Conversion of Biomass Wastes to Hydrogen by Anaerobic Microflora

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Abstract
Fed batch production of hydrogen from palm oil mill effluent (POME) using anaerobic microflora in 5-L bioreactor was studied at 60 ºC and pH 5.5. POME sludge was collected from the anaerobic pond of POME treatment plant in palm oil mill as a source of inocula. The experiment was started in a batch model, the microflora was found to produce a significant amount of hydrogen. A yield of 4708 ml-H_2/L-POME at maximum evolution rate of 454ml-H_2/(L-med. hr) was obtained. A fed batch process was conducted after 50 hr. constant hydrogen production was observed. Through out the study methane gas was not observed in the evolved gas mixture but only hydrogen and carbon dioxide were observed. Under appropriate condition the anaerobic microflora is the most useful organism for hydrogen production from the biomass resources.

Keywords: POME, POME sludge, Production of hydrogen, Microflora

1. Introduction

Hydrogen has been getting wide attention in the last decade as future and clean energy source replacing the utilization of fossil fuels in the energy and chemical industries. Concerning global environmental impacts, for example the green house effect and resource recovery, biohydrogen generation from renewable biomass reduces dependence on fossil fuel, decreases carbon dioxide emissions and recovers bioenergy (1). The major advantage of energy from hydrogen is the zero polluting emissions since the utilization of hydrogen, either via combustion or via fuel cells, results in pure water (2).
Biological production of hydrogen using microorganism is an exciting new area of technology development that offers the potential production of usable hydrogen from a variety of renewable resources (3). Anaerobic biohydrogen produced by photosynthetic bacteria and chemo synthetic bacteria. Chemosynthetic bacteria generate hydrogen without photo energy (4). It is estimated that cost of biohydrogen production by the dark process is 340 times lower than the photosynthetic process (5).

There have been many studies on hydrogen production during wastewater treatment (6,7,8,9). Natural microflora is used in various wastewater treatment processes since a sterilization process is not necessary in this case and since it can be adapted to various kinds of compounds in the wastewater. However, Malaysia has 360 palm oil mills in 2001 (10). Estimated annual production of POME was 32 million tones in the 90's (11). POME consists of various suspended components. POME nutrients content is low for aerobic treatment process but sufficient for anaerobic treatment process (12). In this study, fed batch production of hydrogen from POME was studied by using anaerobic microflora in activated POME sludge.

2. Experimental Work

POME sludge containing anaerobic microorganism and microflora was collected from the anaerobic pond of palm oil mill effluent treatment plant in palm oil mill. Raw POME was collected from the same palm oil mill. The culture medium containing 2.5% POME sludge (w/v) in 4.5 L POME was placed in the fermentor at 60 ºC, pH5.5 and 200 RPM. The initial anaerobic condition in the fermentor was established by replacing the gaseous phase with nitrogen at start of cultivation. To inhibit the activity of photosynthetic bacteria, the culture was carried out without illumination. The amount of evolved gas was measured at room temperature by the water displacement method in a graduated 20L glass tank that had been filled with water of pH 3 or less in order to prevent dissolution of the gas components. The gas composition was determined by gas chromatography (Shimadzu Co., Kyoto, GC-14B) under the following conditions: column: Molecular sieve 5A for H_2 and Porapack-Q for CO_2, carrier gas: helium, flow rate: 33 ml/min, column temperature: 40 ºC, injection temperature: 50 ºC, detector temperature: 50 ºC, detector: thermal conductivity detector (TCD).

