EVALUATION OF THE POTENTIAL OF AN ANAEROBIC SEQUENCING BATCH REACTOR FOR THE TREATMENT OF DAIRY WASTEWATERS

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1 INTRODUCTION

The main objectives of the Portuguese Strategy for Energy are to promote energetic efficiency and endogenous resources utilization, particularly renewable energies, and simultaneously, to ensure quality of life to future generations throughout greenhouse gas emissions reduction. In this context, it is also important to refer the guidelines prescribed on DIRECTIVE 2001/77/EC, concerning the promotion of electricity produced from renewable energy sources in the internal electricity market, where the dairy sector presents a great potential. In fact, intensive dairy farming results in the accumulation of large amounts of slurry at the end of the winter, with very high contents of organic matter and nutrients. Dairy farming wastewater is currently disposed off through land application with little or no pre-treatment. The application to soil of organic residues can have important effects on the environment. In fact, the presence of organic carbon can stimulate soil microbial activity, which may result in carbon losses and nitrate leaching, together with gaseous emissions. However, due to increasing awareness of the general public about potential adverse impact of animal wastes on environmental quality and recent developments in environmental regulations for gaseous-emissions control and nutrient management, alternative wastewater treatment methods become attractive options for dairy producers. In that regard, it is important to develop and implement integrated measures in order to protect the soil quality and fertility, as well as to prevent water pollution.

Composting may be an effective management option to improve the quality of cattle slurry solid fraction (SF) for use as a soil-conditioning agent (Brito *et al.*, 2008). Nevertheless, the remaining liquid fraction, resulting from the solid-liquid separation of livestock slurry also needs to be treated in order to achieve the legal compliance for wastewater discharge.

The Sequencing Batch Reactor (SBR), if designed and operated properly, under anaerobic conditions, may become a promising technology for treating the liquid fraction of dairy farming wastewater, and simultaneously contribute to greenhouse gas emissions reduction and energy production.

Therefore, the present study endeavours to contribute for the development and optimization of an integrated solution for dairy farming wastewater treatment, throughout the operation and monitoring of an anaerobic sequencing batch reactor treating the liquid fraction of the wastewater produced at a dairy farm located in the northwest region of Portugal (Vila do Conde).

2 MATERIALS AND METHODS

The dairy wastewater used in this study was original from a farm with a dairy cow density of 253 animals. The wastewater treatment and management system consisted on the slurry collection, the separation of its solid fraction, and the storage of the liquid fraction in a 2011 m^3 tank for subsequent land application. The experimental set-up consisted of a cylindrical anaerobic SBR (ASBR), made of acrylic, with a total operating volume of 8 L and a thermo-regulated water jacket for temperature control. The reactor was filled-up with ¼ of inoculum (biomass collected from a conventional anaerobic digester used in the stabilisation of activated sludge purged from a domestic wastewater treatment plant) and ¾ of dairy slurry liquid fraction collected from the storage tank diluted with water (1:6). The composition of the biomass inoculum and the dairy farming slurry liquid fraction is presented in Table 1.

TABLE 1 **Composition of the biomass inoculum and the dairy farming slurry liquid fraction (SLF)**

Parameter	**Biomass inoculum**	**SLF**
TS (g/L)	7.0± 0.8	47.5 ± 0.9
VS (g/L)	6.7 ± 0.1	28.7 ± 0.5
Total COD (gO_2/L)	10.0 ± 0.6	36.2 ± 0.0
Soluble COD (gO_2/L)	2.0 ± 0.0	15.5± 0.2
TKN (g/L)	0.9 ± 0.2	2.3 ± 0.3
Phosphorus (mg/L)	not determined	0.6± 0.0

The reactor was operated for 31 days and samples were collected for analysis along ASBR operation time. The mixed liquor pH, temperature, total and soluble organic matter as Chemical Oxygen Demand (COD), total (TS) and volatile (VS) solids, TKN and phosphorus were monitored during ASBR operation time, using standard procedures (APHA, WPCF, 1998). Biogas production was measured with a Ritter MilligasCounter gas meter. The ASBR was operated in the typical sequence of fill, react, settle and draw. A magnetic stirrer was used to provide mixing during the reaction phase. The average operating temperature was 37 ºC.

