Sustainable Protein for All

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Company Introduction and Impact

35% of the worlds habitable land is taken up by livestock (Figure 1). Given biodiversity loss, population and carbon emissions growth, this is unsustainable. AMYBO aims to develop Sustainable Protein for All.

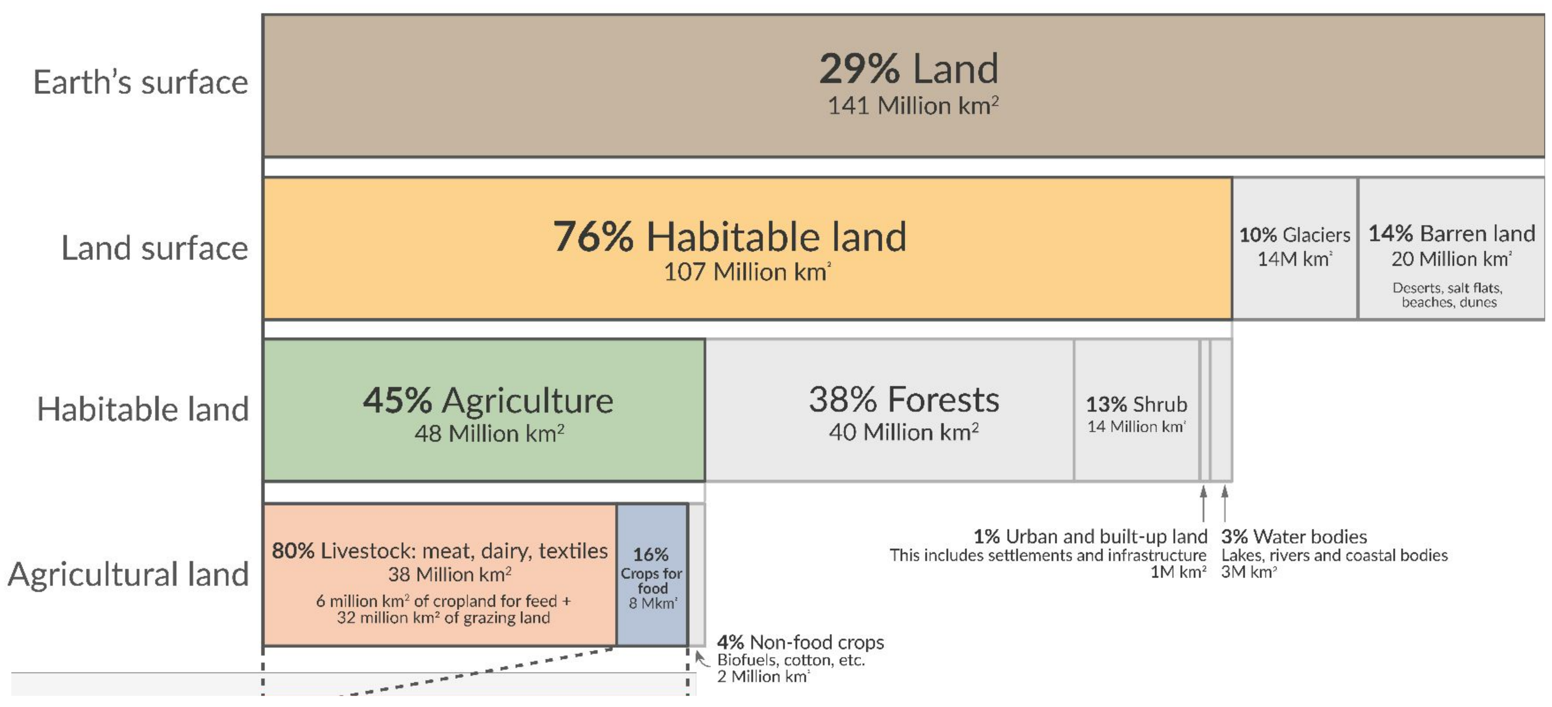

Figure 1: Breakdown of world's habitable land by use from Our World in Data

AMYBO is a non-profit, open source protein fermentation community. They develop affordable bioreactors for researchers so they can contribute to the testing of hydrogen oxidizing bacteria as a novel protein source. The electroPioreactor (Figure 2) is an affordable bioreactor that performs water electrolysis and allows for the monitoring of bacterial growth. AMYBO's ultimate goal with the electroPioreactor is to allow anyone to produce sustainable protein from carbon dioxide and renewable energy.

