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EFFECT OF ORGANIC LOADING RATE ON THE PERFORMANCE OF ANAEROBIC CO-DIGESTION DIGESTER TREATING FOOD WASTE AND SLUDGE WASTE

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ABSTRACT

This research was carried out to evaluate the effect of organic loading rate to the performance of anaerobic co-digestion digester treating organic fraction of food waste (FW) and sludge waste (SW) from wastewater treatment plant. The experiment was conducted in two runs: Run S50, substrate contained 50 % of FW and 50 % of SW in term of volatile solid (VS) concentration; Run S100 (control run) contained 100 % SW in the influent substrate. The experiment was performed in a 3L working volume reactor at ambient temperature with three levels of organic loading rate (OLR) as 2; 4; 6 kgVS/m^3/day, the duration of experiment was 18 days for each level of OLR. As results, the average of biogas production rate (BPR) at OLR 2;4;6 kgVS/m^3/day,in Run S50 and Run S100 was 390 – 520; 860 – 1220; 1140 - 2440 ml/day and 160 – 300; 560 – 640; 700 - 1400 ml/day, respectively. The maximum methane yield (mlCH_4/gVS_{added}/day) of organic loading rate 2; 4; 6 kgVS/m^3/day was 118.96; 326.49; 628.20 for Run S50 and; 58.28; 160.27; 255.54 for Run S100, respectively. In conclusion, Run S50 always produced higher biogas production rate and higher methane yield at all 3 OLR levels. The higer OLR could enhance BPR and methane yield but at OLR 6 kgVS/m^3/day made unstable performance and high concentration of COD in the effluent. Therefore, in this experimental conditions it has better operation at OLR under 6 kgVS/m^3/day for the stable performance of reactors.

Keywords: sludge waste, organic fraction of food waste, anaerobic co-digestion, organic loading rate, methane yield.

1. INTRODUCTION

Anaerobic digestion (AD) is the processes in which organic compounds are utilized by a specific microbial community in absenting of oxygen result of producing biogas with contain methane, carbon dioxide and other trace gases [1]. Anaerobic co-digestion (AC) of different sources of material has been commonly applied recently. Because it can provide many advantages such as neutralized of combined materials, balance of nutrient elements, dilute of toxic compounds, associate of different microbial communities [1,2]. Many authors have studied on anaerobic co-digestion. Park et al. [3] investigated anaerobic co-digestion of primary sludge, waste activated sludge from a municipal wastewater treatment of plant food waste. The result showed that co-digestion food waste and primary sludge alone achieved 72% higher methane production compared to the AD of primary sludge and the maximum of methane production rate was 522.9 mL CH_4/gVS. Budych-Gorzna and colleagues [4] studied the AC of sludge from a municipal wastewater treatment plant by and poultry industry waste, and they found out that the additional substrate not only increased biogas production but also could keep the full scale reactor of stably performance. Xie et al.[2] found out that the highest specific CH_4 yields were 304.2 and 302.8 ml CH_4/gVS at the ratios of pig manure and grass silage were 3:1 and 1:1, respectively when investigated the AC between these materials. In the present research, the anaerobic co-digestion between waste sludge from municipal wastewater treatment plant and organic fraction of municipal solid waste was investigated. The aim of this study was to investigate the effect of organic loading rate on the performance of the anaerobic digesters.

