

Bio-Hydrogen Production Using Heat-Treated Landfill Leachate Sludge

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Abstract. H₂ 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 H₂. The results show that the seed sludge treated at temperature 65°C produced largest amount of H₂. The maximum H₂ yield of 6.29mol H₂/ 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 H₂ production because H₂ production was ceased at acidic pH (pH < 6). This study revealed the great potential of landfill leachate sludge for H₂ 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 (H₂) 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-H₂ production processes, dark fermentation has significant importance because it has higher H₂ 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 H₂ production capable of converting waste into energy using mixed microbial community from wastewater sludge. The benefit of using sludge as inoculum is the symbiotic interaction between H₂ producing bacteria (HPB) that may enhance H₂ production as compared to pure cultures. The most effective fermentative H₂ producers belong to the *Clostridium* sp and is easily enriched via heat treatment [10,11]. Among many enrichment methods, heat treatment is the simplest and relatively effective technique used to remove H₂ consuming bacteria and preserve HPB [10-13]. There are limited studies on leachate sludge from sanitary landfill to produce H₂. Therefore, sludge of landfill leachate has been applied as inoculum for H₂ 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 H₂ producers. Our aim is to investigate the H₂ production 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 µm screen and stored in at 4°C. In order to enrich the H₂ 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; CH₃OONa, 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 concentration to investigate H₂ 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 H₂ Production

Fig. 1 shows the H₂ production at different pretreatment temperatures for the landfill leachate sludge. The biogas produced from all heat pretreated samples only contained H₂ 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. H₂ production was initiated after a short lag time of less than 4 hours. Untreated seed sludge only produced 2.91 mol H₂/mol glucose of H₂. All samples show a significant increase of H₂ production after heat pretreatment. The highest H₂ yield was achieved after heat treatment at 65 and 80°C with the H₂ yield of 6.29 and 6.07 mol H₂/mol glucose respectively ($p < 0.05$). These clearly indicated that heat treatment has successfully improved H₂ production 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 H₂ producing bacteria (HPB) but at a higher temperature (95°C), the extensive heat suppresses HPB.

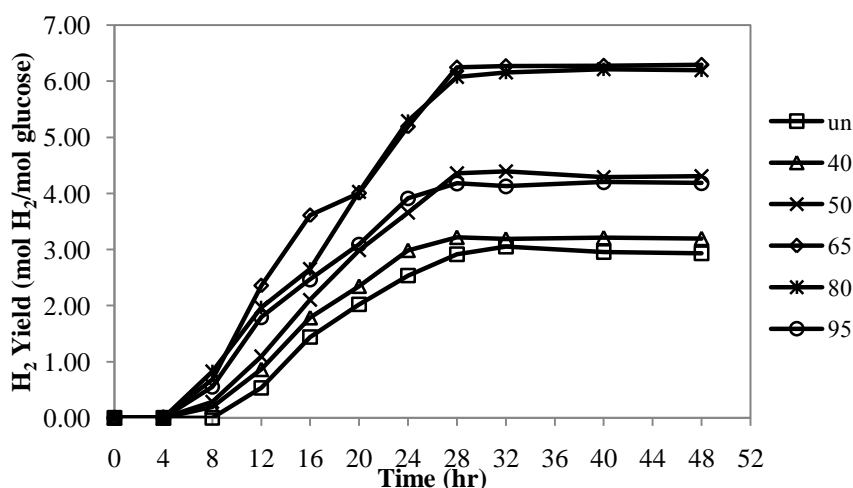


Fig. 1: The effect of heat treatment on the bio-H₂ production.

3.2. Biogas Analysis

Since seed sludge treated at 65°C produced the highest amount of H₂, this prompted us to investigate and optimize fermentation condition. Fig. 2 shows the cumulative H₂ production at different initial pH for sludge treated at 65°C. The highest H₂ production was achieved after 28 hrs at pH 6 and 7 ($p < 0.05$). At pH 8, H₂ yield was slightly reduced by 18% to 5.36 mol H₂/mol glucose whereas at pH 5, H₂ production was delayed

until 16 hr with the H₂ yield of 4.74 mol H₂/mol glucose. In contrast, H₂ production was completely ceased at pH 4. These results showed that H₂ 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 H₂ remained almost constant indicating that it has reached the saturation point and that no further H₂ consuming activities took place. Table 1 shows the H₂ production at initial pH 6 over wide range of temperature ranging from 25 to 80°C. The most active fermentation temperature for H₂ 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 H₂ production at initial pH 6 over wide range of substrate concentration. The maximum H₂ was produced at 10 g/L glucose with 100% substrate consumption. H₂ yield was reduced 67% at 25 g/L glucose with H₂ yield of 2.06 mol H₂/mol glucose. The low H₂ production is associated with substrate and product inhibition. Total volatile fatty acids were increased with increasing glucose concentration and hence inhibit H₂ production [19].

The maximum H₂ production of 6.29 mol H₂/mol glucose can be achieved at initial pH 6 and fermentation temperature of 37°C. The H₂ 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 H₂/mol glucose [11,20]. The interaction and synergism between microbial communities in the landfill leachate seed sludge has successfully produce large amount of H₂.

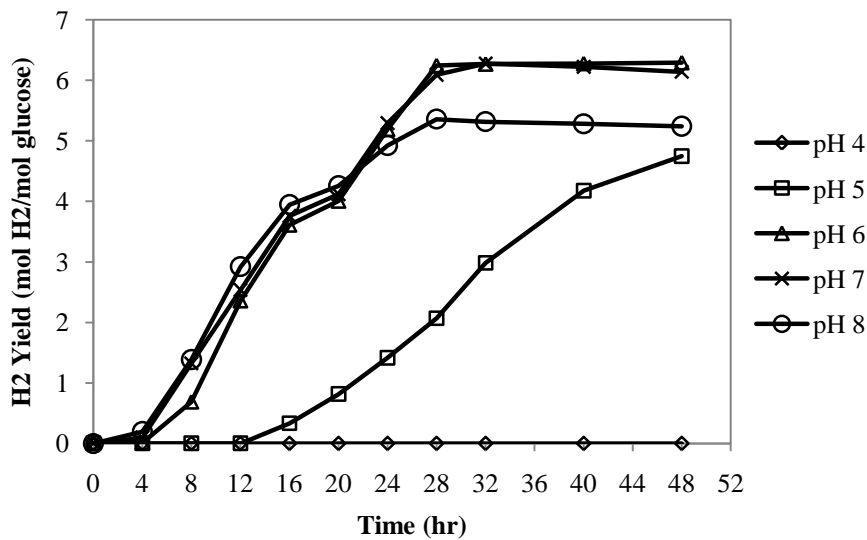


Fig. 2: Time course profile of H₂ production at different initial pH

Table 1: Effect of substrate concentration on H₂ production using landfill leachate sludge

Concentration (g/L)	0	5	10	15	20	25
H ₂ production (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 H₂ production using landfill leachate sludge

Temperature (°C)	25	37	45	50	60	80
H ₂ production (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 H₂ production capacity. Seed sludge treated at temperature 65°C resulted in the maximum H₂ yield of 6.29 mol H₂/mol glucose. The selected seed sludge performed optimally at 10g.L glucose concentration, initial pH 6 and temperature 37°C. H₂ 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 produce H₂ from various wastewaters.

5. Acknowledgement

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6. References

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