Improving Anaerobic Co-digestion of Sewage Sludge with Solar Dried Food Waste

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1. Introduction

Biogas production through anaerobic digestion is a well-established practice combing waste treatment with energy production. Among European countries, Germany is the largest producer of biogas, while on the other hand, Greece is near the end of the list. Although in 2010, the Greek state pledged to produce 350 MW of energy from biogas and biomass until 2020, by 2018 only 18.7% of this target had been achieved. The reason for this slow development in Greece compared to other European countries is the lack of an efficient and reliable supply chain of agricultural and organic residues. More specifically, Greek agro-industrial units that produce waste with added energy value are spatially scattered, which increases the cost of collection, transportation, and storage, thus rendering the viability of waste to energy conversion difficult. To overcome the high cost of logistics, some studies recommend biomass densification (Wang, et al., 2016).

Drying of these wastes reduce the mass and the volume of the waste and consequently the cost of storage, handling and transportation. Until now thermal drying method has been examined as a pre- treatment method in order to reduce the mass and the volume of wastes but it is characterized by high consumption of energy (Maragkaki, et al., 2018; (Alrawashdeh, 2018). Solar energy can play an active role in meeting the energy demand, reducing the cost of the drying process and protecting the environment.

According to the above, it is important to assess solar drying as a pretreatment method for storing wet feedstocks prior to use in anaerobic digestion. Consequently a series of laboratory experiments were performed in continuously – operating reactors at 37^{0}C, fed with solar dried food waste at various concentrations. The addition of solar dried food waste was equal to 20%, 30% and 40% increase of the initial VS influent of sewage sludge.

2. Methodology - materials and methods

2.1. Feedstock

Sewage sludge (SS) was the primary sludge originating from the Municipal Sewage Treatment Plant (MSTP) of the city of Heraklion (population about 200,000). Food waste (FW) used in the present study was collected from hotels in the Municipality of Heraklion. The FW composition was 12.8% fresh vegetables and salads, 3.3% bread and bakery, 51.2% fresh fruit, 3.4% meat and fish, 19.5% cooked meals and snacks, 1.7% dairy (excluding milk) and eggs, 0.1% desserts, 6.6% others and 1.5% impurities (on a wet – weight basis). FW was dried inside a solar greenhouse situated in a village outside Heraklion, Crete, Greece.

Four types of influent feedstock were utilized: **D1**: 100% SS; **D2**: SS + FW (20% increase of VS in D1 influent); **D3**: SS + FW (30% increase of VS in D1 influent); **D4**: SS + FW (40% increase of VS in D1 influent), in order to investigate the biogas production of this mixture in different concentrations and sludge co-digestion. The characteristics of the feedstock are summarized in Table 1.

Table 1: Characteristics of feedstocks used in this study

Parameters	D1	D2	D3	D4
pH	6.1 ± 0.3	5.9 ± 0.2	5.9 ± 0.2	5.8 ± 0.3
TS (g/L)	47.6 ± 7.0	55 ± 7.6	60.9 ± 8.6	65.6 ± 9.4
VS (g/L)	33.2 ± 3.7	39.6 ± 5	43.6 ± 4.5	47.5 ± 5.6
TCOD (g/L)	57.6 ± 12.6	72.9 ± 12.6	74.9 ± 13.9	78.0 ± 17.2

d-COD (g/L)	5.1 ± 2.5	10 ± 2.8	12.3 ± 3.2	14.7 ± 3.7
TKN (g/L)	1.9 ± 0.1	2.4 ± 0.3	2.6 ± 0.2	2.5 ± 0.4

2.2. Experimental setup

The greenhouse consists of four parallel concrete corridors 5 m wide and 10 m long, completely covered by a special plastic material resistant to unfavourable climatic conditions. Materials are mixed inside the greenhouse using a mixing engine (rotation drum) to prevent the formation of crusts and ensure an evenly granulate dry material and sufficient aeration of the dry material.