3. Results and Discussion

In the previous reports artificial wastewater containing glucose was used in the screening process of active microflora in POME sludge for the production of hydrogen. A total biogas of 2238 ml/L-med consisting 68% of hydrogen was produced by microflora (13). Also the active microflora in activated POME sludge for the production of hydrogen was found from the final stage of anaerobic treatment plant (14). In the present study, the microflora in activated POME sludge was controlled to produce hydrogen from POME by using high temperature at 60 ºC and controlled pH of 5.5. Product formations by microflora depend on the microorganisms that dominate in the microflora. Use of high temperature assisted in the production of hydrogen. The activity of acidogens or hydrogen producing bacteria increased with temperature (15), 50 ºC-60 ºC was the optimal temperature for the production of hydrogen. The optimal pH for the production of hydrogen was observed in the pH range of 5-6 (16,17). pH 5.5 is the optimal pH for the production of hydrogen as reported by Fang and Liu (18). It was found that the control of pH is crucial to hydrogen production, due to the effects of pH on the hydrogenised activity (19) and/or on the metabolism pathways (20).
The hydrogen yield was calculated and the result is listed in Table 1. The experiment was started in batch model. A time course of fermentation pattern from POME during the

cultivation of anaerobic microflora in POME sludge at 60 ºC and pH5.5 is shown in Figure 1. The production of biogas started after 12 hr. The biogas comprised hydrogen and carbon dioxide no methane gas was detected. The result agreed with that obtained by Fang and Liu (18) and Morimoto et al. (15).

Table 1. Amount of hydrogen produced from POME at 60 ºC and pH 5.5

Process	Feeding Time hr	H_2Yield ml/L-med	Evolution Rate ml/(L-med hr)
Batch	-	4708	454
First Fed Batch	24	2382±65	313±29
Second Fed Batch	8	1597±83	436±37

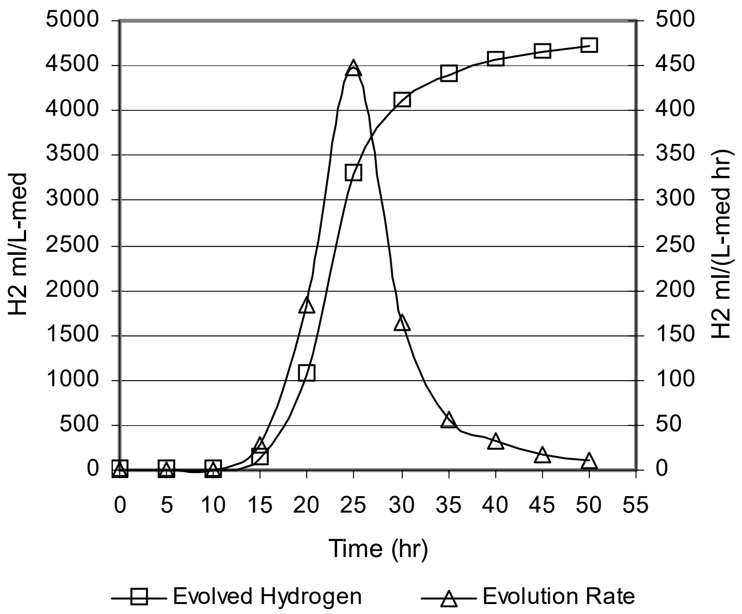

Figure 1. Time course of fermentation pattern during the batch hydrogen production from POME at 60 ºC and pH 5.5.

The microflora POME sludge produced a yield of 4708 ml-H_2/L-POME in 38 hr at maximum evolution rate of 454 ml-H_2/(L-POME hr). After 50 hr the fed batch process or feeding of fresh POME began. 2 L of reaction medium (44.4% of medium) was taken and 2 L of fresh POME added to the reaction medium with the same temperature (60 ºC) after every 24 hr for 15 batches, with the results presented in Figure (2).