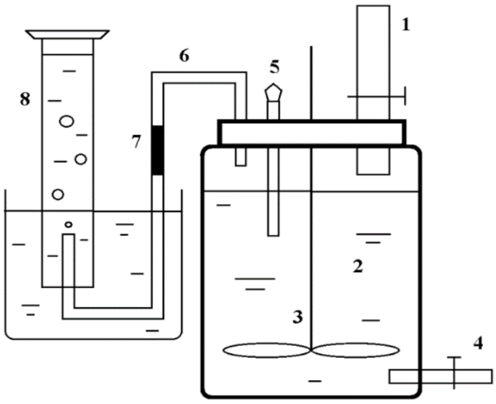
2. MATERIALS AND METHODS

2.1. Substrates and seed sludge

Sludge waste (SW) was the mixture of sludge from primary settling tank and activated sludge from secondary sedimentation tank of Binh Hung Municipal Wastewater Treatment Plant. The component of SW was 73.33 % volatile solid (VS); 1.11 % total nitrogen (TN); 0.3 % total phosphorus (TP). Organic fraction of food waste (FW) was collected from a market and the households in District 8 of Ho Chi Minh City. FW was consisted of 40 % rice, 30 % fish, 20 % vegetables and 10 % banana skin in weight. Components of FW were sliced, grinded to be homogenized. FW contained 133.33 %; 0.52 %; and 0.39 % of VS; TN; and TP, respectively. SW and FW were stored at 4 ^{o}C before mixing to carry out the anaerobic co-digestion experiment. Seed sludge for each experiment was taken from anaerobic reactors treating the same substrate component.

2.2. Experimental organization

Anaerobic reactors with working volume of 3 L were operated for 54 days at room temperature (Fig. 1). To evaluate the effect of OLR on digestion performance, three levels of organic loading rate (OLR) as 2; 4; and 6 kgVS/m^3/day were applied. The experiment was carried out in two runs in which the substrate component was 50 % DS : 50 % FW (Run S50); and 100 % DS (Run S100). To promote the performance of reactors during start-up, 100 mL of acclimated seed sludge was added to the reactors. Substrate was homogenized by a blender, added more distilled water, and adjusted pH to 7.5 before injecting into the reactor with specific organic loading rate. The stirrer, pH electrode, biogas pipe collector, inflow tube were installed from the lid of reactors, the outflow tube was installed in the bottom of reactors. After sealing, each reactor was purged with N_2 gas before sealing to remove oxygen. The substrate inside reactor was manually stirred once per hour. The pH of reactor was monitored and adjusted everyday but pH electrode. Samples from digesters were collected for analyzing VS, COD concentration. The biogas production was collected daily by pushing the water in the graduated cylinder.



1. Inflow
2. Substrate
3. Stirrer
1. Outflow
2. pH electrode
3. Biogas pipe
4. Header
5. Gas sampling graduated cylinder

*Figure 1***.** The diagram of the anaerobic digester.

2.3. Analytical methods

Liquid samples were taken and analyzed such parameters of VS, COD concentration by following the procedure of Standard Methods for the Examination of Water and Wastewater [5]. The daily biogas volume was measured using water column replacing. The biogas composition was analyzed using gas chromatography-mass spectrometry (GC-MS). The pH value was continuously monitored by a pH controller.

3. RESULTS AND DISCUSSION

3.1. pH

Figure 2 shows the pH profile during time course of the experiment. It is clearly to recognize that the pH value of both runs was stable in the range of 7.0 – 8.2 from the start-up to the end of the experiment. The increase of organic loading rate from 2 kgVS/m^3/day to 4 kgVS/m^3/day did not effect to the pH value. The pH was slightly increased while organic loading rate was brought up to 6 kgVS/m^3/day in both runs. The pH profile was in the suitable range for the operation of anaerobic digestion reactor. Previous study also mentioned that pH values at neutral range are appropriated for the microbial community of methane fermentation process [6, 7].

