Report on Microalgae Photobioreactor Design, Construction and Testing at Northumbria University

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Problem statement

Within the framework for UK-Gulf Joint Academic Development Center project a photobioreactor to grow and harvest different types of microalgae and microorganisms has been constructed at Northumbria University.

There is plenty of available research in growing and cultivating microalgae cultures for lipid content and biodiesel production, which species are the best candidates, what environmental conditions will give the best biomass yield and highest lipid percentage as well as methods for refining the product into biodiesel. However, in almost all of this research the microalgae are cultivated using generic chemistry lab equipment or in an inefficient, open trench design. Neither of these styles of cultivation reflect the need for an economically viable system for producing biofuel from microalgae. In order to evaluate how algal biofuels could be produced on an industrial scale, a closed system Photobioreactor should be designed. Built within a set budget using commercially available materials, the design will need to prioritise economic efficiency at minimal ecological cost.

Aims

Using comprehensive research taken from other papers, design, build and evaluate a photobioreactor to provide conditions under controlled experiments for the comparison of the cultivation of four different strains of microalgae to maximize their growth rate. After cultivation of the microalgae, filter and dry the wet biomass and then extract lipids from the dry algal biomass and examine the calorific content.

Objectives

- Conduct a literature review of subjects surrounding a photobioreactor to gain a comprehensive understanding in order to design the reactor.
- Design a photobioreactor and create a model using Solidworks.
- Build the photobioreactor within the constraints of the project budget.
- Cultivate and harvest the biomass produced by the microalgae.
- Filter and dry the biomass and then extract lipids from the dry biomass.
- Examine calorific content of lipids extracted from the biomass.
- Evaluate the photobioreactor based on the results of the experiment and then provide ideas for future work in which the reactor can be improved.

