The Effects of F/M Ratio on in Treatment of Wastewater from Brewery Slurry by an Anaerobic Sequencing Batch Reactor

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ABSTRACT
In this study, the influence of F/M (total organic carbon (TOC)/mixed liquor suspended solids (MLSS)/day) ratio in the anaerobic batch treatment method was performed on the distillation effluent of barley shochu. The operation was to add 0.7 L seed sludge, supply 0.2 L of waste liquid every day and react until it reached 1.5 L. The Four loading types can be changed by changing the dilution rate. Through this operation, MLSS was changed in the range of 10 to 24 g/L, TOC was changed in the range of 1000 to 5000 mg/L, and the F/M ratio was changed in the range of 0.09 to 0.50/day. Appropriate treatments can be maintained to a F/M ratio of 0.36/day. Furthermore, a methane production rate is 2.1 L/day with a methane content of 60% and a methane production yield of 0.9 L/g with TOC removal rates in the range of 70-90%.

Keywords: *Anaerobic sequencing batch reactor, barley wastewater, F/M ratio, methane production rate, TOC removal rate.*

1. INTRODUCTION

An important point of the activated sludge treatment system is to settle the sludge and separate it from treated water. In this case, the TOC inflow into the supply port and the ratio of the microbial concentration (F/M ratio) are large, the reaction proceeds quickly and the TOC decreases with the flow rate. In this state, the sedimentation performance increases and the separation effect is good [1]. In other words, it is important to change the F/M ratio. The continuous type can handle a large amount, but the installation area becomes larger and difficult to apply to small processing types.

Sequential batch reactors (SBR) have been introduced for wastewater treatment. In this system, wastewater flows into a single batch reactor to remove undesirable components. This method is suitable for the treatment of wastewater from small-scale food factories and agricultural wastewater. Anaerobic processing is the main method in batch processing [2]. This is because the purpose of anaerobic treatment is to convert high-load wastewater into methane, which requires a stable state. It is not preferable that organic matter concentration changes in the tank [3]. On the other hand, on a small scale, by allowing the concentration change caused by the treatment, the F/M ratio at the end of the reaction decreases, the sedimentation property increases, and treatment in a single tank becomes possible. Anaerobic sequencing batch reactor (ASBR) is a method based on this idea [4] which has been reported by [5-6]. The ASBR are high rate anaerobic treatment processes that operate in the following cyclic steps, reaction, settling and also have benefits to conversion of organic matter to biogas during reaction [7]. The object of this research is the waste liquor of Japanese wheat. This study did not take a long reaction time by diluting and reducing the load, but for rapid treatment of light load and simple treatment.

2. MATERIALS AND METHOD

The barley shochu (Japan's national distilled beverage) distillation effluent was used by thawing a sample frozen and stored after decanter treatment by a manufacturer in Yatsushiro City, Kumamoto Prefecture, Japan. The raw water was diluted with tap water, the content of each mineral was adjusted to the concentration as shown in Table 1 and 5g/L of sodium hydrogen carbonate was added to adjust the pH value. The schematic of the experimental setup as shown in Figure 1. The bench scale anaerobic sequencing batch reactor (ASBR) used in this study is an automatic biological fermentation tank (2.4L) (MB-C2, Sanki Seiki Co. Tokyo) with a working volume of 1.4 L, while 0.4 L of headspace was connected to the biogas collector. The temperature is automatically maintained at 37±1°C in the hot water bath. The pH of the mixture was measured by a pH probe. The Barley shochu distillate was pumped into the feed port and continuously mixed through the mechanical experimental reactor stirrer in the reactor.

Anaerobic granular sludge from a mesophilic UASB reactor at the same facility was seeded into the reactor. Volatile suspended solid (VSS) and suspended solid (SS) concentrations of the inoculum were about 30 g/L and 40 g/L with 0.7L, respectively. The semi-ASBR cycle was conducted in 4 days. The operation was conducted with added 200 mL of barley shochu effluent per day with 1 h feeding, 1hr settling and 1hr drainage as shown Figure 2. The load amount was changed by changing the dilution ratio. Steady state was defined by a sustained biogas production within ±15% deviation. TOC, volatile fatty acids (VFA), pH, biogas production and methane content were determined. The experiment was repeated three times.

