Hydrothermal pretreatment of food waste for anaerobic digestion: Enhancement and optimization of biochemical methane potential

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Highlights

- The optimum hydrothermal temperature of food waste components was inconsistent.
- Low hydrothermal temperature was conducive to produce methane for food waste.
- 140 °C is the critical temperature for the generation of melanoidin.
- The methane production of two-staged hydrothermal groups increased significantly.

1. Introduction

The global increase in food waste (FW), particularly pronounced in developing countries where urbanization rates are rising, underscores a pressing issue [1, 2], with China, the largest developing nation, experiencing a notable escalation in FW production. This trend highlights the urgent need for sustainable waste management strategies. Anaerobic digestion (AD), as a biological treatment technology, has demonstrated favorable outcomes in terms of environmental benefits and energy consumption. Chen et al. [3] reported that AD is a green technology through the fuzzy evaluation method based on Life Cycle Assessment (LCA) and cost-benefit analysis. The final gas product of AD is mainly methane, which accounts for 50-70% of biogas [4]. However, hydrolysis in AD process is relatively slow and is considered the main rate-limiting step in the AD process [5]. Substrate pretreatment is necessary to address limitations in hydrolysis rate. In recent years, hydrothermal pretreatment (HTP) has become the focus of researchers due to its high efficiency, cost-effective and non-use of external catalysts [6]. HTP coupled AD has proved to be the preferred solution for the treatment of FW.

2. Methods

Homemade FW (35% Rice (C_R), 20% pork (C_P) and 45% cabbage (C_V)) was used in this experiment. The physical property parameters of inoculated sludge are as follows: 9.35% (Total solids, TS), 7.20% (Volatile solids, VS), 77.01% (VS/TS), 7.25 (pH). Single components (C_R, C_P and C_V) and the mixed component (C_M) were subjected to HTP (YZDR500 Yanzheng Instrument ltd., Shanghai, China). Five temperatures (120, 140, 160, 180 and 200 °C) were set in this study. The hydrothermal products were mixed with sludge at 2 g: 10 g (calculated as VS), 5 mol/L NaOH and 5 mol/L H_2SO_4 were used to adjust the pH within the range of 6.8-7.2, and then loaded into the anaerobic fermenting tank. The system is divided into three units: digestion (A), CO_2 absorption (B) and gas measurement (C), and is equipped with magnetic stirrers. The flow chart is shown in Fig. 1 (left). The steps for staged hydrothermal experiment are shown in Fig. 1 (right). Considering the time cost and experimental error caused by low gas production in the later stage, this study carried out a two-week AD experiment.

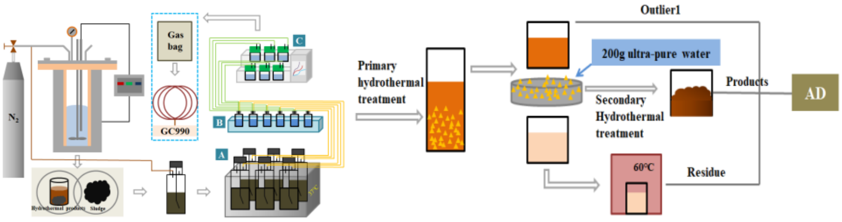

Fig. 1 Experimental flow chart (left) and two-staged hydrothermal experiment (right)

3. Results and discussion

The amount of methane generated by the mixed components after HTP made researchers realize that the formation of melanoidin has a significant impact on the efficiency of AD. Table 1 shows the difference between the calculated methane production M_T and the actual methane production M_E (C_M) if there was no interaction among the components in the HTP process. The difference showed a step increase trend with the increase of hydrothermal temperature. Except for the 120HTP group, the M_T of the other four hydrothermal groups was nearly the same, which may indicate that for the special biomass such as FW, low hydrothermal temperature is more beneficial to maximize the benefit.

Table 1 The amount of methane generated by single and mixed components

	YL(mL·g^{-1}VS)	120HTP(mL·g^{-1}VS)	140HTP(mL·g^{-1}VS)	160HTP(mL·g^{-1}VS)	180HTP(mL·g^{-1}VS)	200HTP(mL·g^{-1}VS)
C_R	214.15	215.34	352.43	299.33	285.64	278.54
C_P	150.85	168.67	268.56	265.11	336.50	329.16
C_V	162.56	163.24	222.25	252.55	254.94	237.06
M_T	178.27	182.56	277.08	271.44	282.00	270.00
M_E	146.14	153.54	184.06	186.18	150.23	93.20

MS (the stage hydrothermal products of the mixed component) fermentation results are shown in Fig. 2. The 120MS group showed a huge methane production potential of 372.18 mL·g^{-1}VS, which increased by 66.28% compared with the M_T of MS. Although the M_E of the 140MS and 160MS groups did not exceed the M_T, it can be observed from Table 4 that the difference between the two groups was reduced significantly. 140 ℃ is the critical temperature for the generation of melanoidin, and it is the typical temperature range for the generation of melanoidin between 140 ℃ and 165 ℃ [7]. Compared with the hydrothermal groups, the staged hydrothermal groups showed better performance in terms of methane production and methane proportion. This result fully demonstrates the effectiveness of staged hydrothermal treatment.

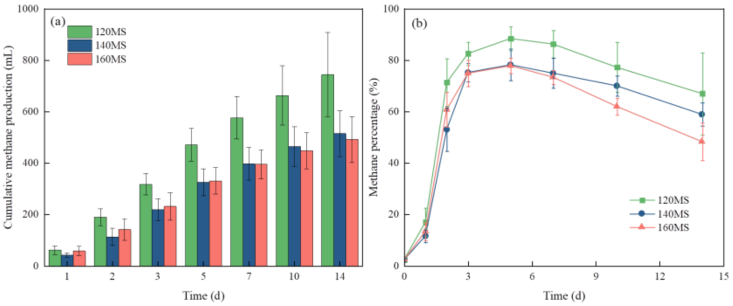

Fig. 2 Methane production (a) and methane proportion (b) of MS (The data of methane proportion at day 0 were obtained from data at 0.2h of AD)

4. Conclusions

Based on the results of methane production of the mixed components, it is reasonably predicted that 140 ℃ is the critical temperature for the generation of melanoidin. The methane production of two-staged hydrothermal groups increased significantly, approaching or exceeding M_T.

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Keywords

Food waste; Hydrothermal pretreatment; Anaerobic digestion; Staged hydrothermal treatment