Understanding and Controlling the Growth of Algae Species on Nanocomposites.

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Abstract

The goal of this research is to understand the attachment and growth of algae on nanocomposites that are made from polylactic acid (PLA) and cellulosic materials. By understanding the growth and attachment of algae, specific substrata could be made that would only grow one algae species each. Changing the composition of the substrata will change the attachment of the algae. Commercially, algae can be used as fuel, a nutrient, and for pollutant removal. In order to be used commercially, it is necessary to cultivate only one species of algae. In nature, multiple species of algae grow together in groups on rocks and other surfaces. A better understanding of the algae attachment will allow a higher yield of algae to be obtained.

Composites

- Algae prefer textured surfaces with spaces approximately the diameter of the algae cell.[1]
- Composites are made of biodegradable PLA and bio-derived cellulose nanocrystal (CNC).
- The nanocomposites we tested were 8 wt% sulfonated-CNC/PLA (SA-CNC/PLA), 8 wt% lignin-CNC/PLA (L-CNC/PLA), 4.45 wt% polyethylene oxide / 3.55 wt% CNC/PLA (PEO-CNC/PLA).
- Composites were made by freeze drying a CNC dispersion, dry mixing powder with PLA, then extruding (Figure 1).[1]
- Extruded composite is then heat pressed into a disk, then cut to a square for stationary attachment tests (Figure 2).

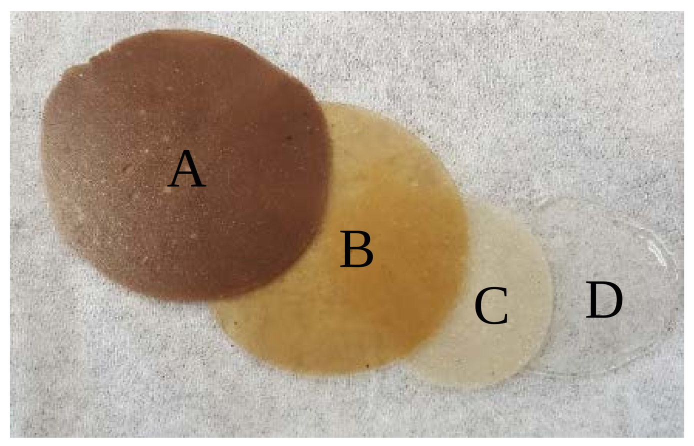


Figure 1. Composites: (A) 8wt% L-CNC/PLA, (B) 4.45 wt% PEO/ 3.55 wt% SA- CNC / PLA, (C)8wt% SA-CNC/PLA, (D)PLA

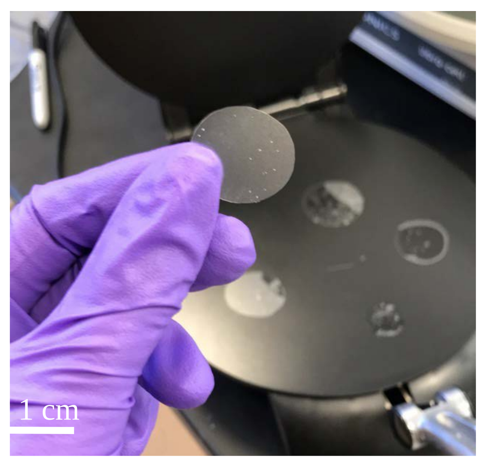


Figure 2. A sample of pure PLA that has been pressed into a disk.

