DOCTORAL THESIS

Enhanced methane gas generation by reutilization of acidogenic off-gas during two-phase anaerobic digestion of food waste

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Enhanced Methane Gas Generation by Reutilization of Acidogenic Off-gas during Two-phase Anaerobic Digestion of Food Waste

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DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of PhD at Hong Kong Baptist University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications.

Signature: _____

Date: January 2015

ABSTRACT

Mass balance analysis of two-phase AD indicated that off-gas (H_2 and CO_2) produced in acidogenic reactor represent up to 30% of the consumed substrate and under most circumstances, this part of energy was not utilized leading to low overall energy recovery. Hence, the objective of this study was to enhance overall energy recovery during two-phase AD of food waste through reutilization of acidogenic off-gas and to further optimize the processes through manipulating the metabolic pathways and controlling acidogenic off-gas production.

In the first phase, feasibility of reutilizing acidogenic off-gas in methanogenic reactor and contribution of acidogenic off-gas to overall energy recovery was investigated. Acidogenic off-gas diversion increased the methane gas (CH_4, 0.28 L/g VS_{added}) production up to 38.6%, of which ~8% was contributed by acidogenic off-gas. Both higher hydrolysis rate and COD production were also achieved with off-gas diversion.

Metabolic pathway determines the distributions of intermediate soluble products, which constitute the quality of acidogenic leachate. Therefore, two experiments focusing on manipulating metabolic pathways were performed. Firstly, the effects of four levels of headspace pressures, 6-12 psi (T1), ~3-6 psi (T2), ~3 psi (T3) and ambient pressure (T4) were investigated. Mixed acids metabolic pathways prevailed in all the treatments with butyrate as the single major component. Then, four different levels of H_2 partial pressure (PH_2) were set the next experiment, self-generated PH_2 (T1, control), 80% of H_2 (T2), 60% of H_2 (T3) and 0.04% of H_2, while the headspace pressure was kept at 3.3 psi. Typical butyrate fermentation pathways dominated in T4 whereas mixed acid fermentation pathways were prevailing in the other three treatments. Because of the improved hydrolysis/acidogenesis and higher quality of acidogenic products, overall CH_4 recovery in T4 (301.0 L/kg VS_{added}) was 44.6% higher than the control.

In Phase III, strategies to enhance acidogenic off-gas production were investigated. First, four types of neutralization modes including daily pH adjustment of leachate to 6.0, methanogenic effluent recirculation, and initial addition of NaOH and lime separately at a dosage of 20.0 and 14.0 g/kg food waste, respectively, were investigated. Obviously, a H_2 production rate of 3.0 and 2.1 L/d with lime and NaOH addition was much higher than 0.7 and 0.4 L/d with effluent recirculation and daily

adjustment, respectively. Also, addition of alkali agents could enhance the COD leaching of food waste, especially with NaOH. A CH_4 production of 11.24 L/d could be attributed to both the elevated leachate quality and the acidogenic off-gas with lime addition. Another experiment investigated the effect of different carbohydrate contents in the substrates on acidogenic H_2 production. Anaerobic hydrolysis of wastes sourced from bakery (T1), Chinese-style restaurant (T2), western-style restaurant (T3) and wet market were performed in LBRs. Food waste collected from western-style restaurant with a carbohydrate content of 69.5% achieved the highest H_2 production of 61.0 L/kg VS_{added}. The highest specific CH_4 production rate at 0.42 L/gVS_{added} was also achieved with western restaurant food waste.

Finally, the possible redirection of fluxes associated with shift of metabolic pathways from the experiment of PH_2 was proposed. Significant increase in the production of butyrate in treatment T4 with PH_2 of 3.3 psi × 0.04% indicated the channeling of electrons towards the production of butyrate. Dynamics of the microbial community were correlated with the distribution of metabolites. In T1 without external gas flushing, lactic acid fermentation was dominant during the initial 7-days. Accordingly, phylotypes affiliated to the genus *Lactobacillus* sp. were detected. A heterlatic fermentation pathway was observed in in both T2 and T4 during first four days, and thereafter the fermentation pathways shifted towards acetate and butyrate as dominant products, which were accompanied by changing the microbial community with phylotypes of *Clostridium* sp. and *Bifidobacterium* sp. becoming dominant.

To conclude, reutilization of acidogenic off-gas by diversion to methanogenic phase is a promising strategy for enhancing overall energy recovery during two-phase AD of food waste. However, improvement of the short-lived acidogenic H_2 production and H_2/CO_2 ratio needs further investigation.

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TABLE OF CONTENTS