ELSEVIER

Process Biochemistry 40 (2005) 1225–1232

PROCESS BIOCHEMISTRY

www.elsevier.com/locate/procbio

Effect of soluble organic, particulate organic, and hydraulic shock loads on anaerobic sequencing batch reactors treating slaughterhouse wastewater at 20 °C

L. Masse*, D.I. Massé

Agriculture and Agri-Food Canada, P.O. Box 90, 2000 Route 108, East Lennoxville, Que., Canada J1M 1Z3

Received 1 September 2003; accepted 18 April 2004

Abstract

Anaerobic sequencing batch reactors (ASBRs) treating slaughterhouse wastewater at 20 °C were subjected to soluble organic, particulate organic and hydraulic shock loads. The normal organic loading rate (OLR) was increased by a factor ranging from 1.5 to 3.6. During the soluble organic shock load, effluent soluble chemical oxygen demand (SCOD), volatile fatty acid (VFA), and suspended solids (SS) concentrations increased from averages of 200, 58 and 249 mg/l, respectively, in control reactors to maxima of 5626, 1642 and 10 723 mg/l, respectively, in overloaded reactors. However, concentrations were rapidly reduced to pre-shock load levels shortly after normal operating conditions were resumed. The particulate and hydraulic shock loads had small and temporary effects on effluent SCOD and VFA concentrations, but high SS concentrations were observed in the effluent of most overloaded reactors. However, solids loss during effluent discharge did not significantly affect long-term performance of the ASBRs, probably because the sludge bed contained high initial volatile SS (VSS) concentration (21.9 ± 3.2 g/l), and also a fraction of the VSS removed from the reactors during effluent discharge was composed of undegraded colloidal solids fed with the substrate, as opposed to bacterial flocs. Nevertheless, maintaining high VSS concentrations in the sludge bed will probably prevent long-term negative effect of biomass loss during sudden shock loads.

Keywords: Anaerobic sequencing batch reactor; Overload; Shock load; Slaughterhouse wastewater

1. Introduction

Anaerobic digestion in high-rate reactors represents an attractive alternative for wastewater treatment at slaughterhouse plants. Slaughterhouse wastewater contains high concentrations of biodegradable organics, mostly fats and proteins, and adequate nutrient concentrations for bacterial growth. It is well buffered and exits the plant at a relatively warm temperature, typically ranging from 20 to 30 °C [1].

The anaerobic sequencing batch reactor (ASBR) is particularly well suited for wastewater treatment at slaughterhouses, because it entails low capital and operating costs as well as minimum daily maintenance. It can be fed on an intermittent basis, as the wastewater is produced, thus eliminating the need for an equalizing tank or recycling line. The ASBR process is efficient with effluent containing high suspended solids (SS) content, such as slaughterhouse wastewater, because it allows prolonged contact between the biomass and the organics. Laboratory ASBRs (42 l) treating hog slaughterhouse wastewater could sustain steady state organic loading rates (OLRs) of 4.93, 2.94 and 2.75 g/l/day at operating temperature of 20, 25 and 30 °C, respectively [2]. At all temperatures, the soluble chemical oxygen demand and total chemical oxygen demands (SCOD) and (TCOD) were consistently reduced by more than 92%.

At the slaughterhouse, the ASBRs could be subjected to sudden shock load conditions. A blood spill could translate into a large soluble overload. The COD content of blood, one of the major dissolved pollutants of slaughterhouse wastewater, was evaluated at 375 g/l [3]. The reactors could also be fed an excess of particulate organics, which would require extended hydraulic retention time (HRT) to process, while a temporary increase in wastewater volume or the sudden break down of one of the reactors may impose an hydraulic overload on the biological process.

* Corresponding author. Fax: +1-819-565-9171.
E-mail address: massel@agr.gc.ca (L. Masse).

0032-9592/$ – see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.procbio.2004.04.012

Borja et al. [4] subjected a mesophilic anaerobic filter reactor (AFR) treating slaughterhouse wastewater to temporary organic and hydraulic shock loads representing 2–2.5 times the steady state load. Effluent volatile fatty acid (VFA) and COD concentrations increased during the overload period, but concentrations returned to normal values within 12 h of steady state operation. The effluent contained high protein and VFA concentrations, and the authors suggested that hydrolysis and acidification were the limiting processes.