3 RESULTS AND DISCUSSION

During the operational cycle of the ASBR, the temperature was 37 ºC and the pH was 7. The initial food to microorganism ratio was 0.3 kg COD kg $VS^{-1}d^{-1}$. This value was slightly lower than the usually reported for anaerobic digestion of dairy manure (Qureshi et al., 2008). The hydraulic retention time was 40 days, which is in the typical range of values for anaerobic digestion of livestock manure (García-Ochoa, 1999).

Figures 1 and 2 present, respectively, COD and solids concentration along a typical ASBR operational cycle.

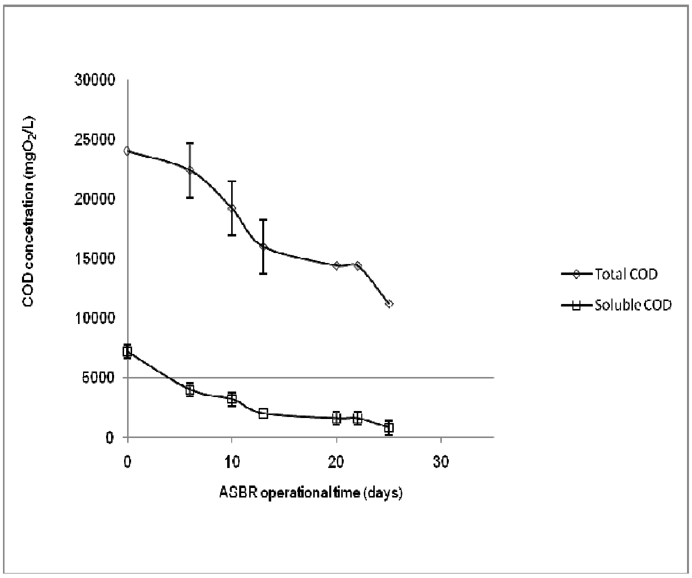

FIGURE 1 **COD concentration along ASBR operational cycle.**

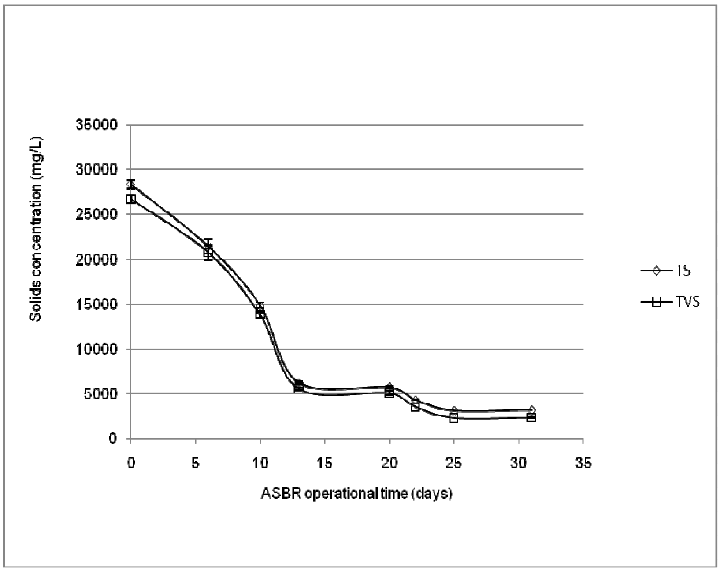

FIGURE 2 **Solids concentration along ASBR operational cycle.**

The results obtained in the present study showed that, despite the high COD values (including dissolved and particulate organic matter) typical of dairy farming wastewater, the soluble fraction was very low, reaching only 15±7 % of the total COD (Figure 1). Indeed, a significant fraction of the organic pollution is present in the form of particles and, hence, may not be readily accessible for microbial uptake. This fact suggests that solubilization and hydrolysis of particulate organic matter may be the limiting step for microbial degradation (Rodrigues et al., 2001). Nevertheless, the apparent COD removal efficiencies were high, the soluble COD being removed with an efficiency of, approximately, 89 %. Concerning total COD removal, it was expected that, during the SBR operating cycle, soluble organic carbon could be made available to microorganisms as a consequence of solubilization and hydrolysis of particulate organic matter. However, in terms of total COD, lower removal efficiencies were detected, reaching 53 %. This result is in accordance with the values reported by Rico et al. (2007) in anaerobic digestion studies using the liquid fraction of dairy manure as substrate. As expected, the soluble COD was removed with a higher efficiency, since the dissolved compounds are more accessible for microbial degradation than the particulate organic matter. The results presented in Figure 1 show that, after 31 days of operation, the remaining COD is still very high (15 g/L), indicating the need of a post-treatment before wastewater discharge.

