Enhancing biogas production from septic tank sludge via hydrothermal pre-treatment and co-digestion with food waste

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Septic tank sludge (STS) is the residue discharged from the septic tanks, where domestic wastewater experiences anaerobic or anoxic storage and organic pollutants were degraded partly by different microorganisms. Therefore, STS contains residual organic substances, live or dead tiny organisms, and inorganic particles [1]. To eliminate these pollutants and pathogens, aerobic composting is commonly used for STS treatment and utilization [2]. In comparison to composting, anaerobic digestion (AD) is also an alternative way in big cities, because it can convert organic waste to biogas, which can be taken as a renewable fuel for boiler, vehicles, and electric generators. However, STS is experiences anaerobic processes in septic tanks, and the performance of STS AD should be limited from the aspects of biogas production and disinfection. Thus, hydrothermal pre-treatment (THP) before AD was proposed in this study because it can dissolve organic matter from solid phase, hydrolyse macromolecular organic substances, increase biochemical degradability, and kill pathogens [6-8]. Furthermore, STS can share digesters with other organic wastes like municipal solid waste [3] and microalgae[4], and co-substrates can provide balance nutrients for anaerobic microorganisms [5]. Thus, food waste (FW), rich in degradable organic substances and other nutrients, can be digested with STS together. As far as we know, this possibility has not been tested before. In this study, the effects of HTP and co-digestion with FW on the performance of STS AD were investigated, aiming to provide a new pathway for STS treatment.

Methods and materials

STS and FW were collected from local treatment plants, and the inoculum was the effluent discharged from an AD tank for FW treatment. Their characteristics are shown in Table 1. HTP was conducted in a high-pressure vessel at 180℃ and 10 bars for 30 min. The biochemical methane potential (BMP) tests were carried out in an AMPTS II system containing dozens of reaction bottles. Each bottle had a total volume of 500 ml with a working volume of 400 ml. All the bottles were placed in a water bath at 35±1℃, and the stirrer in each bottle worked at 60 r/min with an interval time equal to the working time. The biogas was collected through alkaline absorbent, and the methane yield was recorded continuously. In the first batch, three groups of trials were conducted using STS, STS after HTP, filtrate after HTP as the substates, respectively, and the ratio of inoculum to substate was 2:1 based on their chemical oxygen demand (COD). In addition, a blank group was conducted with only the inoculum in the bottle. In the second batch, four groups of trials were carried out including different ratios (1:0, 1:1, 2:1, 0:1 based on COD) of the filtrate after STS HTP and the FW. In each group, three parallel trials were tested, and the average was used for analyses.

Table 1. Characteristics of the inoculum, the septic tank sludge (STS) before and after hydrothermal pre-treatment (HTP), the filtrate of STS after HTP, and food waste (FW)

Parameters	Inoculum	STS before HTP	STS after HTP	Filtrate	FW
Total solid (TS, %)	1.7±0.1	1.0±0.0	1.0±0.0	0.7±0.0	13.0–18.0
Volatile solid (VS)/TS (%)	58.5±0.5	57.3±0.5	57.3±0.5	56.1±0.1	95.0±0.0
Total COD (TCOD, g/L)	12.0±0.3	9.5±0.2	9.5±0.2	6.9±0.1	132.2±0.4*
Soluble COD (SCOD, g/L)	7.1±0.2	1.0±0.0	2.0±0.1	2.0±0.1	36.7±1.3*
Total nitrogen (TN, mg/L)	3300±150	3060±162	2944±227	2669±115	4658±150*
Total phosphorus (TP, mg/L)	180±20	270±30	270±30	160±10	59±8*

* after dilution to TS 10%

Results and discussion

The effect of THP on the AD of STS is shown in Fig. 1a and Fig. 1b. The specific methane production (SMP) of STS reached 211.6 ml/g COD, which was only 41.3% of the theoretical methane production (TMP, 350 ml/g COD). After THP, SCOD increased from 960 mg/L to 2010 mg/L, but 70% of organic matter still remained in solid particles. Nevertheless, the SMP increased to 250.6 ml/g COD, which was 52.4% of the TMP. If screening the fine particles, the SMP increased to 274.9 ml/g COD, indicating some refractory substances in solid phase were removed. Overall, the methane yield was enhanced owing to the THP, but the methane production rate was not improved significantly.

Since the filtrate after the THP of STS had the most methane yield, it was used for the co-digestion with FW, and the results are shown in Fig. 1c and Fig. 1d. It was obvious that the addition of FW increased the SMP, and the values were 213.8 ml/g COD for the filtrate, 220.5 ml/g COD for the ratio of 2:1, 251.3 ml/g COD for 1:1, and 309.1 ml/g COD for only the FW. The BMP results were fitted using the modified Gompertz model, and the parameters are shown in Table 2, where y_m is the maximum methane yield (ml/g COD), and R_{max} is the maximum methane production rate [ml/(g·d)], λ is the lag time (d). It was obvious that the addition of FW accelerated anaerobic digestion and improved biogas recovery.

