Microbial Fuel Cells For Bioenergy Generation

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Introduction

- Microbial fuel cells (MFCs) are devices that use bacteria as the catalysts to oxidize organic/inorganic matter (substrate) and generate current (Fig. 1).
- Traditional substrates (e.g., glucose, starch, corn, etc.) are very expensive. Agricultural/yard wastes (e.g., corn stover, grass) are possible feedstock of MFCs if cellulose in these wastes can be transferred into reducing sugars.

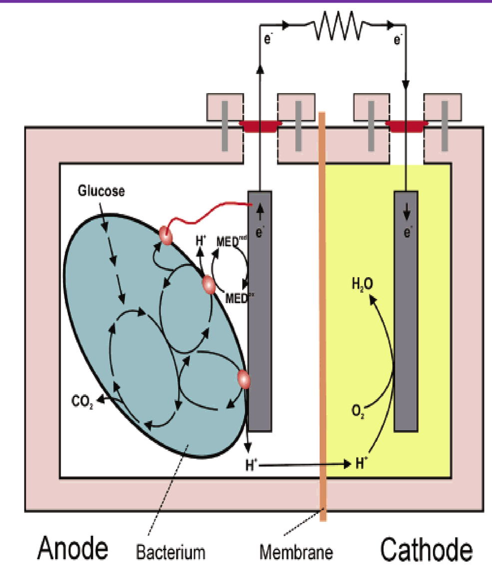
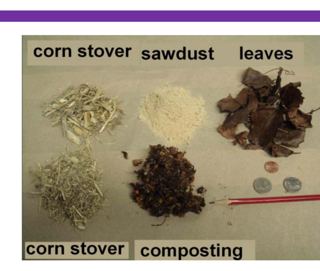


FIG 1. MFC's principles. A bacterium in the anode chamber transfers electrons obtained from an electron donor (glucose) to the anode electrode via either direct contact (nanowires) or mobile electron shuttles (small spheres represent the final membrane associated shuttle). During electron production, protons are also produced in excess, and they migrate through a cation exchange membrane (CEM) into the cathode chamber. The electrons flow from the anode through an external resistance (or load) to the cathode where they react with the final electron acceptor (oxygen) and protons.

Objectives



- Design and construct MFC systems with an air-cathode and a novel, bench-scale integrated solid-phase fermentor (SFMFC) for producing electricity directly from the fermentation of lignocellulosic wastes (picture above); and
- Evaluate the effects of operating conditions and design parameters on the performance of the SFMFCs.

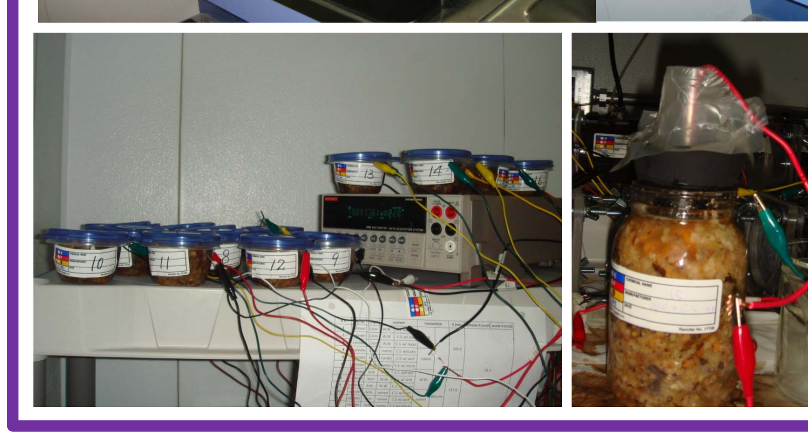
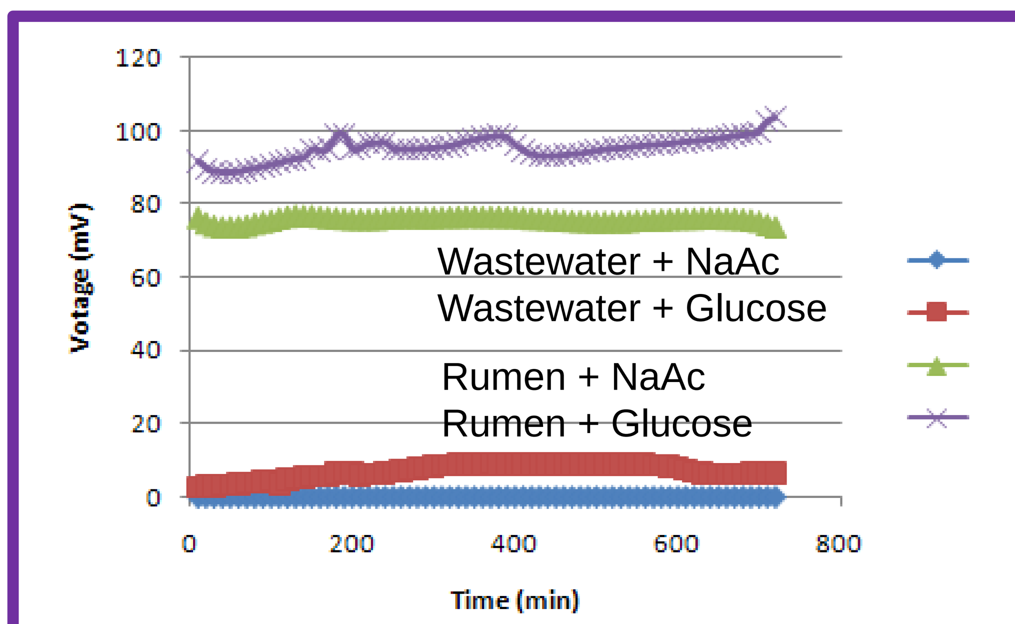


