

Anaerobic Digestion of Organic Fraction of Municipal Solid Waste (OFMSW): Comparative study under different mixing and organic loading rates

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生ゴミ嫌気性消化汚泥への攪拌と有機物負荷量の影響: 長岡技術科学大学 グエン チャ リー, 大橋晶良, 原田秀樹.

1. Introduction:

In recent years, anaerobic digestion of food waste becomes a more viable alternative over traditional landfill and incineration. The need for efficient mixing of sludge in anaerobic digesters has been recognized and stressed in the literature, however the detail information available is inadequate and contradictory.

Therefore, the purpose of this study is to investigate the performance of one-stage fermentation system in treating food solid waste under different mixing and organic loading rates, and evaluate the effect of mixing requirement in the anaerobic digestion of OFMSW.

2. Materials and experimental methods:

Model kitchen food waste was prepared according to the compositions shown in Table 1, and refrigerated in plastic containers at 4 °C. Three laboratory-scale anaerobic digesters having 1.0 liter-working volume were operated in parallel at mesophilic condition (37 °C) by water jacket system (Fig. 1). Fermentor 1 (F1) and Fermentor 2 (F2) were operated at same OLR of 11.6 kgCOD/m³.d and HRT to 15 days. In order to evaluate the effect of mixing, F1 was intermittent mixing (5 minute mixing at 12 hrs. intervals), while F2 was continuously mixing. Besides, Fermentor 3 (F3) was operated at the same continuous mixing condition as in F2 fermentor, at 1.5 times higher OLR (17.8 kgCOD/m³.d) and HRT (10 days).

Biogas production, gas composition, pH, TS, TVS, COD (total and soluble), VFA parameters were monitored daily. Total alkalinity, ammonia, TKN, and C/N ratio were analyzed every five days. All of the parameters follow the analytical procedures in Standard Methods (1985).

3. Results and discussions:

* Intermittent mixing digester (F1):

The biogas production rate ranged from 5.0-7.0 L/L-digester.d, and total biogas was accumulated to 370 L over 70 days operation. High percentage of total solid (TS) removal was achieved in the range of 72-80%. During the first 20 days, the effluent COD soluble was stable at 10,000 mgCOD/L, but after that increased gradually up to nearly 20,000 mgCOD/L till day 70. Likewise, total VFA accumulation at first days was 5,000 mgHAc/L, and then increased gradually up to approx. 10,000 mgHAc/L. The parameter of VFA /Alkalinity ratio was observed to be only 0.65 throughout the operation period. This parameter reflects digester stability, and the value less than 1.0 is preferable for stable operation. From day 40, the C/N ratio was somewhat decreased, because total nitrogen and ammonia were increased. Throughout 70 days operation, approximately 80% of COD input was recovered in the form of methane gas.

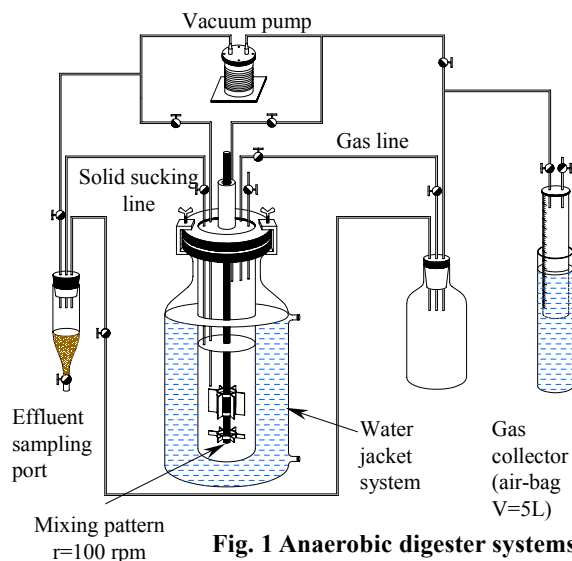


Fig. 1 Anaerobic digester systems

Table 1. Feedstock components and characteristics

Composition items	% (wt/wt)	Parameters	
Rice, noodle, bread	4.0	TS (% wt/wt)	16.6
Coffe-used, tea-leaves	7.3	TVS (% wt/wt)	15.3
Vegetables	47.9	COD-t (gCOD/gTS)	1.37
Fruit	20.6	Total Carbon (% TS)	46.68
Meat	2.7	Total Nitrogen (% TS)	3.65
Fishes	4.7	C/N ratio	12.8
Eggs	0.9	Lipid (gCOD/gTS)	0.48
Bone, clam-shell	4.6	TKN (mg-N/l)	5250
Others	7.3	NH ₄ ⁺ -N (mg-N/l)	3364
Total	100.0	pH	4.3

Table 2. Digester operating conditions

	TS (%)	HRT (days)	OLR (kgCOD/m ³ .d)	Operating conditions
F1	15	15	11.6	- Feed: once per day - Minimal mix: 5-min./12 hrs.
F2	15	15	11.6	- Feed: once per day - Continuous mix: r= 100 rpm
F3	15	10	17.8	- Feed: once per day - Continuous mix: r= 100 rpm

Keywords: anaerobic digestion, food waste, mixing, organic loading rate

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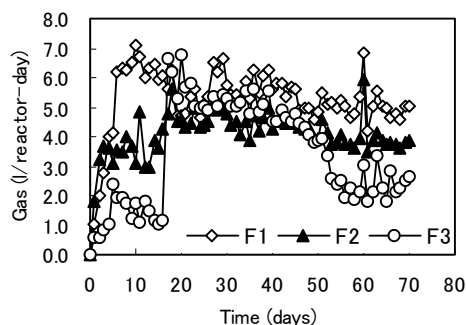


