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Methane production from acidic effluent discharged after the hydrogen fermentation of sugarcane juice using batch fermentation and UASB reactor

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ABSTRACT

Acidic effluent discharged after the hydrogen fermentation of sugarcane juice was used to produce methane by batch fermentation and UASB reactor. Significant parameters affecting methane production including substrate to biomass (S/X) ratio, nickel (Ni) concentration, and cobalt (Co) concentration were optimized by response surface methodology with central composite design in batch mode. A maximum methane yield (MY) of 305.4 mL CH_4/g-volatile solid (VS) $_{substrate\ (sub)\text{-}added}$ was achieved at an S/X ratio of 0.83 g-VS_{sub}/g-$VS_{inoculum}$, a Ni concentration of 0.53 mg/L, and a Co concentration of 0.06 mg/L. Continuous methane production was conducted at various hydraulic retention times (HRT) using the optimum conditions obtained from the batch experiments. The optimum HRT of 4 days in a UASB reactor resulted in a maximum methane production rate (MPR) and MY of 1.27 ± 0.05 L-CH_4/L-culture day and 348 ± 13 mL-CH_4/g-COD, respectively. Total energy generated was 219.23 kJ/L-substrate or 8.77 kJ/g-COD, and COD removal efficiency was 75.60%.

1. Introduction

Biohydrogen production via the dark fermentation process has received considerable attention due to its ease of operation, high rate of hydrogen production, low operation cost, and environmentally friendly nature. During the dark fermentative hydrogen production process, organic substrates such as carbohydrates, lipids, and proteins are hydrolyzed into soluble organic molecules (sugars, fatty acids, amino acids). These are subsequently converted by acidogenic bacteria to hydrogen and carbon dioxide in the gas phase, and volatile fatty acids (VFAs) in the liquid phase. The effluent discharged from the hydrogen fermentation process has a low pH and a high chemical oxygen demand (COD), and should not be disposed of in the environment without pretreatment. The effluent mainly contains acetic acid (HAc) and butyric acid (HBu) that can be further converted to methane by methanogenic bacteria. Both hydrogen and methane are very attractive alternative fuels [1]. Hydrogen is slowly being introduced into the vehicle market, and has enormous potential due to its high energy efficiency and the possibility of use in zero-emission vehicles [1], while methane is already available on the market as a gaseous biofuel and is used in combustion engines. Therefore, the utilization of the acidic effluent obtained from the hydrogen production process for methane production is not only appropriate for environmental treatment but also for energy recovery.

The important parameters controlling methane production have to be optimized to realize the maximum methane production rate (MPR) and methane yield (MY). In this study, the ratio of substrate to biomass (S/X ratio), Ni concentration, and Co concentration (mg/L) were chosen as the key parameters. The S/X ratio is an important parameter for anaerobic digestion of high solids [2]. An S/X ratio that is too high (low inoculum concentration) can be toxic to the microorganisms that secreted enzyme, while an S/X ratio that is too low can inhibit the enzyme [3]. The optimum S/X ratio is varied among the substrates [4]. For example, digesting food waste and the inoculum obtained from mesophilic anaerobic digester at Guelph's wastewater treatment plant in Ontario, Canada, required an S/X ratio of 0.25 to achieve a maximum MY of 1400 mL CH_4/g-

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