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Microbial Electrosynthesis of CO_2 to Fuels and Chemicals: Improving Productivity and Efficiency

Harold D. May (mayh@musc.edu) and Edward V. LaBelle
(Medical University of South Carolina, Charleston, SC, USA)

Background/Objectives. Microbial electrosynthesis, the synthesis of fuels and chemicals from CO_2 with electrons delivered from an electrode to microorganisms, is an intriguing idea that could take us well beyond any other alternative microbial energy process now employed or even being considered. In its simplest form all that is needed are sources of CO_2, electricity, and water (no arable land is required). Microbial electrosynthesis is in its infancy, but developed systems are envisioned to be built and operated with renewable electricity, even intermittent or stranded power, thereby converting and storing electrical energy in chemicals. The CO_2 would come from a waste stream (e.g. cement plant, steel mill, urea plant, fermentative process, natural gas or coal power plant), or possibly be captured from the atmosphere. Here will be discussed the research that our group has been doing with an electroacetogenic biocathode that may then be leveraged as a platform for the production of fuels and chemicals from CO_2.

Approach/Activities. Previous work indicated that the amount of biomass of our electroacetogenic biocathode has been low, which then restricts productivity. It is hypothesized that this is due to a limitation in electrons and nutrients supplied to the microbiome on the cathode. This hypothesis is based on metagenome/metatranscriptome analysis indicating that the microbial community is nitrogen and electron (hydrogen) limited. Furthermore, external electron transfer from an electrode to autotrophic, chemical/fuel producing microorganisms may occur by direct electron transfer from the electrode to the microbes, but our electroacetogenic biocathode is most likely being driven with hydrogen as an intermediate and increasing the capture of that hydrogen is needed to improve productivity and yields of acetate. Finally, up to this point, energy efficiency of microbial electrosynthesis has rarely been examined and our previous electrosynthetic bioreactors were inefficient in this regard.

To counter the aforementioned limitations and improve productivity we have done the following: 1) design a more efficient bioelectrochemical cell with a cathode that may serve as a better delivery system for electrons or hydrogen, 2) apply constant current (galvanostatic mode) to the cathode to ensure sufficient current density to support the desired productivity, and 3) operate the bioreactor with a constant flow of water, nutrients, and CO_2 to ensure a sufficient supply of nutrients and to avoid product inhibition. In the future we will examine the effect of pH control and bacterial cell immobilization on electroacetogenesis and will couple this platform with algae to produce hydrocarbon fuels.

Results/Lessons Learned. There has been significant progress recently in this field by a number of researchers and we will comment on their progress as well as our own. The productivity of our electroacetogenic biocathode operating under the conditions described above has reached 0.78 g L^{-1} $hour^{-1}$ and the overall energy efficiency of the bioelectrochemical reactor is between 35% and 40%. These results have been achieved without the need for expensive additives such as yeast extract or methanogenic inhibitors (no methane is produced by this community anchored by an *Acetobacterium*). The rate of production is nearly on par with starch or syngas fermentation to acetate or ethanol and future improvements are expected with pH control and cell immobilization. These and other technical details of the system and its performance will be discussed along with some economic assessments and future goals.