BIOELECTRIC BOOST:

Optimizing a Yeast-Based Biological Fuel Cell

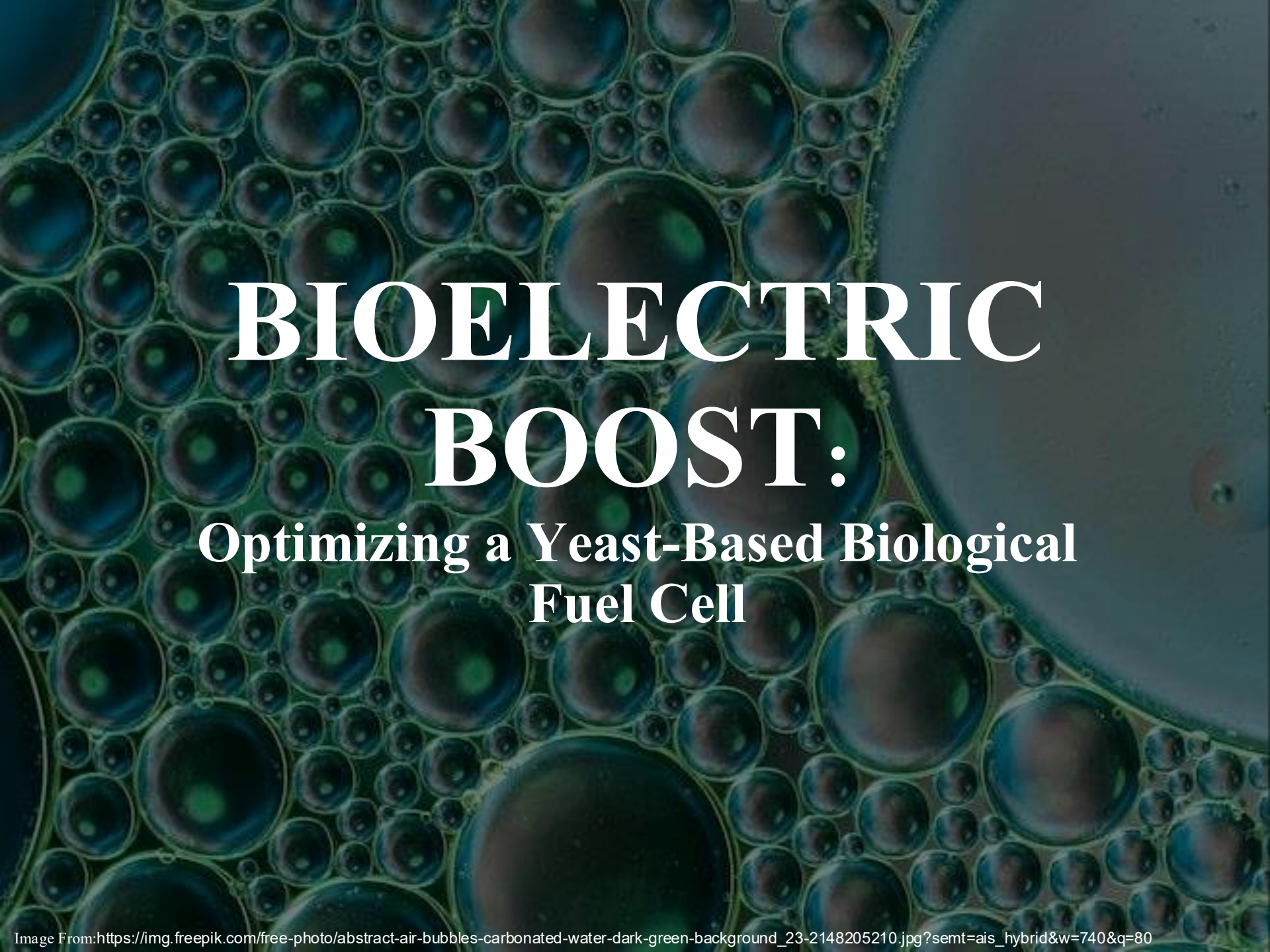


Image From:https://img.freepik.com/free-photo/abstract-air-bubbles-carbonated-water-dark-green-background_23-2148205210.jpg?semt=ais_hybrid&w=740&q=80