Table 1 Mineral content

Parameters	(Mg/L)
$CoCl_2.6H_2O$	6.0
$Na_2MNO_4.6H_2O$	5.0
$FeCl_3$	2.5
$MgCl_2.6H_2O$	2.5
$CuSO_4.4H_2O$	16.7
$CaCl_2$	7.5
$ZnCl_2$	13.7
H_3BO_3	1.0
$NiCl_2.6H_2O$	1.0
$AlCl_3.6H_2O$	1.0
NH_4Cl	500.0
$Na_2S.6H_2O$	250.0

Barley shochu distillation was pumped into the feed port and continuously mixed by a mechanical stirrer in the reactor. Anaerobic granular sludge from a mesophilic UASB reactor at the same facility was seeded into the reactor. Volatile suspended solid (VSS) and SS concentrations of the inoculum were about 30 g/L and 40 g/L with 0.7L respectively. The semi-ASBR cycle was 4 d total, add 200 mL of barley shochu effluent per day with 1 h feeding, 4d reaction, after that 1hr settling, and 1hr drainage (Figure2).The load amount was changed by changing the dilution ratio. Steady state was defined by a sustained biogas production within±15% deviation, and in this period, parameters including TOC, volatile fatty acids (VFA), pH, biogas production, and methane content were determined, creating three replicate measure data points.

Figure 1 Experimental reactor

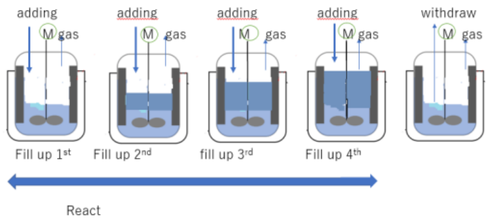

Figure 2 The semi-ASBR operation procedure

2.1. Analytical Method

Samples were centrifuged at 1500 rpm for 10 min and filtered passed through 0.45 μm to determine total organic carbon (TOC) and volatile fatty acid (VFA). Suspended solids (SS), volatile suspended solids (VSS) and bicarbonate alkalinity were analyzed by standard methods [8]. Acetic and propionic were measured as components of VFA by gas chromatograph (GC-4000) with a flame ionization detector. The temperature of the injector and FID were 200 °C and 220 °C, respectively.

Nitrogen as carrier gas with a flow rate of 50 mL/min with the sample injection of 10μL. Biogas production was measured by the water displacement method and methane content was determined using a gas chromatograph (GC-3200) with a thermal conductivity detector. The carrier was Helium and the flow rate used was 30 mL/min. The measured methane volume was adjusted to volume at STP (Standard temperature 0 °C and pressure of 1 atm).

3. RESULTS AND DISCUSSION

3.1. Characteristics of Wastewater

The main characteristics of barley shochu are presented in Table 2. BOD, soluble TOC, and SS concentration were about 90000, 42000 and 4600 mg/L, respectively, with a relatively low of 3.8. The BOD/N/P ratio is about 160/16/1 which is suitable for methane production. These characteristics were similarly reported by Zupanbib GD et al., and Xiangwen Shao et al.[5 - 9].

3.2. Characteristics of Treatment

Figure 3 shows the difference TOC concentration of raw water and treated water. Each load stage is described as Phase1, Phase2, Phase3 and Phase4.

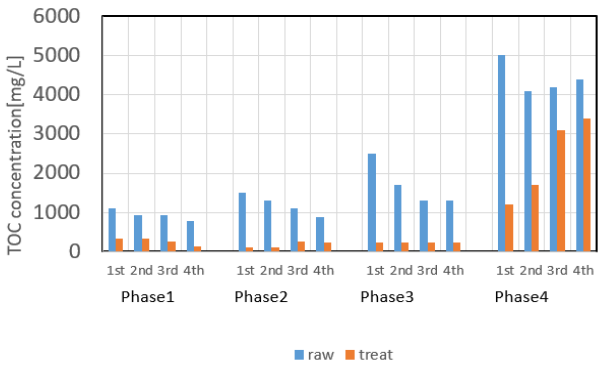

Figure 3 Varied TOC concentration with each phase operations

The results showed that from Phase1 to Phase3, the TOC concentration in the range from 100 to 350 mg/L in treated water with removal rate was as high as 90%. However, in Phase4 the first load removal rate was 72% and it was decreased to 14% with subsequent processing. This is due to the accumulation of volatile fatty acids which make lower TOC removal rate in the tank as shown in Figure 4. It is considered that the removal rate can be maintained by rapidly repeating the discharge to prevent increasing concentration of volatile fatty acids.

In this experiment, propionic acid might be produced by the treatment of barley shochu distillation effluent. In Phase1 and Phase3 shows the lower amount of concentration of propionic acid was about 130 mg/L. However, in Phase4 the concentration reached to 1140 mg/L. The low amount of propionic acid which might be indicated the low amount of organic matter inputs and it`s the effect of inclusion of Co and Ni in the treatments.

Table 2 Characteristics of barley shochu from barely factory, Kumamoto, Japan.

