Growing Algae in a Community College Biology Course: Inquiry Into The Algae-to-Biodiesel Pipeline

Pushpa Ramakrishna[1], David Stern[2], Shawn Kenaley[2], and Tiffany Fleming[2]

[1]Chandler Gilbert Community College, Chandler, AZ
[2]Boyce Thompson Institute for Plant Research, Ithaca, NY

Introduction

Fast-growing algae fix the greenhouse gas carbon dioxide via photosynthesis while accumulating on average 20-35% of their dry-weight in neutral lipids. These lipid molecules can be harvested and reacted with simple alcohols to produce biodiesel. Although the algae-to-biodiesel pipeline is a potential source of liquid transportation fuel, there remain many challenges that scientists presently are attempting to overcome including optimizing culture conditions for algal growth. The Boyce Thompson Institute for Plant Research (BTI) created a classroom algal photobioreactor laboratory (APBL) incorporating current research efforts and provided the curriculum, experimental materials and methods, and expertise for execution in a classroom setting. We present herein a pilot of APBL with honors biology (majors) students at Chandler Gilbert Community College in Chandler, Arizona.

Objectives

Teaching

- Reinforce fundamental biology principles of photosynthesis (P.S)
- Expose students to state of the art biofuel research
- Broaden the student experience
- Prepare them for the workplace

Student learning

- Illustrate how P.S transforms light energy into stored chemical energy
- Explain how the photobioreactor and algal growth is a model for P.S
- Develop a model to illustrate the flow of energy in photosynthesis and cellular respiration
- Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment
- Explain how making alterations to optimize the photobioreactors could reduce human impacts on natural systems

Student enrichment: science and engineering process skills

- Design, construct and carry out an experiment that manipulates one or more variables involved in growing algae
- Data analysis and summarizing results of the experiment
- Discuss the results of their experiments in order to draft a recommendation of the optimal growing conditions for an "oil-producing" microalga.
- Utilize experimental data to define future research needs.

Materials and Methods

Pedagogy

- Creation of a hands-on and minds-on learning experience with a roleplaying activity to teach the abstract concepts of photosynthesis.
- Students researched various types of renewable energies and presented a paper in the classroom.
- Exploration of the connection between global climate change and the production of biofuel via algal photosynthesis.
- Case-based learning with a biofuel startup company
- Inquiry-based laboratory with the APBL.

Experimental Design

Students were assigned the scenario of being scientific advisors to a biofuel startup company and asked to determine the optimal conditions for growing the algae, *Chlorella protothecoides*. Each student group, acting as independent biofuel companies:

- Created a testable hypothesis (Table 1).
- Designed experiments testing algal growth across various light (spectrum) and nutrient regimes: sugar type, nitrogen and/or phosphorus concentration(s), and salinity (Fig. 1 B-G). Photoperiod, light intensity, and ambient temperature across media combinations were identical and a media minus treatment (water) was utilized as a negative control.
- Built the different algal photobioreactors (APB) using the BTI protocols.
- Measured algal growth at various intervals using a hemocytometer (cell/mL) and spectrophotometer (optical density at 550 nm).