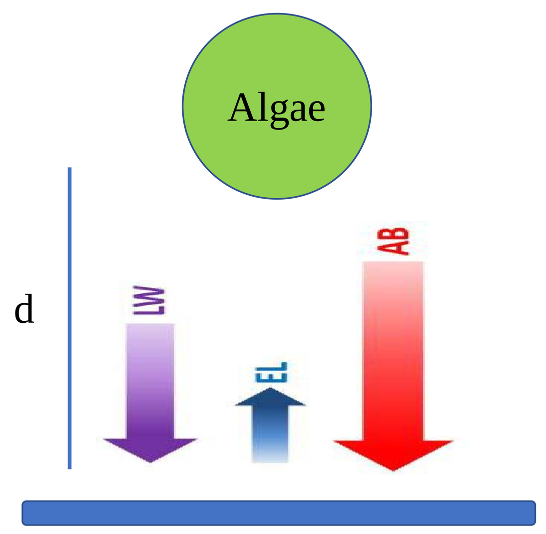
Contact Angles

- Contact angles of substrates were measured using a goniometer and 3 fluids.
- Contact angle data is needed to calculate surface energy, using a modified Young's equation.
- Surface energy values allow us to understand how different substrates affect algae attachment.
- The 3 probe fluids enable calculation of total interaction energy.
- Data obtained shows addition of nanocomposites changes the total interaction energy of the substrate (Figure 3).

Contact Angles

Material	Water	Ethylene Glycol	Hexadecane
PLA	78.5°	56.1°	18.6°
SA-CNC/PLA	77.3°	52.7°	17.1°
L-CNC/PLA	82.5°	58.8°	22.0°
PEO-CNC/PLA	83.6°	64.5°	32.2°

Figure 3. Contact angles of three liquids on the PLA composites.

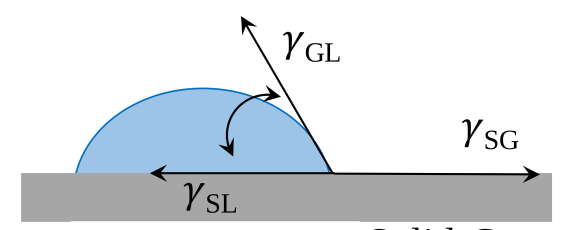


Substrate

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

Total Interaction Energy[3]

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



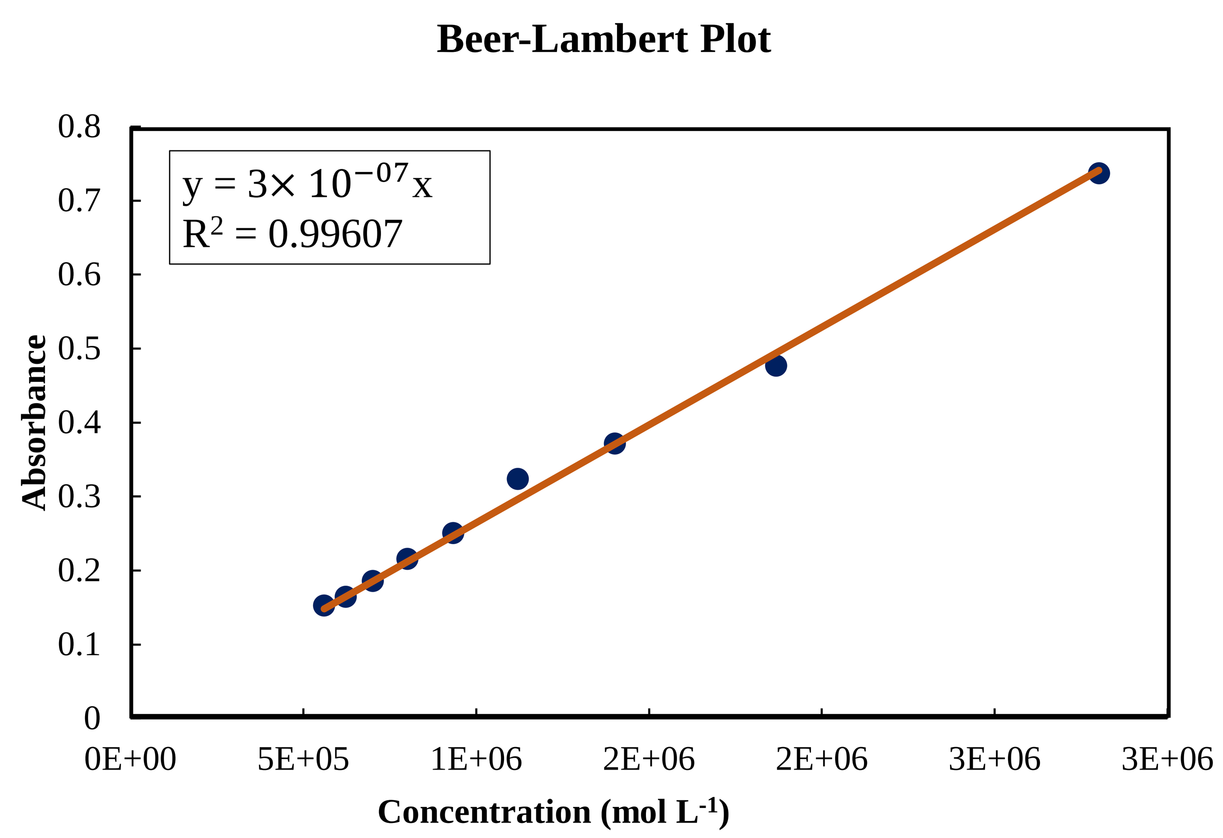
γ_{SG}= Solid-Gas
γ_{SL}= Solid-Liquid
γ_{GL}= Gas-Liquid