The experiments were carried out in four 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 34.1 g/L TS, 19.3 g/L VS and 30.4 g/L COD. The feedstock was prepared weekly and it was added once daily with a total feeding volume of 125 ml and a hydraulic retention time of 24 days.

2.3. 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

The addition of solar dried food waste in sewage sludge improve the biogas production in all cases. The reactor treating the sewage sludge produced biogas equal to 517 ml/$L_{reactor}$/d before the addition of solar dried food waste and 964 ml/$L_{reactor}$/d (D2), 991 ml/$L_{reactor}$/d (D3), 1045 ml/$L_{reactor}$/d. As a result, co-digestion of sewage sludge with solar dried food waste improved biogas production by 1.8 - 2 times. In all cases, biodegradability of mixtures estimated to be higher than 70%, while the VS removal was 53% for the maximum biogas production (40% increase of VS in D1 influent).

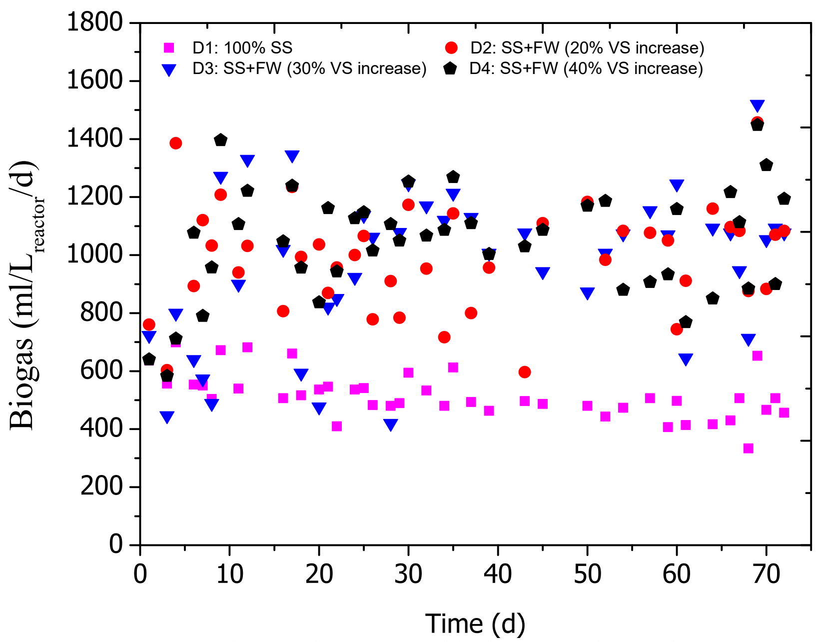

Figure 1: Biogas production during anaerobic digestion of SS and FW mixtures

4. Conclusions

It is well known that co-digesting food waste with sewage sludge increase biogas production significantly. But due to significant seasonal fluctuation of food waste it is difficult to use it in anaerobic digesters throughout the year. In this context, the possible use of solar drying as a pretreatment step for food waste stabilization prior to use in anaerobic digesters could increase the viability of the process. As a result, the solar dried materials will have reduced volumes and weights and could be stored for prolonged periods.

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References

Alrawashdeh, K. A. (2018). Improving Anaerobic Co-digestion of Sewage Sludge with Thermal Dried Olive Mill Wastewater. Waste and Biomass Valorization, pp. 2213–2219.

APHA, (2005). Standard Methods for the Examination of Water and Wastewater, 19th ed. American Public Health Association, Washington DC, USA

Maragkaki, A., Vasileiadis, I., Fountoulakis, M., Kyriakou, A., Lasaridi, K., & Manios, T. (2018). Improving biogas production from anaerobic co-digestion of sewage sludge with a thermal dried mixture of food waste, cheese whey and olive mill wastewate. Waste Management, pp. 644-651.

Wang, D., Huang, H., Shen, F., Zeng, Y., & Hu, Y. (2016). Effects of biomass densification on anaerobic digestion for biogas production. *RSC Advances*, 91748-91755.