Background Research

The Risk of Fossil Fuels

Electricity is essential in our everyday lives, schools, hospitals, and industries. However, most electricity worldwide is still generated from fossil fuels such as coal, natural gas, and oil. Burning fossil fuels releases greenhouse gases like carbon dioxide into the atmosphere, contributing to air pollution and climate change (U.S. Environmental Protection Agency [EPA], 2023).

https://ejfoundation.org/imager/media/117272/Fossil-Fuel_d3867277feb154defec9b24a5714fadb.jpg

High Cost of Electricity

Fossil fuel-based energy production also increases the cost of electricity due to fuel extraction, transportation, and power plan to operations. As fuel prices rise, electric bills for households and businesses also increase. Traditional fossil fuels contribute to environmental pollution and climate change, making it important to develop cleaner energy technologies. One promising innovation is the microbial fuel cell (MFC), a system that uses living microorganisms to generate electricity.

https://www.researchgate.net/figure/Microbes-in-microbial-fuel-cell_fig2_375423270

Background Research

- **What is Methylene blue?**

Methylene blue is a bright blue synthetic dye that has been used for many years in both science and medicine. It was first created in 1876 as a textile dye, but scientists soon discovered it could stain microorganisms, helping doctors identify infections. By 1891, it was also used to treat malaria, making it one of the first synthetic compounds ever used in medical treatment. Today, methylene blue is still used to treat certain medical conditions and remains an important tool in scientific and medical research.(Harvard Medical School.2025)

https://www.cbc.ca/radio/whitecoat/methylene-blue-explainer-1.7531116

- **Methylene blue and Yeast**

Methylene blue can also help improve electricity production in microbial fuel cells. It works as an electron mediator, meaning it helps transfer electrons from microorganisms like yeast to the electrode more efficiently. When yeast breaks down sugar, it releases electrons, and methylene blue helps carry those electrons to generate electricity. This improves the fuel cell performance and increases voltage output.

https://sugarpursuit.com/types-of-yeast-and-how-to-use-them-in-baking/

Statement of the Problem

Electricity in many communities is still produced using fossil fuels, which contribute to air pollution, climate change, and environmental harm. At the same time, rising electricity costs place a financial strain on many families, especially during hot or cold seasons when energy use increases. Although renewable energy technologies offer cleaner alternatives, many are still expensive or not easily available to everyone. Microbial fuel cells offer a promising low-cost option because they can generate electricity using microorganisms like yeast. However, their electricity output is often low and needs improvement. Therefore, this study aims to determine whether using methylene blue can improve electron transfer and increase the electricity produced by a yeast-based microbial fuel cell.

Research Goals

- To construct and operate a yeast-based biological fuel cell and measure its baseline voltage and current output using NeuLog sensors.

- To determine whether the addition of methylene blue increases the electrical performance (voltage and current) of the yeast fuel cell compared to baseline conditions.

Hypothesis/Variables

Hypothesis

If methylene blue is added to the yeast-glucose chamber of the biological fuel cell, then the voltage and current output will increase compared to baseline levels because methylene blue acts as an electron mediator that enhances electron transfer from yeast cells to the electrode.

Variables

- **Independent Variable:** Methylene blue addition to the yeast + glucose bottle (anode), before methylene blue (0 drops / baseline), and after methylene blue (1 drop)
- **Dependent Variables:** Voltage (V) produced by the fuel cell over time, Current (mA) produced by the fuel cell over time

- **Controlled Variables:** Amount of yeast, glucose, phosphate buffer, potassium ferricyanide (cathode), wire, temperature, and data collection setting

Methodology

PHASE 1: Fuel Cell Setup

- The biological fuel cell was assembled and the phosphate buffer was prepared by adding distilled water until the bottle was two-thirds full, shaking to dissolve, and then topping it off to about 1 cm below the top. Yeast (half cap) and glucose (full cap) were added to Bottle #1, followed by buffer until just below the neck, and mixed. Bottle #2 was filled to the same level with buffer and one drop of potassium ferricyanide was added. A filter paper strip was inserted between the two bottles to form a salt bridge. Carbon electrodes were placed into each bottle and connected to NeuLog voltage and current sensors.