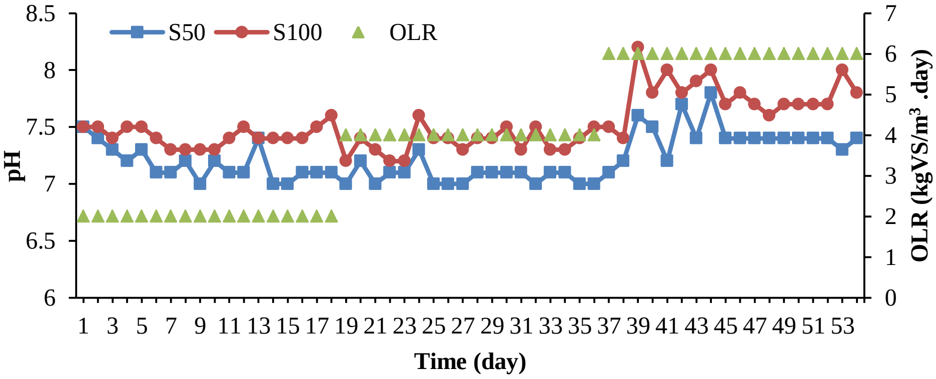


Figure 2. pH profile of anaerobic reactors during the time course.

3.2. Biogas production rate

The biogas production rate (BPR) is illustrated in Figure 3. It is clearly demonstrated that Run S50 had higher BPR than that of Run S100 throughout the time course. BPR in both runs was increased together with the increase of organic loading rate. Methane percentage in biogas was low at the start-up and then getting stable and maintaining at about 63.54 – 67.57% until the end of operational period. At organic loading rate 2 $kgVS/m^3/day$, BPR was the most stable among 3 levels of OLR, the average of BPR in Run S50 and Run S100 was in range of 390 – 520 ml/day, and 160 – 300 ml/day, respectively. At organic loading rate 4 $kgVS/m^3/day$, the BPR of Run S50 was much higher than that of Run S100, BPR was about 860 – 1220 ml/day for Run S50 and 560 – 640 ml/day for S100. When OLR increase to 6 $kgVS/m^3/day$, BPR tended to be fluctuated. The result of COD analyzing indicated that the organic matter in the effluent at this organic level is high, thus the experiment was stopped at day 54 of the experiment even though BPR still had trend to increase at that point. Previous studies also demonstrated the enhancement of biogas production in anaerobic digestion between activated sludge and food waste compare to the single anaerobic digestion of activated sludge [3]. Previous studies also found out the supply of additional nutrients and more efficient use of equipment and cost-sharing by processing multiple waste streams in a single facility [8].

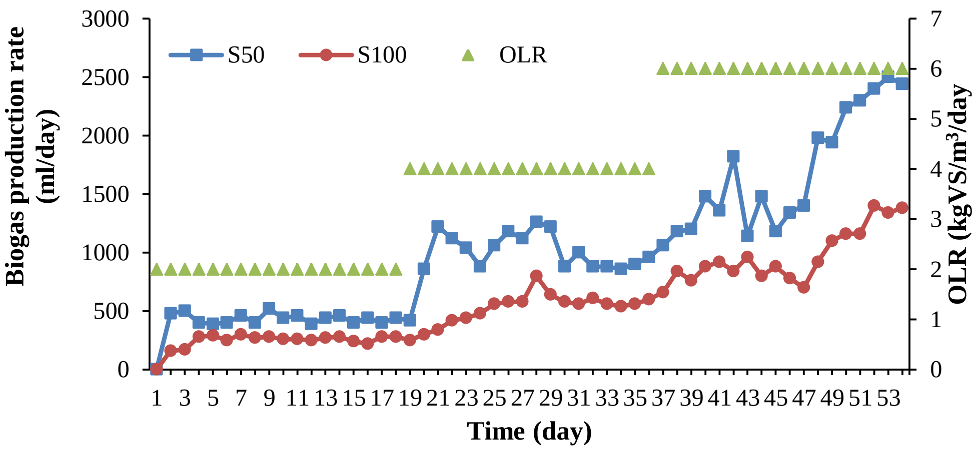


Figure 3. The biogas production rate during time course.

3.3. Methane yield

Methane yield was calculated as the volume of CH_4 produced per mass of VS added to the reactor in a specific time. Figure 4 shows the methane yield during the experimental period.