Modified Young's Equation

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

Algae Concentration

- Two methods for measuring algae concentration: hemocytometer and UV-Vis spectroscopy.
- UV-Vis spectroscopy uses Beer-Lambert law.
- Molar extinction coefficient of algae calculated below.
- Hemocytometer method requires cells to be hand counted and is inaccurate with large cultures.
- The algae concentration of Scenedesmus dimorphus was found to be 5.6×10^6 cells/mL using hemocytometer.



Calculating Molar Extinction Coefficient*

$Beer's\ Law: A = \varepsilon\, l\, c$

Slope = $\varepsilon\, l$ = 3×10^{-07} l = 10mm pathway

ε = 3×10^{-08} L mol^{-1} mm^{-1}

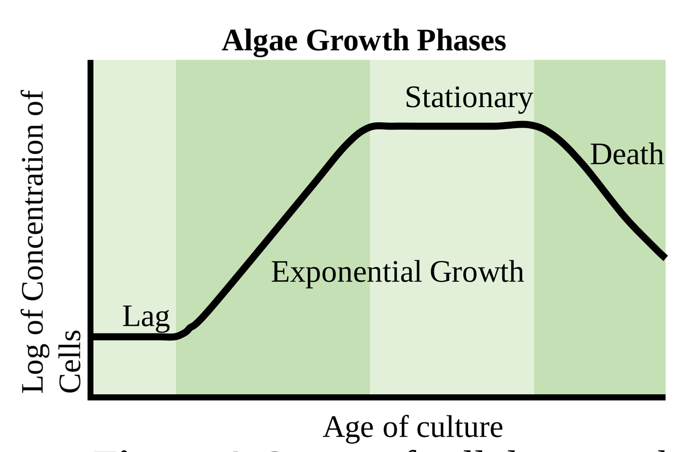


Figure 4. Stages of cellular growth of algae.

Algal Attachment

- Stationary attachment tests were ran to assess algal attachment.
- A concentration of 100,000 cells/mL was dispersed into a beaker containing the heat-pressed composite squares.
- The squares were covered in the dark for 24 hours, then removed and agitated to ensure cell attachment.
- 10-400 cells adhere to our selected surfaces (Figure 6).
- Total sample area: 85,281 μm²

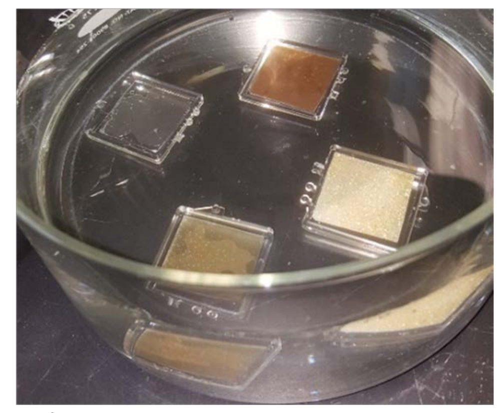


Figure 5. A stationary attachment test with each of the four PLA composites shown.