FIG. 2. MFCs/data acquisition systems. (Top) 4 air-cathode MFCs (left), 4 open-bowl (middle) and 20 close tube-type SFMFCs (right). (Bottom) 16 close-bowl SFMFCs (left) and details of tube-type SFMFCs (right).

Method

- Establishment of test procedures. An Electrochemical Workstation (604D, CH Instruments, Inc.) was modified as a potentiostat by the manufacturer for measuring all major parameters such as voltage, current, current density, power density, Chemical Oxygen Demand (COD), Cyclic Voltammetry (CV), Linear Sweep Voltammetry (LSV), and Electrochemical Impedance Spectroscopy (EIS).
- Test of reactors' performance. MFCs tested are shown in Fig. 2. We evaluated the performance of (a) 16 air-cathode MFCs fed with glucose, acetate and inoculated with wastewater (WW) and ruman solution, (b) 4 open-bowl, (c) 20 close tube-type, and (d) 16 close-bowl SFMFCs fed with corn stover, leaves, and composting.
- Molecular identification of microbial strains in MFCs. We did the microbiology analysis with the clone library on anodes, bulk solutions, and cathodes. Molecular identification was conducted in a period of six months.



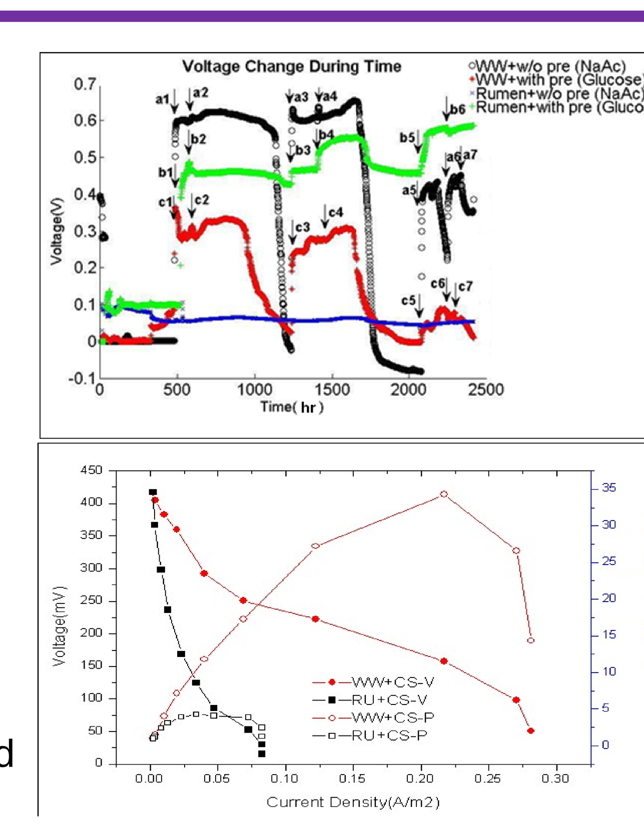


FIG. 3. (Left) Effect of inoculation/substrates on MFCs' voltages. (Right) Time courses of MFCs' voltage as a function of operating conditions (up); and polarization and power density curves of MFCs (bottom).

Results/Summary

- Air-cathode MFCs:
  - The ruman-inoculated reactors have a higher voltage than the reactors inoculated with wastewater (Fig. 3).
  - The voltage of the MFCs will increase up to nearly 300 mV near the end of inoculation and start-up period (usually ~1–2 weeks).
  - Performance of MFCs is affected by the operation conditions. Adding water can greatly affect the performance of the MFCs.
  - Oxidation-reduction potential (ORP) varies (Table 1).
- SFMFCs:
  - The 4 open-bowl SFMFCs can be used to reduce biowastes or biomass, but do not work well for power generation because the poor connection of internal circuit. The voltage of the16 close-bowl SFMFCs can reach ~100 mV within one day, and the highest voltage at steady-state is ~600 mV.
  - The performance of tube-type SFMFCs is pretty good. The highest voltage reached ~300 mV. The voltage will be very low when the reactors are lack of O_2. However, if we provide enough O_2 with the caps being open, the water in the reactors will evaporate very quickly. The design still needs to be optimized.
  - The performance of the tube-type SFMFCs is pretty good. The highest voltage reached ~300 mV. The reactors are very corrosive, and the copper wires (electrodes) were eroded.
- Microbial distribution:
  - The amount of DNA from cathodes is not less than that from anodes. There might be some important microorganism on the cathodes which contributes much towards power generation.
  - We found 33 different strains in our air-cathode MFCs (Fig. 4).