Photobioreactor design

Figure 1. 3D design of photobioreactor

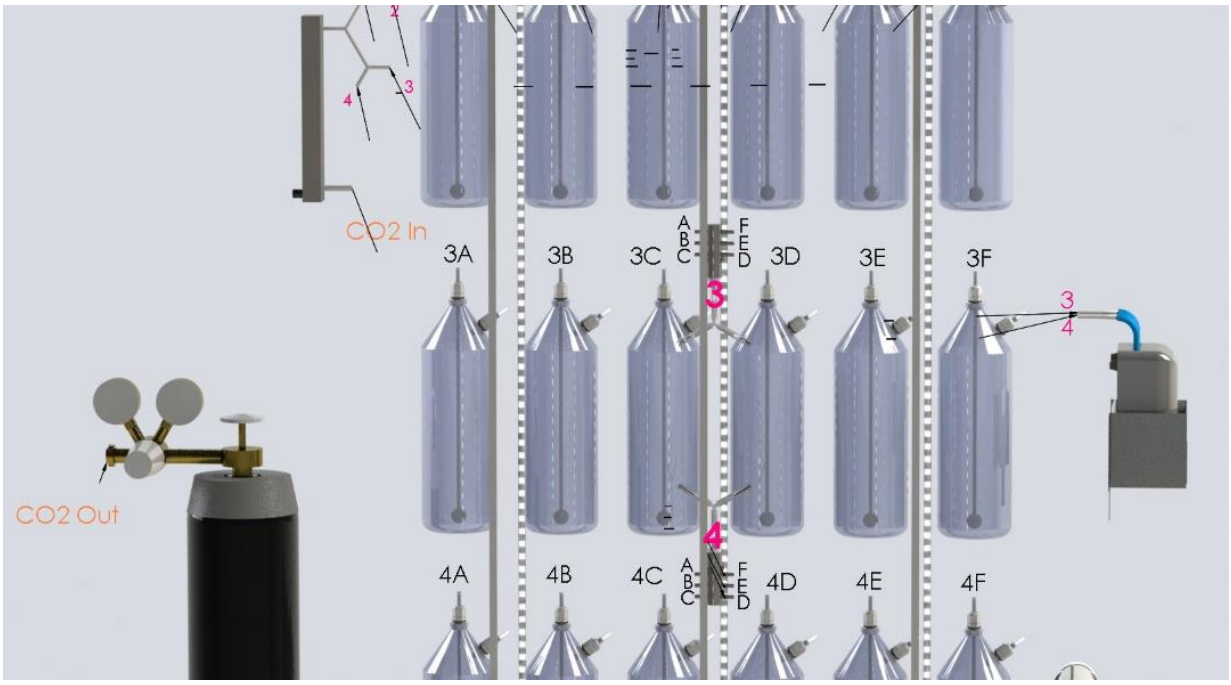


Figure 2. Microalgae growth vessels used with inlet and outlet

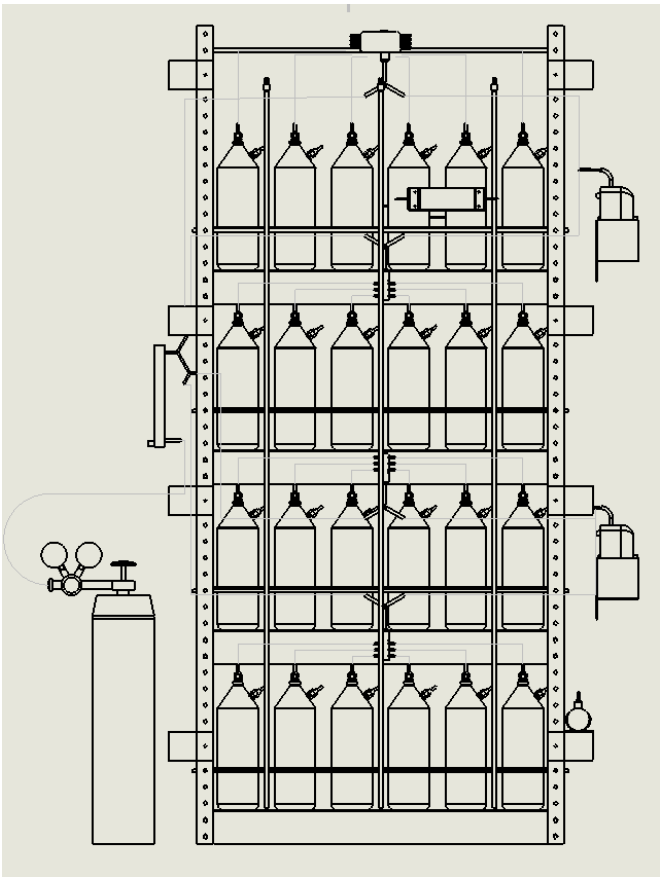


Figure 3. Schematics of the overall photobioreactor setup, including frame, growth vessels, carbon dioxide canister and air pumps.

Figure 4. Implemented lighting for photosynthesis

Microalgae Growth

Microalgae type - Scenedesmus Quadricauda

	Day 5: Only air has been supplied to the culture with a dose of nutrients on the 1st day of growth. The colour of the medium has changed to a translucent green.
	Day 7: Colour of medium slightly darkens, concentration of biomass increases. Only air has been supplied and no additional nutrients.
	Day 8: Colour has noticeably darkened after injection of additional carbon dioxide level above ambient. The culture has reacted well to additional supply of carbon dioxide.
	Day 11: Colour has intensified to dark green with small amount of light passing through the culture. This has followed the addition of extra nutrients and carbon dioxide.
	Final day: Small decrease in intensity of colour, small particles are settling at the bottom of each growth vessel. Water level has dropped, since day 4, most notably in vessel 1D.

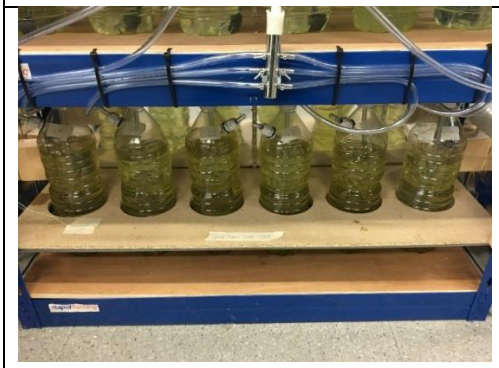
Microalgae type - Chlorella Vulgaris

	Day 5: Showing early signs of quick colouration of the medium, with only the addition of one sample of nutrients and ambient levels of carbon dioxide.
	Day 7: The colour has darkened still with no extra quantity of nutrients or carbon dioxide; small particles are noticeably moving around in the culture.
	Day 8: Addition of carbon dioxide has increased the amount of colouration overnight. This shows that the amount of carbon dioxide available promotes the biomass activity.
	Day 11: Addition of more nutrients has turned the culture to a dark green colour. The medium is now opaque and no bubbles are visible.
	Final Day: Signs of flocculation in the culture and some particles have attached to the sides of the growth vessel. Some sedimentation occurring on the bottom.

