The Effect of Dinitrophenol on Electricity Production by a Microbial Fuel Cell

Mary Untener and Don Comfort, Ph.D.

Abstract

Microbial Fuel Cells (MFCs) provide a renewable way to produce electricity, while also doubling as a method to treat industrial waste water streams. Just like traditional H_2 fuel cells, MFCs produce current by creating a flowing of electrons. In MFCs, unlike hydrogen fuel cells, the electrons are catalytically extracted by microorganisms from complex electron donors, making MFCs a sustainable energy source. This experiment examines the effect of the toxin, dinitrophenol, on the electrical output of a MFC using the bacterium *Pseudomonas aeruginosa*. DNP is a decoupler which destabilizes the lipid bilayer membrane, hypothetically increasing the production of reducing equivalents by the cell. Concentrations of the toxin were varied to determine the dose dependent response of the MFC. It was concluded that the DNP reduced the outputs of the MFC. At a low concentration of 40mg/L, the output was only decreased by 16% making the MFC still functional. However, at high concentrations of 750 mg/L, cell death occurred. While this goes against the hypothesis, cell death upon treatment with a toxin is a reasonable result.

Introduction

Microbial fuel cells are an up and coming technology based on the traditional fuel cell. Traditional fuel cells function by using a catalyst to break down hydrogen molecules into protons and electrons, forcing the flow of these electrons down the potential gradient, and directing that flow external to the fuel cell, as shown in Figure 1. Unlike in traditional fuel cells, MFCs make use of the bacterial metabolism to catalyze the release of electrons from larger molecules, as shown in Figure 2. There are still technical and power density challenges to be solved before MFCs are ready for large scale usage.

Uncouplers are a type of toxin that break down proton gradients that are storing cellular energy. The entire work of the cellular metabolism culminates in the production of a proton gradient, and energy is harnessed when the protons flow down the gradient by traveling through ATP Synthase, as shown in Figure 3. When the uncouplers make the membrane permeable to protons, the protons flow across at any point and the energy is not harnessed by the ATP Synthase enzyme. This means that the entire work of the metabolism does not culminate in the production of energy, and the metabolism goes into overdrive.

Dinitrophenol is an uncoupler that has been shown to increase the metabolic rate (Habeck, 2010), which in turn could allow the cell to catalyze the production of more electrons. This extra electron production could be theoretically used to improve the amount of electricity produced. In this thesis, the effect of a common waste water toxin, dinitrophenol, will be examined as it correlates to the MFC output. It is hypothesized that, because uncouplers increase bacterial metabolic functioning and electron production, the electrical output of the MFC will be increased when DNP is introduced to the system.

The bacterial source to be used in this experiment is *Pseudomonas aeruginosa.* This microbe is found in a variety of environments and is extraordinarily resilient. It is a gram negative, aerobically respiring, opportunistic human pathogen. *P. aeruginosa* is known to produce its own electron mediators, allowing for simplified transfer of the electrons from the bacteria to the electrode. A wide variety of carbon sources can be utilized and broken down by this bacteria's metabolism, allowing it to survive in many different environments (Pant, 2009). Additionally, because this bacterium has been heavily studied and understood, and in the past has been shown to successfully produce electricity in MFCs (Mil'ko, 2008), it is the logical choice for use in this experiment.

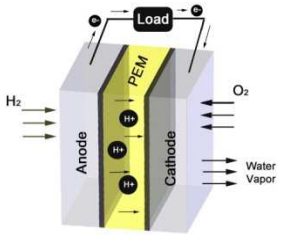

Figure 1: Hydrogen Fuel Cell showing the addition of hydrogen at the anode, transport of the protons across the proton exchange membrane to the cathode where water is generated from H+ and O_2. www.ultracellpower.com/sp.php?fuel

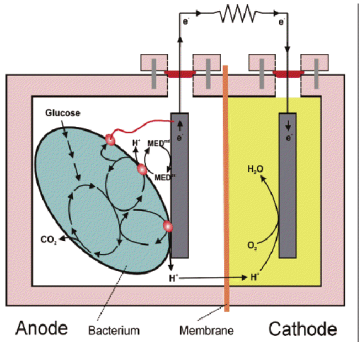

Figure 2: Electron Mediators bringing electrons to the anode (taken from Logan, 2006)

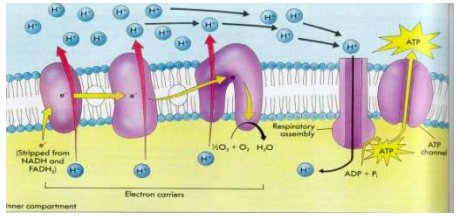

Figure 3: The electron transport chain showing the production and localization of protons and electrons during cellular metabolism. http://sciences.aum.edu/bi/BI4523/student/cardwell/etc2.html

Materials and Methods

Set up as shown in Figure 4
Anoxic anode
- 250 mL Nalgene bottle
- Graphite electrode
- Glucose and nutrient solution
- Pseudomonoas aeruginosa

Cathode
- 250 mL Nalgene bottle
- Graphite electrode
- Salt solution
- Air pump

Membrane
- Positive Exchange Membrane (PEM), Nafion

wiring connects the electrodes to an external resistor and a multimeter to record the data
Data on current is taken every 5 minutes, runs last 4 days
Additions of glucose and DNP are made every 24 hours

Figure 4: Experimental Set up

Results

The power density as it changed with time is shown in Figure 5. The blue line is from a run where *P. aeruginosa* and glucose were present, but no DNP was added. The red line is when 40 mg/L of DNP was added. The green line is when 750 mg/L of DNP was added, and cell death occurred.

The pseudo steady state values of power density were averaged for each run, and it was determined that at the run with the addition of DNP, power density decreased by 16%.

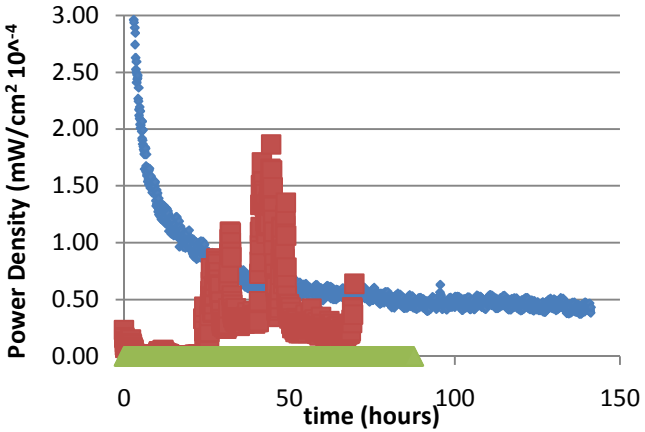

Figure 6: Power density outputs of the MFC

Conclusion

While this disproves the hypothesis, it is a very reasonable result. DNP is a toxin that is harmful to living things. Though it does increase the metabolism, it does so by putting the cell into a state of extreme stress which is detrimental for functioning. This result indicates that the toxic effects on the cells are greater than a potential increase the metabolic rate. At 40 mg/L, because there was still a significant output, some of the bacteria were alive and viable. Additionally, we concluded that since the average output of this run was lower than the average output of the toxin free run, that the population either decreased its functioning due to stress or was partially killed as a result of the toxin. At 750 mg/L the dosage was determined to be toxic. Because the low dosages did not kill the bacteria, the possibility of using MFCs to treat DNP remains. Future experiments could investigate whether the DNP remains in solution, is degraded, or is uptook by the bacteria. This opens up the possibility of using MFCs to treat waste water streams that contain DNP.

References

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Acknowledgments

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