

CO-PRODUCTION OF HYDROGEN AND METHANE FROM POTATO WASTE USING A TWO-STAGE ANAEROBIC DIGESTION PROCESS

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WTC is currently running a bench scale experiment focused on the production and recovery of biogases (hydrogen and methane) from potato waste. The project involves a two-stage anaerobic digestion process, with the first stage operating under conditions optimized for the fermentation of hydrogen and the second stage operating under conditions suitable for methane production. The hydrogen and methane reactors have working volumes of 1L and 5L and hydraulic retention times of 6 hours and 30 hours, respectively. The reactors are operated under continuous flow conditions with COD concentrations of 12,800 mg/l in the feedstock, 7,220 mg/l after the hydrogen reactor and 4,130 mg/L after the methane reactor. Continuous hydrogen and methane production have been demonstrated for more than 90 days. The maximum biogas production rate observed from the hydrogen reactor was 270 mL/h with an average of 112 mL/h and a hydrogen content of 39-51% in the biogas. The methane biogas production rates were 410 mL/h (maximum) and 213 mL/h (average), with a methane content of 59-79%. Based on these results, the potential maximum total (hydrogen and methane) energy yield is 9.58×10^6 kJ ($2.7 \text{ kW} \cdot \text{h}$) per kg dry weight of waste potato.

Introduction

Concerns over the shortage of fossil fuels and greenhouse gas emissions have raised interest in renewable energy. In particular, research in the production and recovery of biogases (hydrogen and methane) has gained momentum because these gases can be stored, can be produced from various biomasses (Kawkes, *et al.*, 2002) and their low solubility allows them to be readily extracted from their liquid culture. Potato is the third largest food crop in the world and Canada is one of the leading producers (4.7 million tonnes annually). Also, there are large amounts of potato waste generated from food and potato processing plants each year that need to be managed in a manner that protects the environment. The goal of our research is to demonstrate a two-stage anaerobic digestion process for the volume reduction of potato wastes with the added benefit of enhanced hydrogen and methane production. The first reactor of the two-stage process will be optimized for hydrogen production since it is more valuable and burns cleaner (no NO_x) than methane (Benemann, *et al.*, 2004).

Materials and Methods

Preparation of the feedstock

A simulated potato waste feedstock was prepared for our research. Commercially available potatoes, from a local grocer, were homogenized for 2 minutes using a blender. To obtain a liquid consistency, 1.0 L of water was added for every 120 g of potato. The homogenized liquid was sieved through No. 20 and No. 40 meshes consecutively to remove small potato chunks that could clog tubing and other parts of the bench top digester unit. The potato waste was heated to 60°C in a water bath for 2 minutes. The heated liquid was subsequently diluted with (100% v/v) water and 0.5 g peptone was added per litre of solution. The characteristics of the resulting feedstock are listed in Table 1.

Parameter	Concentration
Total Solids	11600 mg/L
Volatile Solids	11000 mg/L
Soluble COD	12800 mg/L
Soluble Carbohydrates	26.0 mg/L
TKN	204 mg/L

Table 1: Characteristics of the Waste Potato Feed Stock

Fermenters and setup

Two fermenters (Bioflo 110, Brunswick Scientific) were used for the experiments. The smaller 1 L (working volume) reactor was used for hydrogen production and the larger 5 L reactor was used for methane production. The two fermenters were connected in series and operated under continuous flow conditions (Fig. 1). The biogas produced from each reactor was collected and measured by recording the volume of gas collected in the inverted cylinder over time. A septum, connected to the top of the inverted cylinder, was used to collect gas samples for analysis.