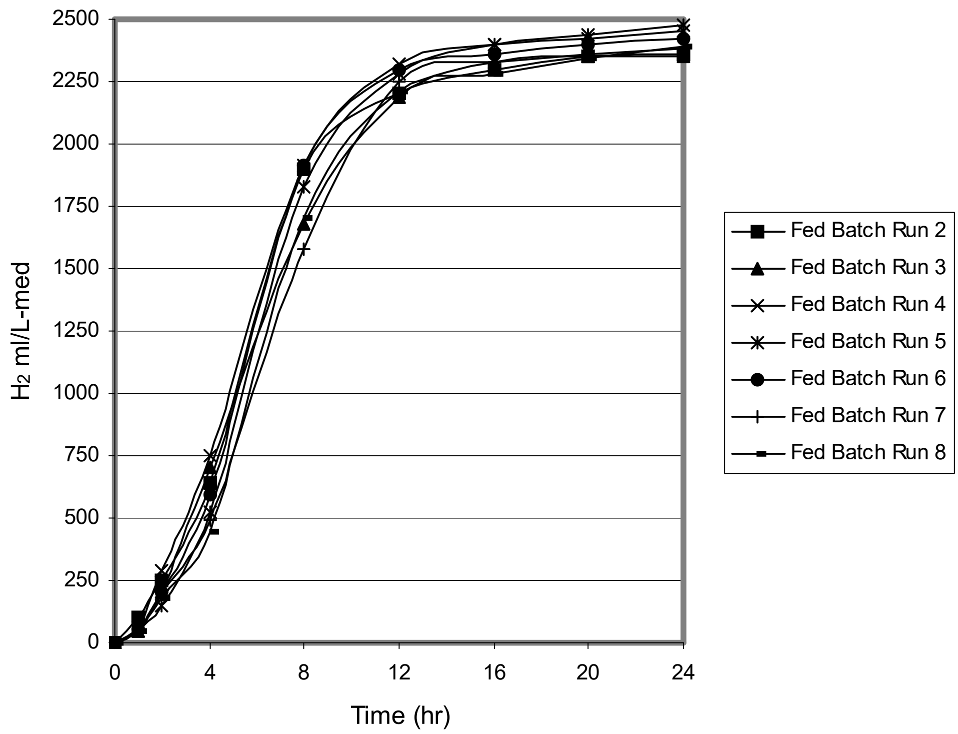

Figure 2. Typical fermentation pattern during the first fed batch process at 60 °C and pH 5.5, feeding time of 24 hr.

The microflora indicate good activity for production of biogas (hydrogen). The production of biogas started after short time, less than 30 min. A hydrogen yield of 2382±65 ml-H_2/L-med was observed at maximum evolution rate of 313±29 mlH_2/(L-POME hr). The depletion of the medium was observed approximately after a process time of 8 hr. Thus, the reproducibility of the fed batch process for the production of biogases was checked by performing a second fed batch fermentation. The feeding time was changed every 8 hr, for 10 batches. The time course of the fermentation pattern is shown in Figure 3. Fast production of biogas was observed, hydrogen yield of 1597±83ml-H_2/L-med observed at maximum evolution rate of 436±37 mlH_2/(L-POME hr). The evolution rate was greater than that observed in the first fed batch process, Figure 4 shows the comparison between both process for hydrogen production. An explanation, in the case of first fed batch process is that the anaerobic bacteria utilized the available substrate approximately in about 8 hr. Thus, the bacterial growth began to decrease due to limitation of the substrate, while in the second fed batch process the bacteria growth might not had been affected by reducing feeding time. Figure 2 and 3 shows typical hydrogen production obtained during the fed batch process, which indicated that the hydrogen-producing bacteria are dominant in the microflora.

