DOCTORAL THESIS

Two-phase anaerobic digestion of high-solid food waste for energy recovery

Xu, Suyun

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TWO-PHASE ANAEROBIC DIGESTION OF HIGH-SOLID FOOD WASTE FOR ENERGY RECOVERY

XU Suyun

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Principal Supervisor: Prof. Jonathan W. C. WONG

Hong KongBaptistUniversity

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Abstract

A two-phase leach bed reactor (LBR) coupled with a methanogenic reactor (UASB or anaerobic filter) is proposed to treat solid substrates like municipal solid waste, food waste and maize etc. The rate-limiting step of anaerobic digestion, hydrolysis of solid substrate, will be retarded in the acidogenic LBR without agitation equipment, especially for substrate with high solids content (>20%). The overall aims of this study are to accelerate the decomposition rate of food waste and increase its biogas yield in the two-phase LBR-UASB system. A series experiments have been carried out in three phases.

In the first phase, three experiments, i.e. pH adjustment, optimization of the inoculum to substrate ratio and micro-aeration, were carried out to accelerate the hydrolysis. Daily leachate recirculation with pH control (6.0) accelerated the hydrolysis rate (59% higher VFAs) and methane production (up to 88%) compared to that of control LBR (no pH control). The performances of LBRs with different inoculum to substrate ratios (ISR), i.e. 0, 5, 20 and 80% (w/w basis) were compared in the second study. Results indicated that ISR of 80% resulted in 4.3-foldincrease in protein hydrolysis but only a modest increase in carbohydrate decomposition. Therefore, ISR of 20% was recommended in the hydrolytic-acidogenic process. In the third study, micro-aeration intensity was optimized to promote the solubilization of food waste and meanwhile the undesirable carbon loss was avoided. LBR with an aeration intensity of 12 min/3 h (258L-air/kg TS/d) showed 59% increase in the COD solubilization and a 3-fold increase in the VFAs production compared to that of control, and also resulted in a maximum methane yield of 0.21 L/g VS_{added}.

Three sets of experiments were carried out in the Phase II in order to investigate the impact of various water regimes on the performance of LBR-UASB system, as well as on the dynamics of microbial community in LBR. Results showed that the quality of the acidogenic leachate was improved by the optimal water regimes, i.e. liquid solid ratio (LSR) 1.0, continuous leachate recirculation in LBR (5 mL/min), high rate of water replacement and methanogenic effluent recirculation to LBR, which led to the substantial increase of methane yield to 0.28 L-CH_4/g VS_{added}. Bacterial diversity analyses through PCR-DGGE indicated that *Lactobacillus* sp. and

Proteobacteria were the most abundant in LBRs either with LSR 1.0 or 0.5. With the high rate of water replacement, bacterial population was not reduced due to its stimulation of specific fast-growing bacteria as evidenced by quantitative real-time PCR. The strategies of effluent recirculation into LBR led to the microbial alternation from *Lactobacillus* sp. (in LBR with water replacement) to *Clostridium* sp. and hetero-fermentation lactic acid species. It is concluded that the performance of two-phase anaerobic digestion of food waste could be improved by the recirculation of methanogenic effluent.

Finally, two feeding modes, i.e. semi-continuous feeding and sequential batch feeding were compared to improve the volumetric capacity of acidogenic LBR in the Phase III. Under semi-continuous feeding mode, the volumetric capacity of LBR was improved to 7.03 g TS/L/din LBR with a stable performance (0.28 L-CH_4/ g VS_{added}). DGGE results indicated that a specialized niche have been formed in the semi-continuous acidogenic LBRs that favored the bacteria such as *Clostridium* sp., *Acetobacter peroxydans*, *Enterococcus* sp., *Lactobacillus diolivorans* and *Bifidobacterium*. It can be concluded that a two-phase LBR-UASB digestion system with semi-continuous feeding mode is ideally set up to produce methane from food waste.

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