ANAEROBIC CO-DIGESTION OF ORGANIC FRACTION OF MUNICIPAL SOLID WASTES AND INDUSTRIAL GREASES

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ABSTRACT

The potential of mesophilic anaerobic digestion for the treatment of residual grease through co-digestion with the organic fraction of municipal solid wastes (OFMSW) was evaluated. Co-digestion process was conducted in a pilot plant working in semi-continuous regime ('wet' process) in the mesophilic range (37 ºC). The hydraulic retention time was 17 days. During the start-up the digester was fed with simulated OFMSW (diluted dry pet food). When the designed organic load was reached, co-digestion process started. The grease used consisted of a waste from the food industry (animal grease), which composition was very similar to that of simulated OFMSW (especially in the long chain fatty acid (LCFA) profile). Grease content in the feedstock was gradually increased, and hence the organic loading, up to 28% with stable operation of the plant. Maintaining the organic loading under steady conditions, animal grease was substituted by vegetal grease. No accumulation of LCFA or volatile fatty acids (VFA) was detected in either case. Total grease removal throughout the experiment was over 88%. In conclusion, anaerobic co-digestion of OFMSW and fat wastes appears to be a suitable technology to treat such wastes, obtaining a renewable source of energy from biogas.
Keywords: *Anaerobic co-digestion; grease; OFMSW; LCFA.*

INTRODUCTION

The treatment of the residual greases is an important technical problem. Their economic recovery is often impracticable because of their association with tissue, soil or fecal matter (Li et al., 2002). Moreover, the amount of such wastes is increasing.

The lipids energetic potential and their biodegradability indicate that anaerobic digestion is one of the best treatment technologies for these wastes. During anaerobic digestion, the lipids are hydrolyzed to LCFA and glycerol. The resulting LCFAs are slowly degraded to VFA and hydrogen (Li et al., 2002, Lalman *et al*., 2001). Finally, VFAs are complete degraded to CH_4 and CO_2. The anaerobic digestion of lipidic wastes may also inhibit the anaerobic microbial activity because of the presence of dissolved LCFAs (Ahring et al., 1992). Some studies have established that a low concentration of 1 g/l LCFA in anaerobic digester is enough to cause an important process inhibition (Hanaki et al*.,* 1981, Angelidaki et al., 2002), although an adaptation period could allow high LCFA concentrations (Cavaleiro et al*.,* 2001). For this purpose, both obtaining a total balanced biomass and co-digesting the lipid wastes with another type of waste are effective measures to minimise the accumulation of LCFAs. Previous experience of co-digestion using fatty wastes has been reported. Ahring et al. (1992) studied the co-digestion of bentonite-bound oil (waste produced during cleanup and decolorization of vegetable oils) and different organic wastes whereas Li et al. (2002) proposed the possibility of treating residual greases through co-digestion with organic fraction of municipal solid wastes (OFMSW).

This paper presents an experimental study about the co-digestion of OFMSW with different residual greases of different composition. A semicontinuous mixed digestor of 14 l was used under mesophilic (37ºC) conditions.

MATERIALS AND METHODS

Substrate

Three different substrates were used in the pilot-plant studies. Synthetic OFMSW, which consisted of diluted dry pet food, and on the other hand, two kind of residual greases used as co-substrates. Pet food was chosen because of its nutritional similarity with OFMSW (fibre, protein and fat content). Residual greases were: animal grease waste from the food industry, which composition was very similar to that of simulated OFMSW (especially in the LCFA profile) and commercial vegetal grease. The main properties of substrates are shown in tables 1 and 2.

Table 1. *Physical properties of simulated OFMSW*

Substrate	Moisture (% wet basis)	Raw protein (% dry basis)	Raw grease (% dry basis)	Raw cellulose (% dry basis)	Ashes (% dry basis)	TVS (% of dry solids)
Pet food	9.0	21.0	10.0	3.3	7.0	91.0

Table 2. *Main LCFA profile for the grease from different substrates*

Source of grease	LCFA profile (%)				
	Lauric	Mystiric	Palmitic	Stearic	Oleic
Pet food	0	2.2	33.0	15	34.0
Food industry	0	3.0	30.0	17	38.0
Vegetal	45.5	18.5	10.4	3	8.7

Reactor configuration and operation

A semi-continuous, completely mixed reactor with a working volume of 14 l was used for the anaerobic digestion of wastes. The digester was inoculated with sludge from an industrial-scale anaerobic digestion plant treating municipal solid wastes (MSW). The temperature of the tank was kept to 37ºC to guarantee mesophilic conditions. The substrate for digester was fed 4 times a day using a time-controlled feed pump and a recirculation system was started 6 hours a day. The hydraulic retention time (HRT) was maintained during all the experiments to 17 days.

During the start-up, the influent organic load was increased from 0.55 to 2.57 $kgTVS\cdot m^{-3}\cdot day^{-1}$, using diluted pet food, to find the optimal value. After seven HRT under stable conditions, the co-digestion process was started using the animal grease. When grease content of influent reached up to 28%, vegetal grease was introduced instead of food waste maintaining the organic load.

For each experimental condition, the reactor was continuously operated for at least one or two times of HRT to reach the steady state.

