Effect of the duration of the first-stage anaerobic digestion on the efficiency of intermediate treatments carried out on Waste Activated Sludge (WAS)

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Anaerobic digestion is the well consolidated fate of the organic-based sludge produced in wastewater treatment plants (WWTPs). However, the structure of waste activated sludge (WAS), that is the sludge produced in the biological processes used for the removal of organic substance and nutrients from wastewater, limits the efficiency of AD. In fact, the approximate methane specific production of pure primary sludge is in the order of 250-300 NmL/g VSS (Elbeshbishy et al., 2012), whereas the methane specific production of secondary sludge is approximately 2.0 – 2.5 times less (Gavala et al., 2003). This lower production follows from the evidence that most of the organic substance found in WAS is made of microorganisms and it is surrounded by cell walls or bounded in complex structures (EPS, extracellular polymeric substance, Xiao et al., 2015). The organic substance contained in microorganisms can only be made available for digestion after strong hydrolysis processes.

The combination of hydrolysis processes and subsequent AD is a well-established set up aimed at enhancing biogas and methane production from WAS. Pre-treatments that make use of mechanical forces, chemical agents, heat or a combination of them are effective in breaking cell walls of microorganisms or the original EPS but they have a quite limited effect to contrast the production of the new EPS that occurs during AD.

In order to optimize the whole AD process by contrasting the effect of the EPS produced during sludge digestion, some authors proposed the application of intermediate hydrolysis treatments (IHTs). According to the IHT configuration, raw WAS is digested in a two-stage digestion set up with an in-between hydrolysis treatment (Shana et al., 2013). However, until now only very few cases study have compared the performances of pre- and inter-stage treatments on sludge destined to AD (Nielsen et al., 2011; Ortega-Martinez et al., 2016). Most of the authors who presented results of inter-stage experimentations did not provide a comparison with pre-treatments carried out under the same working conditions.

Tests that have preceded the present work demonstrated that the whole amount of biogas and methane that is possible to extract from a two-stage digestion with an intermediate hydrolysis process depended on the duration of the first stage digestion (Ruffino et al., 2016). Tests were carried out using two samples of digestate with different hydraulic retention time (HRT) and origin (Ruffino et al., in preparation). One sample was a 7-day digestate collected from the anaerobic digesters of the full scale Castiglione WWTP (approx. 2,000,000 equivalent population). The other sample was a 15-day digestate collected from a pilot plant with an operating volume of 240 L that worked in a semi-continuous modality with an organic loading rate (OLR) of approximately 2 kgTS/m^3·d. Both digestates originated from the digestion of WAS. Samples were subjected to intermediate treatments at respectively 70°C and 90°C for 90 minutes, with 4% NaOH, and subsequently digested under mesophilic conditions. The results, for what concerns the sample of 7-day digestate, were encouraging. Increases of respectively 23% and 16% in the methane specific production were registered compared to the scenario that considers traditional pre-treatments carried out under the same working conditions (70°C and 90°C, NaOH 4%). Conversely, in no cases (working temperatures of 70°C or 90°C) the combination of a 15-day AD process of untreated WAS, followed by an intermediate treatment and a second stage AD, made possible to obtain methane specific production higher than those obtained with pre-treatments.

This work wants to investigate the effect of the duration of the first-stage digestion, carried out on the untreated sludge, on the efficacy of intermediate treatments compared to pre-treatments. In order to produce digestate with controlled HRT, an on-purpose built pilot scale digester was employed. This digester had a total volume of 10 liters and was fed daily with WAS that went from the Castiglione WWTP. Samples of digestate with fixed HRT were subsequently subjected to hybrid (thermo-alkali) intermediate treatments and finally digested in mesophilic conditions in batch apparatuses. Results from

digestibility tests were employed to evaluate the overall sustainability of the intermediate treatments by using thermal balances and economic assessments.

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