Three-stage anaerobic co-digestion of food waste and waste activated sludge

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Introduction

Food waste (FW) and waste activated sludge (WAS) are critical global issues currently (Voelklein *et al*. 2017). Anaerobic digestion (AD) is universally acknowledged as an effective method for organic waste treatment and renewable energy generation (Angelidaki *et al*. 2018). To combine the benefits of high-solids AD and wet AD to improve digester performance and methane production, a three-stage anaerobic digester was developed in this study. The three-stage digester successfully integrated high-solids hydrolysis (stage 1), acidification (stage 2) and wet methanogenesis (stage 3) into one digester. Hitherto, no research has been conducted to operate co-digestion of FW and WAS using a three-stage AD digester. Therefore, the objectives of the present study were (a) to explore the potential and feasibility of the three-stage digester (20 L) for anaerobic co-digestion of FW and WAS, and (b) to further investigate the microbial dynamics in the three-stage anaerobic system for co-digestion of FW and WAS.

Bench-scale three-stage anaerobic co-digestion system and operation

The 20 L bench-scale three-stage anaerobic co-digestion (TSAco-D) system (Fig. 1) was operated in a semi-continuous mode at 35^{0}C for 119 days.

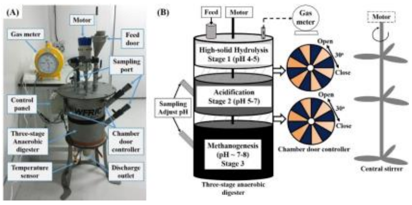


Fig. 1 Three-stage anaerobic co-digestion system: (A) photograph, (B) schematic diagram.

Performance of bench-scale three-stage anaerobic co-digestion

Fig. 2A shows the reactor performance during the bench-scale three-stage anaerobic co-digestion.

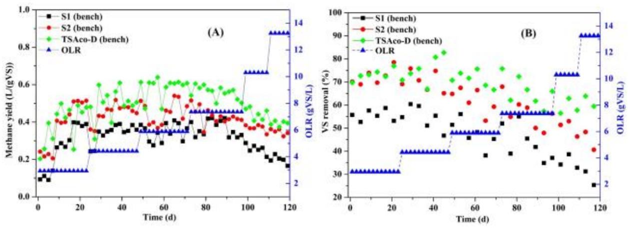
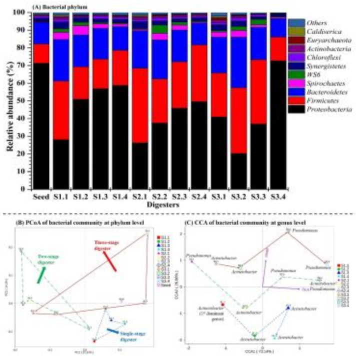


Fig. 2 Methane yields (A) and VS removal efficiency (B) of the bench-scale three-stage co-digestion.

From Fig. 2A, at the same OLR of 5.89-7.36 gVS/L (day 49 to day 97), the average methane yield of TSAco-D (bench) was about 1.62 and 1.31 times higher than those in S1 and S2, respectively. This result indicated that three-stage AD performed more effectively and had a better bearing capacity for a high OLR than one- and two-stage digesters. However, with application of a higher OLR (10.3-13.25 gVS/L) from the 99th day, performance of the digesters decreased considerably, which indicated that the maximum available OLR was between 6 and 7 g VS·L^{-1}. During the whole AD process, the average methane yield of TSAco-D (bench) was 0.496 L/(gVS), which was 51.7% and 13.4% higher than that of S1 (bench) and S2 (bench), respectively. In addition, the VS removal efficiency (Fig. 2B) in the bench-scale TSAco-D was 69.3%, higher than that of S2 (62.4%) and S1 (47.0%).

Predominant bacteria and archaea and microbial dynamics



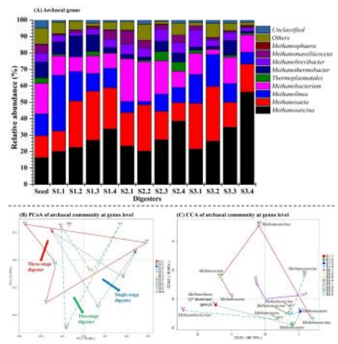


Fig. 3 (left) (A) Species taxonomy and (B) PCoA of bacterial communities. (C) CCA of bacterial community. **Fig. 4** (right) (A) Species taxonomy, (B) PCoA and (C) CCA of methanogenic archaeal communities. S1.1 refers to the one-stage digester with an OLR of 2.94 gVS/L; S2.2 refers to the two-stage digester with an OLR of 5.89 gVS/L; S3.3 refers to the three-stage digester with an OLR of 7.36 gVS/L; S3.4 refers to the three-stage digester with an OLR of 13.25 gVS/L. And so on in a similar fashion.

Bacterial phyla *Proteobacteria, Firmicutes and Bacteroidetes* dominated in one-, two- and three-stage digester while genera *Pseudomonas*, *Tissierella*, and *Petrimonas* were selectively enriched in the three-stage digester due to functional segregation. Taxonomic analysis identified 8 dominant methanogen genera, of which *Methanosarcina*, *Methanosaeta*, *Methanobacterium* and *Methanolinea* collectively accounted for 80%. With increasing OLR and digester stage number, the dominant methanogenic pathway shifted from hydrogenotrophic pattern to acetoclastic pattern and reached a final synergy of these two. *Methanosarcina* was enriched by 1.5-1.7 times in the three-stage digester, contributed to the enhanced methane production.

Conclusions: Anaerobic co-digestion of WAS and FW was investigated in one-, two- and three-stage digesters at mesophilic condition within a wide range of OLRs. The feasibility of the three-stage digester scenario was validated in a bench-scale operation. The maximum available OLR for the long-term operation of the three-stage digester was proposed as 6-7 gVS/L. Through digester functional segregation, beneficial bacterial species (e.g. *Pseudomonas*) and methanogens species (e.g. *Methanosarcina*) were selectively enriched by 1.5-2.8 times, which contributed to the enhanced hydrolysis degree and acidification degree, the shortened start-up period, the increased VS removal, and the enhanced methane production in the three-stage digester.

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References

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