Figure 2 depicts the extremely high solids content of dairy wastewaters. The apparent TS and VS removal rates were 89 % and 91 %, respectively. Such values are higher than the solids removal efficiencies reported by Chen et al. (2008) and Neves et al. (2009) in processes of anaerobic digestion of dairy wastewaters. In fact, the high solids removal efficiencies obtained in the present study can be explained by the solubilisation and degradation of particulate organic matter, but may also be strongly correlated to difficulties in maintaining suspension and homogenization of the mixed liquor, leading to the deposition of solids at the bottom of the reactor, which may remain inside the ASBR for the subsequent operating cycles.

Biogas production is represented in Figure 3. The results showed that, during the initial 19 days of operation, the maximum observed biogas production rate was $1.5x10^{-6}$ m^3 biogas/d and 15 mL of biogas were produced. However, a sudden increase in biogas production rate was observed, reaching a maximum value of $3x10^{-5}$ m^3 biogas/d and a final volume of 190 mL after 31 days of ASBR operation. The specific overall biogas production rate was 0.12 m^3 biogas kg solubleCDO^{-1} d^{-1} and the maximum observed rate was 0.23 m^3 biogas kg solubleCDO^{-1} d^{-1}.

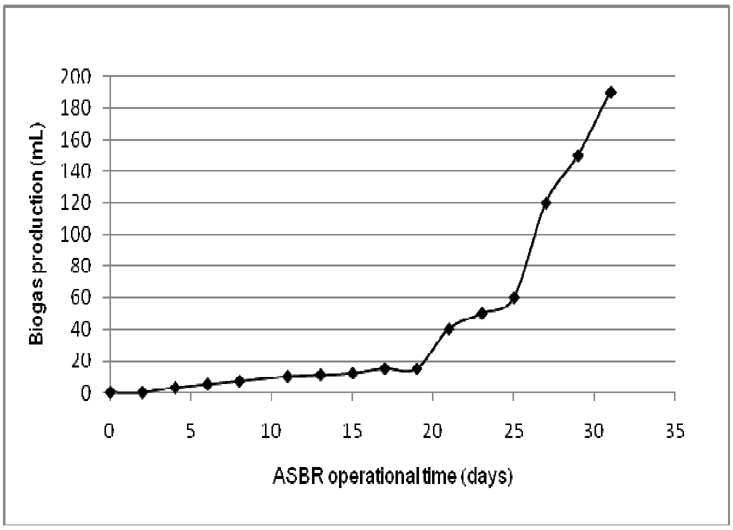

FIGURE 3 **Biogas production along ASBR operational cycle.**

4 CONCLUSIONS

The results obtained suggest that the anaerobic SBR is a feasible system for the treatment and valorisation of dairy slurry liquid fraction. However, due to the high solids and organic matter content typical of dairy effluents, a post treatment is still necessary in order to minimise negative environmental impacts as result of wastewater discharge. Therefore, the application of integrated management and treatment solutions to dairy farming wastewaters is necessary in order to contribute to significantly reduce the organic and nutrient loads of such effluents.

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