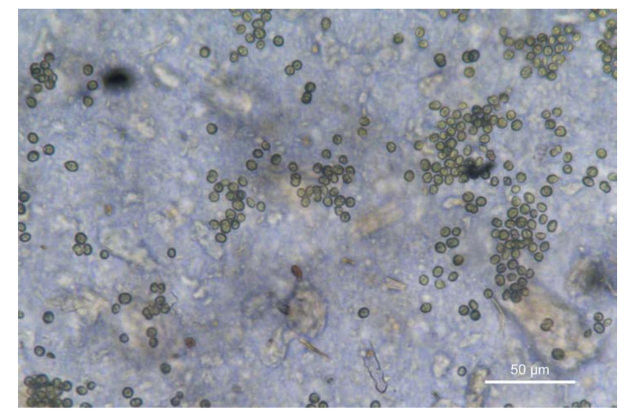


Figure 6. A sample of pressed PLA-8 wt% PEO-CNC composite with algae cells.

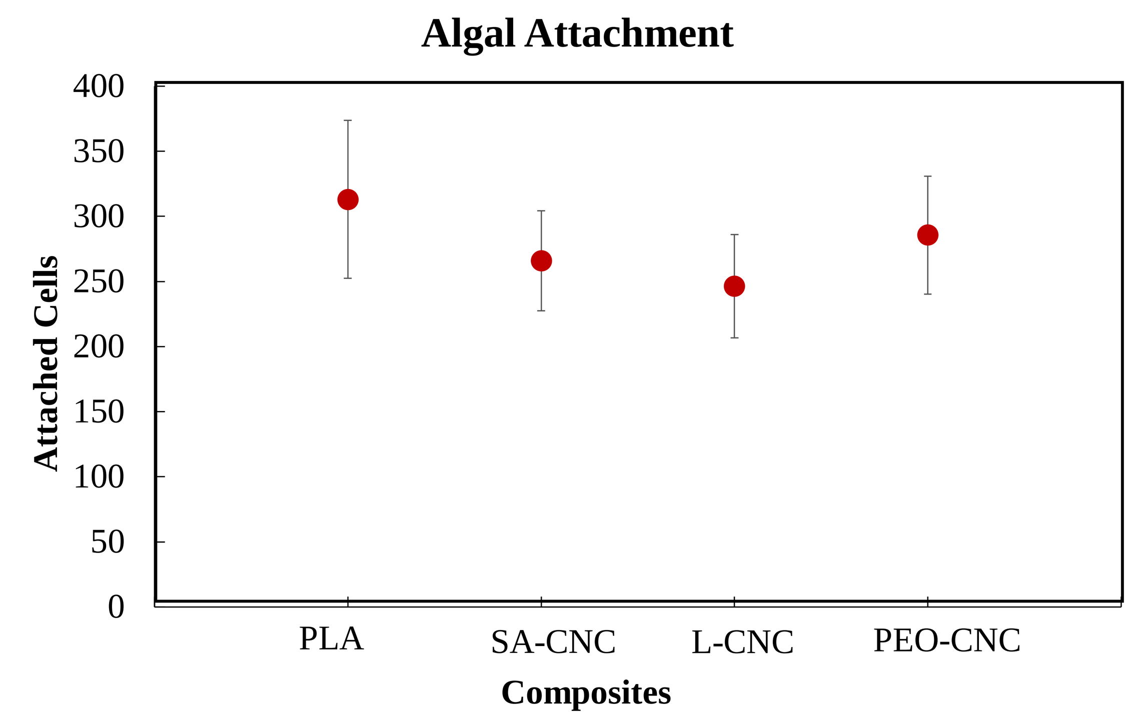


Figure 7. Algal attachment test data

Conclusions

- The UV-Vis spectroscopy method yields nearly the same results as the hemocytometer counting method.
- UV-Vis provides a faster method for monitoring algal cultures.
- A model planktonic algae (S. dimorphus) can attach to PLA and PLA nanocomposites.
- The addition of nanocomposites to PLA changes the surface energy of the substrate.

Future Work

- Observing filamentous algae attachment on varied composites of PLA and cellulosic materials in stagnant and flow environments.
- Understand effects of substrate on the attachment of different algae species.

Acknowledgements

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References

[1] Cui, Y.; Yuan, W.; Cao, J. 2013, *6* (4), 44–54.
[2] Parit, Mahesh. "Thermoplastic polymer nanocomposites." (Auburn University 2016).
[3]Ozkan A., Berberoglu H., 2013, *Physico-chemical surface properties of microalgae*, Colloids and Surfaces B, Vol. 112, pp. 287-293