Anaerobic Co-Digestion of olive oil wastewater with municipal solid and liquid waste: An Urban-Industrial symbiosis concept

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Abstract

The aim of this research was to explore the possibility for joint waste management from industry and municipality (Industrial-Urban Symbiosis (I-US)) through material and energy exchanges between municipality and industry and to improve the efficiency and environmental performance of biofuel production via such a combined waste valorization.

In particular, the production of methane from three waste streams (Olive Industry Wastewater (OIWW), Liquid Fraction of Food Waste (LFFW) and Municipal Wastewater (MWW)), through anaerobic digestion under mesophilic conditions was carried out using a 40L CSTR. The CSTR was started up with synthetic wastewater and in the sequel the feed was replaced by a real wastewater mixture. A feed composition of 91.7% MWW, 3.3% LFFW, 5% OIWW was found to be appropriate as higher percentages of OIWW proved to be detrimental to the operation of the reactor. The mixture fed to the reactor had a COD concentration of approximately 10,000 g/L and NaHCO3 was added in order to maintain the reactor pH at approximately 7.5. The HRT was initially 40d and was progressively reduced to 30d and 20d (feed flow rate of 1, 1.34 and 2 L/d respectively). The VSS of the reactor stabilized at an average of 3.4 g/L. The biogas production rate stabilized at approximately 6.3 L/d, very close to the theoretically predicted based on COD removal and the methane content was 79%. A soluble COD removal of approximately 98% was attained.

Keywords: gaseous biofuels, Industrial-Urban Symbiosis (I-US), food waste, olive oil waste water, wastewater

1. Introduction

Point-source pollution from olive oil industries operation is significant in the Mediterranean region, where more than 98% of global olive oil production occurs. Olive oil mills do not operate continuously, but only during winter months when olives are processed to oil, when huge quantities of untreated or partially treated olive mill wastewaters (OMW) reach adjacent aquatic system [1, 2].

On the other hand, food wastage and its accumulation are becoming a critical problem around the globe due to continuous increase of the world population. The exponential growth in food waste is imposing serious threats to our society like environmental, pollution, health risk, and scarcity of dumping land.

There is an urgent need to find appropriate solutions to reduce the food waste burden by adopting standard management waste practices. Currently, various approaches are investigated for food waste management. Anaerobic digestion is one of the most ecofriendly and promising solutions for food waste management, as it generates energy in the form of methane, contributing thus to the world's ever-increasing energy requirements [3, 4].

Industrial and urban symbiosis is a circular economy concept that is based on the fact that resources from one actor or process may become raw materials for another. Sharing resources between actors saves raw materials and energy, while reducing emissions and waste generation [5].

This study aims to produce methane from three different waste streams: Olive Industry Wastewater (OIWW), Liquid Fraction of Food Waste (LFFW) and Municipal Wastewater (MWW). These streams are collected from the area of West Achaia in Greece. The work is carried out in the framework of the Horizon Europe project SYMSITES [6].

2. Materials and Methods

The characteristics of the three waste streams (Olive Industry Wastewater (OIWW), Liquid Fraction of Food Waste (LFFW) and Municipal Wastewater (MWW) are given in Table 1. The LFFW was the liquid fraction generated by drying and shredding food waste. Throughout the experimental process pH, total alkalinity, Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), total and soluble Chemical Oxygen Demand (tCOD, sCOD), Volatile Fatty Acids (VFAs), biogas production and methane content were monitored in regular intervals, in order to assess the efficiency of the process.

Specifically, VFAs were measured using a gas chromatograph (SHIMADZU GC-2010 plus) equipped with a flame ionization detector and a capillary column

(Agilent technologies, 30 m x 0.53 mm ID x 1μm film, HP-FFAP) and a SHIMADZU AOC-20s autosampler.

Moreover, a GC-TCD (SHIMADZU GC-2014) was used for the measurement of methane content in the biogas generated.

Methane production from the three waste streams through anaerobic digestion under mesophilic conditions 35ºC was carried out using a 40L CSTR (Figure 1), operated at different HRTs with the following operational parameters (Table 2).