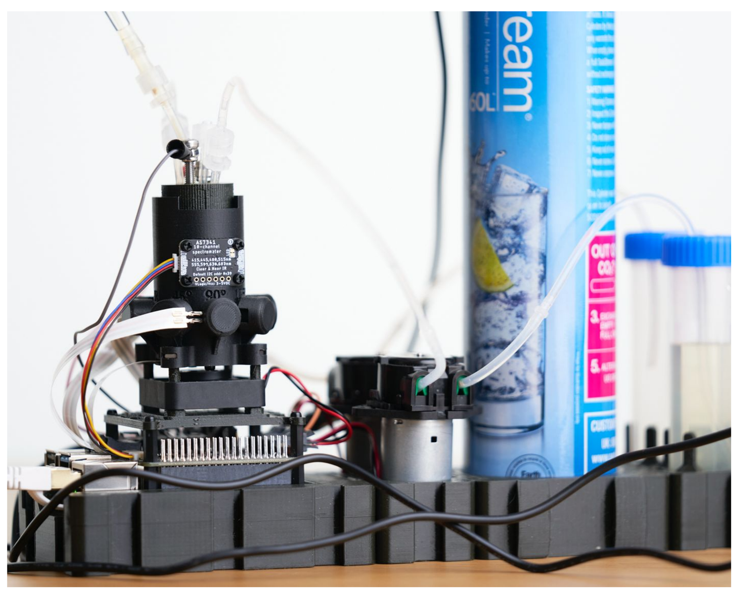

Figure 2: electroPioreactor

What are Hydrogen Oxidizing Bacteria (HOB)?

HOB are strains of bacteria that can convert hydrogen into food using the chemical reaction equation as seen below.

$$4H_2 + O_2 + CO_2 + 0.24NH_3 \rightarrow$$
$$CH_{1.68}N_{0.24}O_{0.46} + 3.54H_2O$$

The process can be facilitated using water electrolysis. Water molecules are split into their component parts. The HOB convert the oxygen and hydrogen, along with added CO_2 and NH_3 into ~70% Protein (nutritionally complete) biomass with water as a byproduct.

AMYBO's Original Solution

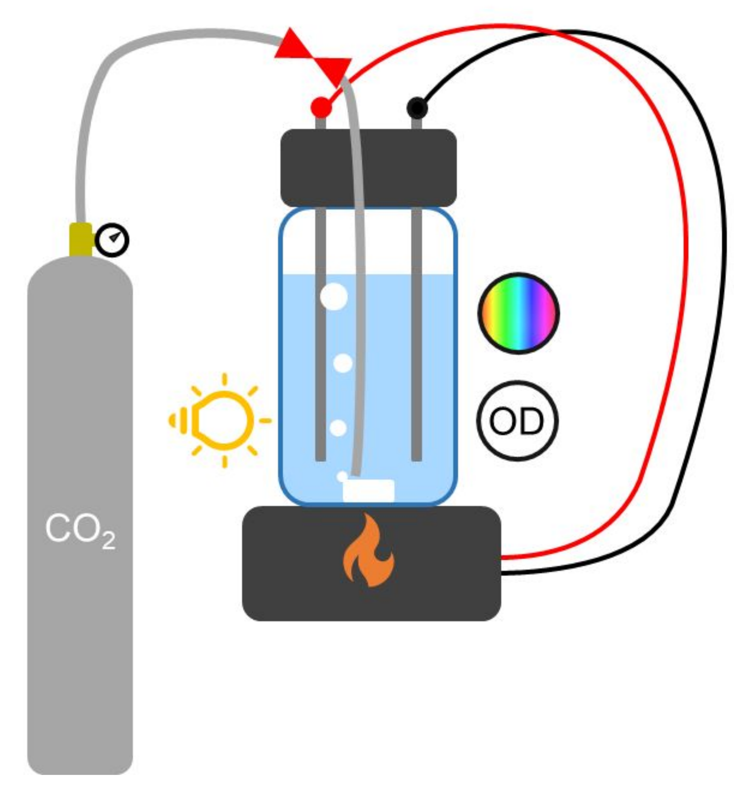

Figure 3: AMYBO electroPioreactor setup

Mixed Culture electroPioreactor v0.01 Setup (Figure 3):

- H^+ ions created via water electrolysis
- CO_2 added through tube
  - Both removes the excess O_2 and feeds bacteria
- NH_3 added with other trace minerals
- Bacterial growth measured using optical density
- Anode and cathode are made with platinum plated titanium mesh and stainless steel, respectively

Current issues:

- Backflow when the CO_2 input line is shut off
- Anode material is expensive and not optimized

Project Statement

AMYBO would like us to improve upon their current system by creating an open-source solenoid pinch valve that eliminates backflow, and optimizing the anode-cathode design and material. All solutions must be designed to be cost effective, reliable, reproducible, and self manufacturable.

