test set up (G),

Static Experiments

Substrates tested: glass, polylactic acid (PLA) disks made using a tortilla press. Substrates were placed in glass containers filled with 20 mL ultra-pure water and 10 mL of undiluted algae, then left undisturbed for 24 and 48 hrs.

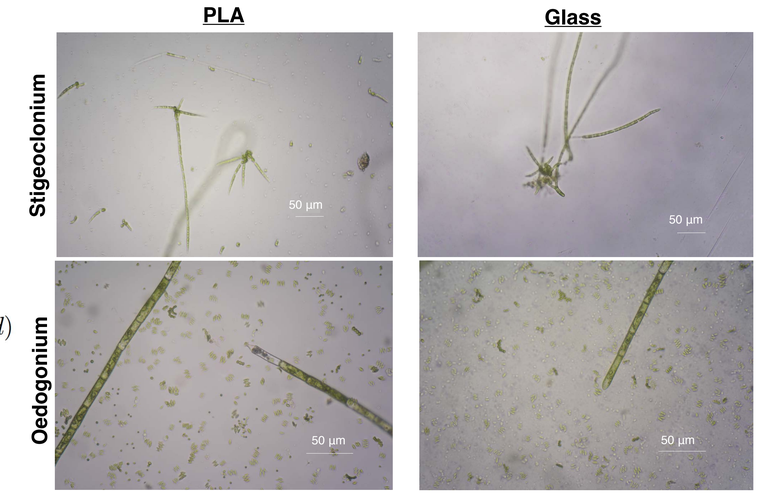
Contact Angle Data for PLA

Probe Fluid	Average Contact Angle
Water	73.0°
Ethylene glycol	48.9°
Hexadecane	17.2°

Surface Energy Parameters (mJ/m²)		
γ^{LW}	γ^{-}	γ^{+}
26.3	11.5	1.3

Data

Static Experiment Results (48hrs)



Flow Experiments

Small flow channels were 3D printed using PLA filament. The channel was connecting to a small pump and had ultra pure water flow through with Stigeoclonium. The channel was left undisturbed for 24 and 48hrs.

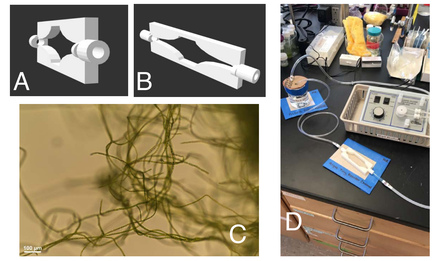


Figure 7. Channel design (A,B), Stigeoclonium viewed through the channel (C), and full pump and channel set up (D).

Conclusions and Future Work

- Green filamentous algae are more difficult to grow in a lab environment, a protocol for keeping a culture was made.
- Successful attachment with Stigeoclonium to both glass and PLA.
- Flow experiment work is ongoing.
- Future work needs to be done with scaled up models.

Acknowledgements

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References

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