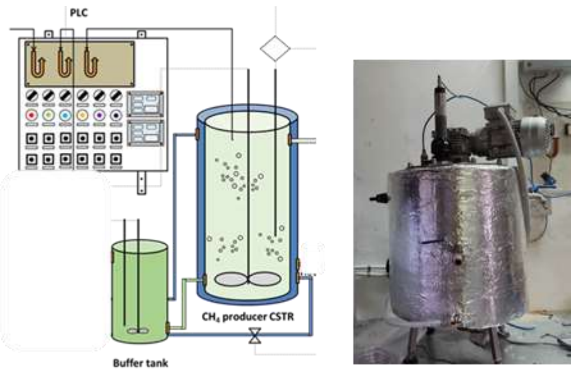

Figure 1. CSTR experimental set-up

The three waste streams

Table 1. Characterization of waste streams

Parameters	OIWW	LFFW	MWW	Feed
pH	3.7	3.5	7.0	7.4
TSS (mg/L)	70	75	220	490
VSS (mg/L)	40	75	165	180
sCOD (mg/L)	138000	13200	720	10000
TN (mg/L)	65	13	40	40
Phenols (mg/L)	145	13200	720	1103
TOC (mg/L)	46900			
VFAs (mg/L)	5240			

The reactor was started up with sludge from the Lykovrysi wastewater treatment plant in Athens, Greece and was initially fed with a glucose-based synthetic wastewater. It was subsequently switched to a mixed urban-industrial wastewater. The percentage of OIWW was initially set at 16.6% but as the reactor pH exhibited a substantial drop it was reduced to 5% in order to secure a safe operation.

The HRT was sequentially reduced from 40 to 30 and then to 20 d in the effort to reduce it as much as possible while maintaining a stable operation with low soluble COD at the effluent.

Table 2. CSTR Operational Parameters

Operational Parameters	
Reactor Type	CSTR
Reactor Volume	40 L
HRT	40 d, 30d, 20d
Feed flow rate	1L/d, 1.34 L/d, 2 L/d
Temperature	35 ºC

3. Results and Discussion

The level of alkalinity as shown in Figure 2 decreased as the HRT was decreased from 40d to 30d and then to 20 d.

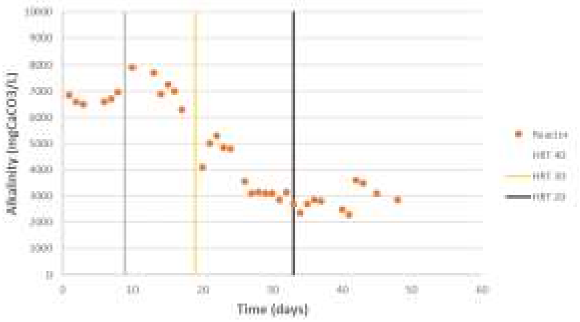

Figure 2. Alkalinity in the CSTR as a function of time

The level of Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS) as shown in Figure 3 was decreased as the HRT was decreased from 40d to 30d and 20 d.

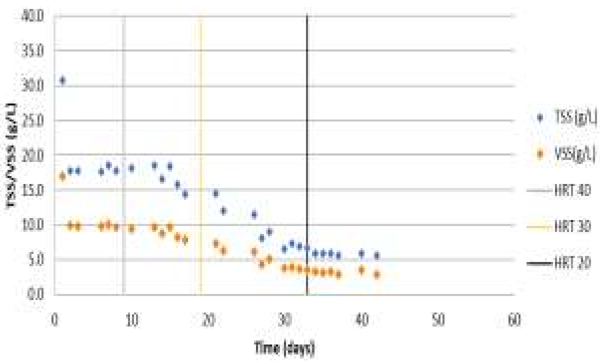

Figure 3. TSS and VSS in the CSTR as a function of time.

The variation of pH is presented in Figure 4 After day 10 a sharp decrease was observed due to a hydraulic malfunction of the system, As the problem was restored the reactor resumed stable operation and reactor pH was maintained at acceptable levels rhruoghout its operation.

