Enhancing the methane potential of the liquor obtained from enzymatic pre-treatment of sewage sludge by the addition of glycerin

L. Negral, E. Marañón*, L. Castrillón, Y. Fernández-Nava and P. Ormaechea

Chemical Engineering and Environmental Technology Department. University Technology Institute of Asturias (IUTA). University of Oviedo. Campus of Gijón. 33203 Gijón. Spain (E-mail: emara@uniovi.es)

Abstract

Inverted Phase Fermentation is a method for thickening sewage sludge that results in a clarified phase beneath a thickened fraction. An increased hydrolysis rate is obtained in both phases. The liquid phase or liquor was digested in UASB reactors. The optimum methane yield was obtained for hydraulic retention time of 1 day (0.32 m^3 CH_4/kg VS, 2.31 m^3 $CH_4/m^3_{reactor}$ day). When this liquor was co-digested with 1% (v/v) crude glycerin, the optimum methane yield was obtained when operating at hydraulic retention time of 2 days (0.67 m^3 CH_4/kg VS, 2.76 $m^3CH_4/m^3_{reactor}$ day). Co-digestion of the liquor with crude glycerin not only improved specific methane yield, but also organic matter biodegradation (up to 89% total COD and up to 76% VS removal).

Keywords

Inverted phase fermentation; sewage sludge; crude glycerin; anaerobic co-digestion

1. Introduction

Improvement of the hydrolysis step and co-digestion are strategies used to enhance anaerobic digestion of sewage sludge. Inverted Phase Fermentation (IPF) is an enzymatic treatment (42ºC, 48 hours under anaerobic conditions) which uses the enzymes present in sludge to enhance hydrolysis [1, 2]. Due to the generation of CO_2, IPF results in a clarified phase (liquor) beneath a thickened solid phase (concentration factors > 2). An increased hydrolysis rate is achieved in both phases. Another advantage of this treatment is that of achieving 99.9% destruction of *Escherichia coli* [3].

The addition of small amounts of glycerin as a co-substrate for anaerobic digestion provides an important source of "cheap" biodegradable carbon for microorganisms that leads to enhanced biogas production. However, the amount added for co-digestion must be low in order to avoid acidification in the reactors, due to high C/N ratios [2, 4]. This research study analyses the increase in methane yield in the sewage liquor when adding crude glycerin as co-substrate.

2. Experimental

Sewage sludge was heated to 42ºC during 48 hours under anaerobic condition to achieve hydrolysis by the endogenous enzymes. The CO_2 released concentrates the solids in an upper layer that can be separated from the bottom clarified layer (liquor). This liquor was removed for anaerobic digestion using UASB reactors operated under mesophilic conditions (at 37ºC) and different hydraulic residence times (different organic loading rates) were applied to find the optimum conditions. Co-digestion of the liquor with 1% v/v crude glycerin from a biodiesel plant was also studied. All the experiments were run by duplicate. Substrates and digestates from the reactors were characterised using standard methods. Biogas was measured on a thermal effect mass gas flow meter (HI-TECH F 101 D), the results being expressed at 0º C and 101.3 kPa. Biogas composition was analysed on an Agilent 7890A gas chromatograph.

3. Results and Discussion

Figure 1 plots the methane yields obtained in the mesophilic digestion of the liquor in UASB reactors for the different operating conditions (HRTs from 3 days to 0.75 days). The volumetric methane yield

increased when decreasing HRT until a maximum value of 2.3 m^3 $CH_4/m^3_{reactor}$day for HRT = 1 day. Lower HRT (0.8 and 0.75 days) led to instability of the process. With respect to the specific methane yield it can be observed than the maximum value was achieved operating at HRT = 2 days. It is worth noting that the higher the loading rate (the lower the HRT), the longer the time required for methane production to become stable.