Valve Subteam

Goal: Design a solenoid pinch valve to pinch 20cm 1/16" ID Silicone tubing
Constraints: Must be open source, controllable, eliminate backflow, normally closed

The valve team must pinch the 20cm 1/16" ID Silicone tubing used in the cap of the electroPioreactor as seen in Figure 4. The valve team utilized a lever to amplify the 20N spring force applied by the solenoid. The design can be seen in Figure 4. The solenoid is powered by the Pioreactor.

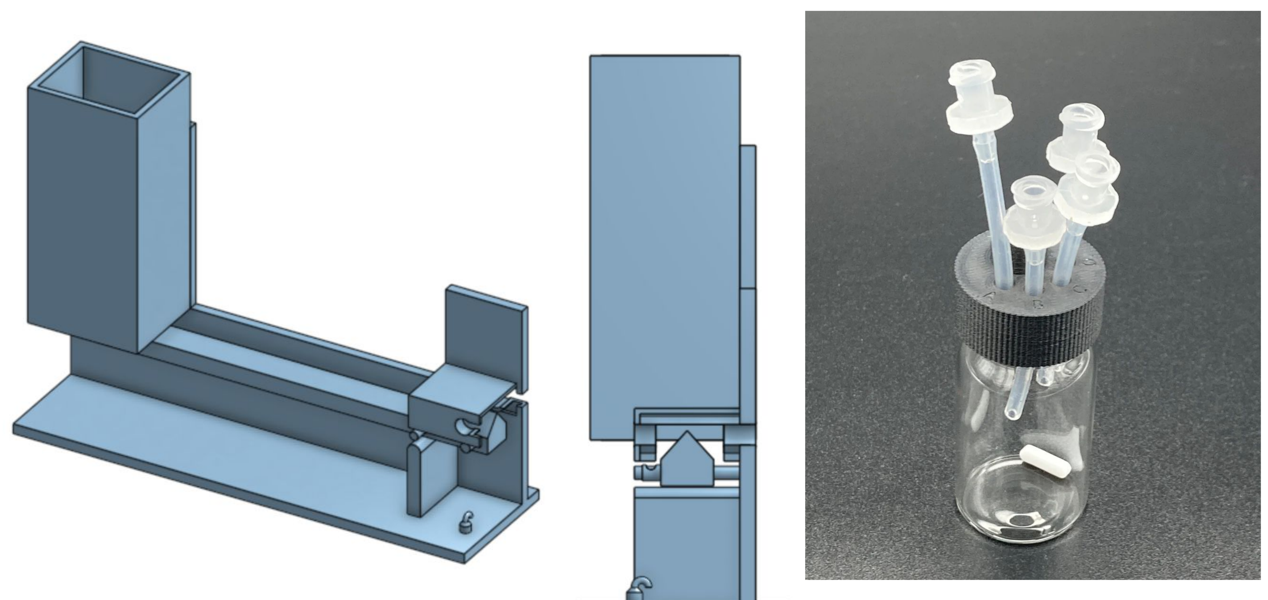

Figure 4: (Left) Solenoid pinch valve with mechanical advantage of 5
(Right) 20cm 1/16" ID Silicone tubing to be pinched

Testing

The valve, as pictured in Figure 5, pulls a maximum of 2.36A when powered with 11.31V. The image on the left pictures the valve open, and the image on the right shows the valve closed and unpowered. It is able to fully pinch the required 20cm 1/16" ID Silicone tubing used in the cap of the electroPioreactor.

