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Biological Hydrogen Production with Variables of Cellulose Concentration and Digested Sludge Density

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1. Introduction

Hydrogen gas is an ideal fuel, not only as a clean energy source but also as an energy carrier. For the global environmental considerations, biological H_2 production from renewable biomass represents an important development in the area of bioenergy production (Bockris, 1972). Due to economic growth, organic fraction of municipal solid waste (OFMSW) has increased year-by-year. Because cellulose is a major component in OFMSW, the conversion of cellulose to H_2 by microbial fermentation represents a partial answer to waste accumulation and the depletion of hydrocarbon fuels reserves and carbon dioxide release (Barbir et al., 1995).

During mixed batch experiments, chosen value of the ratio of initial substrate concentration to initial biomass concentration will influence microcorganisms culture history. Therefore, a factorial design was employed in planning experiments that study the effects of cellulose concentration (S_0) and sludge density (X_0) on H_2 production in this study. To evaluate the effect of both parameters' settings on H_2 production, the data of specific H_2 production potential were subjected to regression analysis to examine respective their interrelations between S_0/X_0 ratio and S_0.

2. Materials and Methods

The pretreated anaerobic digested sludge was introduced for mixed batch experiments. This sludge was taken from a ten-liter laboratory digester and brought to a 15-minute boil to inhibit the bioactivity of H_2 consumers. The mixed batch experiments were performed under a mesophilic condition of 37 °C using a glass bottle of 120 mL volume as a cellulose digester. 25 digesters with various weights (grams) of microcrystalline cellulose and digested sludge were operated simultaneously, and the experimental design is listed in Table 1. The H_2 in biogas was determined using a GC-TCD with a 2-m stainless column packed with Porapak Q. The total solids (TS) and volatile solids (TVS) were determined according to Standard Methods.

Table 1. The calculated parameter values and their S_0/X_0 ratio and S_0.

Digested Sludge (g)	**Hydrogen Production Potential (mL/gCellulose)**				
	Cellulose (g)				
	0.1	**1.0**	**2.0**	**3.0**	**4.0**
10	ND	ND	ND	ND	ND
20	ND	ND	ND	ND	ND
30	ND	30	22	15	6
40	ND	45	35	25	10
50	ND	62	41	29	14

	S_0/X_0	S_0	S_0/X_0	S_0	S_0/X_0	S_0	S_0/X_0	S_0	S_0/X_0	S_0
10	3.5	1.25	35.0	12.5	69.9	25.0	104.9	37.5	139.9	50.0
20	1.7	1.25	17.5	12.5	35.0	25.0	52.4	37.5	69.9	50.0
30	1.2	1.25	11.7	12.5	23.3	25.0	35.0	37.5	46.6	50.0
40	0.9	1.25	8.7	12.5	17.5	25.0	26.2	37.5	35.0	50.0
50	0.7	1.25	7.0	12.5	14.0	25.0	21.0	37.5	28.0	50.0

3. Results and Discussion

H_2 Production under Various Cellulose Concentration and Sludge Density. To examine H_2 production with variables of cellulose concentration (S_0) and digested sludge density (X_0), 25 batch digestions were performed, changing cellulose and digested sludge inside 120-mL digesters from 0.1 to 4 grams and 10 to 50 grams (Table 1) corresponding to S_0 from 1.25 to 50 g/L and S_0/X_0 ratio from 0.7 to 139.9 gCellulose/gVSS, respectively. An examination of Table 1 reveals that specific H_2 production potential increased with

biological hydrogen production; cellulose concentration; digested sludge density
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increasing magnitude of digested sludge; however, they decreased with increasing cellulose. Moreover, there was no significant biogas production found in the samples of low magnitudes of cellulose and digested sludge. It should be emphasized that, for example, no biogas production was obtained at samples 2 and 8 when employing the same S_0/X_0 ratio (35 gCellulose/gVSS) for samples 2, 8, 14 and 20 were observed. These results suggested that the influence of H_2 production not only related simply to the variables of S_0 and X_0 but also to their proportion, that is S_0/X_0 ratio.

