Start-up of an AnMBR for winery wastewater treatment

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Abstract
The anaerobic membrane bioreactor (AnMBR) is an interesting technology when intensive and compact treatments are needed to reduce space requirement. Its application to winery wastewater is worth considering due to its high organic load and low nutrient content. Moreover, as sludge and hydraulic retention times are independent parameters, the AnMBR can cope with influent fluctuations. A mesophilic AnMBR was started up at lab scale achieving over 97% of organic matter removal and biogas production up to 0.44 L CH_4 $L^{-1}_{digester}$ d^{-1} when organic loading rate was 1.8 kg COD m^{-3} d^{-1}. During operation, membrane flux declined progressively due to membrane fouling; therefore chemical cleanings were carried out to recover initial flux.

Keywords
Winery wastewater; anaerobic membrane bioreactor; organic matter removal.

INTRODUCTION

The growing concern in the development of new intensive and compact technologies is due to the more and more stringent regulations regarding waste disposal and the aim of reducing energy and space requirements, particularly in industrial facilities as wineries. Winery wastewater cannot be discharged into the environment harmlessly due to its particular characteristics: high biodegradable organic load, low nutrient content and acidic pH. Anaerobic membrane bioreactor (AnMBR) is a promising technology as the production of biogas is expected to cover its energy cost; including heating, stirring and membrane filtration, providing an effluent free of suspended solids. In addition, biogas produced in an AnMBR has higher methane content, because at short hydraulic retention times (HRT) carbon dioxide is removed with the effluent as it is more soluble in water than methane (Skouteris *et al.*, 2012).
The main goal of this work is to start-up an AnMBR for winery wastewater treatment and to operate the AnMBR with real winery wastewater.

MATERIALS AND METHODS

The AnMBR was set-up as a conventional stirred anaerobic digester of 5-L coupled with an external flat-sheet membrane unit (Orelis, Rayflow Module) with 100 cm^2 of membrane area. The digester was a jacketed vessel mechanically stirred at 100 rpm and heated at 35°C. Digester feeding was performed by pressure equilibrium connecting the digester to a 500 mL cylinder maintained at a constant volume, thus the working volume was set at 4 L. The influent flow rate only depended on the permeate flow rate that progressively decreased due to membrane fouling, achieving an average value of 1.3 L d^{-1} corresponding to 10.8 LMH. Influent wastewater was fed from a 10-L tank placed in a coolbox to avoid early degradation. Biogas production was quantified with an on-line measuring device (Ritter MGC-1) connected to the headspace of the digester. During the start-up period, synthetic wastewater was fed to the system avoiding the typical winery wastewater variability in terms of chemical oxygen demand (COD) content. Synthetic wastewater was prepared with diluted white wine (Artiga *et al.*, 2005) and, in order to cope with nutrient requirement, NH_4Cl and K_2HPO_4 were supplied to achieve a COD:N:P ratio of 800:5:1 (Moletta, 2009), as well as, $NaHCO_3$ was added reaching an alkalinity of 500 mg $CaCO_3$ L^{-1}.
Biomethane potential (BMP) tests were carried out at mesophilic temperature (35°C), using four different wastewaters, following the procedure defined in VDI 4630 (2006) and Angelidaki *et al.* (2009). Analytical methods were performed following the Standard Methods (APHA, 2005).

RESULTS AND DISCUSSION

Start-up of an AnMBR

The start-up of the AnMBR was performed with synthetic wastewater with a COD concentration progressively increased from 1.6 to 5.8 g COD L^{-1}, which corresponded to an organic loading rate (OLR) of 0.6 and 1.8 kg COD m^{-3} d^{-1}, respectively. The changes in influent COD concentration are shown in Figure 1, as well as effluent COD and volatile fatty acids (VFA) concentration. It is observed that an effluent with a low COD and VFA concentration was obtained during almost all the start-up period. However, it should be noticed that when COD increased sharply (day 51), VFA tended to accumulate and pH decreased until 5, causing digester failure. Therefore, COD was increased more slowly in order to favour biomass acclimation and growth, achieving COD removal efficiencies over 97% during the whole stable operation.