Parameters	**Value (Mean)**
Soluble TOC (Mg/L)	**42000**
pH	**3.8**
Suspended solid (SS) (Mg/L)	**4600**
BOD (Mg/L)	**90000**
Total N (Mg/L)	**7682**
Total P (Mg/L)	**540**

As can be seen in Figure 5 shows the methane production rate was increased following the phase, however the production rate decreased with the number of treatments at any phase. On the other hand, the amount of methane produced rate was 0.90 L/g-TOC (R2 = 0.90) and the methane content in Phase2 was almost 60% as shown in Figure 6. Table 3 shows the suspended solids (SS) and mixed liquor suspended solids (MLSS) in the waste liquid. The results show that the concentration of SS was increased from 40 Mg/L to 444 mg/L in Phase1 to Phase4, respectively. On the other hand, the concentration of MLSS was constant from Phase1 to Phase3 of 20 g/L and slightly increased to 24 g/L in Phase4.

Table 3 Concentration of suspended solids (SS) and mixed liquor suspended solids (MLSS) in raw water mixture

Phase	Raw water mixture liquid	
	SS (Mg/L)	MLSS (g/L)
Phase 1	40	20
Phase 2	120	20
Phase 3	130	20

Phase 4	444	24

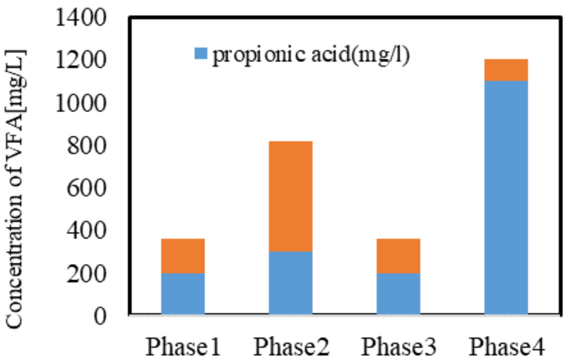

Figure 4 Varied VFA concentrations with each phase operation

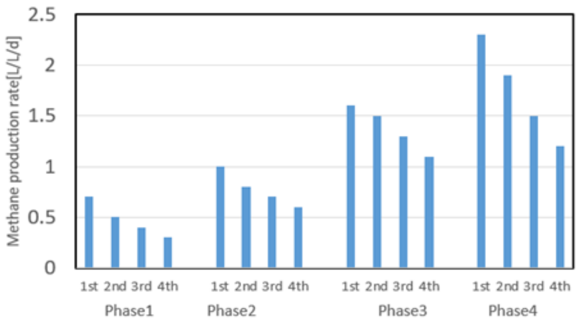

Figure 5 Varied methane production rate with each phase operation

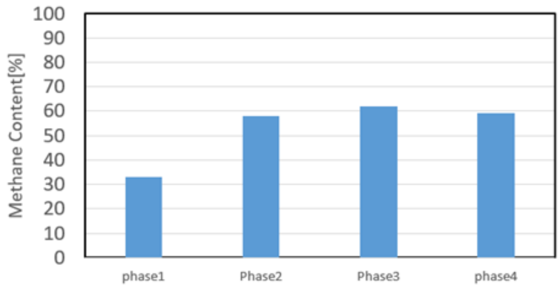

Figure 6 Varied methane content with each phase operation

3.3. Effects of F/M on Treatment

The F/M ratio is highly correlated with the methane production rate. Here, the F/M ratio was calculated as the TOC of the mixed solution immediately after charging and the residence time (one day). The fluctuation of the F/M ratio was small, and the maximum was 0.07/day. In Phase4, it was increased from 0.36 to 0.5. This might cause the TOC removal rate to decrease. **Figure 7** shows the relationship between the F/M ratio and the methane production rate[10]. The highest methane production in the F/M ratio of between 0.3 and 0.4. It can be assumed that the appropriate processing is up to 0.36. Furthermore, as can be seen in **Figure 8**, TOC removal rate in the range from 70% to 90% in the treatment of F/M ratio between 0.1 and 0.36 and decreased immediately in the next treatment.

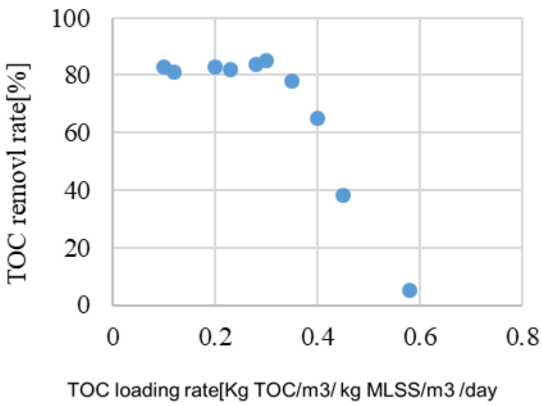

Figure 7 Relationship between TOC loading rate (F/M ratio) and TOC removal rate

4. CONCLUSION

The treatment of diluted barley shochu effluent using the anaerobic sequencing batch reactor method (ASBR) in this study can be performed normally within the range of 0.36/day using the F/M ratio as an index.

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