Improving anaerobic digestion stability, effluent quality and ammonia recovering with a microbial electrolysis cell integrated system

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Anaerobic digestion (AD) is nowadays widely used for processing various kinds of wastes, as livestock manure. Despite it is considered as a robust process, when it is performed at thermophilic range, beside a number of advantages, it is more sensitive to inhibition due to diverse substances that may be present in the waste stream, as ammonia. Furthermore, the AD process does not modify the total content of N of the digestates. So, it is interesting to find new technologies that can help to maintain effluent quality within the desired limits, while recovering nutrients from the digestates.

Apart from the usual strategies that are used to control ammonia toxicity in AD, as co-digestion, reduction of ammonia content of the substrates by air stripping (Bonmatí and Flotats, 2003), or dilution of the substrates (Rajagopal et al., 2013), the use of bioelectrical systems (BES), as microbial electrolysis cells (MEC) is emerging as an alternative. BES are bioreactors that use microorganisms attached to one or both electrode(s) in order to catalyse oxidation and/or reduction reactions. In a MEC, a little amount of electrical energy is applied to boost a non spontaneous process, as can be the recovery of ammonia. A MEC fed in the anode compartment in series with the effluent of an AD will allow, on the one hand, to remove organic matter; and on the other hand, part of the ammonium contained in the digestate will diffuse to the cathode compartment through de cationic exchange membrane that divides them, and could be recovered with a subsequent stripping and absorption process and reused as a fertilizer (Sotres et al., 2013).

The aim of this study is to assess the combination of the AD process with a MEC in series operation, as a system to improve the effluent quality, and in parallel, as a technique to increase the stability and robustness of the AD process against organic and nitrogen overloads.

A thermophilic lab-scale continuous stirred tank reactor (CSTR) was used to study its performance when treating pig slurry. The hydraulic retention time (HRT) was fixed at 10 days. The reactor was operated during 336 days in 5 different phases. In Phase 1, the organic loading rate (OLR) was of 3.02±0.60 kg_{COD} m^{-3} day^{-1} and the nitrogen loading rate (NLR) was of 0.17±0.03 kg_N m^{-3} day^{-1}. In Phase 2, the previous OLR and NLR were doubled (6.25±1.05 kg_{COD} m^{-3} day^{-1}; 0.34±0.06 kg_N m^{-3} day^{-1}, respectively) to evaluate the stability of the reactor to an overload, and the AD effluent was used to feed a MEC, as a polishing step and a system to recover ammonia. In Phases 3, 4 and 5, a recirculation loop between the MEC and the DA was introduced, with 25, 50 and 75% of recirculation, respectively, to study the effectiveness of this recirculation as an AD optimization and stabilization strategy.

The AD achieved an average COD removal efficiency of 47% in Phase 1, with a maximum of 63% (Figure 1). When the AD was submitted to a 100% increase in the organic and nitrogen loading rate, in Phase 2, the system failed, with a reduction of 70% of the produced biogas and the COD removal efficiency decreased till 28% at the end of the phase. The integration of a MEC coupled to an ammonia stripping unit as a post-treatment allowed maintaining the COD removal efficiency on average at 46%, in spite of the AD destabilization, while recovering up to a 40% of the ammonia contained in the digestate. Finally, the AD-MEC system operated with a recirculation loop between them (phase 3, 4, and 5), helped to recover the AD, increasing up to a 110% the level of biogas production achieved before the inhibition, and attained a more stable and robust operation.

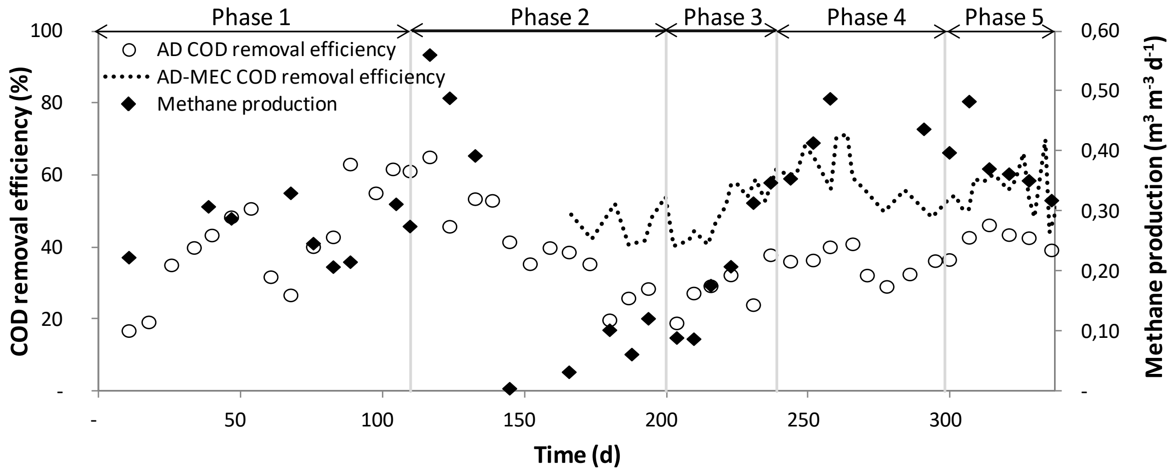

Figure 1. Methane production and COD removal efficiency of the AD alone and the AD-MEC integrated system. Phase 1 to 5 correspond to the different conditions tested as described in the text. The recirculation loop between AD and MEC was introduced in Phase 3 (25%) and increased to 50% and 75% in Phases 4 and 5, respectively.

These results show that the AD-MEC integrated system is a promising strategy for stabilizing AD against organic and nitrogen overloads, while improving the effluent quality and recovering nutrients for their reutilization.

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