Enhancing methane production in anaerobic co-digestion process by anaerobic co-pretreatment

Yen Wah Tong[1,2], Jingxin Zhang[1], Kai-Chee Loh[2]

[1]NUS Environmental Research Institute, National University of Singapore, 1 CREATE Way, 138602, Singapore
[2] Department of Chemical and Biomolecular Engineering, National University of Singapore, 4 Engineering Drive 4, 117585, Singapore
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Presenting author email: chetyw@nus.edu.sg

The effects of biological co-pretreatment on biogas production from anaerobic co-digestion of food waste (FW) and waste activated sludge (WAS) were investigated. FW and WAS underwent anaerobic co-pretreatment to improve hydrolysis efficiency followed by co-digestion.

Introduction: The hydrolysis of particulate organic matter is an important limiting factor for anaerobic co-digestion of FW and WAS (Zhang et al., 2014a). Therefore, there is little doubt that the performance of anaerobic co-digestion of FW and WAS will be improved if the hydrolysis of food waste and WAS can be enhanced concurrently. It was reported that a biological solubilization process mixing FW, water and microorganisms was effective for pretreating FW, during which the size of substrate particles was reduced and solubilization increased prior to AD (Gonzales et al., 2005). However, the pH decreases sharply during hydrolysis of sole FW substrate due to the accumulation of VFAs and a low pH (< 5) will negatively influence the performance of hydrolysis and acidogenesis. In contrast, the hydrolysis of WAS is an alkali-producing process (Zhang et al., 2014b), but a high pH value is also not beneficial for the hydrolysis of WAS. It was reported that the optimal pH for the growth of acidogenic bacteria ranges from 5.0 to 6.5. Therefore, it is hypothesized that if a mixture of WAS and FW is used as co-substrates for biological solubilization pretreatment (biological co-pretreatment), the hydrolysis performance of FW and WAS might be mutually improved because 1) the alkalis generated from WAS can be used to buffer VFAs and maintain optimum pH for hydrolysis, and 2) a lower pH aids in enhancing WAS solubilization by accelerating the hydrolysis of proteins and carbohydrates (Yuan et al., 2006). It is little doubt that the improved hydrolysis efficiency of FW and WAS plays an important role in enhancing the subsequent AD for methane production. To clarify it, biological co-pretreatment of FW and WAS and its effects on biogas production in the subsequent AD were investigated in this study.

Materials and methods: A 2 L (Ø 150 × 240 mm) glass reactor with a mechanical stirrer was used as a biological co-pretreatment reactor (hereafter referred to as R1). The mixing speed was set at 150 rpm. The co-pretreatment time was set as 0h, 15 h, 24 h and 35 h, respectively. The detailed pretreatment process was described previously in our paper (Zhang et al., 2017). Two 1 L cylindrical glass bottles were used as anaerobic digesters. An anaerobic reactor was fed with the pretreated mixture of FW and WAS (M1) while the control digester was fed with the fresh mixture of FW and WAS without pretreatment (M2). After inoculating with 800 ml seed sludge, these two reactors were magnetically stirred (mixing speed 400 rpm) and operated under a semi-continuous mode (feeding every two or three days) at 35±1 ℃. The organic loading rate (OLR) was increased gradually from 2.3 to 14.1 g VS/L. In the control group for AD of mono-FW, an anaerobic reactor was fed with the pretreated FW (F1). The control anaerobic digester was fed with the fresh FW without pretreatment (F2). All the experiments were conducted in triplicate. COD, TCOD, total nitrogen (TN) and ammonia were determined using colorimeter (HACH DR900, USA). The pH was recorded using a pH analyzer (Agilent 3200M, USA). TS and VS were determined based on the weighing method after being dried at 103-105 ºC and burnt to ash at 550ºC. The CH_4 production was determined using a gas chromatograph (Clarus 580 Arnel, PerkinElmer, USA). Main VFAs were determined by a gas chromatograph (Clarus 580GC, PerkinElmer, USA).