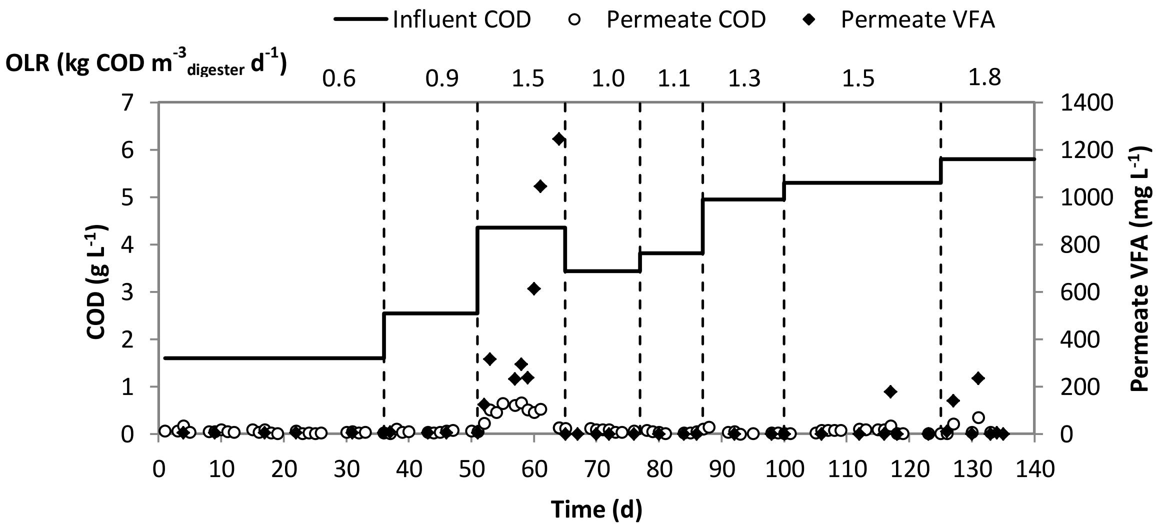

Figure 1. Evolution of VFA and COD concentration in the AnMBR

Biogas production progressively increased according to the amount of COD provided in each step. High methane concentration of 85-89% was obtained since AnMBR worked at a short HRT of 3.5 d. The average methane production is presented in Figure 2, which is calculated as the slope of the accumulated volume produced during each period, observing a similar step tendency reaching 0.44 m^3 CH_4 $m^{-3}_{digester}$ d^{-1} when influent COD was 5.8 g L^{-1}.

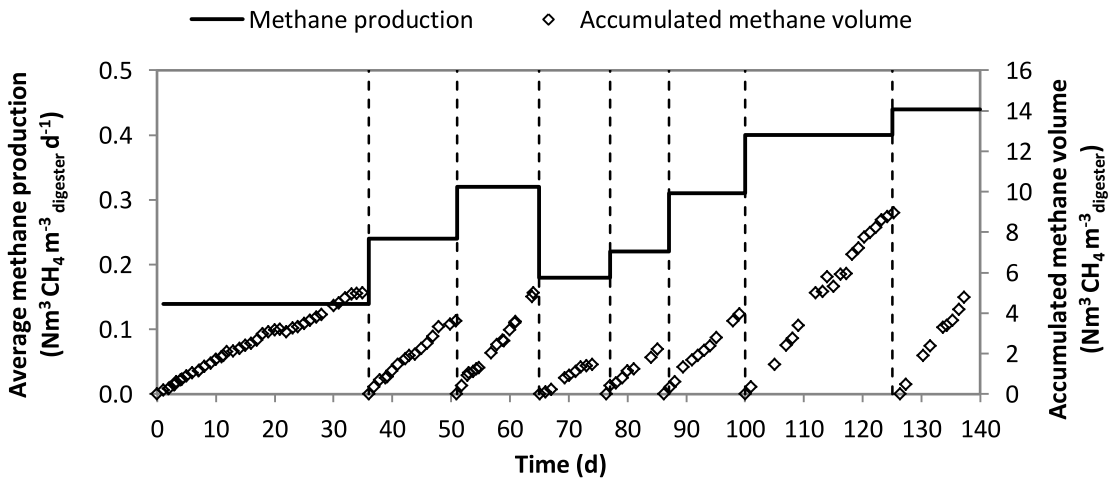

Figure 2. Methane production in the AnMBR

It is well known that membrane fouling is the main drawback of MBR application (Judd and Judd, 2011). In this case, the cross flow through the membrane module helped to reduce solid deposition on the surface. Nevertheless, when flux decreased below 8 LMH a chemical cleaning was carried out, following the procedure given by the manufacturer. In Figure 3, it is shown that flux declined sharply at the beginning of the operation, therefore cleanings were frequent. Then, when COD concentration was higher, a more stable flux was achieved around 9 LMH. Although volatile suspended solid (VSS) concentration in the digester was considerably higher, solid deposition on the membrane was visually observed to be lower. Fouling reduction was favoured by a higher biogas production, since biogas bubbles passing through the module probably helped to detach the particles from the surface.