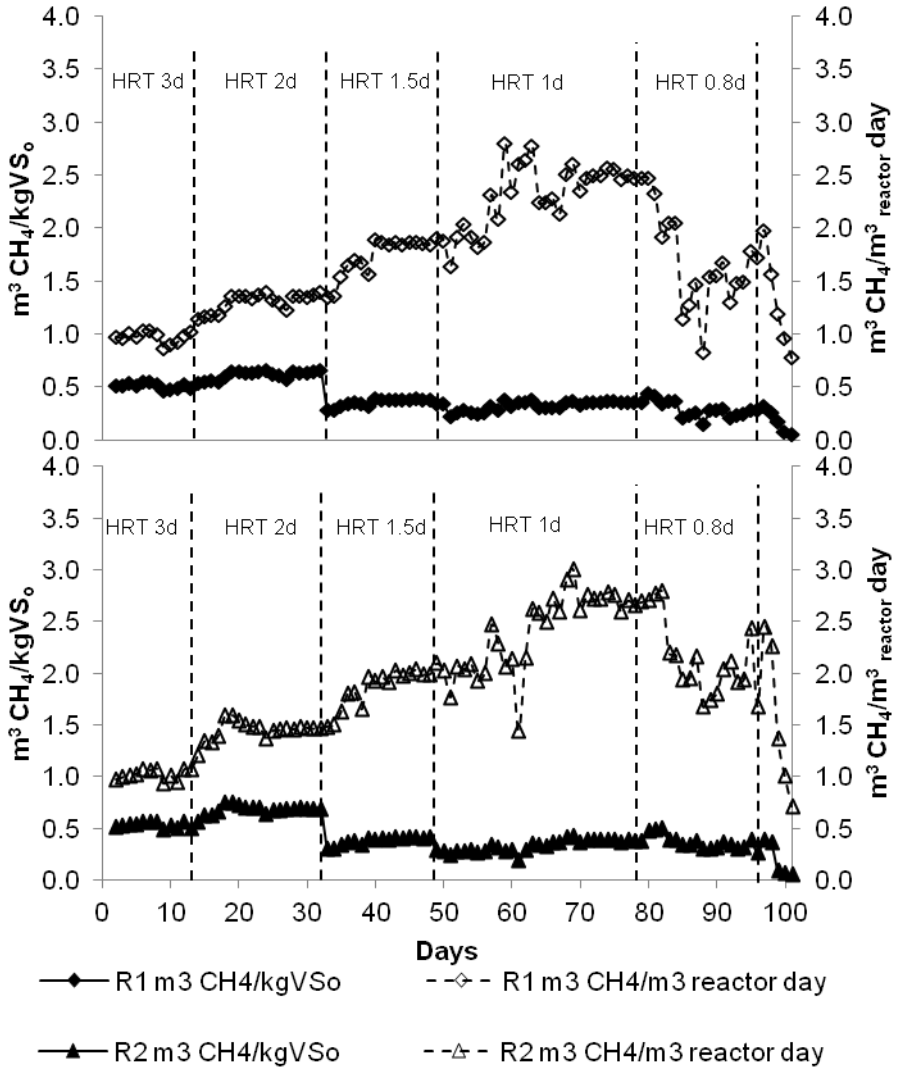

Figure 1. Methane yield in the mesophilic digestion of the liquor from hydrolysed sewage sludge in UASB reactors (R1, reactor 1; R2, reactor 2).

Figure 2 shows the results of the co-digestion of the liquor from IPF with 1% crude glycerin. As the organic loading for the mixture liquor-glycerin was higher than that for the liquor, 2 days was found to be the optimum in the co-digestion of liquor and glycerin. Lower or higher HRTs resulted in resulted in lower methane yields. The sensitivity to changes in HRT was higher than that observed in mono-substrate digestion. This behaviour was also found by other researchers in the co-digestion of sewage sludge and glycerin in CSTR [2].

The addition of glycerin enhanced biodegradation (89% versus 70% total COD removal, and 76% versus 39% VS removal), obtaining a specific methane yield of 0.67 versus 0.32 m^3/kg VS, which represents an increase of 109%. Optimum operating conditions were: 1 day HRT (OLR 18.5 kg COD/m^3day, 6.7 kg VS

kg VS/m^3day) for the liquor; and 2 days HRT (13.7 kg COD/m^3day, 4.6 kg VS/m^3day) when adding glycerin.

Table 1 shows the composition of the influent and effluent for the optimum operating conditions in the mesophilic anaerobic digestion of the hydrolysed sludge liquor and of the hydrolysed sludge liquor plus glycerin. Although the volumetric biogas yields were similar, the improvement resulting from co-digestion was clearly observed in terms of specific methane yields, supposing an increase of more than 100%. In terms of degradation efficiency, co-digestion with crude glycerin likewise improved the results: 89% versus 70% in total COD removal, and 76% versus 39% in VS removal.