The AFRs are particularly robust to soluble shock loads, because biomass immobilization on support reduces the risk of biomass washout. With the ASBR process, on the other hand, biomass retention depends on an adequate settling of the microorganisms before effluent removal. Under shock load conditions, high biogas production rate could create turbulence during the settling phase, thereby preventing complete biomass sedimentation.

Most studies on anaerobic reactor stability were conducted with mesophilic or thermophilic systems. Psychrophilic reactors are considered more stable than thermophilic systems [5], but biomass loss could be detrimental at lower operating temperatures, because of slow bacterial growth. The objective of this study was to evaluate the performance and stability of ASBRs treating hog slaughterhouse wastewater at 20 °C under sudden and temporary organic and hydraulic shock load conditions.

2. Materials and method

2.1. Substrate

Raw wastewater was collected once a month at a hog slaughterhouse in St-Valérien, Québec. In the laboratory, the wastewater was mixed, screened through a 1 mm sieve to remove hair and large particles, transferred to 10 l jugs, and stored at 2 °C. The wastewater was allowed to reach room temperature before reactor feeding. Wastewater characteristics during the experimental period are presented in Table 1.

During the soluble shock load experiment, wastewater SCOD was increased by adding 1.1 l of pure uncoagulated blood to 11.1 l of slaughterhouse wastewater. The uncoagulated blood had a COD of 140 ± 6 g/l (the coagulated fraction had been removed). During the particulate organic shock load, the suspended solids concentration was increased by removing about 75% of the supernatant of settled slaughterhouse wastewater before feeding the experimental ASBRs. Wastewater SCOD was similar to that in control reactors, but the particulate COD (PCOD) was substantially increased (Table 1). During the hydraulic shock load, all reactors were fed the same wastewater, but the HRT of the experimental ASBRs was decreased from 2 to 1 day.

2.2. Experimental set-up

A schematic of the four 42 l ASBRs used for the experiment was presented in Massé and Masse [2]. Before the initiation of this study, the ASBRs were fed hog slaughterhouse wastewater for 18 months at 20 °C. At the start of the experiment, the sludge was removed from all ASBRs, mixed in Nalgene bottles under anaerobic conditions, and redistributed to the bioreactors. The four ASBRs were then operated at 20 °C under normal conditions, defined as an OLR of 2.60 ± 0.36 g/l/day and an HRT of 2 days (Table 2). Throughout the experiment, the OLR was based on the amount of TCOD fed per volume of sludge present at the start of a cycle per total cycle time.

The ASBRs were batch-fed over a 1 h period. During the react phase, ASBR content was mixed for 1 min every 30 min

Table 1
Characteristics of the slaughterhouse wastewater fed to control ASBRs (normal operating conditions) and during each shock load experiment

Parameters (mg/l except pH)	Normal operating conditions[a]	Soluble organic shock load	Particulate organic shock load	Hydraulic shock load
COD total	7083 ± 1211	19367 ± 2821	13595 ± 3057	7924 ± 584
Soluble	3623 ± 752	15252 ± 3420	3041 ± 902	4189 ± 263
particulate	3460 ± 840	4385 ± 1347	10554 ± 3724	3742 ± 621
SS total	1592 ± 321	1845 ± 281	6883 ± 3459	1769 ± 217
Volatile	1418 ± 298	1709 ± 262	5560 ± 2496	1614 ± 194
VFA total	467 ± 108	793 ± 129	435 ± 103	508 ± 10
TKN	547 ± 78	1887 ± 229	NA	525 ± 61
NH_4	174 ± 59	318 ± 87	NA	121 ± 50
Total protein	2257 ± 492	9806 ± 1060	NA	2527 ± 121
Soluble protein	1531 ± 465	8885 ± 943	NA	2107 ± 129
Total fat	168 ± 46	379 ± 52	317 ± 4	227 ± 80
Alkalinity	903 ± 226	NA	667[b]	958 ± 59
pH	6.85 ± 0.44	NA	6.88[b]	6.89 ± 21

NA: not analysed
[a] Average over the 7 months experimental period.
[b] Only one sample analysed.