Microalgae Type - Spirulina Arthrospira

	Day 5: Comparison of visibility through the bottles with the lights on and off. With the LED strips on, it can be seen the medium is cloudy and semi-translucent. This medium was expected to turn green, not a milky colour.
	Day 7: Medium is still cloudy, with the visibility through the bottle dropping. Larger particles can be seen in the growth vessel.
	Day 8: No change with the addition of a higher concentration of carbon dioxide.
	Day 11: Mixture has become transparent again but a green colour can be seen when the LED strips are turned off. Mixture became clearer (apart from 3E) after the nutrients and a higher level of carbon dioxide was supplied.
	Final day: All bottles apart from 3E are clear; however all have particles floating around in the medium. Further investigation is required as to understand why this culture changed from cloudy to clear and why there was no green pigmentation.

Microalgae type – Pond Algae

	Day 4: Medium remains very clear with no obvious growths. The medium seems inactive.
	Day 7: Medium still remains clear with no growths. This is possible due to colder temperatures experienced in the room/at the bottom of the photobioreactor.
	Day 8: Growths appear in each vessel and some green colouration appears.
	Day 11: Further deepening of the green colour from day 8 which suggests the cultivation was slower than the other samples. Larger particles are floating in the medium. Also some red spores elsewhere in the vessel.
	Final day: The water is now a murky green but still clear, unlike rows 2 and 3, which suggests biomass concentration is not as high.

Microalgae Biomass Collection

Figure 5. Collected microalgae solution

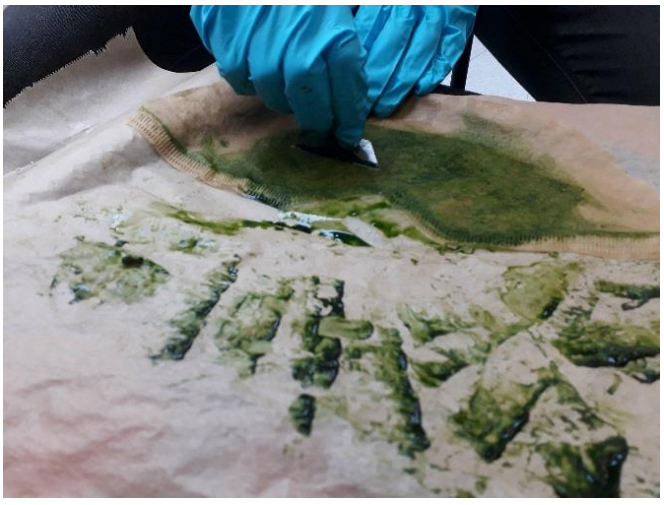


Figure 6. Microalgae to dry

Figure 7. Microalgae biomass collected

Figure 8. Microalgae ready for centrifuge

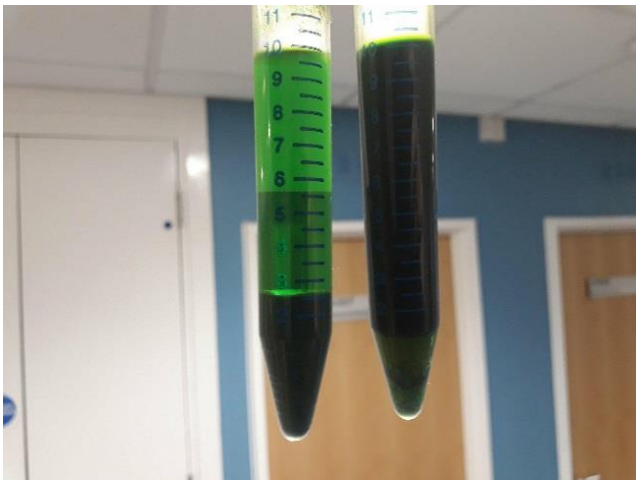


Figure 9. Microalgae after centrifuge