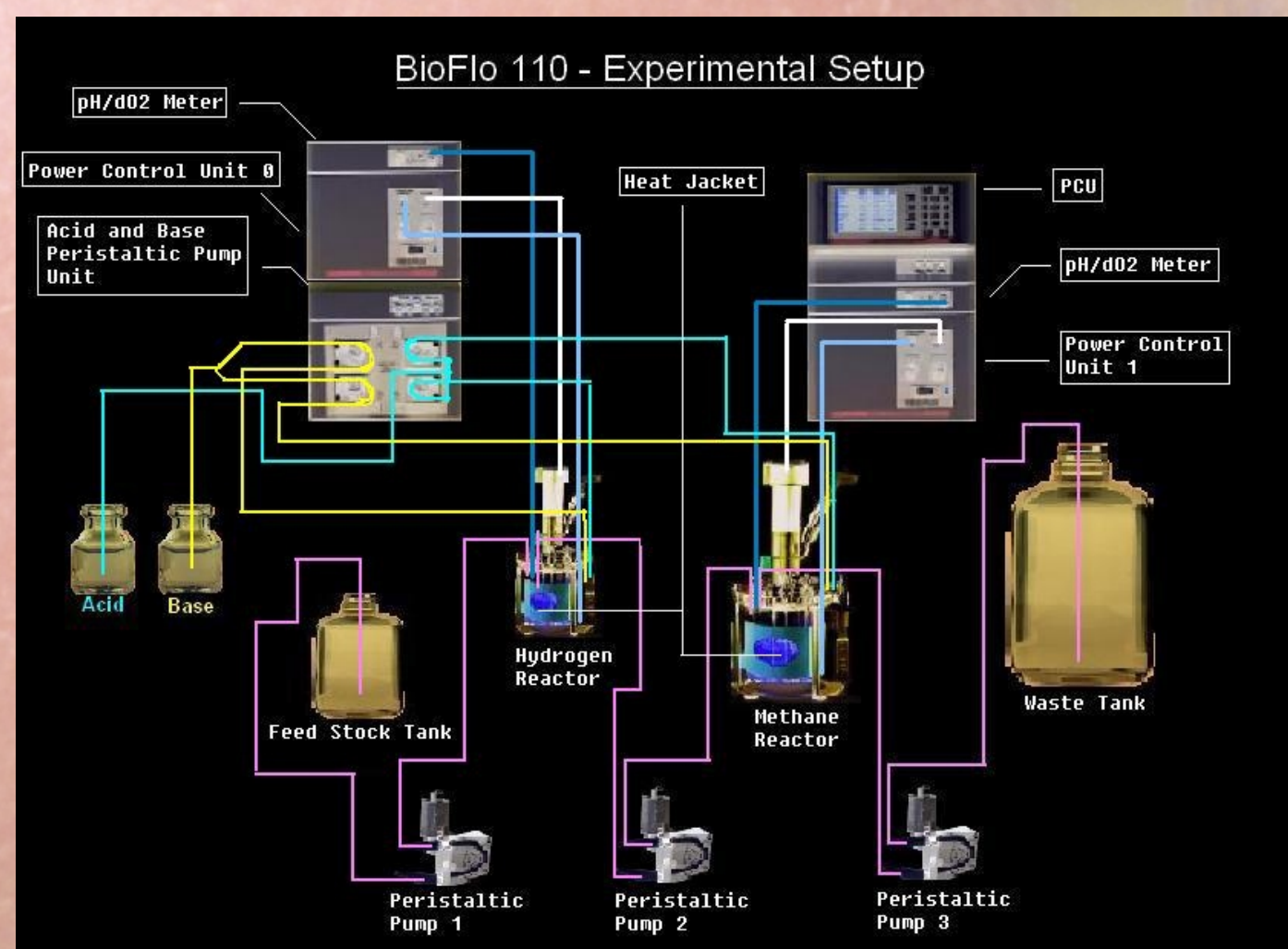


Fig. 1 The setup of the experiment

Reactor Start-up and operations

Digested sludge taken from local wastewater treatment plant was used to seed both reactors. For the hydrogen reactor, the seed sludge was pre-cultivated in a sucrose medium for a few days (Zhu, *et al.*, 2004). The feed stock was switched to potato waste when high hydrogen production was confirmed. The digested sludge was used without pre-cultivation for the methane reactor start-up. The operational conditions for both reactors are tabulated in Table 2.

Parameter	H ₂ reactor	CH ₄ reactor
Volume	1 L	5 L
Hydraulic retention time	6 h	30 h
pH	5.5	7.0
Temperature	35 °C	35 °C
Stirring	200 rpm	150 rpm

Table 2: Conditions for hydrogen and methane reactors

Results

Hydrogen production

Fig. 2 shows the hydrogen biogas production rates measured from the first-phase reactor. Typically, these values represent an average of 3 or 4 readings taken at 2 hour intervals during the course of a day. From the 4th day, the potato feedstock replaced the sucrose feed. Hydrogen biogas was produced continuously for 90 days. The maximum biogas production rate measured was 270 mL/h observed on the 17th day and the average rate calculated over the 90 day period is 112.2 mL/h. The hydrogen fraction fluctuated between 39 and 51% (v/v). The average COD concentration of the hydrogen bio-reactor effluent was 7,220 mg/L. During the period from the 74th day to 77th day, leakage in the feed line prevented normal feeding of the reactor. The hydrogen biogas production recovered 2 days after the feeding was resumed on the 78th day.