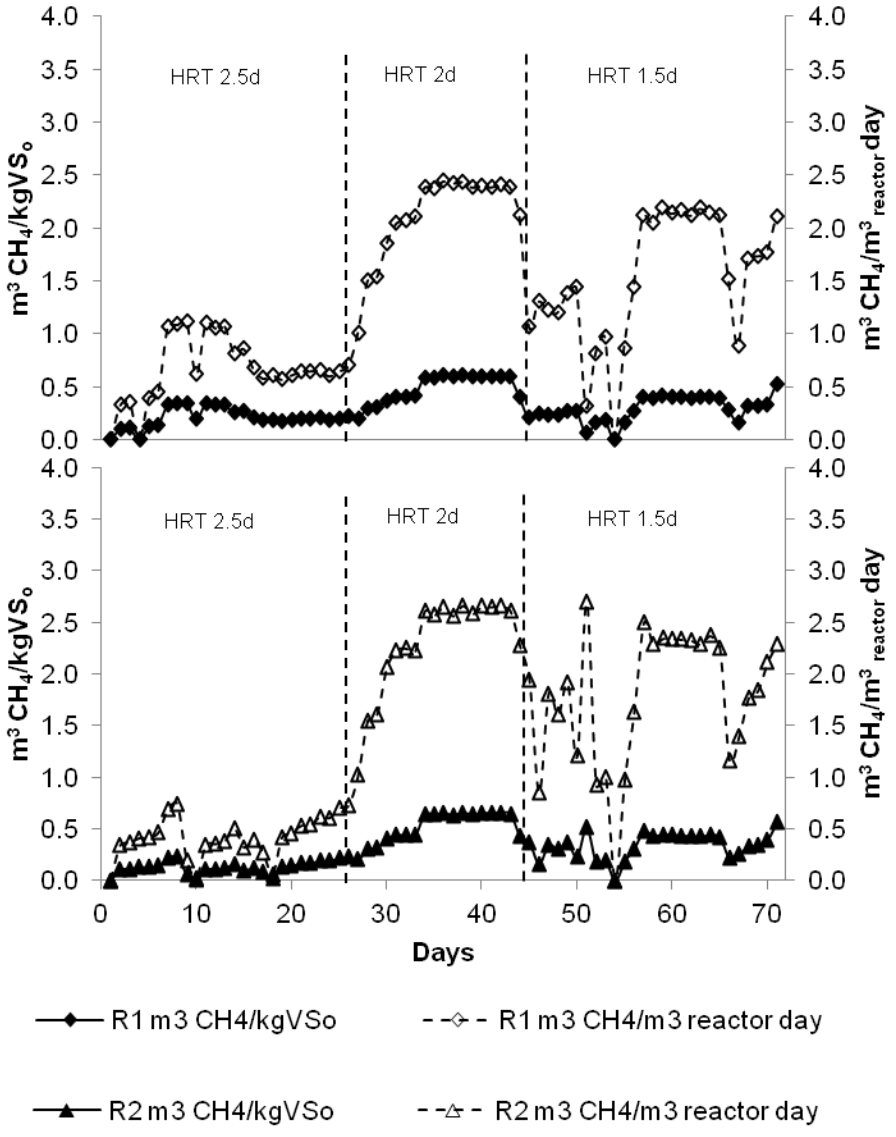

Figure 2. Methane yield in the mesophilic digestion of the liquor from hydrolysed sewage sludge + 1% glycerin in UASB reactors (R1, reactor 1; R2, reactor 2).

Table 1. Characterization of the influent and effluent from the UASB reactors for the optimum operating conditions in the digestion of hydrolysed sludge liquor with and without addition of glycerin as co-substrate (mean values for the two UASB reactors)

	Sludge Liquor HRT 1 day OLR = 18.5 kg COD/m^3day SLR = 6.7 kg VS/m^3day		**Sludge Liquor + 1% Glycerin** HRT 2 days OLR = 13.7 kg COD/m^3day SLR = 4.6 kg VS/m^3day	
	Influent	Effluent	Influent	Effluent
tCOD (g/kg)	18.46	5.51	27.36	3.11
sCOD (g/kg)	10.61	2.07	15.45	1.95
TS (g/kg)	10.17	6.24	10.65	3.98
VS (g/kg)	6.70	4.07	9.16	2.22
V.A. (kg/m^3)	1.85	0.12	1.33	0.07
m^3 biogas/kg VS	0.47		0.91	
m^3 CH_4/kg VS	0.32		0.67	
m^3 biogas/$m^3_{reactor}$day	3.35		3.77	
m^3 CH_4/$m^3_{reactor}$day	2.31		2.75	
% CH_4	69.0		73.0	

4. Conclusions

Endogenous enzymic hydrolysis of sludge may be applied as a pre-treatment to obtain a concentrated solid phase, which can be composted or digested, and a liquor very rich in volatile fatty acids, which can be biodegraded in one day, obtaining 0.32 m^3 CH_4/kg VS or which may be used as a source of raw materials. The methane yield can be increased to 0.67 m^3 CH_4/kg VS by adding small amounts of glycerin, though operating at higher HRT. The volumetric yield achieved was also higher for the co-digestion of the liquor and glycerine (2.75 m^3 CH_4/$m^3_{reactor}$day). Considering the results obtained, co-digestion of the sludge liquor with small amounts of crude glycerin may be an appropriate strategy for the valorisation of sewage sludge.

5. Acknowledgments

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7-ENV.2010.3.1.1-2 ENV) under Grant Agreement no. 265269. http://www.end-o-sludg.eu/

6. References

[1] Müller, J.A. 2001. *Water Science and Technology* **44** (10), 121-128.

[2] Fountoulakis, M.S., Petousi, I., Manios, T. 2010. *Waste Management* **30** (10), 1849-1853.

[3] Le, M.S., Hu, R., Tyrrel, S., Cartmell, E. 2008. *Aqua Enviro 13th European Biosolids and Organic Resources Conference.* Manchester, UK.

[4] Castrillón, L., Fernández-Nava, Y., Ormaechea, P., Marañón, E. 2013. *Bioresource Technology* **127**, 312-317.

[5] Castrillón, L., Marañón, E., Fernández Nava, Y., Ormaechea. P., Quiroga, G. 2013. *Bioresource Technology* **136**, 73-77.