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Treatment of brewery slurry in thermophilic anaerobic sequencing batch reactor

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Abstract

Treatment of brewery slurry in a thermophilic anaerobic sequencing batch reactor (ASBR) was studied using conventional fully mixed semi-continuous digestion as a control. The process phases were adapted to fit the brewery slurry discharge schedule. ASBR experiments were conducted under different organic loading rates (OLR) from 3.23 to 8.57 kg of COD/m^3 day of reactor and control was conducted with OLR of 3.0 kg of COD/m^3 day. The ASBR COD degradation efficiency was from 79.6% to 88.9%, control experiment efficiency was 65%. ASBR VSS removal efficiency was from 78.5% to 90.5%, control experiment efficiency was 54%. The ASBR methane production yield was from 371 to 418 L/kg COD inserted, control experiment methane yield was 248 L/kg COD inserted. The ASBR process was superior to conventional fully mixed digestion, and is fully adaptable to brewery slurry discharge, needs no additional collection and settling pools and experiences no solids settling problems.

Keywords: Anaerobic sequencing batch reactor; Biogas production; Brewery slurry; Thermophilic anaerobic digestion

1. Introduction

Brewery plants produce large quantities of wastewater containing high concentrations of degradable organic pollutants. Such wastewater is well suited to anaerobic treatment and there are many conventional ways in which to treat brewery wastewater effectively. These range from fluidised bed bioreactors (Ochieng et al., 2002) to the most commonly used upflow anaerobic sludge blanket (UASB) reactors (Parawira et al., 2005; Leal et al., 1998; Cronin and Lo, 1998; Yu and Gu, 1996) which treat all of the brewery wastewater. Such processes are well established; some are single staged, others typically are equipped with a pre-acidification stage (Suzuki et al., 1997). Kormelinck (2003) reports 84% chemical oxygen demand (COD) degradation with a COD load of 5000 mg/L and methane yield of 256 L/kg COD inserted. Other authors report COD removal rates from 57% (Parawira et al., 2005) or 62% (Leal et al., 1998), to 80–90% (Cronin and Lo, 1998; Austermann-Haun and Rosenwinkel, 1997) which is the conventionally accepted value. Some 5% of brewery wastewater is a slurry consisting of wastewater with high content of solids and high COD. The major difficulty in using UASB reactors for treatment of brewery wastewater is associated with treatment of such high solids wastewaters. It is common practice to remove solids before treatment so that only the soluble part of the wastewater with perhaps small amounts of residual solids (up to 500 mg/L) is admitted to the UASB reactor.

Application of anaerobic sequencing batch technology to wastewater with high solids content can offer improvement in performance and stability compared to conventional anaerobic digestion. The anaerobic sequencing batch reactor (ASBR), which involves a repetitive four-stage cycle: fill, react, settle and withdraw, can successfully retain

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and treat high solids content wastewater without any problems related to clogging of solids. Although the ASBR process is a relatively new concept, research in this field has been used, with some success, for the treatment of swine waste (Massé et al., 2003), dairy wastewater (Dugba and Zhang, 1999) and even municipal sludge (Hur et al., 1999).

Anaerobic digestion has often been reported to affect the settleability of anaerobically digested effluents adversely. This is especially true with effluents like sludge or slurry which contain a high solid content. Therefore the most significant challenge in the ASBR process with wastewater having a high solids content is achieving sufficient settleability and solid–liquid separation but at the same time retaining enough of the active biomass to support further processing. This problem can be successfully managed (Hur et al., 1999) by adjustment of the settling stage and choice of an appropriate hydraulic retention time (HRT).

The objective of this study is to evaluate the performance of the ASBR process under conditions used successfully to treat brewery slurry and to examine the feasibility of collecting and using biogas from the brewery wastewater solids, which, in the conventional process, are usually discarded.

2. Methods

2.1. Brewery slurry

Beer production levels in a brewery are very uneven and consequently wastewater discharge from the brewery is erratic with considerable variations in flow, COD and temperature. Slurry discharges track the production process which averages three production days per week for 50 weeks per year – 150 production days annually. Such a production rate is ideal for the direct application of the ASBR process to the slurry discharge.

Table 1 shows the characteristics of the brewery wastewater which was used in this research. Brewery slurry was collected monthly and stored in cold storage at 4 °C. Slurries with high solids content and high COD separated from the brewery wastewater (S1 + S2), have a COD load of 6720 kg/day and a flowrate of 120 m^3/day. The residual water has a COD load of 6646 kg/day and a flowrate of 2430 m^3/day. Thus some 50% of the wastewater COD load derives from brewery slurry, which represents only 5% of the brewery wastewater flow. The COD of slurry S1 was between 20,000 and 22,000 mg/L and of slurry S2 was between 71,000 and 78,000 mg/L. The total suspended solids (TSS) and volatile suspended solids (VSS) varied more than the COD. For slurry S1, the TSS was between 5 and 10 g/L, and for slurry S2 the TSS was between 20 and 50 g/L. The ratio VSS/TSS was always >90%.

2.2. Experimental arrangement

A laboratory-scale experimental setup is shown in Fig. 1. A 30 L thermophilic lab scale pilot ABSR for treating slurry was fed in real time, as in brewery production with slurry discharge. The slurry S2 was fed continuously for 3 days, and the slurry S1 was fed batchwise twice daily over 3 days for a total of six batches. The volume ratio S1:S2 was 1:2. The ABSR cycle was 7 days. In the first phase the equipment was charged over a 3 day period, then in the second phase, it was allowed to react for 4 days. In phase 3, the system was allowed on day 7 to settle for 3 h and this was followed by phase 4 – withdrawal. The HRT values were 26, 17.5, 15, and 13.5 days.

Our strategy was to increase the organic loading rate (OLR) gradually to the limit where methanogenic process would collapse as a result of overload. A 7 day cycle was chosen to match the brewery's wastewater discharge rate but the HRT could be easily shortened by 30% with practically no change in results. The temperature in the ASBR was kept at 55 °C throughout the cycle. This thermophilic temperature was selected as the most appropriate for ASBR experiments. Theoretically, when slurries S1 and S2 (Table 1) are mixed the temperature is between 50 and 55 °C, which favours a thermophilic process. For control process we used a conventional fully mixed semi-continuous digester with 20 days HRT and equivalent feed once daily (the S1:S2 ratio of 1:2 was established prior to the feed).

2.3. Experimental analysis

The chemical oxygen demand (COD), total suspended solids (TSS) and volatile suspended solids (VSS) were determined using standard methods (APHA, 1998). Samples of

Table 1
Brewery wastewater characteristics[a]

	Wastewater flow (m^3/day)	Average COD (mg/L)	T (°C)
S1 Beer filter slurry	40	20,000–30,000	0–10
S2 Grist dewatering slurry	80	50,000–80,000	70–80
Wl Strain pan wastewater	39	15,000	80
W2 Condensate “Pfaduko”	30	350	90
W3 Washing, cooling and compressing CO_2 wastewater	99	180	27
W4 Reverse osmosis concentrate	400	0	12
W5 Wastewater from production	947	3500	30
W6 Wastewater from beer filling	915	3500	26

[a] Union Brewery Environmental Report, 2005.