Fig. 2 Daily biogas production rates

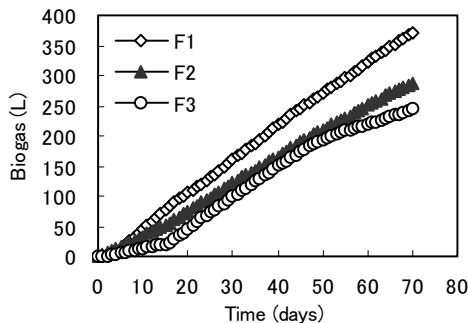


Fig. 3 Biogas production over 70 days

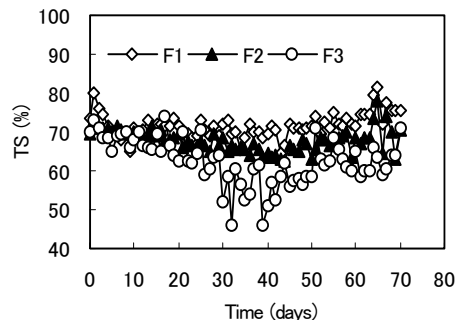


Fig. 4 Total Solid percentage reduction

** Continuous mixing digester (F2):*

Under continuous mixing, the biogas production rate in F2 was not so high as F1 (only 3.7-5.0 L/L-digester.d), and lower total biogas (288 L) during 70 days was observed. Continuous mixing may cause poor solid settling in the mixing region, as a result the TS percentage removal was only 60-70%. Although the effluent soluble COD was similar level to F1 during the first 25 days, it increased rapidly up to 30,000 mgCOD/L within the following 15 days, and remained unchanged afterward. From day 25 the total VFA accumulation gradually increased to 15,000 mgHAc/L. The C/N ratio throughout the experimental duration was not changed. Instability of digester may be illustrated by the ratio of VFA/Alkalinity. From day 25 on, this ratio increased and was being fluctuated in the range of 0.7-1.1. The process appears somewhat on the edge of process failure. Approximately 65% of input COD was recovered as methane gas during the overall operation period.

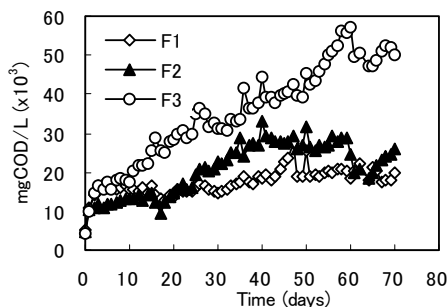


Fig. 5 Effluent COD-soluble

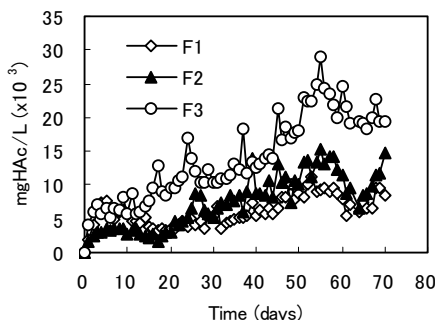


Fig. 6 Total VFA accumulation

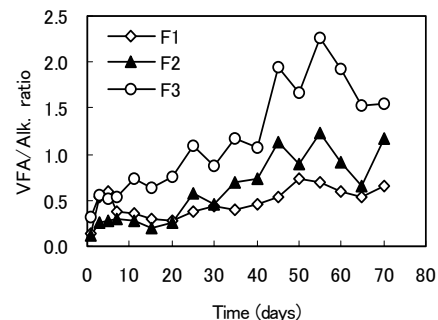


Fig. 7 The VFA/Alkalinity ratio

** High organic loading rate digester (F3):*

Biogas production rate in F3 ranged from 3.0 to 5.0 L/L-digester.d. Because of high organic loading and continuous mixing, the percentage of TS removal was in fluctuation from 45% to 70%. The effluent COD soluble increased rapidly from 10,000 mgCOD/L to 52,000 mgCOD/L, just as the total VFA accumulation increased drastically as the operation time elapsed. The C/N ratio also increased gradually from 9.0 to 16.0 over 70 days. The methane gas recovery in F3 was 67% of COD input. The process performance of F3 exhibited only stable during the first 20 days, represented by the VFA/Alk. ratio of less than 1.0. From day 25 and on, the value varied from 1.0 till 2.2, resulting in instability and failure point of performance.

From these results, the continuous mixing condition was found to be not favorable for fermentation of food waste, especially at rather OLR high and short HRT. F2 and F3 failed to achieve a high biogas production rate, probably due to vigorous and continuous mixing. On the contrary, intermittent mixing mode (5 min at 12 hrs intervals) in F1 provides sufficient contact efficiency between solid substrate and microorganism.

4. Summary:

In anaerobic digestion of OFMSW, minimally mixed conditions (F1) resulted in good performance at OLR of 11.6 kgCOD/m³.d, and 15-day HRT. Highest biogas production rates (5.0 to 7.0 L/L-digester.d) were achieved. Among three digesters, continuous and vigorous mixing was not always favorable for fermentation process of food waste, especially when applying high OLR.

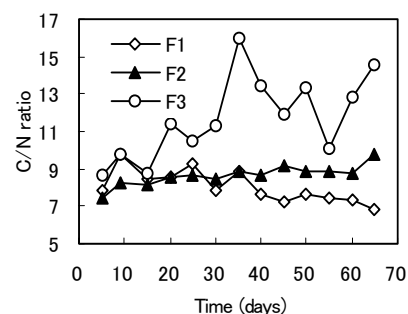


Fig. 8 Profile of C/N ratio monitoring

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