All Photos were taken by research unless otherwise noted

Methodology

PHASE 2: Baseline Measurement

- After connecting the NeuLog sensors, the fuel cell was allowed to equilibrate for 30 minutes. During this time, voltage and current readings were monitored to observe stabilization of the system. After 30 minutes, the stabilized voltage and current values were recorded as the baseline measurements. Observations of physical changes, such as bubbling, color of the solution, and electrode positioning, were also documented. These baseline readings provided a comparison point to evaluate the effect of methylene blue on fuel cell performance.

All Photos were taken by researcher unless otherwise noted

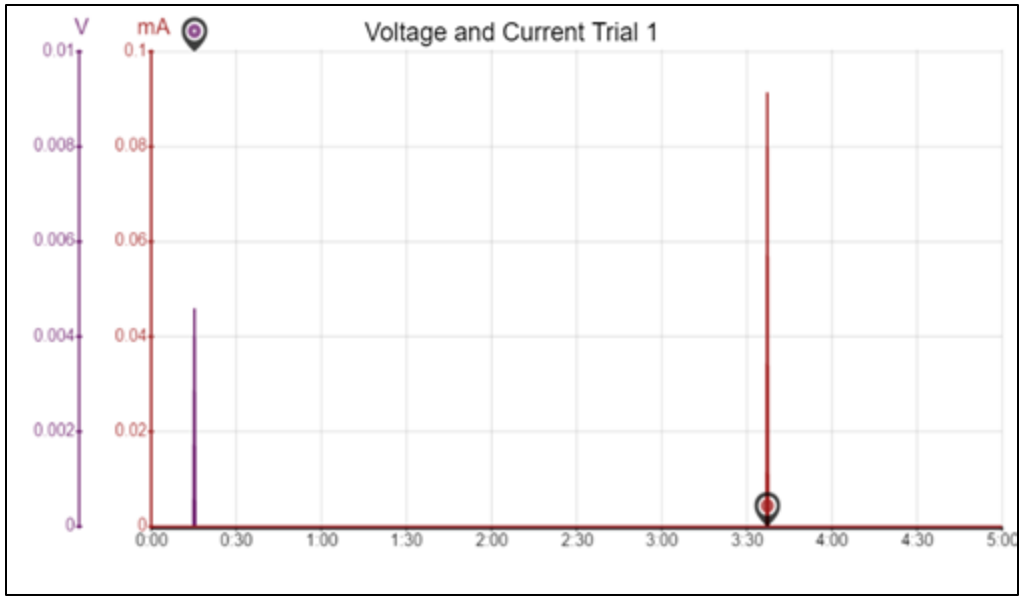
Methodology

PHASE 3: Data Analysis

- The effect of the electron mediator was tested. One drop of methylene blue was added directly to the yeast and glucose bottle (anode chamber) after baseline data had been recorded. NeuLog recording was resumed immediately to capture changes in voltage and current over time. Electrical output was monitored continuously. Changes in voltage trends and solution color were observed and recorded. A second trial was conducted using the same procedure to ensure reliability and reproducibility of results. The collected data were later used to generate voltage-versus-time and current-versus-time graphs, and power output was optionally calculated using the formula