Interrelation among H_2 Production Potential, S_0/X_0 Ratio and S_0. To find out the effect of S_0/X_0 ratio on H_2 production potential, the data of specific H_2 production potential (Table 1) were plotted against their respective S_0/X_0 ratios as shown in Fig. 1. Specific H_2 production potential decreased with increase of S_0/X_0 ratio for each individual S_0, while their overall development tendency depended both on the S_0/X_0 ratio and S_0. Additionally, the specific H_2 production potential decreased linearly with increase of S_0 from 12.5 to 50.0 g/L (Fig. 2). These findings led to the reasoning that the S_0/X_0 ratio in this case interacted with the S_0 on H_2 production potential. Thus, the contour plots (Fig. 3) were constructed using Eq. (1).

$$\text{Specific } H_2 \text{ production potential} = 56.9667 + 2.7727\,S_0 - 5.0726\,(S_0/X_0) - 0.0691\,S_0^2 + 0.0033\,(S_0/X_0)^2 + 0.0922\,S_0\,(S_0/X_0) \quad \text{......} (1).$$

Consider the fitted equation (Eq. 1) graphed in Fig. 3. The constant H_2 production potential curves have the shape commonly referred to a "ridge" system. According to the model obtained, the trend of the ridge confirmed that both chosen values of S_0/X_0 ratio and S_0 were important for the digested sludge generating H_2, and that there was a negative effect of S_0/X_0 ratio on the H_2 production potential variation found in the $(S_0)\times(S_0/X_0)$ interaction. The contour plots depict values of H_2 production potential ranging from 10 to 60 mL/gCellulose, depending both on the S_0/X_0 ratio and the S_0 conducted in this study.

4. Conclusions

1. Each gram of the microcrystalline cellulose had a high H_2 production potential of 60 mL by use of pretreated digested sludge. The H_2 composition of the biogas was greater than 50% and there was no significant methane found in the biogas.
2. The experimental results emphasized S_0 and its interactions with S_0/X_0 ratio on H_2 production.

5. References

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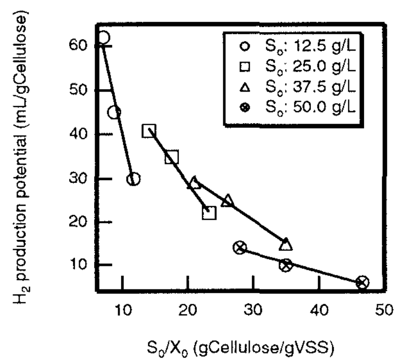

Fig. 1. Influence of S_0/X_0 ratio on the specific hydrogen production potential at cellulose concentrations (S_0) of 12.5, 25.0, 37.5 and 50.0 g/L.

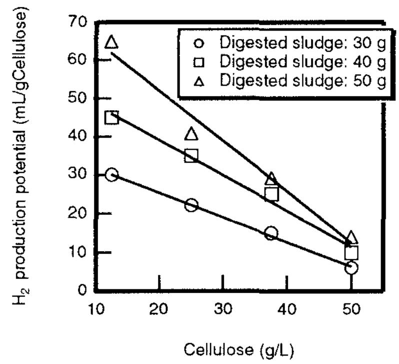

Fig. 2. Influence of cellulose concentration on the specific hydrogen production potential at digested sludge charges of 30, 40 and 50 grams added to the digesters.

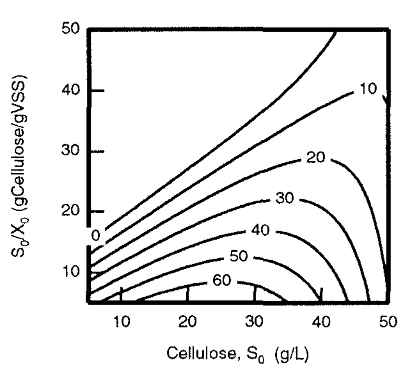

Fig. 3. Constant specific hydrogen production potential (mL H_2/gCellulose) contour lines against S_0/X_0 ratio and cellulose concentration (S_0).

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