Table 1. ORPs at cathode (L), bulk solution (M), anode (R) and voltage in different air-cathode MFCs after 10 weeks of operation.

Reactor #	ORP (L), mV	ORP (M), mV	ORP (R), mV	Voltage, mV
4	-341	-351	-358	119
5	-279	-311	-179.3	150
6	-151.6	-220	28.4	60
10	-144.4	-263	-54.7	98
11	-213	-289	-178.6	178
12	-83.5	-247	-140.1	99

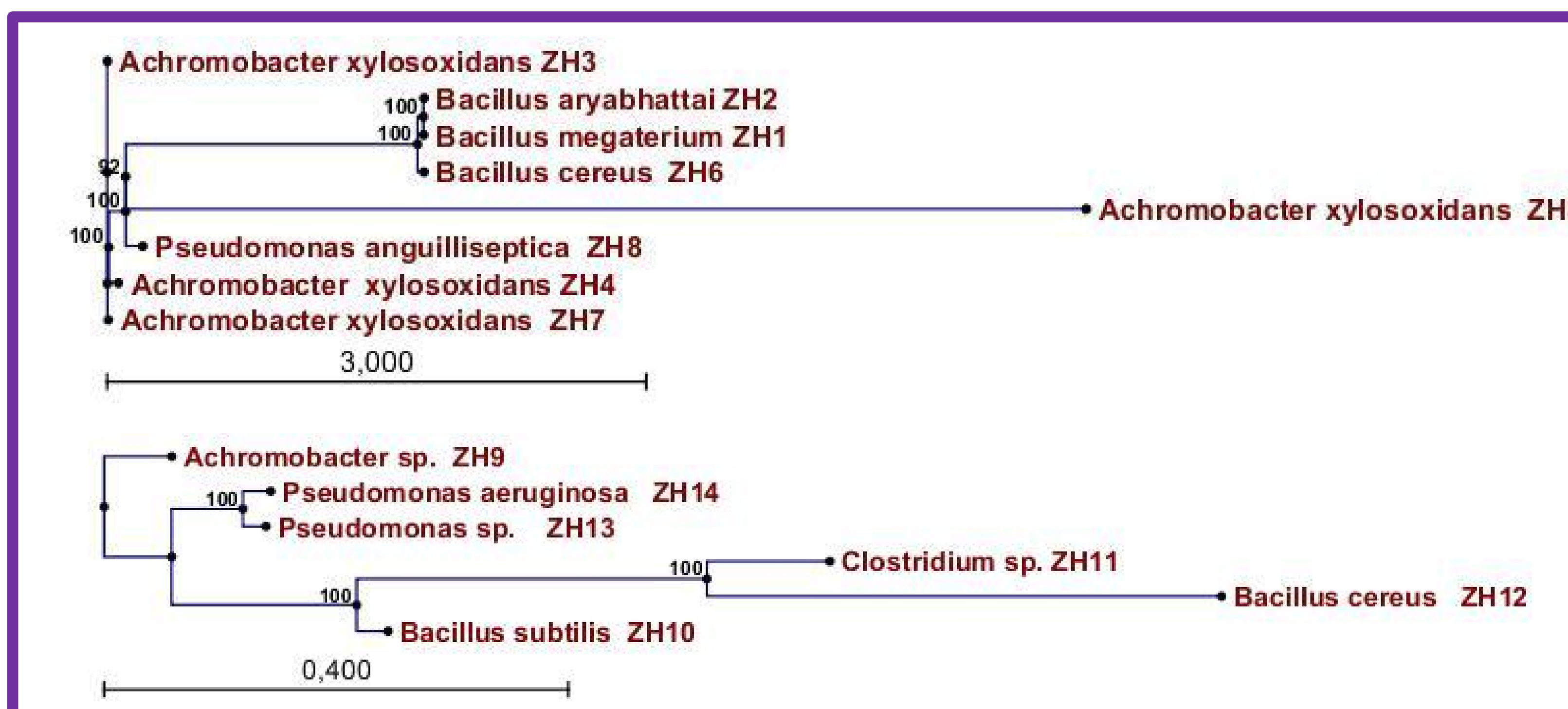


FIG. 4. Phylogenetic relationship based on comparative analysis of the 16S rDNA sequences obtained from sample 1 obtained from the anode (top), and sample 2 from the bulk solution (bottom) of air-cathode MFCs.

Acknowledgement

- Nebraska Center for Energy Sciences Research and Nebraska Public Power District fund this project, which is greatly appreciated.