All Photos were taken by researcher unless otherwise noted

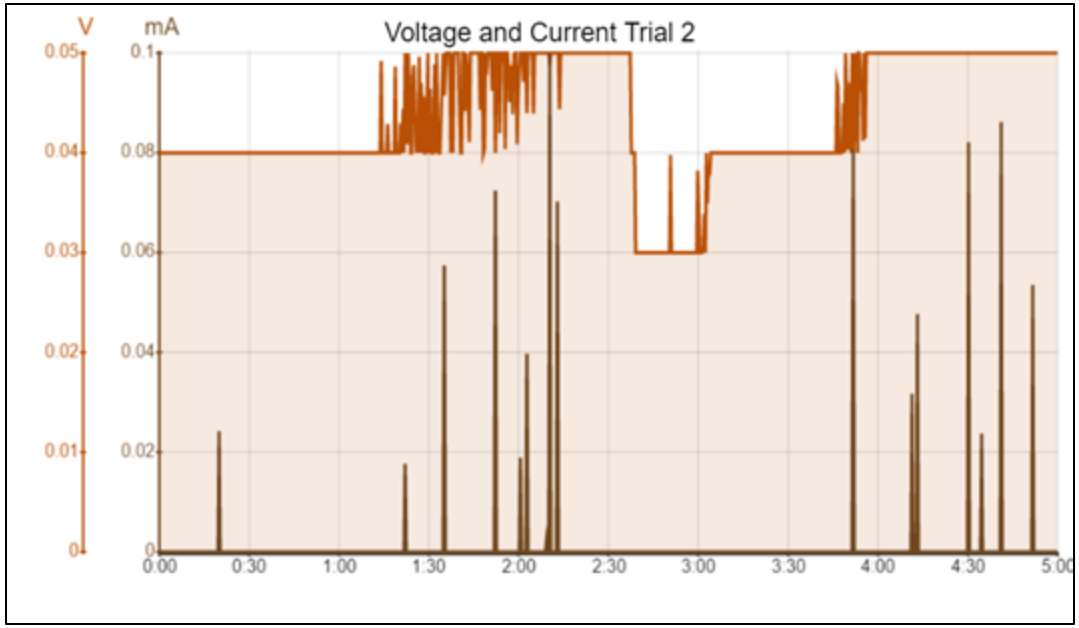
Results



- Trial 1 showed weak and unstable fuel cell performance. Voltage remained near zero, and current was mostly zero except for short spikes. This suggests Trial 1 had limited electron transfer to the electrode or inconsistent circuit contact. Therefore, Trial 1 is best described as a trial with high variability and low output.

- Trial 2 demonstrates stronger afuel cell performance than Trial 1. Voltage increased and stabilized (especially after methylene blue), showing improved electron transfer in the system. Current readings fluctuated with spikes, but the overall results support that the yeast fuel cell produced measurable electricity and that the mediator helped the system work more effectively.

Voltage and Current : Trial 1



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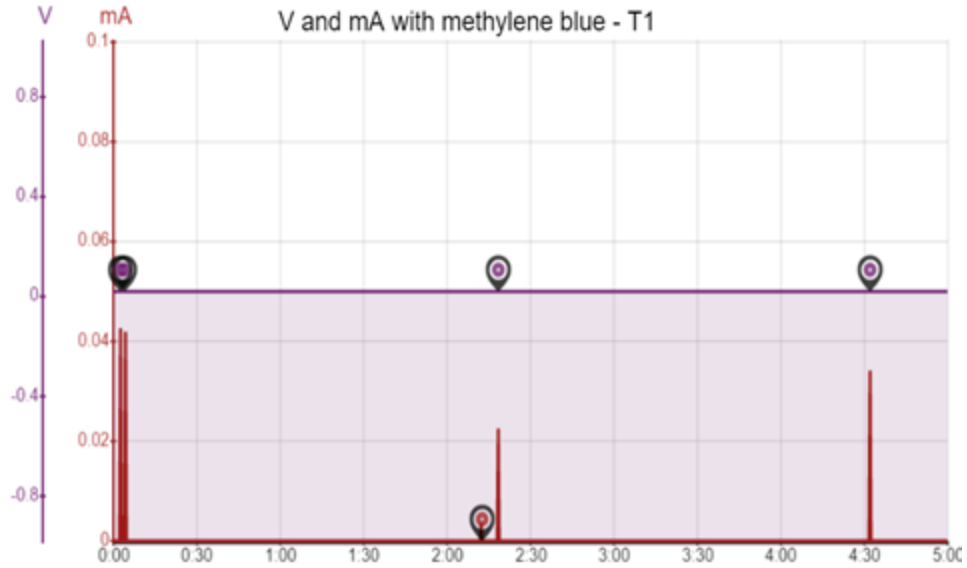
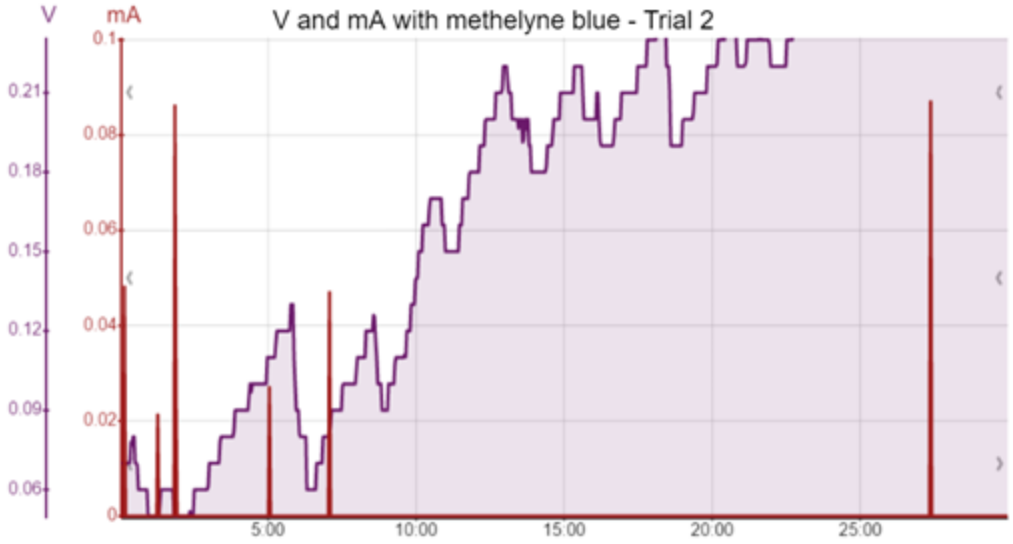
Results