Results and Discussion: 1) Biological co-pretreatment of FW and WAS - To optimize the biological co-pretreatment time, the effects of different pretreatment time (0h, 15h, 24h and 35h) on hydrolysis and acidogenesis were investigated as shown in Table. 1. When the co-pretreatment time increased from 0 to 24 h, the degree of hydrolysis and acidification increased sharply to 36% and 39% respectively. With the increase of pretreatment time to 35 h, the improvement in hydrolysis and acidogenesis increased slowly or plateaued. This indicates that the hydrolysis and acidogenesis efficiency was limited at 35h of pretreatment. Therefore, the optimum co-pretreatment time is 24 h. 2) Effects of biological co-pretreatment on methane production - As shown in Fig. 1A, the accumulated methane yield in the two digesters increased gradually, corresponding with the increase of OLR from 2.28 to 14.1 g VSFW+WAS/L. At an OLR of 7.31 g VSFW+WAS/L on day 37, the methane yields in the two digesters were between 23.7 ± 0.4 L and 24.9 ± 0.5 L. When the OLR was raised to 14.1 g VSFW+WAS/L, the methane yield in M1 increased to 50.1 ± 1.1 L while it was 40.2 ± 0.8 L in M2. As compared with M2, digester M1 achieved a higher methane yield of 25%. The improved methane yield might be ascribed to the positive effects of biological co-pretreatment by accelerating the solubilization of particulate organic matter and improving the hydrolysis rate of both FW and WAS prior to AD. Even though total methane yields in the two digesters followed an incremental trend with the increase of OLR, methane yields per g VS_{FW+WAS} began to decrease when the OLR increased to 11.25 g VS_{FW+WAS}/L. However, specific methane yield in M1 was still maintained at 293.6 ml/g VS on day 61, which was significantly higher than the 229.6 ml/g VS in M2. On day 60, the VS reduction of M1 reached 77.2 ± 3.2 %, which was 10.1% higher than that of M2.

Conclusion: Biological co-pretreatment process improved the hydrolytic and acidogenic efficiency of WAS and FW, enhancing the performance of subsequent anaerobic co-digestion for methane production. The results showed that AD with co-pretreatment process has a 24.6% higher methane yield and an increase of 10.1% in the VS reduction. Hydrolysis of FW could create an acidic environment which accelerates WAS decomposition, while the alkaline compounds produced by WAS digestion can buffer organic acids generated from AD of FW. The developed biological co-pretreatment method enhanced the positive synergy between WAS and FW, which is useful for improving the performance of subsequent AD.

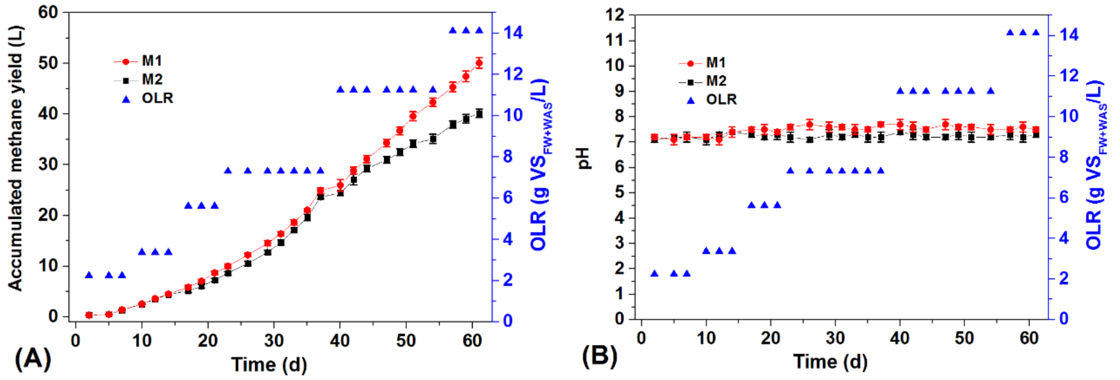

Fig. 1. Variations of accumulated methane yield (A) and pH (B) in the anaerobic digesters (M1, M2) at different organic loading rate.

Table 1

Characteristics of mixture of food waste and waste activated sludge with different biological co-pretreatment time

Parameter	pH	SCOD (g/g VS)	TCOD (g/ g VS)	Polysaccharide (g glucose/ g VS)	TVFA (g COD/ g VS)	Ammonia (mg/ g VS)	Total nitrogen (mg/ g VS)	Hydrolysis degree (%)	Acidification degree (%)
Without co-pretreatment	7.2 ± 0.2	0.19 ± 0.01	1.23 ± 0.06	0.13 ± 0.02	0.02 ± 0.003	4.2 ± 0.3	5.5 ± 0.2	15	11
Co-pretreatment 15 h	6.3 ± 0.1	0.32 ± 0.01	1.23 ± 0.06	0.19 ± 0.02	0.09 ± 0.003	5.6 ± 0.5	11.5 ± 0.2	26	28
Co-pretreatment 24 h	5.0 ± 0.1	0.44 ± 0.02	1.23 ± 0.06	0.21 ± 0.01	0.17 ± 0.005	7.0 ± 0.4	13.8 ± 0.3	36	39
Co-pretreatment 35 h	4.5 ± 0.2	0.49 ± 0.01	1.23 ± 0.06	0.16 ± 0.01	0.21 ± 0.006	9.4 ± 0.4	18.7 ± 0.5	40	43

1. The degree of hydrolysis can be expressed as the quotient between soluble COD and TCOD of solid sample.

2. The degree of acidification was defined as the ratio of COD-equivalent TVFA to the soluble COD.

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