Effect of TOC/TN ratio and degradability of substrates on the performance of high-solid anaerobic digestion: gas and methane production

Huimin Zhou[1], Qingliang Zhao[1*], Liangliang Wei[1], Lili Li[1], Junqiu Jiang[1], Kun Wang[1]

[1] State Key Laboratory of Urban Water Resources and Environments (SKLUWRE), School of Environment, Harbin Institute of Technology, Harbin 150090, China

Keywords: High-solid anaerobic digestion, TOC/TN ratio, degradability, gas and methane production.

Presenting author email: qlzhao@hit.edu.cn

High solid anaerobic digestion (HS-AD), characterized by high input TS concentration (≥ 15%, w/w), small occupation, low heating demanding, and high volumetric biogas production, has been one of the most popular solid waste treatment technology in the field of organic wastes treatment/disposal since the 1990s (Fagbohungbe et al., 2015). The performance and efficiency of the HS-AD are always restricted by many factors, in which the TOC/TN ratio and degradability of the substrates have been highly concerned. Despite numerous studies declared that the optimal TOC/TN for anaerobic digestion ranged from 20:1 to 30:1 (Kainthola et al., 2019; Xue et al., 2020), however, Romano & Zhang (2008) found that the TOC/TN of about 15 was suitable for the anaerobic digestion of onion. In addition, the degradability also affected gas production significantly. To the best of our knowledge, how the TOC/TN and degradability of the substrates influenced the HS-AD remained unclear. Therefore, the experiments were designed and carried out to explore the influence of these two factors on HS-AD.

Dewatered sludge (TS 19.79% and VS 8.98%) was used as the inoculum. The total volume of the reactor was 1 L, equipped with air collecting holes and sampling ports, and placed in a gas bath thermostat at 37℃. Reactors were inoculated with 800 g dehydrated sludge, substrates were added at a mass ratio of 5:1 (sludge: substrate) based on VS. Wheat straw powder (WSP) and low-gluten flour (LGF) were selected to represent refractory and easily degradable substrate with high TOC/TN ratio, while chicken breast meat powder (CBMP) and peptone powder (PP) represented refractory and easily degradable substrate with low TOC/TN ratio. The characteristics of the four substrates were listed in Table 1. The above-mentioned four substrates were combined in pairs according to TOC/TN and the degradability to form four composite substrates with a total TOC/TN ratio of 25:1. Except for CK (1), eight kinds of substrates fed into the reactors were WSP (2), LGF (3), CBMP (4), PP (5), WSP and CBMP (6), WSP and PP (7), LGF and CBMP (8), LGF and PP (9), respectively.

Table 1. Characteristics of substrates during HS-AD.

Item	Particle size	TS	VS	C	H	O	N	S	TOC/TN
Unit	mm	%	%TS	%TS	%TS	%TS	%TS	%TS	-
WSP	<1	92.90	87.33	41.36	5.84	39.38	0.50	0.25	82.72
LGF	<1	89.61	89.35	40.69	6.07	41.83	0.77	0.25	52.70
CBMP	<1	100.00	97.91	51.28	6.61	21.55	15.18	1.30	3.38
PP	<1	95.44	93.86	44.76	6.09	27.80	15.89	0.90	2.82

The variation of daily biogas production (DBP), daily methane production (DMP), cumulative biogas production (CBP), cumulative biogas production (CMP), total ammonia nitrogen (TAN), and VFAs during the HS-AD process were shown in Fig.1. More gas production peaks were obtained for eight kinds of substrates during the experiments, and also exhibited a longer lag time than the results of low-solid AD (Fig. 1 a & b). Overall, the anaerobic digestion using the CBMP as substrates exhibited more excellent gas productivity (Fig. 1 c), followed by LGF, PP, WSP, whereas the others were quite lower. For comparison, the methane production declined as CBMP, PP, WSP, and others. Therefore, in the AD system with TS content up to 20%, the TOC/TN ratio was

important to the gas and methane production process, especially under a low TOC/TN ratio condition. In addition, those substrates with refractory characteristics exhibited relatively better methane productivity than those easily biodegradable ones. Both the gas and methane productivity of the anaerobic digestion with the composite substrates were quite low, also with an insignificant variation of the VFAs and TAN (Fig. 1 e & f), indicating that the substrate degradation effect was poor and no synergistic promotion effect was observed in the degradation of the substrate under experimental operating conditions. Experimental results observed above were quite different from conventional AD, which could further expand our knowledge and understanding of HS-AD.

