Biogas production in pilot digesters treating a mixture of olive mill wastewater and agro-industrial by-products

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1. Introduction

Agro-industries such as olive oil mills, cheese factories and dairy farms represent a considerable share of the Greek economy. The by-products of three-phase olive oil production such as olive mill wastewater (OMW) and olive cake pose a serious environmental risk. In Greece, the biogas industry has been growing in recent years and more than 10 biogas plants for power production with agro-livestock residues have been established in the last seven years. Furthermore, there are 11 WWTPs treating sewage sludge for biogas production. Germany is the largest producer of biogas in the EU while Greece is near the bottom of the table. Greece's key problem is the lack of an efficient and reliable supply chain. More specifically, the location of the waste production units for biogas production is scattered, fragmented and, in many cases, almost unknown.

Anaerobic co-digestion of different organic residues has been widely investigated to enhance digestion performance of biogas production and solids reduction (Liu et al., 2016; Xie et al., 2017). The most common co-digestion scenario is that a main basic feedstock (e.g. animal manure or sewage sludge) is mixed with a minor amount of a secondary feedstock (e.g. food waste, glycerin, cheese whey) to feed the digester (Maragkaki et al., 2017; Zhang et al., 2017).

The aim of this work was to examine, on a pilot scale and in continuous experiments, the effect of different waste mixtures available in Crete on methane production for bioenergy generation and to find environmentally friendly and economically feasible solutions to re-use and valorize the majority of agricultural wastes and by-products in Crete, Greece. The specific aim of the present work was to investigate biogas production for raw OMW mixed with varying amounts of PM and different liquid feedstocks (CW or LPM) in order to have a total solids (TS) ratio of approximately 10%. Moreover, the approach and results could facilitate the development of biogas production in other Mediterranean regions with similar sources of organic residues. Different substrate mixing ratios were evaluated in order to determine the most effective in terms of achieving the highest methane yield.

2. Materials and methods

2.1 Agro-industrial by-products and Feedstock

Initially, the reactor was inoculated with anaerobic sludge originating from the anaerobic digester of the Municipal Sewage Treatment Plant (MSTP) of the city of Heraklion. Liquid Pig Manure was collected from a local pig farm breeding 70 sows (Voutes, Crete). Fresh OMW used in the present study was obtained from an olive oil production plant located in Heraklion, which uses a three-phase decanter centrifugation process for the extraction of olive oil. Because of its seasonal production and tendency to ferment, in order to secure a constant feed composition throughout the experimentation period the OMW sample was stored in the freezer at -18 ^{o} C. The cheese whey (CW) was obtained from a local cheese factory located in the same region, using traditional technologies for cheese manufacture. Finally, fresh poultry manure was delivered from a battery chicken farm in Episkopi, Crete. Wastes were characterized and immediately frozen to avoid biological activity. OMW and PM were mixed with LPM or CW with a total solids (TS) ratio of approximately 10%.

2.2 Experimental procedure and operational parameters

Two types of influent feedstock were utilized: a mixture of 30 % v/v OMW and 70 % PM and LPM with a total solids (TS) ratio of approximately 10%, and a mixture of 40 % v/v of OMW and 60 % PM and CW in order to investigate the biogas production of olive oil by-products / poultry manure co-digestion. The continuous experiments were carried out in 220 L digester with 180L working volume. Initially, the reactor was inoculated with anaerobic sludge. Feedstock was added once daily, with a total feeding volume of 6 L daily and a hydraulic retention time (HRT) of 30 days, at a constant temperature of 35±2 ^{o}C. The co-substrate A was 30 % v/v OMW and 70 % PM and LPM with a total solids (TS) ratio of approximately 10% with an organic loading rate (OLR) 2.2 $kgVSm^{-3}d^{-1}$ (mean value 2.2 $kgVSm^{-3}d^{-1}$) (Reactor 1) and the co-substrate B was 40 % v/v OMW and 60 % PM and CW with a total solids (TS) ratio of approximately 10% with an OLR of 2.2 $kgVSm$-$^{3}d^{-1}$ (Reactor 2).

The digesters were not operated in parallel, so the OMW and PM originated at different periods. The digesters were operated for at least 2 subsequent HRTs under steady state conditions characterized by stable biogas production and relatively constant pH throughout the run. Influent and effluent samples were analyzed for TS, VS, pH, T-COD, d-COD and methane content in biogas.

2.4 Analytical methods

The influent and effluent were analyzed for pH and total (TS) and volatile (VS) solids according to APHA (1995) using a pH-meter (Crison, model GLP 21) and appropriate laboratory ovens. Total and dissolved chemical oxygen demand (T-COD and d-COD respectively) and total phosphorus (TP) were determined spectrophotometrically by use of standard test kits (Hach-Lange). Total nitrogen (TN) was measured with Semi-Micro-Kjeldahl Method according to standard methods (APHA, 1995). Biogas yield was monitored continuously by a gas flow meter (Ritter Company, drum type gas meters TG 05). Biogas composition was analyzed using a gas chromatograph (Agilent 6890N GC System). Analyses of all individual samples were carried out in triplicate. The statistical analysis of the data and the results of this study (analysis of average values, variance and standards deviation) were performed using Origin 9 (OriginLab, USA).

3. Results and Discussion

Two types of influent feedstock were utilized: a mixture of 30 % v/v OMW and 70 % PM and LPM and a mixture of 40 % v/v of OMW and 60 % PM and CW. The experiments showed that after co-digestion of 40 % v/v OMW and 60 % PM and CW, daily biogas increased from 0.7 ± 0.4 L/Lreactor/d to 1.2 ± 0.3 L/Lreactor/d, meaning that the increase of OMW and CW co-digestion improved biogas production by 1.7 times. The composition of the methane in the biogas was 60 ± 4.7 % for Mixture A and 61 ± 3.4 % for Mixture B (fig. 1). Reduction in the volatile solids ranged between 50 and 57 % while the average removal of dissolved chemical oxygen demand (COD) was 50% and 58% for the two examined scenarios. Therefore, co-digestion of OMW, PM and CW is an attractive treatment option for these wastes, because manure improves the buffer capacity of the mixture and a high methane yield can be achieved.

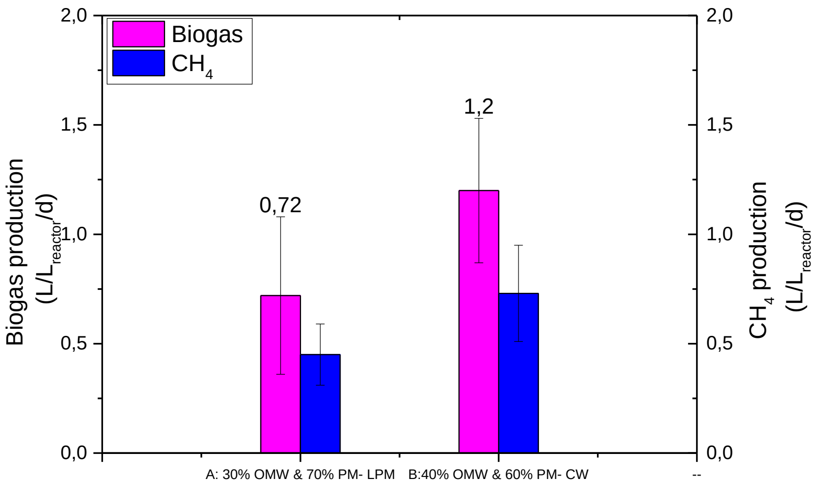

Figure 1. Mean values of Biogas & CH_4 production during the experiments.

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