- Trial 1 showed that there was no sustained increase in voltage over time. The current graph showed several sharp spikes, but these spikes were brief and did not remain steady and did not show the continuous biological electron flow.

- After methylene blue was added in Trial 2, the voltage gradually increased over time, eventually stabilizing around approximately 0.20–0.22 volts. The gradual rise is consistent which enhances the movement of electrons from yeast metabolism to the electrode. The results show that methylene blue improved the performance of the yeast-based fuel cell in Trial 2 by increasing voltage output over time.



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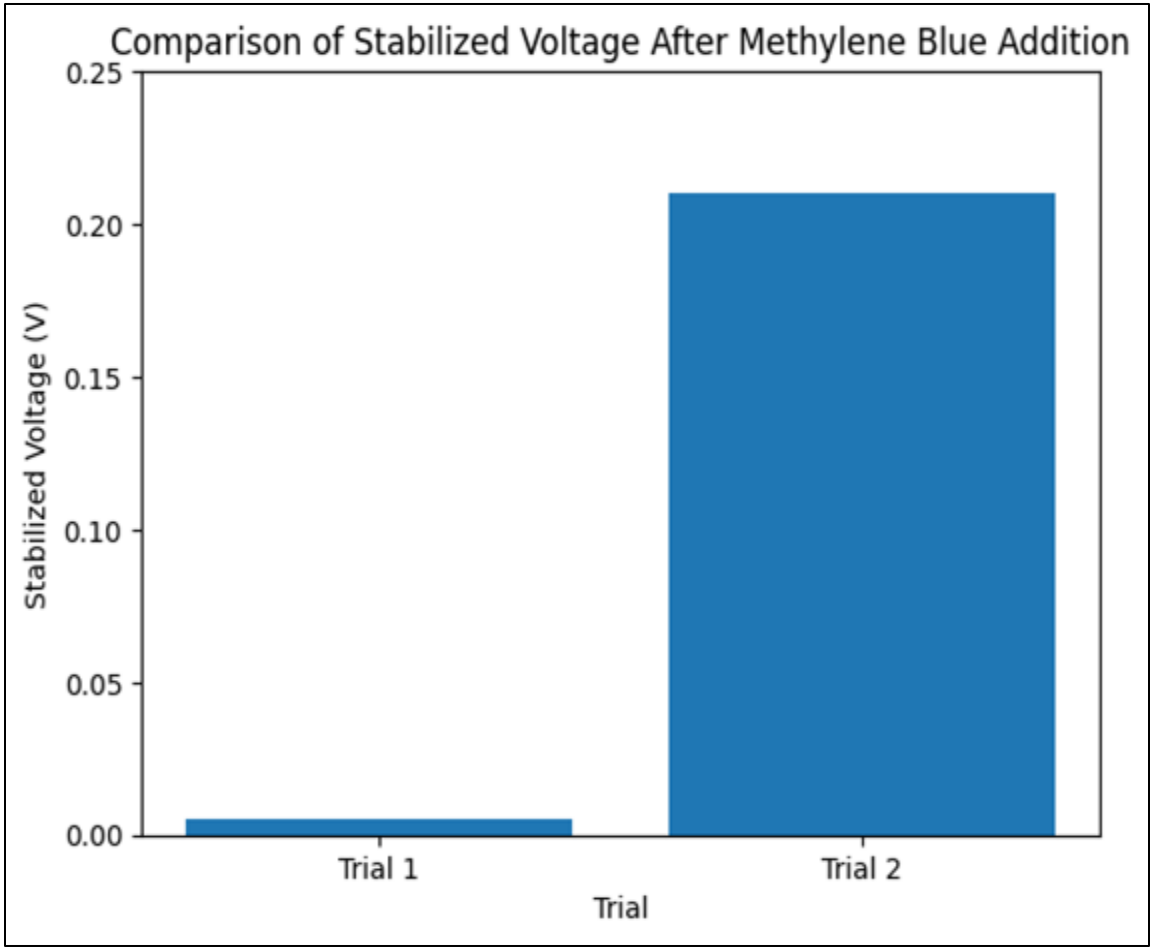
Results



