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Syntrophic interactions drive the hydrogen production from glucose at low temperature in microbial electrolysis cells

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HIGHLIGHTS

- ▶ H_2 production from glucose at 4 °C in MECs overcomes the dark-fermentation bottleneck.
- ▶ H_2 yield at 4 °C is comparable with that obtained at mesophilic temperatures in MECs.
- ▶ Combining pyrosequencing with CV reveal the syntrophic interactions in MECs at 4 °C.
- ▶ Psychrotolerant fermenters and exoelectrogens allowed current generation from glucose.
- ▶ Methanogenesis and homoacetogenesis were negligible in glucose-fed MECs at 4 °C.

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ABSTRACT

H_2 can be obtained from glucose by fermentation at mesophilic temperatures, but here we demonstrate that hydrogen can also be obtained from glucose at low temperatures using microbial electrolysis cells (MECs). H_2 was produced from glucose at 4 °C in single-chamber MECs at a yield of about 6 mol H_2 mol^{-1} glucose, and at rates of 0.25 ± 0.03–0.37 ± 0.04 m^3 H_2 m^{-3} d^{-1}. Pyrosequencing of 16S rRNA gene and electrochemical analyses showed that syntrophic interactions combining glucose fermentation with the oxidization of fermentation products by exoelectrogens was the predominant pathway for current production at a low temperature other than direct glucose oxidization by exoelectrogens. Another syntrophic interaction, methanogenesis and homoacetogenesis, which have been found in 25 °C reactors, were not detected in MECs at 4 °C. These results demonstrate the feasibility of H_2 production from abundant biomass of carbohydrates at low temperature in MECs.

1. Introduction

Microbial electrolysis cells (MECs) are a new method for electrochemically producing hydrogen using current generated by exoelectrogenic microorganisms. However, most MEC studies have examined systems at ambient temperatures using acetate as the fuel. It was recently shown that H_2 gas could also be produced in an MEC at relatively low temperatures (e.g. 4 and 9 °C) using acetate, making this technology a promising method for biohydrogen production even in very cold climates (Lu et al., 2011). However, it is important to consider the utilization of fuels other than acetate at low temperatures because most biomass available for biofuels production is primarily stored as fermentable carbohydrates such as glucose and cellulose. In previous bioelectrochemical system (BES) studies, including both MECs and microbial fuel cells (MFCs), there have been large differences in substrate metabolism and reactor performance in mesophilic environments using fermentable carbohydrates, such as glucose, compared to studies using acetate (Freguia et al., 2008; Lee et al., 2008). It is therefore important to better understand how fermentable substrates are degraded by microorganisms in MECs at low temperatures.

Glucose is a simple carbohydrate that can be converted to electrical current in BESs (Rabaey et al., 2003; Selembo et al., 2009). A few exoelectrogenic bacteria can directly oxidize glucose (e.g. *Rhodoferax ferrireducens*, *Klebsiella pneumoniae*, and *Aeromonas hydrophila*) and transfer electrons to electrodes (Logan, 2009). In mixed-culture systems, previous studies imply that syntrophic interaction between fermenters and exoelectrogens is the major route to metabolize glucose for current production under mesophilic conditions (Freguia et al., 2008; Zhang et al., 2011). Glucose is first oxidized to organic acids or H_2 by fermentation, followed by consumption of fermentation products by the exoelectrogens, which eliminates feedback inhibition of glucose fermentation

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