Journal of Environmental Management 217 (2018) 788–796

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Influence of food waste addition over microbial communities in an Anaerobic Membrane Bioreactor plant treating urban wastewater

N. Zamorano-López [a, *], P. Moñino [b], L. Borrás [a], D. Aguado [b], R. Barat [b], J. Ferrer [b], A. Seco [a]

[a] CALAGUA – Unidad Mixta UV-UPV, Departament d'Enginyeria Química, Universitat de València, Avinguda de la Universitat s/n, Burjassot, Valencia, 46100, Spain

[b] CALAGUA – Unidad Mixta UV-UPV, Institut Universitari d'Investigació d'Enginyeria de l'Aigua i Medi Ambient – IIAMA, Universitat Politècnica de Valencia, Camí de Vera s/n, Valencia, 46022, Spain

ARTICLE INFO

Article history:
Received 10 July 2017
Received in revised form
22 March 2018
Accepted 4 April 2018
Available online 24 April 2018

Keywords:
Anaerobic digestion
AnMBR
Biogas
Food waste
Illumina
Microbial community

ABSTRACT

Notorious changes in microbial communities were observed during and after the joint treatment of wastewater with Food Waste (FW) in an Anaerobic Membrane Bioreactor (AnMBR) plant. The microbial population was analysed by high-throughput sequencing of the 16S rRNA gene and dominance of *Chloroflexi*, *Firmicutes*, *Synergistetes* and *Proteobacteria* phyla was found. The relative abundance of these potential hydrolytic phyla increased as a higher fraction of FW was jointly treated. Moreover, whereas Specific Methanogenic Activity (SMA) rose from 10 to 51 mL CH_4 g^{-1} VS, *Methanosarcinales* order increased from 34.0% over 80.0% of total *Archaea*, being *Methanosaeta* the dominant genus. The effect of FW over AnMBR biomass was observed during the whole experience, as methane production rose from 49.2 to 144.5 L $CH_4 \cdot kg^{-1}$ influent COD. Furthermore, biomethanization potential was increased over 82% after the experience. AnMBR technology allows the established microbial community to remain in the bioreactor even after the addition of FW, improving the anaerobic digestion of urban wastewater.

1. Introduction

The anaerobic digestion (AD) of waste has become popular due to its environmental sustainability, as it not only reduces waste production, but also enables bioenergy production (Mao et al., 2015). Methane-rich biogas is produced during the degradation of organic matter through different microbiologically-controlled stages, such as hydrolysis, fermentation, acidogenesis and methanogenesis.

An Anaerobic Membrane Bioreactor (AnMBR) decouples the hydraulic retention time (HRT) from the sludge retention time (SRT), allowing the application of AD to low strength wastewaters treatment, such as urban wastewater (WW). This technology has a suitable effect over AD of WW even when treating urban influents with high concentration of sulfates, which can lead to low methane yields (Giménez et al., 2011). Moreover, the use of membrane technology provides full biomass retention in the digester with reasonable digester volumes, enhancing the heterogeneity of the system and improving domestic WW treatment (Smith et al., 2015).

The AD of food waste (FW) can also contribute to reducing the amount of organic wastes sent to landfills, as required by the European 1999/31/CE Directive. Also, this enhanced version of AD can be a proper way for food disposal and comply with the European 98/2008/CE Directive. Incorporating the FW into the WW influent for joint treatment via AD can improve energy recovery and has other benefits, such as savings in municipal solid waste transportation, reducing fossil fuel consumption and landfill volumes (Kujawa-Roeleveld et al., 2006). The small carbon footprint of food waste disposers and associated water consumption have been reviewed by Mattsson et al. (2015). Several studies have addressed the treatment of FW (Fisgativa et al., 2017; Vrieze et al., 2015). However, only a few have focused on AnMBR (Galib et al., 2016) to convert this organic enhanced waste stream into energy.

Microbial population in AD processes provides valuable information and must be considered jointly with process parameters monitoring (Tan et al., 2016). A heterogeneous pool of molecular biological tools can be used to characterize microbial populations. Next generation sequencing (NGS) has especially changed the study of microbial ecology in complex environments such as anaerobic digesters, being Illumina the most applied sequencing technique, due to its reduced cost and the useful information it provides on the

* Corresponding author.
E-mail address: nuria.zamorano@uv.es (N. Zamorano-López).

https://doi.org/10.1016/j.jenvman.2018.04.018
0301-4797/

microbial population. High-throughput sequencing of biomarkers such as the 16S rRNA gene is a valuable tool for the identification and quantification of key microbial groups in AD (Bartram et al., 2011; Degnan and Ochman, 2012; Vanwonterghem et al., 2014).

Most previous studies have focused on the methanogenic population of anaerobic digesters, due to its importance in the operational efficiency and energy recovery (Alvarado et al., 2014; Wilkins et al., 2015). However, a global overview of the microbial communities, considering both the *Archaea* and *Bacteria* domains, is needed to understand the implications of these microorganisms in limiting AD steps such as hydrolysis and fermentation. Thus, besides monitoring performance parameters, a thorough analysis of microbial populations with the new molecular tools is needed to better understand AD seeking the improvement of this process management (Carballa et al., 2015).

