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Anaerobic whey treatment by a stirred sequencing batch reactor (ASBR): effects of organic loading and supplemented alkalinity

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Abstract

An assessment was made of cheese whey treatment in a mechanically stirred anaerobic sequencing batch reactor (ASBR) containing granular biomass. The effect of increasing organic load and decreasing influent alkalinity supplementation (as sodium bicarbonate) was analyzed. The reactor operated on 8-h cycles with influent COD concentrations of 500, 1000, 2000 and 4000 mg/L, corresponding to volumetric organic loads of 0.6 to 4.8 mgCOD/L.d. Organic COD removal efficiencies were always above 90% for filtered samples. These results were obtained with an optimized alkalinity supplementation of 50% (ratio between mass of $NaHCO_3$ added and mass of influent mg$NaHCO_3$/mgCOD) in the assays with 500 and 1000 mgCOD/L and of 25% in the assays with 2000 and 4000 mgCOD/L. Initial alkalinity supplementation was equal to the mass of influent COD (100%). The system showed formation of viscous polymer-like substances. These were probably of microbiological origin occurring mainly at influent CODs of 2000 and 4000 mg/L and caused some biomass flotation. This could, however be controlled to enable efficient and stable reactor operation.

Keywords: ASBR; Granulated biomass; Cheese whey; Organic load; Alkalinity

1. Introduction

Dairy industries generate residues, of which whey is the most important due to the volume produced (about 80 to 90% of milk volume). Whey is also important because it is highly polluting (approximately one hundred times greater than that caused by an equivalent volume of domestic wastewater). While whey may have further uses, many small and medium-size dairy industries do not have the technical know-how nor the economic incentive to do so, making it necessary to consider its treatment as a waste stream.

Cheese whey has a very high organic content (60 to 80 gCOD/L) and may impair biomass granulation during biological treatment. This would in turn result in biomass wash-out. Anaerobic treatment of whey has therefore frequently encountered difficulties in maintaining stable operation (Yan et al., 1988; Malaspina et al., 1996). In addition, whey in natura has low bicarbonate alkalinity and tends to rapidly acidify due to its very high biodegradability (about 99%). Supplemental alkalinity is required so as to avoid anaerobic process failure. (Lo and Liao, 1986; Wildenauer and Winter, 1985). This alkalinity supplementation can be minimized by using operation conditions directed at obtaining better treatment efficiency, such as using higher hydraulic residence times or dilution of the influent (Kalyuzhnyi et al., 1997; Yan et al., 1988; Kato et al., 1994).

Liquid phase recirculation might be an alternative to increase alkalinity and dilute influent (Malaspina et al., 1996). Another way would be to separate the acidogenic phase from the methanogenic one. Circulation of the

Abbreviations ASBR, anaerobic sequencing batch reactor; COD, chemical oxygen demand; TVS, total volatile solids.

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Nomenclature

Symbols

BA	bicarbonate alkalinity, $mgCaCO_3/L$
C_{ES}	filtered substrate concentration in the effluent, mgCOD/L
C_{ET}	non-filtered substrate concentration in the effluent, mgCOD/L
C_I	non-filtered substrate concentration in the influent, mgCOD/L
C_S	filtered substrate concentration in the reactor, mgCOD/L
C_{So}	initial value of C_S, mgCOD/L
C_{SR}	residual filtered substrate concentration in the reactor, mgCOD/L
SOL	specific volumetric organic load, mgCOD/gSVT.d
k_1	apparent first order kinetic parameter ($=\mu_{MAX}/Y_{X/S}k_S$), 1/(h.mg-SVT/L)
VOL	volumetric organic load, gCOD/L.d
EOR_F	specific organic matter removal for filtered samples, mgCOD/gSVT.d
EOR_T	specific organic matter removal for non-filtered samples, mgCOD/gSVT.d
t	time, h
t_c	total cycle time, h
TSS	total suspended solids concentration, mg/L or mg/g-sludge
TVA	total volatile acid concentration, mgHAc/L
V	volume of the wastewater in the reactor, L
V_F	volume fed per cycle, L
TVS	total volatile solids concentration, mg/L or mg/g-sludge
VSS	volatile suspended solids concentration, mg/L or mg/g-sludge
X	biomass amount, g-tvs

Greek Letters:

ε_T	substrate removal efficiency considering non-filtered substrate concentration, %
ε_S	substrate removal efficiency considering filtered substrate concentration, %

methanogenic reactor effluent would bring about dilution of the influent, conferring good system stability with no need to correct alkalinity (Garcia et al., 1991; Germerli et al., 1993; Yilmazer and Yenigün, 1999; Martins et al., 2000).

Anaerobic sequencing batch reactors (ASBR) have been investigated both for treating high strength wastewaters (dairy, piggery and landfill leachate) as well as for low-strength ones (domestic wastewater). Although investigations focus more on bench-scale reactors, results have been promising showing the real potentials of this system as an alternative to continuous flow ones (Zaiat et al., 2001; Ratusznei et al., 2003).

The main objective of this work is to investigate the influence of volumetric organic load and optimization of alkalinity supplementation on the efficiency and stability of the ASBBR and hence contribute to more appropriate designs of full-scale systems.

2. Materials and methods

Assays were performed in a mechanically stirred ASBR with effective volume of 5 L containing granular biomass (New Brunswick Scientific Co. BIOFLO III) as depicted in Fig. 1. The reactor was provided with a six-vertical-blade turbine impeller and operated at influent concentrations of 500, 1000, 2000 and 4000 mgCOD/L. An additional turbine impeller was installed at a height represented by ‘b’ in Fig. 1 to promote mixing in the floated biomass. Furthermore, the system temperature was controlled by means of water circulation through a jacket at the base of the reactor.

The inoculum used in all experiments came from a UASB reactor treating poultry slaughterhouse wastewater. Inoculum concentrations in terms of total solids (TS) and total volatile solids (TVS) were about 62 and 51 g/L, respectively. The amounts of sludge used in each experimental condition, in terms of TVS, are shown in Table 2. Operation temperature was 30±2 °C and 8-h batches were used. The treated influent consisted of dehydrated reconstituted whey, containing

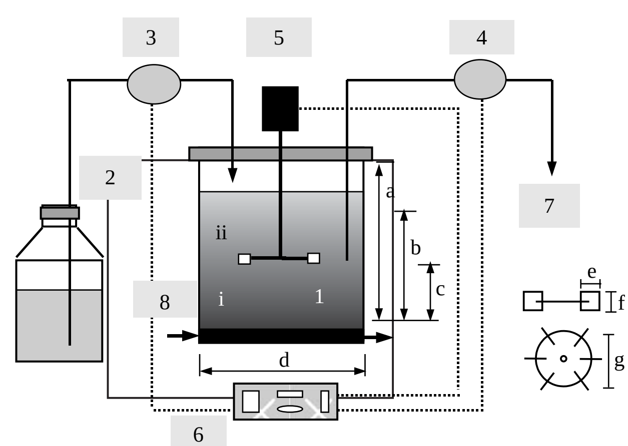

Fig. 1. Scheme of the mechanically stirred anaerobic sequencing batch reactor [1, BIOFLO III (New Brunswick Scientific) bioreactor with capacity of 5 L (a=26 cm; b=20 cm; c=16 cm; d=18 cm) and turbine impeller with six flat blades (e=2 cm; f=1.5 cm; g=6 cm) containing granulated biomass (i, region of high biomass concentration; ii, region of high biomass concentration); 2, influent; 3, feed pump; 4, discharge pump; 5, stirring system; 6, automation system; 7, effluent; 8, temperature control through water circulation].