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Bio-Hydrogen Production Using Heat-Treated Landfill Leachate Sludge

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Abstract. H_2 is the most promising sustainable energy to replace fossil fuel. This study has investigated the potential of landfill leachate sludge as sludge inoculum to produce H_2. The results show that the seed sludge treated at temperature 65˚C produced largest amount of H_2. The maximum H_2 yield of 6.29mol H_2/ mol glucose was achieved at 37˚C, pH 6 and 10 g/L glucose after 48 hours. Initial pH also played an important role in H_2 production becauseH_2 production was ceased at acidic pH (pH < 6). This study revealed the great potential of landfill leachate sludge for H_2 production.

Keywords: Hydrogen; landfill leachate; heatpretreatment; sludge; pH

1. Introduction

The reliance and rapid consumption on fossil fuel as the primary energy has depleted fossil fuel reserves and contributed to the global warming. Hydrogen (H_2) is the most promising alternative for sustainable energy with the highest energy yield per unit weight (122 KJ/g) as compared to other gaseous fuels [1-3]. Among the bio-H_2 production processes, dark fermentation has significant importance because it has higher H_2 production rate in the absence of light and applicable to different types of waste such as agricultural waste [4-6] and wastewaters [7-9].

Lately, fermentative H_2 production capable of converting waste into energy using mixed microbial community fromwastewater sludge. The benefit of using sludge as inoculum is the symbiotic interaction between H_2 producing bacteria(HPB) that may enhance H_2 production as compared to pure cultures. The most effective fermentative H_2 producers belong to the *Clostridium*sp and is easily enrich via heat treatment [10,11].Among many enrichment methods, heat treatment is the simplest and relatively effective technique used to remove H_2 consuming bacteria and preserve HPB [10-13].There are limited studies on leachate sludge from sanitary landfill to produce H_2. Therefore, sludge of landfill leachate has been applied as inoculum for H_2 production. In a sanitary landfill, organic waste is allowed to decompose biologically to an inert and stable state producing landfill leachate[1,14,15]. Hence the sludge of landfill leachate may contain a diverse microorganism which includes potential H_2producers. Our aim is to investigate the H_2production ability of sludge obtained from landfill leachate.

2. Materials and methods

2.1. Inoculum and treatment condition

The sludge inoculum was collected from a leachate collection pond of Jeram Sanitary Landfill, Selangor. The sludge inoculum was sieved through a 400 μmscreen and stored in at 4˚C. In order to enrich the H_2 producing bacteria, the sludge was heat treated at 40, 55, 65, 80 and 95˚C for 30 minutes [5,8,12]. Non-treated seed sludge was used control.

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2.2. Experimental conditions

Batch fermentations were conducted in triplicates in 200 mL serum bottles containing 150 mL of media. Seed sludge added into each vial was 2% v/v. In all samples, the medium contained the following organics and nutrients (g/L): peptone, 10; yeast, 3; NaCl, 5; CH_3OONa, 3; cysteine, 0.5. Each vial was purged with argon gas for 2 min and sterilized at 115˚C for 15 min. The cultures were incubated at desired temperature, initial pH and substrate concentrationto investigate H_2 production.The volume and composition of biogas and the concentration of volatile fatty acids were measured up to 48 hr.

2.3. Analysis

The volume of biogas produced was collected by water displacement method. The biogas composition was analysed by gas chromatography (Agilent Valve, 7890A) equipped with thermal conductivity detector (TCD) and a molecular sieve column (Molsieve 5A, 60/80 mesh). Concentrations of glucose and organic acids including acetic acid, butyric acid, lactic acid, formic acid and propionic acid were analysed using a high performance liquid column (HPLC) (1200 series, Agilent Technologies) equipped with refraction index detection (RID) and Animex Hi-Pex H column (300×7.7 mm, Agilent). The initial and final pH was measured by a pH meter (Hanna instruments, HI991001).The statistical analysis used in this study was ANOVA using SPSS 16.0 (SPSS Inc., USA).