In this study, a joint treatment of FW and urban WW has been performed in an AnMBR demonstration plant, generating high energy recovery yields in terms of methane and biogas production (Moñino et al., 2017). The notorious improve of the AD of urban WW once the FW addition was over, suggested that microbial population established during the experience was more efficient than the previous one established. Hence, microbial insights of the AnMBR demonstration plant are here explored, revealing the remarkable influence of FW substrate and membrane technology over microbial populations.

2. Materials and methods

2.1. Demonstration plant

The AnMBR demonstration plant used in this study is situated in the Carraixet WWTP, in Alboraya (València, Spain) (see the process flow diagram in Fig. 1). The influent for this plant is taken from the pre-treatment of the Carraixet WWTP, after screening and removal of grit and grease. Then, it is treated in a 0.5 mm screen rotofilter, homogenized in the regulation tank (RT) and pumped into a 1.3 m^3 anaerobic reactor (0.4 m^3 head-space volume). This digester is connected to two external membrane tanks of 0.8 m^3 total volume each (0.2 m^3 head-space volume), set in parallel, which allow to do chemical membrane cleaning or another maintenance operation needed without interrupting the biological process performance. In the membrane tanks, vacuum filtration is applied to obtain the effluent, which is stored in a Clean-in-Place tank. Sludge is continuously recycled from the anaerobic reactor to the membrane tanks and the SRT is controlled by purging a fraction of the sludge from the anaerobic reactor intermittently during the day. A commercial food waste disposer and a 0.5 mm space screen rotofilter are used for the pre-treatment of the FW, which is stored in a co-substrate tank (CT) with a usable volume of 0.180 $m^3$and is also connected to the anaerobic reactor. A three-way valve alternates wastewater and FW inputs from the RT or CT, respectively.

The FW fraction is supplied according to the Penetration Factor (PF) established, which is defined as the percentage of households using food waste disposers. Two scenarios were evaluated, assuming that 40% or 80% of the population were grinding the food FW. These scenarios were explored as they might be feasible in small areas where household food waste disposers can be implemented. According to the national plan for waste management (PNIR 2008–2015), a mean value of 0.63 kg $FW \cdot hab^{-1} \cdot d^{-1}$ is generated in Spain. The Statistical National Institute of Spain reported in 2010 an urban wastewater generation of 282.4 $L \cdot hab^{-1} \cdot d^{-1}$ in 2010 (last available data). From this volume 225.92 $L \cdot hab^{-1} \cdot d^{-1}$ (an 80% approximately) is considered to have a domestic origin. Experimental results determined that a FW and WW mixture of 2.52 $L \cdot hab^{-1} \cdot d^{-1}$ is generated during FW grinding in household disposers. Hence, a resulting ratio of 11.2 mL of grinded FW per L of WW was fed to the pilot plant: 4.48 and 8.96 mL of FW per L of WW, representing a 40% and 80% PF scenario, respectively.

2.2. Operational conditions

Four different pseudo steady-state periods (Table 1), determined after stabilising solids concentration and methane production in the AnMBR, were selected for microbial community analysis. In Periods 2 and 3, the AnMBR treated both FW and wastewater

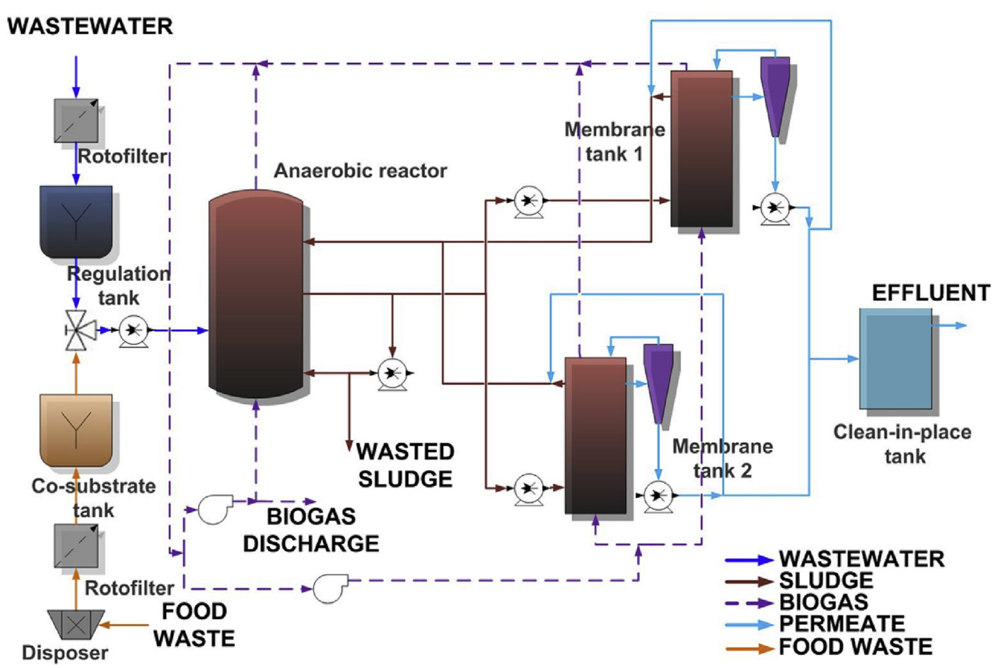

Fig. 1. AnMBR demonstration plant process flow diagram.