II.J.1 Purdue Hydrogen Systems Laboratory: Hydrogen Production*

Jay Gore (Primary Contact), R. Kramer, J. Patterson, E. Ting, L. Pelter
Purdue University
500 Central Drive
West Lafayette, IN 47907
Phone: (765) 496-2829; Fax: (765) 494-9321
E-mail: gore@ecn.purdue.edu

DOE Technology Development Manager: Roxanne Garland
Phone: (202) 586-7260; Fax: (202) 586-2373
E-mail: Roxanne.Garland@ee.doe.gov

DOE Project Officer: Katie Randolph
Phone: (303) 275-4901; Fax: (303) 275-4753
E-mail: Katie.Randolph@go.doe.gov

Contract Number: DE-FC36-06GO86050

Subcontractor:
National Renewable Energy Laboratory, Golden, CO

Project Start Date: September 16, 2006
Project End Date: September 30, 2010

*Congressionally directed project

Objectives

Investigate and evaluate initial processes for the production of hydrogen from various waste streams using microbial fermentation and investigate possible paths for implementation of the research in an energy source.

Technical Barriers

This project addresses the following technical barriers from the Production section (3.1.4) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan (Revision 2007):

(AR) H_2 Molar Yield
(AT) Feedstock Processing Cost
(AU) Systems Engineering

Technical Targets

Biological H_2 Production	Units	2013/2018	Purdue 2009
Hydrogen Yield Percentage	%	33/50	utilizing organic wastes

Accomplishments

- Issues associated with the feedstock homogeneity were addressed only to a certain extent in the first year using mixing techniques. More recent work addressed these issues more completely by using statistical sampling techniques. Experiments with homogenized distillers grain in addition to food waste are in progress.
- Biomass water content in the first year was relatively high at 98% and is now reduced to as low as 60% with improved material handling and pH control techniques.
- A second solar collector was added to the apparatus this year allowing both biomass waste processing as well as steam generation. The efficiency of the solar collector system for steam generation was measured to be 58%. This capacity addition has decreased the system thermal response time and will allow more detailed estimation of biomass processing efficiency in year three.

✧ ✧ ✧ ✧ ✧

Introduction

This project allows the creation of a Hydrogen Research Laboratory in a unique partnership between Purdue University's main campus in West Lafayette and the Calumet campus. This laboratory is engaged in basic research in hydrogen production and storage and has initiated engineering systems research with goals established as per the U.S. DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program. Hydrogen storage research of this project is reported in report IV.H.1.

Bio-production of hydrogen is potentially an important renewable source of energy. Using organic wastes for bio-production of hydrogen not only has the potential to generate cost-effective and renewable energy but also can reduce pollution in the environment and provide a source of fertilizer for growing crops. The purpose of the current research effort is to investigate, obtain data, and evaluate initial processes for the production of hydrogen from various waste streams using microbial fermentation and investigate possible paths for implementation of the technology as a local electric and thermal energy source. This effort is targeted to assure that the developed technology will be applicable for integration into various current and future energy supply options including the Department of Energy Road Map.

Approach

We are considering methods to optimize hydrogen production from waste through the use of a fermentation process. The optimization procedure will form the foundation for the subsequent development of a modular device that will use various waste streams, including garbage, animal or human waste, and distillers grain for the production of hydrogen. This hydrogen will be separated from the bio gas stream by use of nano catalyst or a membrane for use in a fuel cell or reciprocating engine to produce electricity locally. Methods to sequester carbon dioxide as part of the process are also being considered. Energy for the pre- and post-processing of feed streams is being obtained from a solar collector system. A steam generator is being added to the solar system for the production of potable water. Computer simulations of the process indicate that the system can be installed in a shipping container and used to provide local electric and thermal energy. Initial efforts have reduced the amount of water in the processed waste material from 98% to 60% with minimal decrease in hydrogen production. By reducing the fraction of water it will be possible to reduce the volume and weight of the bio reactor and increase the system efficiency.