It was illustrated that Run S50 had higher methane yield than that of Run S100 throughout the time course. The maximum methane yield ($mlCH_4/gVS_{added}/day$) of organic loading rate 2 $kgVS/m^3/day$; 4 $kgVS/m^3/day$; 6 $kgVS/m^3/day$ was 118.96; 326.49; 628.20 for Run S50, respectively and; 58.28; 160.27; 255.54 for Run S100, respectively. Methane was increased together with the increase of organic loading rate. However, the higher OLR the un-fluctuated values of methane was observed. Previous studies also found out the comparable methane yield in the investigation of co-anaerobic digestion between organic fraction of food waste (FW) and sludge waste (SW) from wastewater treatment plant [9, 10].

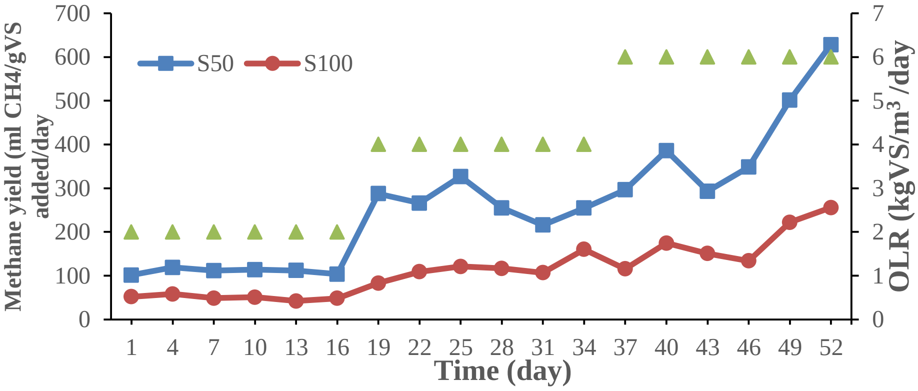


Figure 4. Methane yield during the time course.

3.4. Chemical oxygen demand (COD)

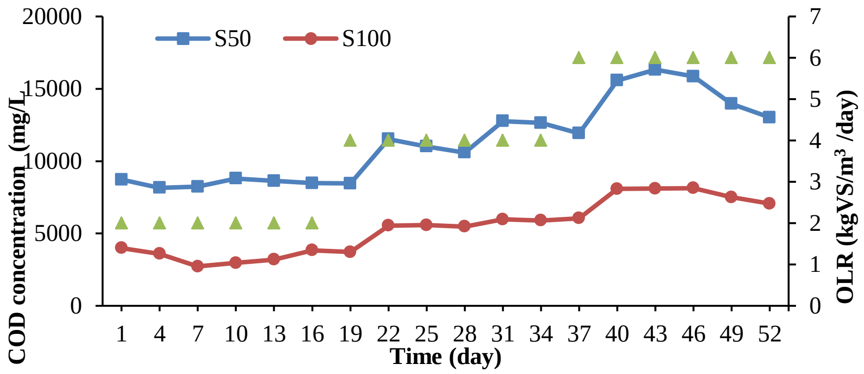


Figure 5. The COD concentration during time course.

The COD concentration was at high level in both runs during the operational time and it was higher in Run S50 than that of Run S100 as presented in Figure 5. In Run 50, The COD concentration was lowest at 8160 mg/L and highest at 16320 mg/L. In Run S100, COD was not significant increase when OLR was increased, the COD values was lowest at 2770 mg/L and highest at 8080 mg/L. At organic loading rate as 6 kgVS/m^3/day, COD in the effluent was high in both runs indicated that this OLR is too high for current experimental conditions and it is necessary to expand the solid retention time for enhancing the removal of organic matter containing in the substrate. In addition, it is requirement to operate a further advanced treatment of the effluent from anaerobic digester for protection the receiving environment.

4. CONCLUSION

The effect of oganic loading rate on performance of co-anaerobic digesters between FW and SW was investigated. It was found out co-digestion of different organic source could improve biogas production rate. In addition, the higher OLR could make higher methane yield. It is suggested that it is suitable to operate at OLR lower than 6 kgVS/m^3/day in order to achieve the stable condition of reactor and enhance the recovered efficiency of organic matter in the substate.

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