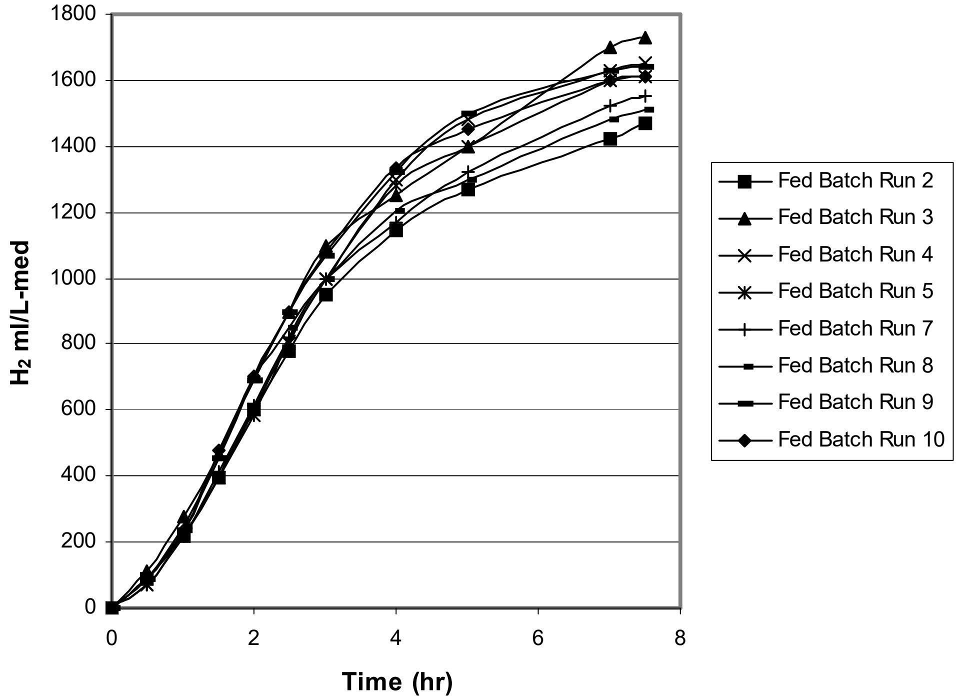

Figure 3. Typical fermentation pattern during the second fed batch process at 60 ºC and pH 5.5, feeding time of 24 hr.

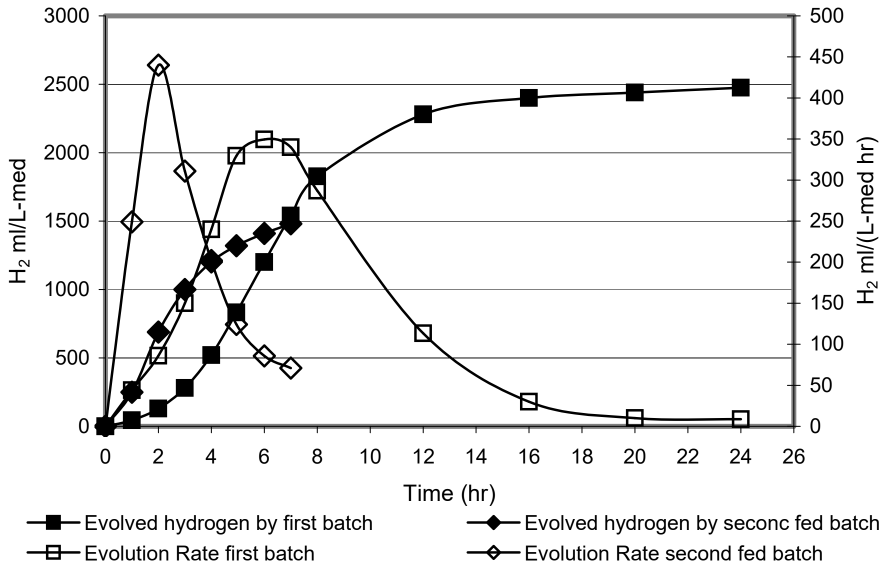

Figure 4. Comparison between the first and second fed batch process for hydrogen production, at 60 ºC and pH 5.5.

The yield observed in this study was substantially higher than that reported by microflora (9,15,17,21), and pure culture of isolate (16,22). Moreover, the maximum evolution rate of 484 ml-H_2/(L-med. hr) is comparable to that reported by pure culture of isolate (16,22). The percentage of hydrogen in the evolved gas does not changed during the fermentation pattern. The result obtained in this study also indicates that the nutrients present in raw POME supported the bacterial growth for the production of hydrogen. Thus, under appropriate condition the anaerobic microflora would be the most useful microorganism for the production of hydrogen from biomass resources.

4. Conclusion

Fed batch production of hydrogen from POME by using microflora in POME sludge was studied. The fermentation reaction was controlled to produce hydrogen by using high temperature at 60 ^{o}C and controlled pH at 5.5. The anaerobic microflora in the POME sludge was found to transform POME nutrients into hydrogen. Through out the study methane gas was not observed in the evolved gas. A typical hydrogen production characteristic was observed during the fed batch process. Thus anaerobic microflora could be proposed as the most useful microorganism for the production of hydrogen from biomass resources without sterilization.

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