Treatment of dairy wastewater in UASB reactors inoculated with flocculent biomass

H Nadais[1]*, I Capela[1], L Arroja[1] and A Duarte[2]

[1] *Environment and Planning Department, University of Aveiro, 3810-193 Aveiro, Portugal*

[2] *Chemistry Department, University of Aveiro, 3810-193 Aveiro, Portugal*

Abstract

This work assesses the possibility of using flocculent sludge in UASB reactors applied to the treatment of dairy wastewater and studies the effect of hydraulic retention time (6, 8, 12 and 16 h) on the performance of the reactors. The results show that the performance of flocculent sludge is similar to what has been reported in literature for granular sludge. It was observed that by raising the HRT from 6 to 12 h the performance of the system is improved concerning the maximum applicable load, the COD removal efficiency and methane production, but by raising the HRT from 12 to 16 h the differences are not meaningful. To attain soluble COD removals, VFA removals and protein mineralisation near 80% and fat removals above 60% it is necessary to operate the UASB reactors at an HRT of at least 12 h. In addition to this the reactors must be operated at loads under 2.5 g COD/ℓ·d in order to attain a conversion to methane of the removed COD above 70%.

Keywords: UASB, hydraulic retention time, optimum load, flocculent biomass, dairy wastewater

Introduction

The absence of granulation in UASB reactors used for the treatment of dairy wastewater has been considered as a major limitation to the application of this technology to this kind of complex substrates. According to Lettinga et al. (1998), the operation of UASB reactors does not need granular sludge and it is possible to use flocculent sludge with good settleability. It is known that in the case of the anaerobic degradation of dairy wastewater (DWW) the limiting step is the hydrolysis of particulate substrates (Pavlostatis and Giraldo-Gomez, 1991) or the degradation of the long-chain fatty acids, LCFA, to volatile fatty acids, VFA, (Hanaki et al., 1981). According to Yang and Anderson (1993) in the anaerobic degradation of DWW the bacterial population of fat hydrolysers and LCFA oxidisers should comprise as much as 60% of the total biomass in order that the granular sludge may be able to completely degrade the fat present in the wastewater.

According to the same authors it is possible that a biomass with the required ecological structure is unable to remain in granular form being selectively washed out from the reactors once it has been formed. Moreover, the results from Yang and Anderson (1993) show that the ecological population shift was rather slow with granular sludge. It is natural that flocculent sludge being predominantly acidogenic (Lettinga, 1996) will result in a better degradation of complex substrates, compared to granular sludge which is mainly methanogenic (Lettinga, 1996). Hwu (1997) verified that in expanded granular sludge bed (EGSB) reactors the bacteria that degrade LCFA to VFA were found in the fine biomass particles and not in granular aggregates. This might be an explanation for some results in the literature indicating a low degradation of milk fat in anaerobic reactors with granular sludge (Yang and Anderson, 1993; Petruy and Lettinga, 1997). These findings led Hwu (1997) to operate granular sludge reactors with biomass recirculation, an HRT of 24 h and upflow velocities of 1 m/h, a set of flow conditions that are more typical of UASB reactors than of EGSB reactors. On the other hand UASB reactors inoculated with flocculent sludge bear higher solids content in the feed than the granular sludge reactors (Lettinga et al, 1998), and so the former is more adequate for the treatment of dairy wastewater. In full-scale DWW treatment plants generally a partial acidification takes place in the equalisation basin raising the solids content of the reactor feed.

The objective of this work was to study the application of UASB reactors inoculated with flocculent biomass for the degradation of dairy wastewater at mesophilic temperature. In order to study the influence of the hydraulic retention time (HRT) and the organic load on the reactor behaviour, UASB reactors were operated at HRTs of 6, 8, 12 and 16 h with organic loads ranging between 1 and 8 g COD/ℓ·d.

Experimental

For this study cylindrical UASB reactors were used with a height of 1.70 m and a working volume of 31.7 ℓ, built out of PVC and topped with three-phase separators as described by Fergala (1995). The reactors were kept at a temperature of (35±1)°C in a climate room. Every hour the sludge bed was intermittently mixed with a mechanical agitator at 40 r/min for 10 min, to prevent channelling and to improve the feed-biomass contact.

Initially the reactors were fed with wastewater from a dairy industry (COD 700 to 1 200 mg/ℓ; fats 75 to 150 mg/ℓ; pH 9.5 to 11) supplemented with alkalinity and nutrients as in Gujer and Zendher (1983). From the third month onwards the feed was prepared by dilution of semi-skimmed milk with tap water and addition of alkalinity and nutrients. Table 1 presents a summary of the operating conditions. All routine chemical analyses were performed according to *Standard Methods* (1995). The VFAs were determined with a gas chromatograph Chrompack GC 438-s with an FID detector (T=250°C) equipped with a CP-Sil

* To whom all correspondence should be addressed.

☎ +351 234 370 200; fax: +351 234 429 290;

e-mail: nadais@dao.ua.pt

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