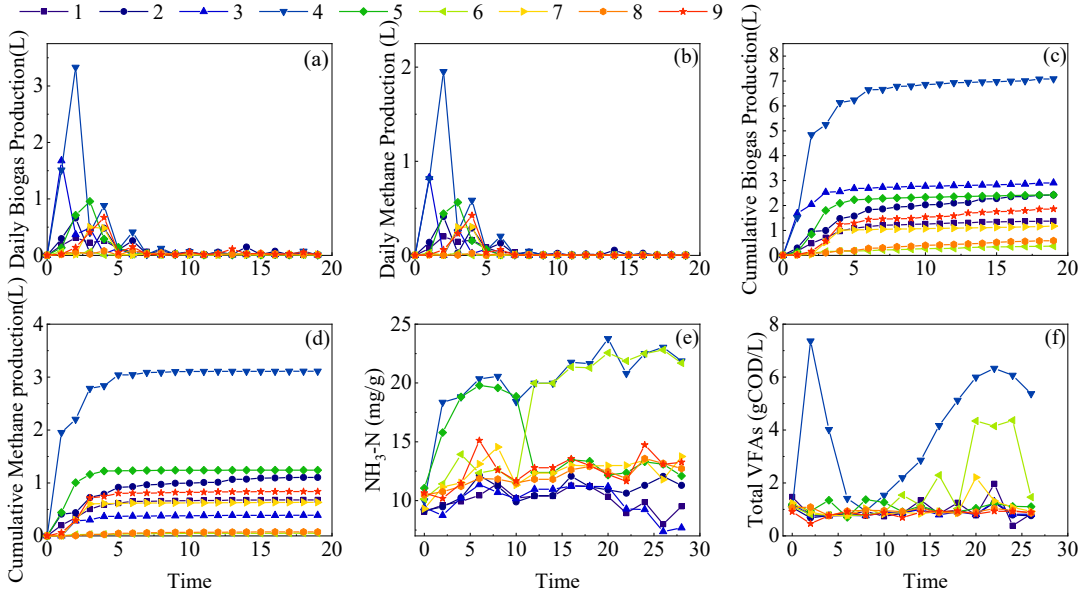

Fig.1 Dynamics of (a) DBP, (b) DMP, (c) CBP, (d) CMP, (e) TAN, (f) Total VFAs during HS−AD process.

In summary, the gas and methane production efficiency in HS-AD were higher when the TOC/TN ratio of the substrate was low, and the methane yield of CBMP reached the highest value of 216 mL/gVS. The refractory substances in HS-AD exhibited higher gas and methane production efficiencies, which were 1.50 ~ 1.83 times higher than those of easily degradable substances. The results obtained above might provide references for the design and operation of the future HS-AD process.

This work was supported by the National Key Research and Development Program of China (2018YFC1900902). The authors are very grateful to the laboratory colleagues for their help.

Fagbohungbe, M.O., Dodd, I.C., Herbert, B.M.J., Li, H., Ricketts, L., Semple, K.T. 2015. High solid anaerobic digestion: Operational challenges and possibilities. *Environmental Technology & Innovation*, **4**, 268-284.

Kainthola, J., Kalamdhad, A.S., Goud, V.V. 2019. Optimization of methane production during anaerobic co-digestion of rice straw and hydrilla verticillata using response surface methodology. *Fuel*, **235**, 92-99.

Romano, R.T., Zhang, R. 2008. Co-digestion of onion juice and wastewater sludge using an anaerobic mixed biofilm reactor. *Bioresource Technology*, **99**(3), 631-637.

Xue, S., Wang, Y., Lyu, X., Zhao, N., Song, J., Wang, X., Yang, G. 2020. Interactive effects of carbohydrate, lipid, protein composition and carbon/nitrogen ratio on biogas production of different food wastes. *Bioresource Technology*, **312**.