

## II.H.6 Fermentation Approaches to Hydrogen Production

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direction determined annually by DOE



### Approach

We have two approaches to address the H<sub>2</sub> molar yield barrier in meeting its 2013 target (4 mol H<sub>2</sub> per mol glucose). The first approach is to conduct genetic engineering of the model microbe *Clostridium thermocellum* by blocking competing metabolic pathways in order to maximize H<sub>2</sub> production. During H<sub>2</sub> production from lignocellulose fermentation, *C. thermocellum* produced an array of organic acids (acetic, formic, and lactic acids) and ethanol byproduct. The generation of these organic wastes consumes cellular energy, which could have been directed toward additional H<sub>2</sub> production. Later in FY 2007, we will begin to develop genetic tools and techniques to selectively block the ethanol-producing pathway in *C. thermocellum* to improve its H<sub>2</sub> molar yield.

A second, independent method involves optimizing an electrohydrogenic approach to convert the organic waste byproducts generated during dark fermentation to additional H<sub>2</sub> to improve its overall molar yield. This will be done via a subcontract to Pennsylvania State University. In the absence of O<sub>2</sub> and by adding a slight amount of potential (~250 mv) to the circuit, H<sub>2</sub> has been produced from acetate with a molar yield of 2.9 - 3.8 (versus a theoretical maximum of 4.0) in a modified microbial fuel cell called a bioelectrochemically assisted microbial reactor (BEAMR) [1]. Later in FY 2007, we will examine the BEAMR process in harnessing the energy from the typical fermentation waste products into H<sub>2</sub>. The approach of integrating BEAMR following dark fermentation not only has immense potential for improving H<sub>2</sub> molar yield, but also in reducing waste acid accumulation.

### Accomplishments

This project was not funded in FY 2006 and the PI was on a different assignment from March 2006 to March 2007. The principal investigator returned to NREL in April 2007 to resume the project. During the last two month performance period, progress was made in three areas:

- Work is underway in culturing the model microbe *C. thermocellum* ATCC 27405, a typed strain of known genome sequence that facilitates the genetic engineering approach.
- Work is underway to set up the bioreactor system for online measuring of H<sub>2</sub> and CO<sub>2</sub> production during fermentation.

### Objectives

- Perform microbial pathway engineering to improve H<sub>2</sub> molar yield via fermentation.
- Integrate dark fermentation with an electrohydrogenic approach to improve H<sub>2</sub> molar yield.

### Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells, and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(AR) H<sub>2</sub> Molar Yield

(AS) Waste Acid Accumulation

(AT) Feedstock Cost

### Technical Targets

**TABLE 1.** Progress toward Meeting DOE Technical Targets in Dark Fermentation

Characteristics	Units	2013 Target	2006 Status
Yield of H <sub>2</sub> from glucose	Mole H <sub>2</sub> /mole glucose	4	2.4 (from cellulose)
Feedstock cost	Cents/lb glucose	10	13.5 (as of 2003)

- We recently completed and awarded a subcontract, “Electrochemically assisted microbial fermentation of acetate,” to Pennsylvania State University to conduct the BEAMR research. This work started on July 16, 2007.

### FY 2007 Publications/Presentations

1. Datar, R., J. Huang, P.-C. Maness, A. Mohagheghi, S. Czernik, and E. Chornet. 2007. Hydrogen production from the fermentation of corn stover biomass pretreated with a steam-explosion process. *Intl. J. Hydrogen Energy* 32, 932-939.
2. Turner, J., G. Sverdrup, M. K. Mann, P.-C. Maness, B. Kroposki, M. Ghirardi, R. J. Evans, and D. Blake. Renewable hydrogen production. Accepted for publication in *J. Intl. Energy Research*.
3. “Hydrogen production via the fermentation of lignocellulosic biomass,” presentation at the 2<sup>nd</sup> Energy Center Hydrogen Initiative Symposium, Purdue University, W. Lafayette, IN, April 12–13, 2007.
4. “Fermentation of residual algal biomass to fuels,” presentation at Colorado State University, Fort Collins, CO, June 18, 2007.

### References

1. Liu, H., S. Grot, and B. E. Logan. 2005. Electrochemically assisted microbial production of hydrogen from acetate. *Environ. Sci. & Technol.* 39, 4317-4320.