Algal Power: The Future of Energy

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BACKGROUND

The development of alternative fuels to fulfill the globe's energy demands has become crucial to creating a sustainable planet. Algae is a unique alternative that can be utilized to create energy through method such as direct combustion, and a variety of oil extraction processes. The research and development of algae as a biofuel is still in its infancy, and has been limited by cost. The goal of this project is to research and develop a practical process for growing, harvesting and processing algae at a small scale to provide enough energy for a two-person high efficiency dwelling. Research, experiment, and conceptual designs will be implemented to further explore the viability of this promising energy .The results of the project's experimental approach will be analyzed to determine the simplicity, cost effectiveness and practicality of algal energy production at a small scale. This project was conducted from September 2019-May 2020 with the help of the project sponsor Professor Felix DeVito as several other UNH faculty and facilities.

Project Statement: "Create a cost-effective on-site algae to energy system to heat a two person home"

METHODS

Tabletop experimentation began with the growth of various algae species in standardized conditions. Nannochloropsis oculata was determined to have the highest energy potential, fastest growth rate, and locality and was subsequently chosen for further testing. Throughout the process, nutrient levels and growth conditions such as pH, dissolved oxygen and nitrogen levels were measured and monitored to maximize growth. Density of the algae was determined by microscopic cell count in a given volume and extrapolated to a larger scale.

Research was conducted on different kinds of cultivation methods and an open system raceway decided upon. This was selected after comparing a variety of growth methods and determining it was the most cost-effective method and simplest to operate

Flocculation is a process which causes small particles to clump together, allowing them to be more easily removed from water. Flocculation techniques were researched and evaluated by cost, efficiency and accessibility. After assessing the feasibility of each option, our team decided the best flocculants for this procedure would be lowering the pH with sulfuric acid as well as adding chitosan.

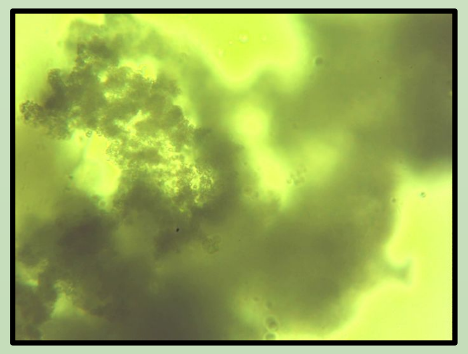
Once the flocs are formed, the algae would be collected and dried using solar drying. This process involves the algae being laid in a thin layer under constant lighting. Drying experimentation was carried out with Muskgrass, a macroalgae. It was harvested using an aquarium net and dried for an average of four days. It was found that the macroalgae decreased in mass 95% throughout this drying time.

To derive energy from algae, the oil within each cell can be extracted or the algae biomass can be burned as a fuel. Oil extraction methods investigated were using an expeller press, using a food processor and chemical removal with transesterification. These oil extraction techniques were outlined in detail to allow the next group to test them out and assess feasibility. A combustion experiment was also designed for the next team to evaluate the feasibility of burning the algae directly for energy.

