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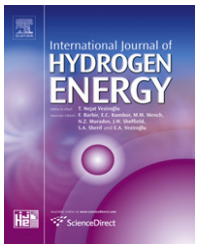

Simulating the impact of suppression of methanogenesis in continuous flow biohydrogen reactors

Hisham Hafez [a,*], Elsayed Elbeshbishy [b], George Nakhla [b,c], M. Hesham El. Naggar [b]

[a] GreenField Ethanol Inc., Chatham, Ontario, Canada N7M 5J4
[b] Department of Civil Engineering, The University of Western Ontario, London, Ontario, Canada N6A 5B9
[c] Department of Chemical and Biochemical Engineering, The University of Western Ontario, London, Ontario, Canada N6A 5B9

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ABSTRACT

A calibrated model of the patent-pending integrated biohydrogen reactor clarifier system (IBRCS) using BioWin was used to evaluate the impact of sludge and/or feedstock pre-treatment for methanogens inhibition in a dynamic simulation for 90 days with and without methanogens suppression. Dynamic simulations at four different OLRs ranging from 6.5 to 103 gCOD/L-d have shown that without any pre-treatment, the system was capable of washing out methanogens and enriching hydrogen producers. The average methane gas content in the reactor's headspace was 4% after 7 days of continuous operation, decreasing sharply to less than 0.5%, while the maximum reduction in hydrogen gas was <10%. The hydrogen gas content in the headspace ranged from 65% to 72%. Simulating the impact of extended SRT ranging from 3 days to 20 days on the performance of the IBRCS revealed that up to an SRT of 5 days hydrogen production was predominant with a reasonable deterioration in the production rate by 20%. Biomass distribution showed that at SRTs up to 20 days, acetoclastic methanogens were naturally eliminated. However, hydrogenotrophic methanogens had a significant impact on the overall hydrogen production rate where most of the hydrogen gas produced was consumed at SRTs of 10 days and 20 days.

1. Introduction

Biological hydrogen production from renewable sources [1] has the potential to meet the growing demand for energy. It offers a feasible means for sustainable supply of H_2 with low pollution and high efficiency, thereby considered a promising eco-friendly energy source [2]. Comparing the production rates of H_2 by various biohydrogen systems and the associated operational complexity, confirms that dark fermentation systems offer an excellent potential for practical applications [3], and hence the great interest from the scientific community.

In dark fermentation, when mixed cultures are used, hydrogen-consuming bacteria (e.g. methanogens and homoacetogens) must be eliminated or inhibited to prevent hydrogen consumption [4–6]. When mixed cultures are treated under harsh conditions, hydrogen-producing bacteria have the ability to form spores which give them a better chance to survive than some non-spore forming hydrogen-consuming bacteria [7]. Thus, mixed cultures have to be pre-treated to suppress methanogens and hydrogen-consuming bacterial (e.g. methanogens and homoacetogens). Pre-treatment methods for enriching hydrogen-producing bacteria

* *Corresponding author*. Tel.: +1 519 784 6230; fax: +1 519 352 9559.
E-mail addresses: hishambahaa@gmail.com, h.hafez@greenfieldethanol.com (H. Hafez).
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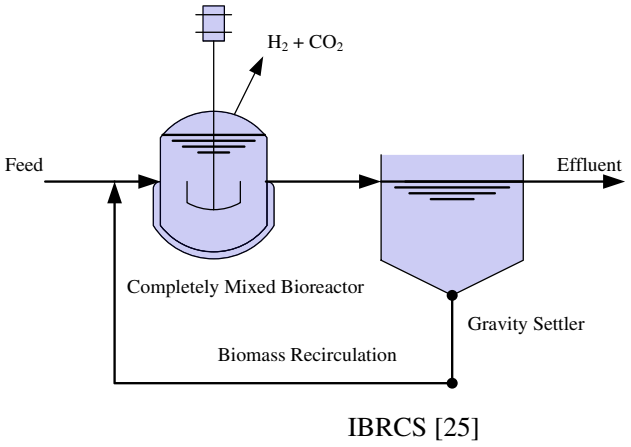

Fig. 1 – Experimental Set up for the integrated biohydrogen reactor clarifier system.