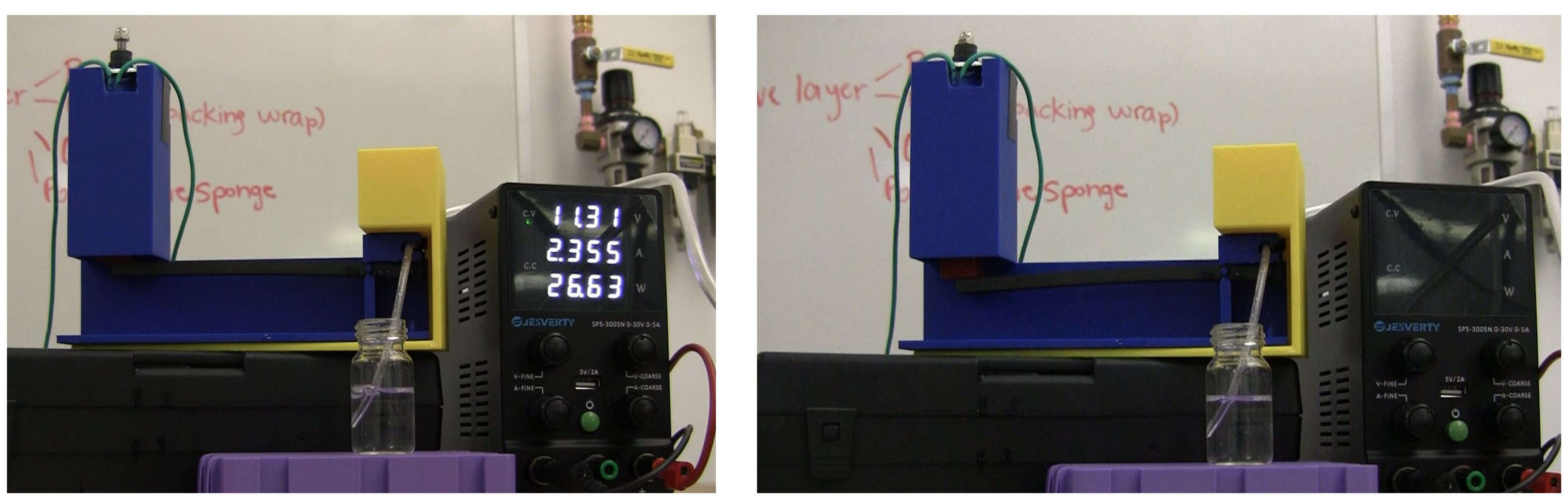

Figure 5: (Left) Solenoid pinch valve open (Right) solenoid pinch valve closed

Conclusions and Future Work

Valve is functional and controllable by the electroPioreactor. Future work involves adding support to the pinch mechanism so it stays aligned with the solenoid hat, reducing the footprint, and making the pinch support thinner to allow for better integration.

Anode Subteam

Goal: Optimize anode and cathode for water electrolysis
Constraints: Cheaper and more easily manufacturable than platinum plated titanium mesh

The team tested nickel, stainless steel, and graphite rods for their ease of manufacture, low cost, and high current density. Additionally, platinum plated titanium rods were tested as controls. The team ran current tests using a potentiostat. The solution used was a mixture of deionized water and sodium bicarbonate. The results of these tests are shown in Figure 6.

