Anaerobic treatment of a synthetic dairy effluent using a hybrid digester

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Abstract

A mesophylic laboratory scale hybrid anaerobic: digester, combining an upflow sludge blanket and a fixed-bed design, was evaluated for the anaerobic treatment of synthetic dairy effluent. In the first experimental study, the chemicall oxygen demand of the dairy effluent was increased stepwise from 3 700 to 10 300 $mg l^{-1}$. In the second experimental study the chemical oxygen demand (COD) of the synthetic dairy effluent was kept constant at 10 000 $mg l^{-1}$ and the hydraulic retention time (HRT) was shortened stepwise from 4.1 to 1.7 d. A COD removal of between 90 and 97% was achieved at organic loading rates of between 0.82 and 6.11 kg COD $m^{-3} d^{-1}$. At an HRT of 1.7 d, the digester achieved a methane yield of 0.354 $m^3 CH_4$ per kg $COD_{removed}$ The best results in terms of methane yield were achieved at an HRT of 1.9d. The data also showed that the maximum operational potential of the digester had been reached, as indicated by the drop in methane yield observed at the end of the second experimental study. The results clearly show that this particular type of digester would he suitable for the anaerobic treatment of dairy effluents. An important consequence of the data from this study is that a two-phase set-up will be required to protect the methanogens. in the digester from inhibitively low pH values and high concentrations of volatile fatty acids (VFAs) produced during the acidogenic phase. The two phase system will allow pH control in the acidogenic phase, should it be needed at a full-scale or pilot-scale treatment plant.

Introduction

Water management in the dairy industry is well documented (Jones, 1974; Water Research Commission, 1989), but effluent production and disposal remain a problematic issue for the dairy industry. A survey in 1989 (Water Research Commission, 1989) concluded that South African dairies apply either very basic or very inefficient effluent treatment procedures. Moreover, a more recent survey of the South African dairy industry (Strydom et al., 1993) revealed that effluent disposal is currently the most important water-related factor where improvement is desirable. Dairy effluent disposal in South Africa usually results in one of two problems: firstly, high treatment levies are charged by local authorities for industrial effluents; and secondly, further pollution can be caused when untreated effluents are either discharged into the environment or used directly as irrigation water. For the year 1991 (Strydom et al., 1993), a total of R1.5 m. on effluent disposal was spent by dairies which process 70% of the milk in South Africa. The second problem of disposal was more prevalent at large dairies situated near dairy farms in rural areas, where access to adequate waste-water treatment works is not available.

To enable the dairy industry to contribute to water conservation, an efficient and cost-effective effluent treatment technology has to be developed. To this effect, anaerobic digestion offers a unique treatment option to the dairy industry. Not only does anaerobic digestion reduce the COD of an effluent, but little microbial biomass is produced. The biggest advantage is energy recovery in the form of methane and up to 95% of the organic matter in a waste stream can be converted into biogas (Weber et al., 1984).

Many high-rate digester designs are currently available, and some have successfully been used for the treatment of dairy effluents. Lettinga and Hulshoff-Pol (1991) reported that of the 205 full-scale upflow anaerobic sludge blanket digesters in use world-wide in 1991, six were used to treat dairy effluents. The fixed-bed digester is another high-rate digester that has been used for the treatment of dairy effluents (De Haast et al., 1983). A high-rate combination design, using the upflow anaerobic sludge blanket (UASB) and the fixed-bed digester types, was developed by Guiot and Van den Berg (1984). This design was successfully used to treat landfill leachate (Myburg and Britz, 1993) and baker's yeast factory effluent (Van der Merwe and Britz, 1993). Landfill leachate and yeast effluent both have high COD concentrations and both are difficult to degrade biologically. On the other hand, dairy effluents are fairly easily biodegradable, since they consist mainly of diluted dairy products. Thus, the aim of this study was to evaluate, on laboratory-scale under mesophilic conditions, the use of the hybrid digester as an option in the treatment of a synthetic dairy effluent.

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Materials and methods

Digester design

A laboratory-scale hybrid anaerobic digester (Myburg and Britz, 1993) was used. The digester had an operational volume of 5.0l and combined a UASB and a fixed-bed digester design with a gas/solids separator at the top of the digester. This high-rate hybrid digester successfully combines advantages of both systems while avoiding their drawbacks. It also facilitates an important phenomenon of microbial community acclimation to the elevated VFA concentrations. The gas exited through the top, while the substrate was introduced into the digester at the base. The overflow of the digester emptied through a U-shaped tube to prevent atmospheric oxygen from entering the system. The temperature of the digester was maintained at 35°C using a heating tape and an electronic control unit (Meyer et al., 1985) and the digester was insulated. The volume of the biogas was determined using a