RESULTS

Cultivation

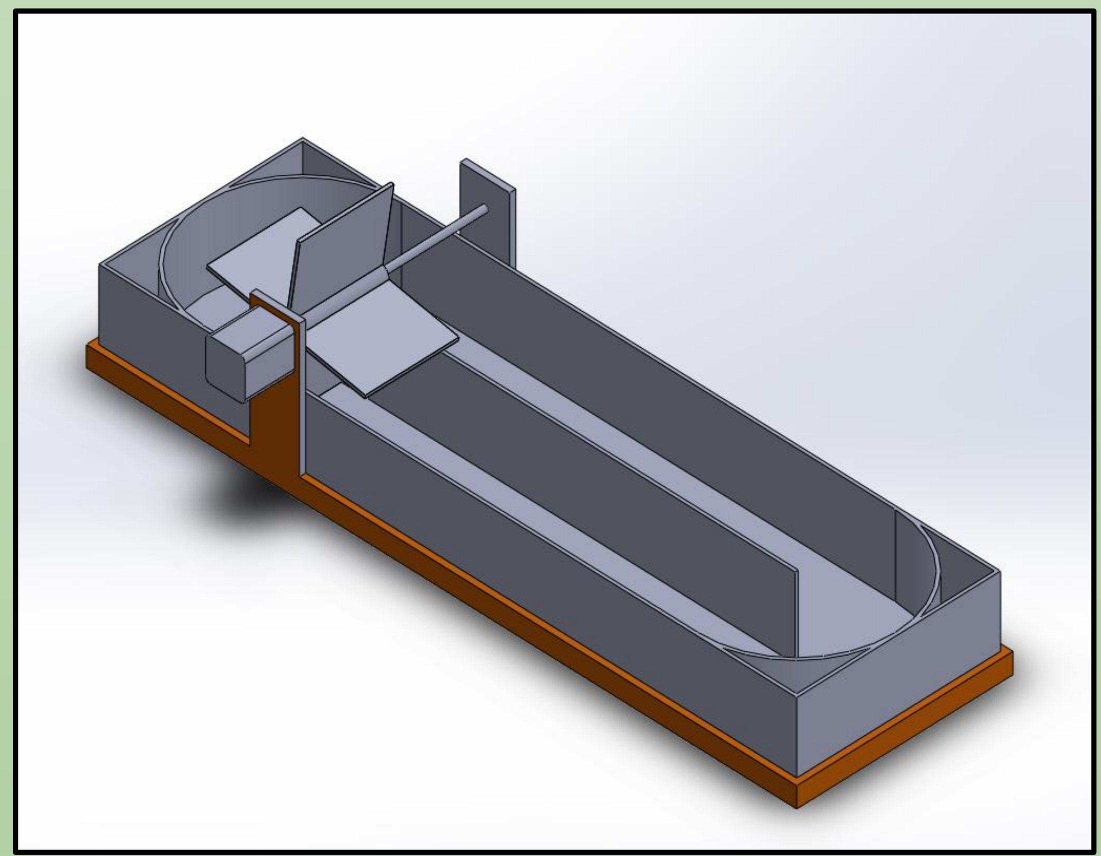
Algae Species Chosen:



The species worked with were two microalgae samples, porphyridium cruentum and nannochloropsis oculata (N. oculata), along with one locally sourced macroalgae determined to be Muskgrass. N. oculata was chosen for continued use because of its fast growth rate, the fact that it is a local species found in new Hampshire and studies have shown it has a high oil content.

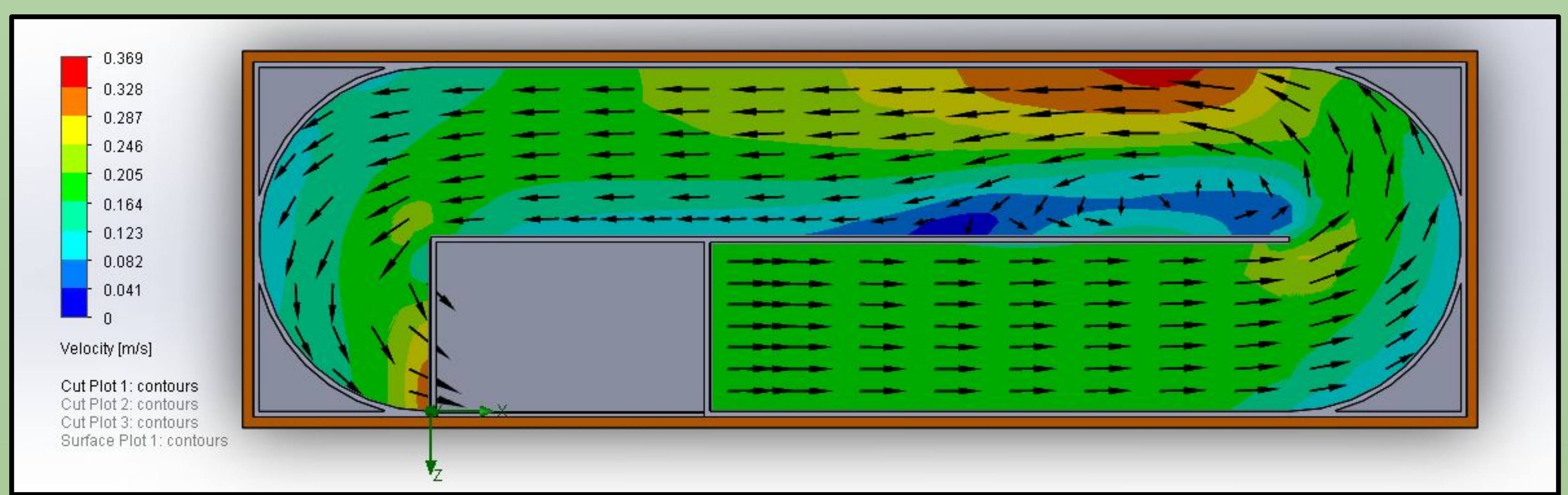
Raceway

Design Parameters:



- Open System Raceway
- Dimensions
  - Length: 1.4 m
  - Width: 0.4 m
  - Height: 0.15 m
  - Arc Radius: 0.2 m
- Designed based on Reynold's Number of 10,000
- Melamine board support the overall build of raceway and used to suspend the paddlewheel system

Analysis:



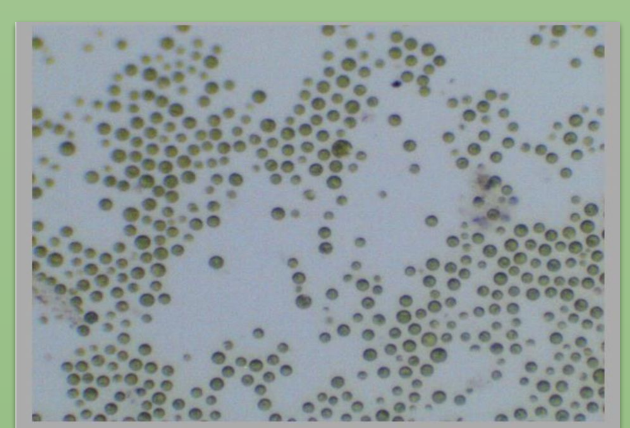
SolidWorks:
- Flow Simulation with velocity analysis

MatLab Computation:
- Power requirement of 0.893 W

Algae Density:

Magnification: 400x
DPI (Dots per inch): 300
Resolution: 640 x 480
Thickness Assumed: 0.001 mm
640/300=2.13 inches =0.0840 mm
480/300=1.6 inches = 0.0630 mm

	Algae Cell Count	Algae Cells/mm^2	Algae Cells/mm^3
Mean	575	108823	108823497



Average Algae Cell Diameter: 0.001 mm
Average Algae Cell Volume: 7.85398*10^-10 mm^3
Volume of Raceway: 0.081m^3
Volume of Algae for 10,500 BTU's Fuel: 8,000 g

$$108823497\left(\frac{cells}{mm^3}\right) * 8100000mm^3 * 0.00785\left(\frac{mm^3}{cell}\right) * 0.05 * 0.001\left(\frac{grams}{mm^3}\right)$$
$$= 3.46 * 10^8 grams\ dried\ algae$$

EXPERIMENTS

Flocculation

Experiments with flocculation were not able to be carried out due to COVID-19 but Chitosan is predicted to be the most environmentally friendly option because it is derived from fish waste. Aluminum sulfate has been known to work consistently as a flocculant and lowering the pH can have negative effects on the Oil Separation process. Exact Dosages are unknown so further experimentation with flocculation must be carried out in the future.

Drying

Drying experiments were conducted with muskgrass. The muskgrass was harvested from the pond sample with an aquarium net. It next was laid underneath fluorescent light on top of aluminum foil. The samples were allowed to dry for an average of four days and their masses were recorded before and after. On average there was a 95% decreased in mass. This demonstrates that an incredibly large mass of algae will need to be grown in order to generate a small amount of processable fuel.

Oil Separation

Due to COVID-19 experiments for oil extraction were not able to take place. Literary research and analysis was done on oil extraction methods to determine theoretical feasibility and efficiency of the methods.

- Food Processor:

This process could use many different chemicals and alcohols to achieve results while costing around the same, the use of potassium hydroxide and methanol results in the highest % oil extracted of around 70-80%

- Expeller Press:

This process is simple to use and efficiency can be 70-95% of oil extracted. The higher efficiency usually comes with the addition of a hexane solvent.

- Transesterification:

Transesterification is the process of creating a biodiesel via replacing a glycerol with methanol. This is done using a strong base (Potassium Hydroxide). This yields 90% to 95+% biodiesel and is usually done on an industrial scale.

CONCLUSION

The most efficient algae species to cultivate is Nannochloropsis Oculata. Chitosan is the most environmentally friendly flocculant and transesterification will produce the highest biodiesel yield.

With algae produced at the density of 1.09*10^8 cells/mm^3, a raceway volume of 0.081m^3, an average cell volume of 0.00785 mm^3, and an average mass loss from water at 95%, this raceway could produce 3.46 *10^8 grams of algae. Algae growth of N. Oculata could be rapid enough to be used to meet the heat requirements of a 350 ft^2 house.

Due to the halt of experimentation, the ability to heat a 2 person home with the team's developed methods is still unknown. However, through literary analysis of research, the most efficient and practical method of using algae for energy is through oil separation.

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