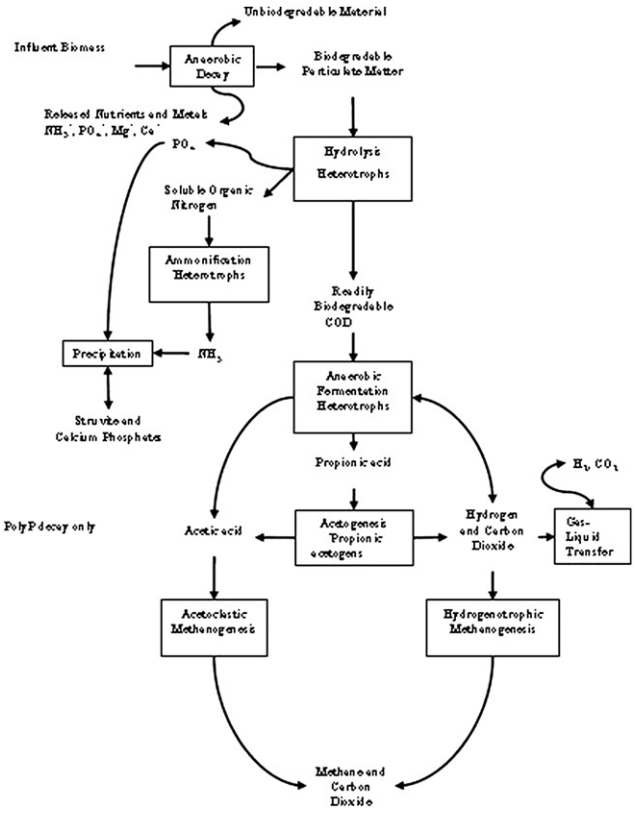

Fig. 2 – Conceptual schematic for the anaerobic degradation model in BioWin (Adapted from BioWin manual).

from mixed cultures mainly include [6] heat-shock (at relatively low temperatures of 75 °C and 85 °C [8,9] as well as relatively high temperature of 104 °C [10]), acid, base [11], aeration [12], freezing and thawing [1], chloroform [13], sodium 2-bromoethanesulfonate or 2-bromoethanesulfonic acid and iodopropane [12,14]. Pre-treatment methods are primarily judged based on their efficiency in eliminating methanogenic activity and enhancing hydrogen yield [6]. Even though heat-shock was the most widely used pre-treatment method for enriching hydrogen-producing bacteria from inocula [15], it is not always effective for enriching hydrogen-producing bacteria from mixed culture inocula compared with other pre-treatment methods, as it may inhibit the activity of some non-spore forming hydrogen-producing bacteria [11].

Numerous pure cultures of bacteria have been used to produce hydrogen from various substrates. The majority of studies involving anaerobic hydrogen production have involved the use of *Clostridium* bacteria; high yields have been obtained using inoculum of pure cultures, mixed anaerobic communities where *Clostridia* were shown to be the dominant organisms, as well as individual strains isolated from waste material [16–18]. Tests with pure bacterial cultures for fermentative hydrogen production were conducted in batches and used glucose as substrate [19–21]. However, continuous hydrogen production from organic waste is more feasible for industrialization to realize the goals of waste reduction and energy production [15]. The disadvantage of using a pure strain is that sterile feedstock conditions (free of methanogens and/or hydrogen-consuming bacteria) should be maintained throughout the process, which is impractical on a large industrial scale [22]. Various pre-treatment methods were applied on real feedstocks. Freezing and thawing and sterilization were superior pre-treatment methods for fermentative hydrogen production [23,24].

The aforementioned paragraph highlights the different methods of pre-treatment that were applied to either bacterial inoculum or feedstocks. Although, it appears that most of these methods are effective for methanogens suppression, on a large scale application where continuous hydrogen production will be used, they all seem impractical and economically unfeasible. Thus, in the present study a process model using BioWin (EnviroSim Associates LTD., Flamborough, Ontario, Canada) that was developed, calibrated, verified and presented in our earlier work [3], will be used to dynamically simulate and evaluate the impact of pre-treatment for methanogens suppression on a novel integrated biohydrogen reactor clarifier system (IBRCS) [25] (see Fig. 1). The system is comprised of a continuously stirred-tank reactor (CSTR) for biological hydrogen production, followed by an uncovered gravity settler for decoupling of solids retention time (SRT) from hydraulic retention time (HRT). In addition, the model will be used to define the maximum SRT for biohydrogen systems that maximizes process performance and

Table 1 – Operational conditions.

	Glucose (g/L)	HRT (h)	SRT (h)	OLR (gCOD/L-d)	Final pH
OLR-1	2	8	50 ± 5	6.5	5.5
OLR-2	8	8	45 ± 4	25.7	5.5
OLR-3	16	8	45 ± 6	51.4	5.5
OLR-4	32	8	42 ± 6	103	5.5
OLR-5	48	8	27 ± 3	154	5.5
OLR-6	64	8	26 ± 2	206	5.5

Note. Values represent average ± standard deviation.