- The bar graph shows a significant difference in voltage between Trial 1 and Trial 2 after the addition of methylene blue. Trial 1 produced a very low stabilized voltage of approximately 0.005 V, indicating minimal sustained electron transfer. Trial 2 produced a much higher stabilized voltage of approximately 0.21 V.

- This large difference suggests that Trial 2 successfully demonstrated enhanced electron transfer within the yeast-based fuel cell after the addition of methylene blue. The mediator improved the movement of electrons from yeast metabolism to the electrode, resulting in higher measurable voltage.
- Overall, the data support the hypothesis that methylene blue enhances the electrical performance of a yeast-based biological fuel cell. Trial 2 demonstrates that when the system is properly stabilized, the mediator significantly increases bioelectric output.

All graphs/table were created by the researcher unless otherwise noted

Discussion

- The problem addressed in this study was that microbial fuel cells often produce very small amounts of electricity because microorganisms do not efficiently transfer electrons to electrodes.
- The experiment tested whether methylene blue, an electron mediator, could improve electron transfer and increase electrical output in a yeast-based fuel cell.
- In Trial 2, voltage increased significantly after methylene blue was added, stabilizing around 0.20–0.22 V. This supports the hypothesis and aligns with the background explanation of mediator-assisted electron transfer.
- The fading of the blue color in the yeast bottle confirmed that methylene blue was being reduced, meaning it was actively accepting electrons.
- Overall, **the results support the hypothesis that methylene blue enhances bioelectric output and helps optimize microbial fuel cells.**
- Improving microbial fuel cell efficiency is important because it may contribute to cleaner renewable energy technologies that reduce pollution and potentially lower energy costs in the future.

Conclusion

- The purpose of this experiment was to determine whether methylene blue improves the electrical output of a yeast-based biological fuel cell.
- The results support the hypothesis that adding methylene blue increases voltage production.
- This indicates that methylene blue successfully acted as an electron mediator, improving electron transfer from yeast metabolism to the electrode.
- The findings demonstrate that biological systems can generate measurable electricity and that electron mediators can optimize fuel cell performance.
- This study investigated whether methylene blue improves the electrical output of a yeast-based biological fuel cell.
- Improving microbial fuel cell efficiency may contribute to future renewable energy technologies that help reduce pollution and dependence on fossil fuels.

Why our Results Important?

- Microbial fuel cells are a clean energy source that can reduce fossil fuel use and pollution.
- Cleaner energy helps protect human health and the environment.
- Developing alternative energy technologies, even small-scale ones, contributes to long-term solutions that could help lower energy production costs.
- This research helps improve microbial fuel cells for future affordable and sustainable energy.

Future Plans

- Repeat trials to improve accuracy and consistency of results.
- Test different methylene blue amounts to find the best voltage output.
- Measure and compare the power produced by the fuel cell.
- Study how temperature and sugar levels affect electricity generation.
- Test other electron mediators to improve efficiency.
- Investigate how long the fuel cell can produce electricity.
- Explore real-world uses, such as wastewater treatment and renewable community energy.

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