Theoretically, the SMP of co-digestion can be calculated using the SMP from single substate, if there was no synthesis effect or antagonistic effect. By comparing the theoretical values and the actual values, it was found that the introduction of the filtrate did not influence the AD of FW significantly. This implied that the two wastes can be treated together in FW digesters to save the expense on the STS treatment facilities.

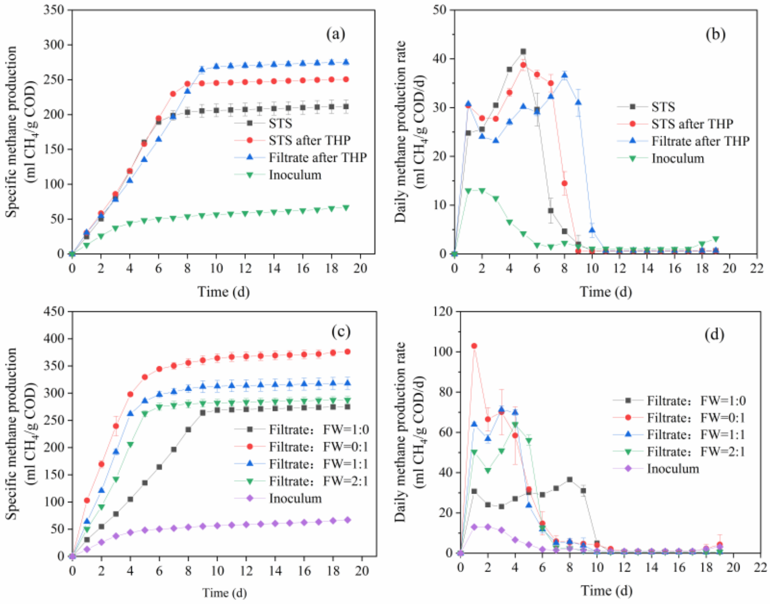

Fig. 1 methane production from septic tank sludge (STS) and food waste (FW) in batch anaerobic digestion (a. and c. accumulative methane production; b. and d. daily methane production)

Table 2. Parameters of the Gompertz model for the anaerobic digestion of septic tank sludge (STS) before and after hydrothermal pre-treatment (HTP) and the co-digestion of THP filtrate and food waste (FW)

Samples	y_m (20d) (ml/g COD)	R_{max} (ml/d·g COD)	λ (d)	R^2
Inoculum	60.9	10.2	0.65	0.969
STS	211.1	43.24	1.90	0.995
STS after THP	252.8	43.1	1.91	0.992
Filtrate after THP	281.9	37	1.99	0.989
Filtrate:FW=0:1	368.7	85.6	1.01	0.995
Filtrate:FW=1:1	315.6	79.9	1.41	0.997
Filtrate:FW=2:1	286.9	68.4	1.63	0.992

Conclusions

STS had a low organic content, and THP can dissolve some organic solids in addition to pathogens inactivation. When using the filtrate after THP as the substrate, the methane production reached the maximum with a conversion rate of 59.4%. The filtrate did not influence the AD of FW, and they can co-digested for saving the cost. For STS, the optimal treatment sequence should be THP, dewatering, and co-digestion of filtrate with FW.

References

1. Manga M, Camargo-Valero MA, Anthonj C, Evans BE. Fate of faecal pathogen indicators during faecal sludge composting with different bulking agents in tropical climate. Int J Hyg Environ Health. 2021; 232: 113670.
2. Rodriguez-Canche LG, Cardoso VL, Maldonado-Montiel T, Martinez-Sanmiguel M. Pathogen reduction in septic tank sludge through vermicomposting using eisenia fetida. Bioresour Technol. 2010; 101: 3548-53.
3. Valencia R, den Hamer D, Komboi J, Lubberding HJ, Gijzen HJ. Alternative treatment for septic tank sludge: co-digestion with municipal solid waste in bioreactor landfill simulators. J. Environ Manage. 2009; 90: 940-5.
4. Lu D, Liu X, Apul OG, Zhang L, Ryan DK, Zhang X. Optimization of biomethane production from anaerobic co-digestion of microalgae and septic tank sludge. Biomass Bioenerg. 2019; 127: 105266.1-105266.9.
5. Sun ZY, Liu K, Tan L, Tang YQ, Kida K. Development of an efficient anaerobic co-digestion process for garbage, excreta, and septic tank sludge to create a resource recycling-oriented society. Waste Manag. 2017; 61: 188-194.
6. Sapkaite I, Barrado E, Fdz-Polanco F, Pérez-Elvira SI. Optimization of a thermal hydrolysis process for sludge pre-treatment. J. Environ Manage. 2017; 192: 25-30.
7. Yan S. Thermal pretreatment of sewage sludge to enhance anaerobic digestion: a review. Crit Rev Env Sci Tec. 2015; 45: 669-702.
8. Hii K, Parthasarathy R, Baroutian S, Gapes D, Eshtiaghi N. Hydrothermal processing of sludge - a review. Chemeca 2013: Challenging Tomorrow. Brisbane, Qld: Engineers Australia; 2013; 491-498.