Analytical methods

The feed and digester content were analysed 2 to 3 times a week. Total solids (TS), volatile total solids (TVS), pH, alkalinity and chemical oxygen demand (COD) were determined according to the *Standard Methods* (19 Th Edition). The total biogas production was daily measured. On the other hand, biogas composition was analysed by gas chromatography with a thermal conductivity detector (TCD) (Hayesep column 3m 1/8” and 100/120). The profiles of VFA and LCFA were determined by GC with flame ionization detector (FID) (HP Innowax capillary column 30m x 0.25mm x 0.25mm). The quantification of the total lipid content was carried out using a Soxlet method.

RESULTS AND DISCUSSION

Start-up process

Figure 1 illustrates the performance of the process. During start-up, the organic loading was weekly increased at a 10% rate. According to figure 1, acidification of the digester and a significant decrease in the removal efficiencies of TVS was detected with organic loading higher than 2.1 kg $TVS \cdot m^{-3} \cdot day^{-1}$. Therefore, an organic loading of 0.97 kg $TVS/m^3 \cdot day$ was fixed as the most appropriate for steady. In this way, the organic load increase due to the co-digestion process never reached the critical value.

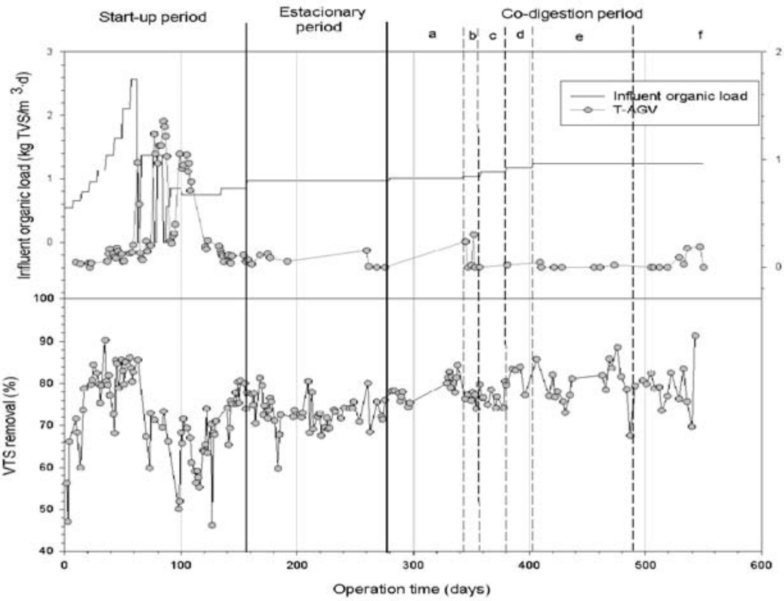

***Figure 1**. Performance of digester in set-up and co-digestion process*

Co-digestion process

After a stationary period working at fixed organic load, the co-digestion process was started with food industry grease. The influent lipid content was gradually increased up to 28% and hence the organic load. Figure 1 shows the performance of digester with 4, 7, 14, 21 and 28 % of influent grease content, corresponding to *a, b, c, d* and *e* periods respectively. When co-digestion process started, the biogas yield decreased from 0.44 to 0.35 m^3CH_4/kg TVS removed (table 3). After 68 days (four times of HRT) for biogas yield recovery and biomass adaptation, grease content was increased again. No acidification problems were detected, even operating with 28% of grease content. Moreover, both the CH_4 biogas content and the total grease removal followed a progressive increase whereas the biogas yield was kept over 0.36 m^3CH_4/kg TVS removed.

When food industry grease was replaced by vegetable one (*f* period in figure 1), no system instability was detected. Although the biogas yield increased considerably, the CH_4 content was held (table 3). Therefore, energetic recovery was higher than with co-digestion with the animal grease. This point is probably caused by a grease removal increase and a different LCFA profile. The concentration of dissolved LCFA was low during all the study (less than 15 mg/l).

Table 3*. Operational conditions during the co-digestion of OFMSW and residual grease.*

Grease in influent* (%)	Theoretical organic load (kg TVS/m^3·day)	% CH_4 in biogas	Biogas production (m^3 CH_4/kg TVS removed)	Grease removal (%)
0	0.97	58.3	0.44	-
4	1.01	58.3	0.35	-
7	1.04	55.9	0.32	87.9
14	1.11	57.2	0.42	90.0
21	1.17	59.0	0.32	95.1
28	1.24	61.0	0.39	94.0
28**	1.24	61.0	0.44	97.0

* *Without considering the 10% of grease in pet food*
** *Corresponding to vegetable grease*

CONCLUSIONS

The main conclusions based on the results from this study are summarized below:

1.- During the start-up process, the maximum organic loading rate for anaerobic digestion of the simulated OFMSW used was below 2.1 kg TVS/m^3·day.

2.- Anaerobic co-digestion process appears to be a suitable technology to treat lipid content wastes. Over 88% of influent grease were degraded without acidification problems or soluble LCFA accumulation. As a result, the CH_4 biogas proportion was increased when the influent grease content was high.

3.- An anaerobic digestor with a biomass adapted to one kind of grease can treat other grease with different profile without neither acclimatisation process nor process efficiency losses.

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