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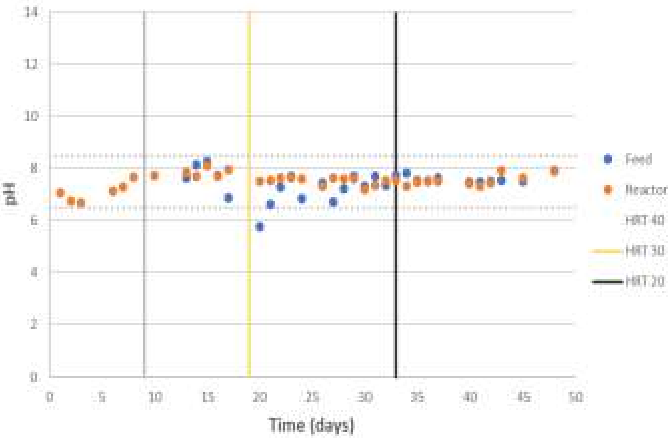

Figure 4. pH in the reactor as a function of time.

Figure 5 presents the variation of the soluble COD in the feed and in the reactor effluent. It is seen that it is kept at very low levels at all times, following the exhaustion for the HRT of 40 d

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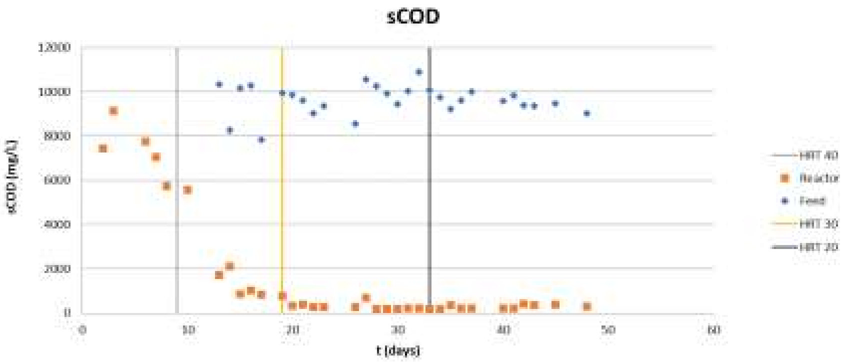

Figure 5. Soluble COD as a function of time.

Figure 6 presents the biogas and methane production rate as a function of time. The biogas production rate was decreased when the HRT was decreased and this is attributed to the reduction of the VSS in the reactor. Once a stable operation was established at the HRT of 20d, the mean biogas production rate was 8 L/d and the methane 6.3 L/d corresponding to a methane content of 79%. This is very close to the mean theoretical value calculated on the basis of COD removal.

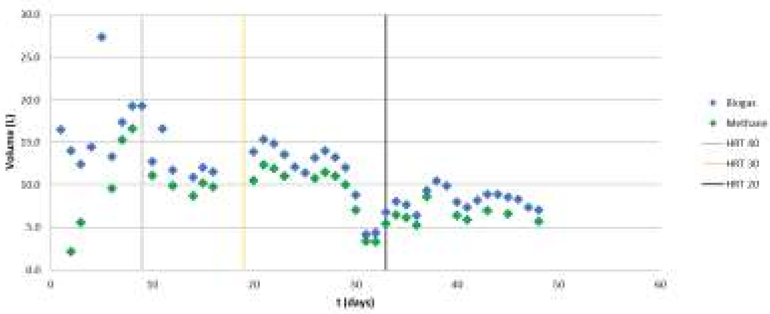

Figure 5. Biogas productivity as a function of time.

4. Conclusion

In this paper, we evaluated the efficiency of a methanogenic reactor, CSTR type, to handle a mixed industrial/municipal waste stream consisting of Olive Industry Wastewater (OIWW), Liquid Fraction of Food Waste (LFFW) and Municipal Wastewater (MWW). It was shown that the CSTR can operate at an HRT of 20 days without a problem when fed with a mixture having a COD of approximately 10g/L and a composition of 91.7% MWW, 3.3% LFFW, 5% OIWW. At this HRT the mean biogas production rate was 8 L/d and the mean methane content was 79%.

Overall, the co-digestion of these I-US waste streams in a CSTR reactor proves to be an effective anaerobic digestion system capable of processing anaerobically difficult waste streams while generating biomethane.

Acknowledgment

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