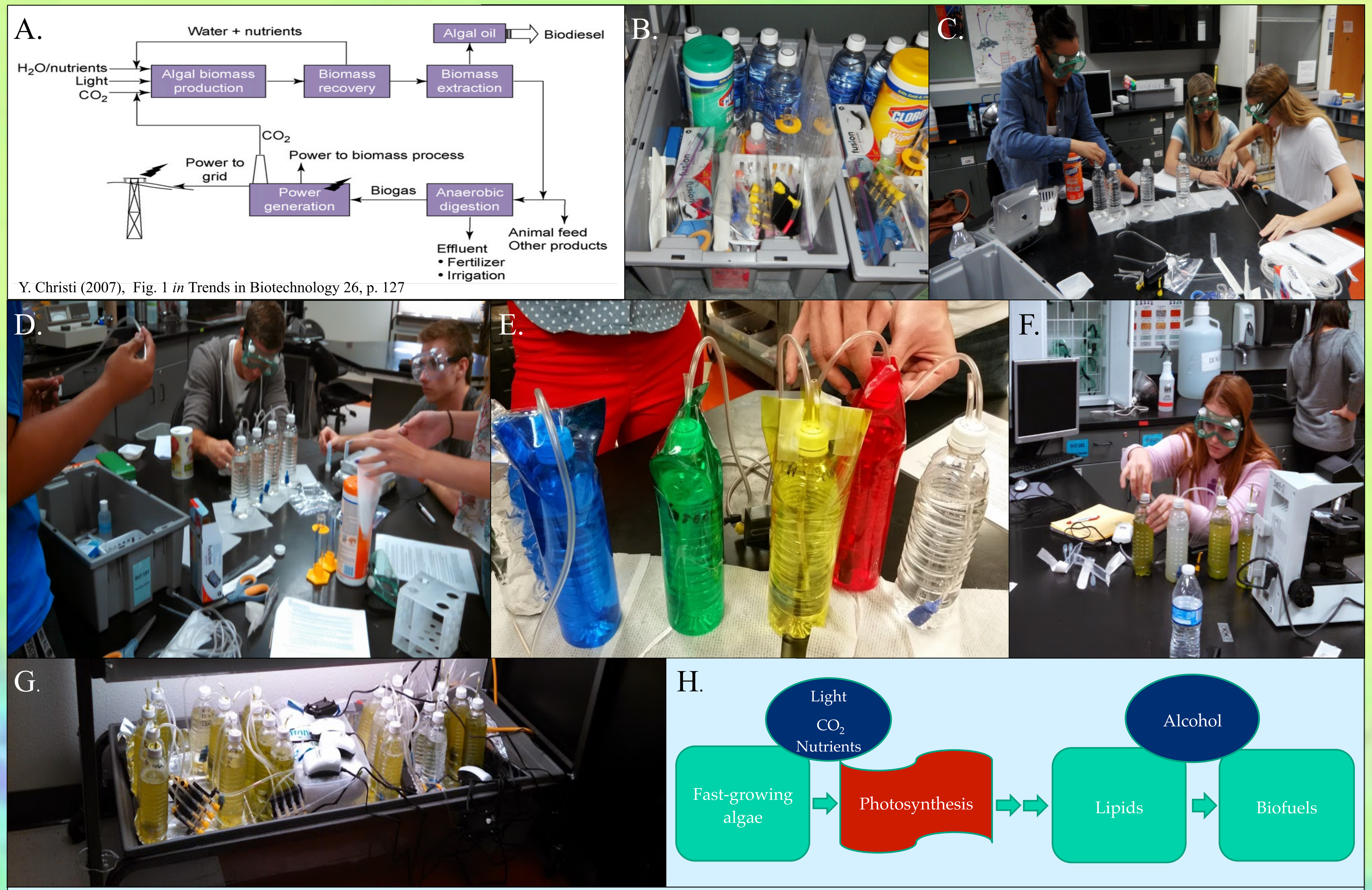

Fig. 1. (A) Schematic of algae-to-biodiesel pipeline (B) APBL Materials (C-D) Students building algal photobioreactors (E) APB using different light intensities (F-G) APB experiments using different types of variables (H) Schematic of algae growth downstream products.

Table 1. Sample student designed APBL demonstrating the application of science process skills to the real world scenario of a biofuel company. Table 1 illustrates hypothesis generation, student generated experimental design with variables, results, and conclusion.

Student Groups	Examples of student generated testable hypothesis	Variables tested	Best yield of algae cells (Spectrophotometer measurement)	Conclusion
Team 1	If higher salt concentrations are used in the solution, then the growth of algae will lessen.	Salt concentrations of 3%, 6%, 25%, 50% sea water were tested in APBs	20.3 x 10^7 cells/ml at 3% salt concentration	Hypothesis supported
Team 2	If the amount of urea in the photobioreactor is increased, then the amount of algae growth will increase.	4 APB tests of 0g, 0.4g, 0.8g, 1.2 g of urea	15.0 x 10^7 cells/ml at 0.8 g of urea	Hypothesis falsified
Team 3	If the amount of aquarium salts are increased in the APBL and the optical density is measured, then the growth of algae increases.	Aquarium salts of 0g, 0.2g, 0.4g and 0.8g were used in 4 APBs	20.7 x 10^7 cells/ml at 0.2 g aquarium salt (tube 2)	Hypothesis falsified
Team 4	If different types of sugars are used in the different photobioreactors, then glucose will have the highest algal growth	Variables used were no sugars, glucose, fructose and sucrose in 4 APBs	2.7 x 10^7 cells/ml at 12.6 g glucose	Hypothesis supported

Results

Cell concentration by culture media was analyzed and, according to these results, students prepared recommendations for optimal algal growth for the company and "informed stakeholders." Statistical analysis was not conducted since the sample sizes were too small. The design of experiments and hypotheses tested are presented in Table 1.

Conclusion

Students chose a particular variable and designed their own experiments to determine the optimum conditions for algal growth. Students conceived innovative ideas for other experiments including determining how the wavelength of light influences algal growth. Student teams had animated discussions on hypothesis generation, and on independent and dependent variables. This inquiry-based laboratory enabled students to think and perform experiments like scientists. Students realized the importance of keeping the bench top clean and maintaining a sterile environment. One student group had contamination issues with fungal growth. They had to discard the experiments in the middle and begin all over again.

The APBL was piloted in the undergraduate honors biology classroom and due to time constraints in the freshman class, reproducibility of the experiments were an issue. Incorporating the APBL in future semesters across many biology sections will enable us to increase the sample sizes.

This holistic approach to student learning where fundamental biological concepts were reinforced with a case based inquiry lab using state of the art biofuel research excited the students interest and impacted their learning.

Future Work

- Students will be provided resources to study additional variables to determine the optimum conditions for algal growth.
- Students can determine optimum conditions for algal growth, by combining results from the different teams and test it with new APBL experiments.
- Students will be given the opportunity to participate in a civic engagement module on energy policy, thereby providing an interdisciplinary focus.

Acknowledgements

Laboratory curricula and classroom materials (creation and/or distribution) were made possible by funding from the National Science Foundation (NSF; award no.1240478) and United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA; grant no. 2011-67009-30055).

References

(1) Kirrolia et al. Renew. Sust. Energ. Rev. 20: 642-656, 2013.
(2) Pragya et al. Renew. Sust. Energ. Rev. 24:159-171, 2013.