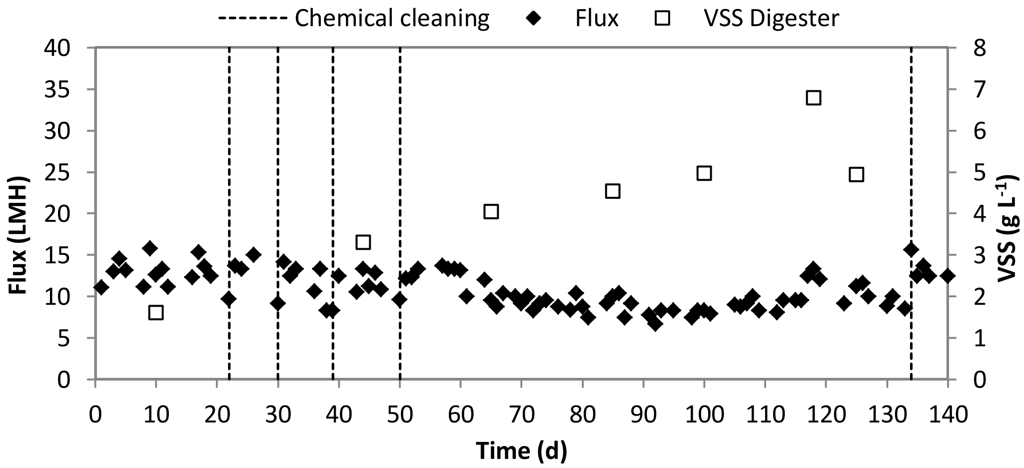

Figure 3. Flux and VSS of the AnMBR

Biomethane potential test

Two real winery wastewaters were tested in order to assess their methane potential. They were collected from two wineries located in Sant Sadurní d'Anoia (Barcelona). The main characteristics are shown in Table 1, noticing a higher content of particulate COD in RW1 than RW2, and very low NH_4^+-N concentration in both substrates.

Table 1. Wastewater characterisation

	Parameters				
	COD_t (g L^{-1})	**COD_s (g L^{-1})**	**VSS (g L^{-1})**	**NH_4^+-N (mg L^{-1})**	**VFA (mg L^{-1})**
RW1	5.91 ± 0.03	1.23 ± 0.03	1.92 ± 0.02	12.4 ± 0.5	2,012 ± 5
RW2	1.9 ± 0.1	1.15 ± 0.04	0.09 ± 0.04	12.9 ± 0.5	258 ± 5

The wastewaters tested showed similar profiles at the beginning of the BMP test (Figure 4), achieving a methane production of 0.17-0.18 Nm^3 CH_4 kg^{-1} COD_{added} in just 4 days since COD was mostly soluble and rapidly biodegradable. However, RW1 reached better production at a longer period, which was probably due to its higher content of particulate organic matter that provided nitrogen not taken into account previously, as only soluble nitrogen species were analysed. Biodegradation, determined in terms of total COD consumption, was 79.6% and 72.7% in RW1 and RW2, respectively. In order to cope with this lack of nutrients, in many cases, the winery wastewater is mixed with the blackwater produced by the winery itself, increasing nutrient concentration enough for a proper biomass growth.

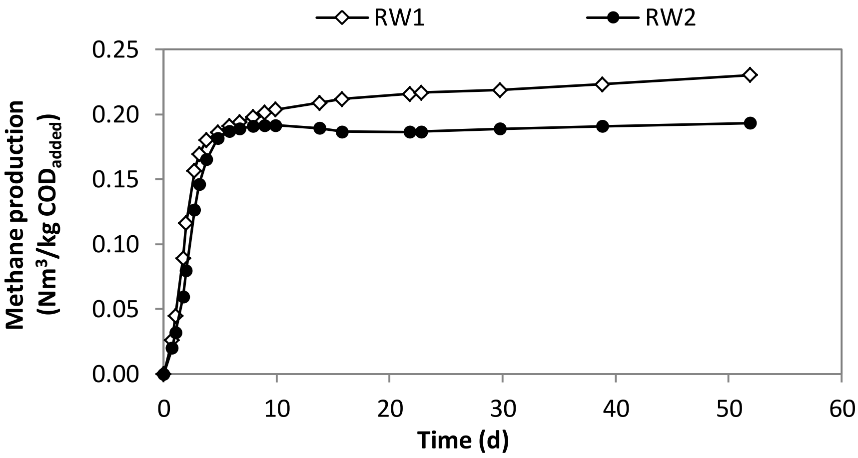

Figure 4. Methane production profiles obtained in the BMP test

CONCLUSIONS

AnMBR has shown good performance for synthetic winery wastewater treatment, reducing organic matter concentration with low nutrient requirement. However, it requires relatively constant influent characteristics at short HRT due to the low growth of anaerobic biomass; otherwise VFA would accumulate causing digester failure. A relatively high biodegradation and biogas production was observed in the BMP test, although the effect of a lack of nutrients in the real substrate should be studied deeper in continuous operation. Further research will be focused on real winery wastewater treatment, evaluating AnMBR application to this field and the possibility to mix urban and winery wastewater to cover nutrient requirement.

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