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Improving net energy gain in fermentative biohydrogen production from glucose

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ABSTRACT

Our previous studies had demonstrated enhanced fermentative hydrogen production from sucrose in batch reactors with dairy manure as a supplement providing nutrients, buffering, and hydrogen-producing organisms. In this study, manure leachate is evaluated as a supplement in glucose fermentation in batch and continuous flow reactors at 25 °C without any nutrient supplements, initial pH adjustments, buffering, or stirring. Hydrogen yields found in this study are comparable to or better than those reported at higher temperatures. When the heat energy expended to maintain the test temperatures is considered, positive net energy gain of ~10 kJ/L of reactor volume was achieved while most literature reports translated to negative net energy gain. Anaerobic digestion (AD) and microbial fuel cells (MFC) were evaluated as follow-up processes to extract additional energy from the end products of dark fermentation (DF). This evaluation showed that DF followed by MFCs to produce electricity to be a more energy-efficient approach.

1. Introduction

Hydrogen production by dark fermentation (DF) of feedstock such as pure substrates and a variety of wastewater streams has been reported previously. Efforts to enhance fermentative hydrogen yield from pure substrates have evaluated the following options as they control reaction pathways and end products of DF [1,2]: using pure cultures; optimizing nutritional supplements, operating pH; temperature, and substrate concentration; and manipulating headspace hydrogen partial pressure and mixing intensity. For hydrogen production by DF to be sustainable, it would be desirable to utilize readily available and naturally occurring mixed cultures with minimal external inputs such as nutritional supplements [3]; for the process to be energy-efficient the hydrogen yield has to be maximized and all energy inputs should be minimized.

Fermentation temperature has been reported as a key parameter for improving biodegradation kinetics [4,5] and hydrogen yield [6], as well as to minimize inhibitory effects of VFA and suppress solvent producers [4,7]. Even though temperatures beyond a certain threshold limit inactivate enzymes responsible for fermentative hydrogen pathway [5], almost all researchers have operated their reactors at mesophilic temperatures (>30 °C) [8,9]. If DF reactors are operated at above-ambient temperatures, the net energy gain could be positive only if the energy gain from improved hydrogen yield offsets the energy requirement for reactor heating. But, reported hydrogen yields from glucose, for example, under mesophilic conditions have averaged about 2 mol of H_2/mol of glucose due to the thermodynamics limitations [10]. The relationship between net energy gain per unit volume of the reactor (kJ/L), hydrogen yield (moles H_2/mole glucose) and the fermentation temperature under ideal reactor conditions is shown in Fig. 1, for typical glucose concentration of 10,000 mg/L (calorific value of hydrogen = 120,000 kJ/kg H_2; density of liquid substrate = 1000 g/L; and specific heat of

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