Results

In this study, additional inoculua have been tested and the concentration of hydrogen in the produced gas has been correlated with the experimental variables: pH, temperature, and substrate concentration. Test samples and data are being exchanged between Purdue Calumet and Lafayette and trials to test repeatability are underway. A micro gas chromatograph is used to determine gas composition. Testing to determine operating parameters for hydrogen production from distillers grain is also underway. The testing project is based upon a central composite experimental design. We are currently at the third iteration for the optimization of the hydrogen production levels. This process identifies combinations of operating variables that maximizes hydrogen production. Figure 1 depicts the third generation optimization of hydrogen concentration using the Simplex methodology with an optimum point at 36.9°C, starting pH 6.2 and 1.0 g/25 ml concentration. The multiple testing device is fully operational and is being used to generate data. This device provides the capability to conduct multiple simultaneous tests with automated data processing and monitoring. Continuous production testing is currently being conducted at Purdue Lafayette. Initial approaches to a dry substrate design are being investigated at Purdue Calumet and Lafayette. The model for the modular energy system was updated based upon new experimental values. Efforts using a catalyst process for capture of carbon dioxide have been initiated. Distillers grain has been used to produce hydrogen and matrix tests of operating conditions are starting. During the summer of 2009, the production of potable water from the solar system will be tested; a second bank of collector tubes and a steam generator will be installed.

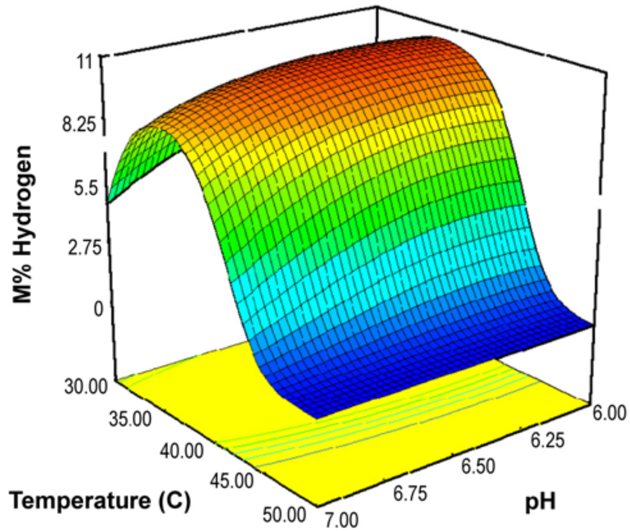

FIGURE 1. Mole percent hydrogen produced from fermentation of food waste as a function of temperature and initial pH for 1 g/27 ml concentration.

Conclusions and Future Directions

The biological hydrogen production component of the project has been conducted with a focus on optimizing the microbial fermentation process for hydrogen generation and for preliminary system energy analysis. We have increased the hydrogen production levels by over 50% with current techniques and operating parameters as compared to the prior year. Newly developed techniques have greatly increased both accuracy and precision. Water content has been decreased from 98% to 60% with a small decrease in hydrogen production levels.

We will continue investigating optimal hydrogen production cultures for different substrates, reducing the water content in the substrate, and integrating results from the vacuum tube solar collector pre- and post-processing tests into an enhanced energy system model. The automated testing device developed will be used to further consider optimal hydrogen production conditions using statistical testing procedures. We will also explore existing catalytic methods including nano catalysts for capture of CO_2 from the fermentation process. Next year these optimization efforts will continue and be used to develop a preliminary design and operating procedures for a bench top bio reactor. A conceptual design for a bench top biological reactor for anaerobic hydrogen production will be developed. Issues considered will include material flow, physical design, thermal control, hydrogen production rates, interface to pre- and post-processing, and operating parameter control. Preliminary issues associated with the design of a commercial prototype modular energy system will also be considered.

FY 2009 Publications/Presentations

1. Kramer, R., Patterson, J., Ting, E., Pelter, L., and Gore, J., "Purdue Hydrogen Systems Laboratory Part I," *2009 Annual Merit Review & Peer Evaluation*, Washington, D.C.

2. Kramer R., "Demonstration of Biological Waste Processing System for Hydrogen Production and Local Energy Production", *Lugar-Visclosky Energy Forum and Expo*, October 2008.