3. Results

3.1. Effect of Pretreatment Temperature On Fermentative H_2 Production

Fig. 1 shows the H_2 production at different pretreatment temperatures for the landfill leachate sludge. The biogas produced from all heat pretreatedsamples only contained H_2 and carbon dioxide. No methane was detected in these samples throughout the batch fermentation indicating the absence of methanogenic activities of the landfill leachate sludge. H_2 production was initiated after a short lag time of less than 4 hours. Untreated seed sludge only produced 2.91 mol H_2/mol glucose of H_2. All samples show a significant increase of H_2 production after heat pretreatment. The highest H_2yield was achieved after heat treatment at 65and 80˚Cwith the H_2 yield of 6.29 and 6.07 mol H_2/molglucose respectively ($p<0.05$). These clearly indicated that heat treatment has successfully improved H_2production of the landfill leachate sludge and is consistent with Baghchehsaraee*et al.*(2008). At a lower temperature such as 40 and 50˚C the heat is insufficient to enrich H_2 producing bacteria (HPB) but at a higher temperature (95˚C), the extensive heat suppresses HPB.

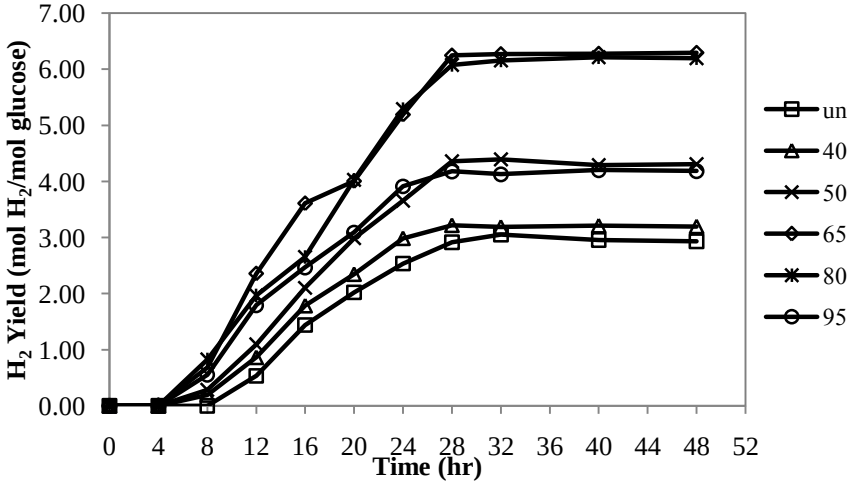

Fig. 1: The effect of heat treatment on the bio-H_2 production.

3.2. Biogas Analysis

Since seed sludge treated at 65˚C produced the highest amount of H_2, this prompted us to investigate and optimize fermentation condition. Fig. 2 shows the cumulative H_2 production at different initial pH for sludge treated at 65˚C. The highest H_2 production was achieved after 28 hrs at pH 6 and 7 ($p<0.05$). At pH 8, H_2 yield was slightly reduced by 18% to 5.36 mol H_2/mol glucose whereas at pH 5, H_2 production was delayed

until 16 hr with the H_2 yield of 4.74 mol H_2/mol glucose. In contrast, H_2 production was completely ceased at pH 4. These results showed that H_2 production is more favorable at moderate acidic, pH 6 and also accordance to other literatures [4-6,8,12,16-18]. Upon reaching 28 hrs, the amount of H_2 remained almost constant indicating that it has reached the saturation point and that no further H_2 consuming activities took place. Table 1 shows the H_2 production at initial pH 6 over wide range of temperature ranging from 25 to 80˚C. The most active fermentation temperature for H_2 production is 37˚C but it was totally inhibited once the temperature increase to 50˚C. This may be due to the HPB become dormant or died at a higher temperature during the fermentation process. Table 2 shows the H_2 production at initial pH 6 over wide range of substrate concentration. The maximumH_2 was produced at 10 g/L glucose with 100% substrate consumption. H_2 yield was reduced 67% at 25 g/L glucose with H_2 yield of 2.06 mol H_2/mol glucose. The low H_2 production is associated with substrate and product inhibition. Total volatile fatty acids were increased with increasing glucose concentration and hence inhibit H_2 production [19].