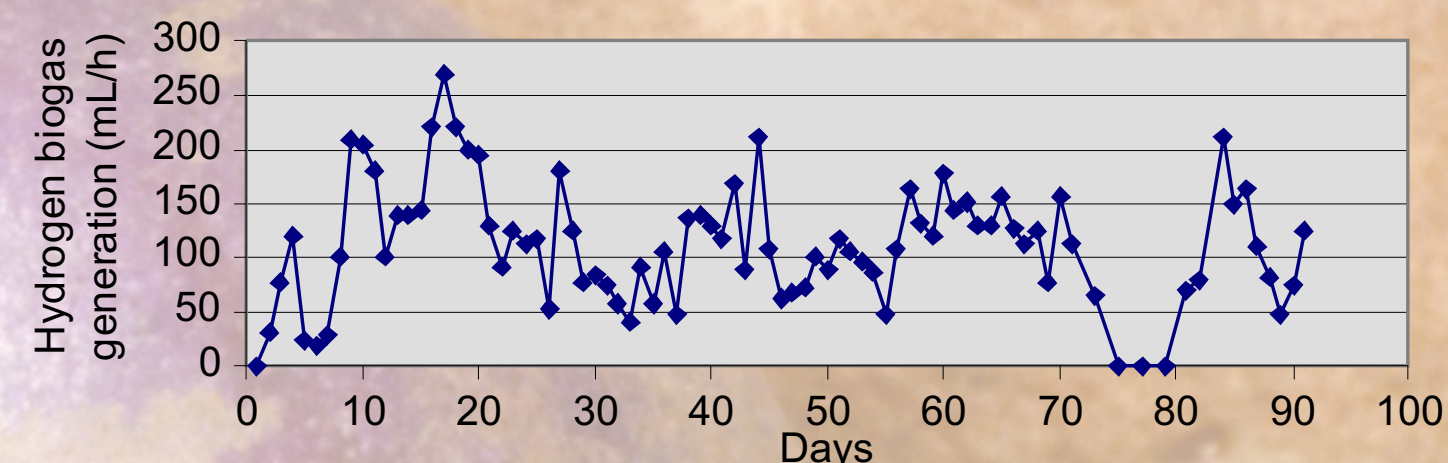


Fig. 2 H₂ biogas production

Methane production

Once the hydrogen production was considered stabilized (after the 20th day), the effluent from the hydrogen reactor was transferred to the second-phase methane reactor. Fig. 3 shows the methane biogas production rate measured from the methane reactor. (Measurements were undertaken in a method similar to the hydrogen biogas measurement.) During the 70 days of operation, the methane biogas was produced continuously. The maximum biogas producing rate observed was 410 mL/h and the average rate was 213 mL/h. The concentration of methane in the biogas was between 69 and 79% (v/v). The average COD concentration in the methane bio-reactor effluent was 4,130 mg/L.

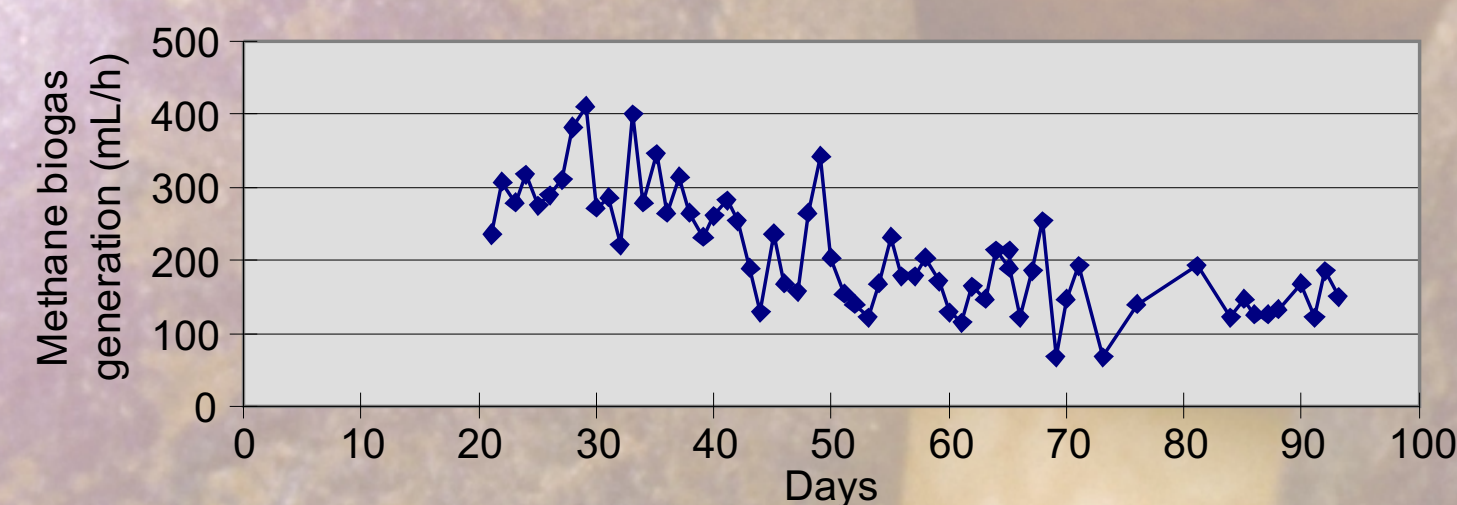


Fig. 3 CH₄ biogas production

Energy yield from the potato waste

Based on the hydrogen and methane biogas production rates, the average energy yield obtained is 4.96×10^6 kJ ($1.4 \text{ kW} \cdot \text{h}$) and the maximum energy yield is 9.58×10^6 kJ ($2.7 \text{ kW} \cdot \text{h}$) from each kilogram (dry weight) of potato waste. The results indicate that the process is promising for full scale applications, although further investigation is required to more fully understand the reasons for the fluctuation in hydrogen and methane production rates.

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