Biogas production from co-digestion of food waste with liquid pig manure and olive mill wastewater

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1. Introduction

The increasing production of municipal solid waste (MSW) and its sustainable management are a major concern in many countries (Bong, et al. 2018). Food waste (FW) is one of the most important components of municipal solid waste. Yearly between 1,3 and 1,6 billion tons of food are lost along the food – supply chain, and this accounts for one third of the food produced globally for human consumption, affecting several natural resources (Braguglia, et al. 2018).

Anaerobic digestion (AD) is considered as one of the best environmental – friendly alternatives for the FW management, because of its limited environmental footprints, high potential for energy recovery producing carrier material for biofertilizers. The high biodegradability of food waste makes it a promising organic substrate for AD. Although, mono-digestion of food waste has been described as problematic, mainly because this substrate often leads to digester instability and even failure at higher organic loading rates (OLR, above 2.5 g VS/L/d), especially under thermophilic conditions, due to the accumulation of VFAs and ammonia inhibition (Xu, et al. 2018). In order to overcome the above problems, many researchers have proposed the co – digestion of food waste together with other wastes. The use of co-substrates usually improves the biogas yields from anaerobic digesters due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates (Mata-Alvarez et al., 2014). This article focuses on food waste and also on a representative, seasonally produced agro-industrial waste with high organic content found in Greece and other Mediterranean countries: olive mill wastewater. Since OMW is seasonally available, it can be treated in existing facilities that already digest FW.

2. Methodology – materials and methods

2.1 Agro – industrial by – products, food waste residues and feedstock

The olive mill wastewater (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. Food waste (FW) was collected from the students' restaurant at the Technological Educational Institute of Crete, Heraklion. The liquid pig manure (LPM) was obtained from a small farm located in Heraklion. Wastes were characterized and immediately frozen to avoid biological activity. All Feedstock was stored at -20 ^{o}C, during the whole experimentation period in order to maintain its physicochemical characteristics.

Two types of influent feedstock were utilized: **D1**: 75% LPM + 25% FW; **D2**: 75% LPM + 20% FW + 5% OMW. In order to prepare the different types of influent feedstock, a mechanical mixer (approximately 4.0 mm) was used in the beginning in order to homogenize the FW and then a household mixer was used to make the final influent feedstock of the three materials. The two types of feedstock were prepared every day with a total solids (TS) ratio of approximately 8%. The characteristics of the feedstock are summarized in Table 1

Table 1: Characteristics of experimental materials as feedstock

Parameters	**D1**: 75% PW + 25% FW	**D2**: 75% PW + 20% FW + 5% OMW
pH	6.7 ± 0.2	6.7 ± 0.1
TS (g/L)	82.9 ± 6.5	78.6 ± 6.9
VS (g/L)	73.5 ± 5.7	68.2 ± 5.2
TCOD (g/L)	108.5 ± 9.4	98.3 ± 17.1
d-COD (g/L)	36.1 ± 8.4	30.8 ± 8.2
N (g/L)	0.55 ± 0.05	0.47 ± 0.03

2.3 Experimental setup

The experiments were carried out in two 4 L (3 L working volume) lab – scale continuous stirred – tank reactors (CSTR). The reactor operated under mesophilic conditions (37 ± 2 ^{o}C). Initially, the reactor was inoculated with anaerobic sludge originating from the Municipal Sewage Treatment Plant (MSTP) of the city of Heraklion, and contained 21.3 g/L TS, 14.8 g/L VS and 39.2 g/L COD. The feedstock was prepared everyday and it was added once daily with a total feeding volume of 100 ml for a 4 L (3 L working volume) digester and a hydraulic retention time of 30 days.

2.4 Analytical methods

The influent and effluent were analyzed for pH and total (TS) and volatile (VS) solids and total nitrogen (TN) according to (APHA 1995) using an electrode (Crison, GLP 21) and appropriate laboratory ovens. Total and dissolved chemical oxygen demand (T-COD and d-COD respectively) were determined spectrophotometrically by use of standard test kits (Hach-Lange). Biogas yield was monitored on a daily basis by the water displacement method as described elsewhere in the literature. Biogas composition was analyzed using a gas chromatograph (Agilent 6890N GC System).

3. Results and discussion

All co-digestion experiments are exhibited a successful operation up to the loading rates and mixing ratios that were examined. The differences in biogas production, composition and COD, VS removal was very small which leads us to the conclusion that both feedstock have the same behavior in anaerobic digestion and we can replace the amount of FW with OMW without affecting the biogas production. The highest biogas production was observed in D1 digester with a value of 923 ± 207.9 ml/$L_{reactor}$/d. In contrast the highest biomethane production was observed in D2 digester with a value of 583.3 ± 139.6 ml/$L_{reactor}$/d.

Table 2: Biogas and biomethane production, biogas composition, COD and VS removal for the two digesters

Parameters	**D1**: 75% LPM + 25% FW	**D2**: 75% LPM + 20% FW + 5% OMW
Biogas production (ml/l/d)	922.98 ± 207.89	908.43 ± 190.46
Biogas composition (%) CH_4	62.27 ± 0.08	65.30 ± 0.05
Biomethane production (ml/l/d)	555.45 ± 150.50	583.26 ± 139.59
d-COD removal (%)	78.52	82.11
TCOD removal (%)	71.02	68.39
VS in (g/l)	73.5 ± 5.8	68.2 ± 5.2
VS out (g/l)	20.0 ± 3.6	22.2 ± 4.8
VS removal (%)	72.75	67.43

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