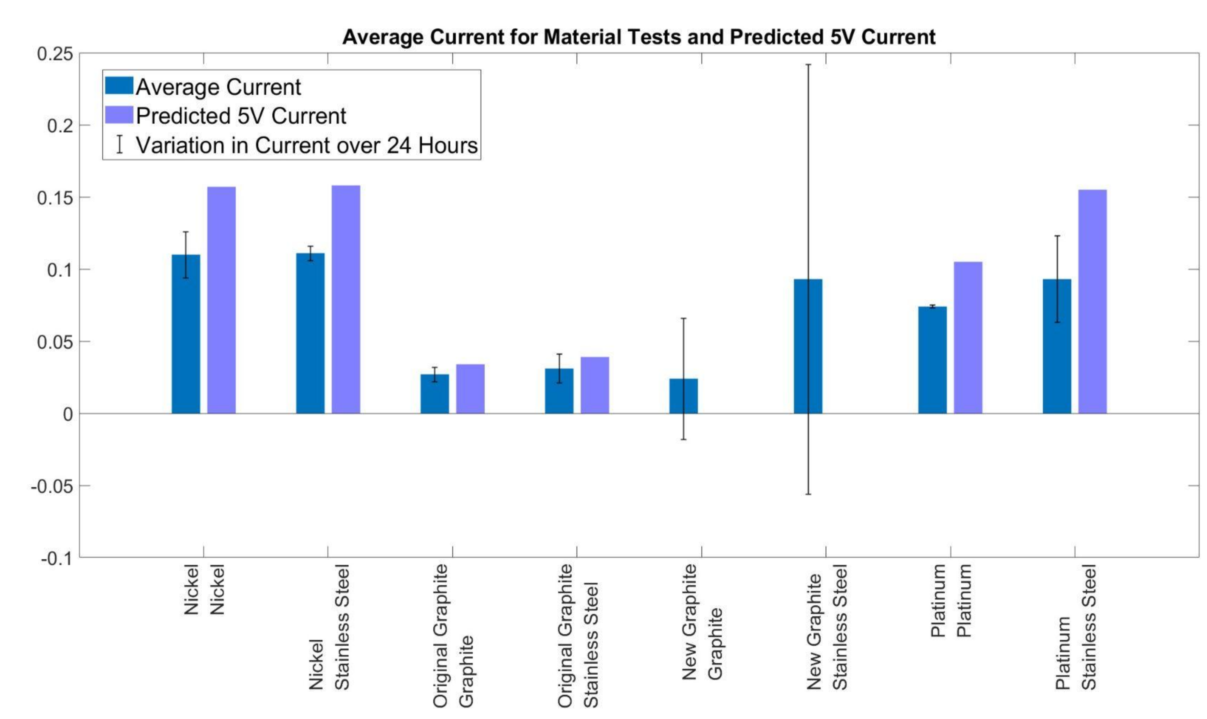

Figure 6: Current density test results

The team tested if the HOB would grow in solution with the selected materials. Implied growth rate results are shown in Figure 7. As we were not replacing growth media, relevant data is only of the exponential phase and highest implied growth rate reached. Importantly, we cannot be sure data is a reflection of bacterial growth as there was significant falloff from our anode and cathode. Therefore, we cannot make any concrete conclusions. Visual inspection of the vials after experimentation did show bacterial growth, which is promising.

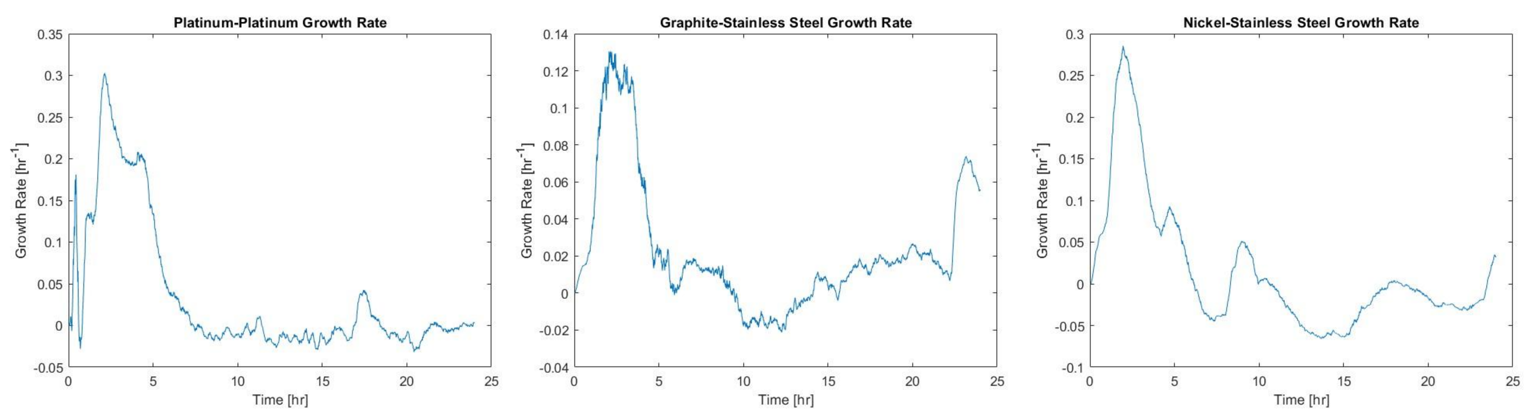

Figure 7: Implied growth rate results (Left) Platinum-Platinum (Middle) Graphite-Stainless Steel (Right) Nickel-Stainless Steel

Conclusions and Future Work

Based on the data results, nickel-stainless steel is worth investigating further as it is easily manufacturable, cost effective, had high current density with little fluctuation in current over time, and the HOB had a high implied growth rate.
Other future work includes optimizing the anode for surface area and fouling.

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