The maximum H_2 production of 6.29mol H_2/molglucose can be achieved at initial pH 6 and fermentation temperature of 37˚C. The H_2 yield obtained from this study was much higher as compared to others. In general, heat pretreated inoculum seed sludges were only capable of generating 0.5 to 2.3 mol H_2/molglucose [11,20]. The interaction and synergism between microbial communities in the landfill leachate seed sludge has successfully produce large amount of H_2.

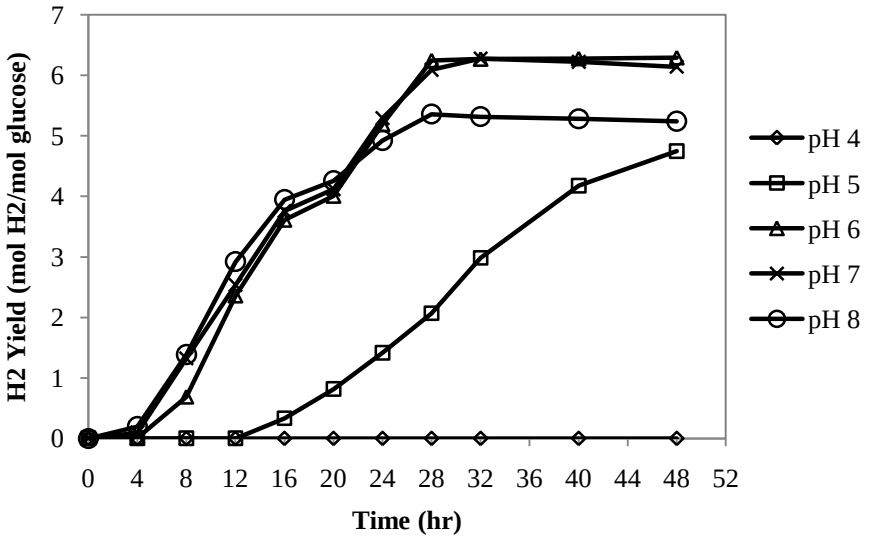

Fig. 2: Time course profile of H_2 production at different initial pH

Table 1: Effect of substrate concentration on H_2 production using landfill leachate sludge

Concentration (g/L)	0	5	10	15	20	25
H_2production (mol H_2/mol glucose)	N.A.	3.40	6.29	3.60	3.08	2.06
H_2 produced (L)	0.005	0.361	1.35	1.138	1.263	1.057
Glucose consumption (%)	N.A.	99.5	100.0	67.5	51.7	52.6
Total volatile fatty acid (g/L)	0.81	4.81	5.69	10.27	8.29	6.94
Final pH	6.01	4.23	4.36	4.84	5.02	5.12

Table 2: Effect of temperature on H_2 production using landfill leachate sludge

Temperature (˚C)	25	37	45	50	60	80
H_2production (mol H_2/mol glucose)	2.65	10	4.41	0.00	0.00	0.00
H_2 produced (L)	0.069	6.29	0.484	0.000	0.000	0.000
Glucose consumption (%)	10.7	1.35	52.5	0.0	0.0	0.0
Final pH	5.21	4.36	4.54	5.81	6.02	5.98

4. Conclusion

The results of this study demonstrated that sludge inoculum from landfill leachate has high H_2 production capacity. Seed sludge treated at temperature 65˚Cresulted in the maximum H_2 yield of 6.29mol H_2/mol glucose. The selected seed sludge performed optimally at 10g.L glucose concentration, initial pH 6 and temperature 37˚C. H_2 production was reduced and suppressed beyond these optimum conditions. The

study shall be proceeded to examine the entire microbial community in seed sludge treated at temperature 65˚C and the capability of this seed sludge to produceH_2 from various wastewaters.

5. Acknowledgement

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6. References

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