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FULL-SCALE COMBINATION OF ANAEROBIC DIGESTION AND CONCENTRATION BY EVAPORATION IN *GARRIGUES* (LLEIDA, SPAIN): EVALUATION AFTER 2 YEARS OF OPERATION

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ABSTRACT

Evaporation process is a reliable strategy to manage pig slurry, removing water and recovering nutrients by concentration. The described treatment plant, TRACJUSA, applies the VALPUREN™ process, which is based on the combination of anaerobic digestion and evaporation. The benefits of this combined process have been previously reported at laboratory scale. This paper studies the influence of anaerobic digestion on the general process after two years of full-scale operation.

Biogas yield is highly correlated with the OLR of pig slurry and with the COD/VS ratio, which is a function of slurry characteristics and farm management practices. The key of the evaporation process is to concentrate nutrients what allows to obtain a high-quality condensate that can be reused. The influence of VFA content in the effluent of anaerobic digestion was studied together with the influence of acidification step, which occurs before evaporation. It can be concluded that farm management, stable anaerobic digestion, and acidification step prior evaporation, are the main factors that influence the successful performance of a centralized treatment plant of this kind.

Keywords. Anaerobic digestion; pig slurry; post-treatment; evaporation.

INTRODUCTION

The northern part of *Garrigues* county (Lleida, Spain) presents a large nitrogen surplus from pig slurry. Redistribution of this slurry is limited by transport and spreading costs, due to its high water content and relatively low nutrient concentration. Based on waste management planning, it was concluded that centralized treatment plants were a need. The technology applied was the VALPUREN™ process (P9900761), which involves anaerobic digestion followed by phase separation, acidification and water evaporation of the liquid fraction, and solid fraction drying. The plant started operating in 2001 and currently serves more than 90 farms. The flow diagram of the plant is described in Burton and Turner (2003). Anaerobic digestion prior to evaporation presents several advantages as previously reported by Bonmatí and Flotats (2003): (1) to provide a part of the energy required, (2) to remove volatile organic matter, providing evaporation free condensates, or almost free, of organic matter. Another key process is the fall in pH in the acidification step prior to evaporation that ensures a low concentration of free ammonia in slurry, and prevents its volatilisation.

The aims of this paper are: (1) to evaluate the combination of anaerobic digestion-evaporation processes at industrial plant scale, (2) to evaluate the influence of the plant inflow characteristics on the anaerobic digestion process, and (3) to evaluate the anaerobic digestion process of the framework plant's general operation.

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MATERIALS AND METHODS

Samples from the plant's storage tanks (inflow), digested slurry and condensates from the evaporator were all analysed. The study period was from June to November 2003, when the variations of some operational parameters allowed analysing its significance on the plant performance.

Volatile solids (VS), volatile suspended solids (VSS), chemical oxygen demand (COD), biological oxygen demand (BOD), total Kjeldhal nitrogen (TKN), ammonia nitrogen (NH_4^+-N) and pH were analysed according to Standard Methods (APHA, 1995). Volatile fatty acids (VFA) in digested slurry were determined by gas chromatography (FFAP capillary column and FID). Biogas composition was determined by gas chromatography (PORAPAK-N packed column and TCD). The qualitative composition of evaporation condensates was determined by gas chromatography (DB5MS capillary column with MSD). A batch anaerobic biodegradability test, ABT (based on Field *et al.,* 1988), and an inoculum activity test, IAT (adapted from Soto *et al.,* 1993, methanogenic activity test), were performed.

RESULTS AND DISCUSSION

During the study period the volumetric biogas production (B, *m^3 biogas/day*) and biogas yield (Y, *m^3 biogas/kg VS added*) obtained at the TRACJUSA plant (Figure 1) were lower than values quoted in literature (Chynoweth *et al.*, 1998). Several different factors could be proposed to explain those low values: (1) the high NH_4^+-N content of the inflow, (2) organic overloading, (3) the presence of toxics or inhibitory compounds, (4) the low methanogenic activity of inoculum or (5) the low biodegradability of substrate. Figure 1 shows the evolution of B, organic loading rate (OLR) and VFA content. According to Figure 1, there seemed to be a correlation between B and OLR. When OLR increased, there was an immediate effect on B values. But there was a period of time from August to September (between the arrows in Figure 1) when an increase in OLR (up to *2.5 kg VS/m^3 day*) did not imply a corresponding increase in B of the order observed in the rest of the period studied. A correlation between Y and OLR is shown in Figure 2. As expected, Y falls as OLR rises, but the differences between the slopes indicates different behaviours.

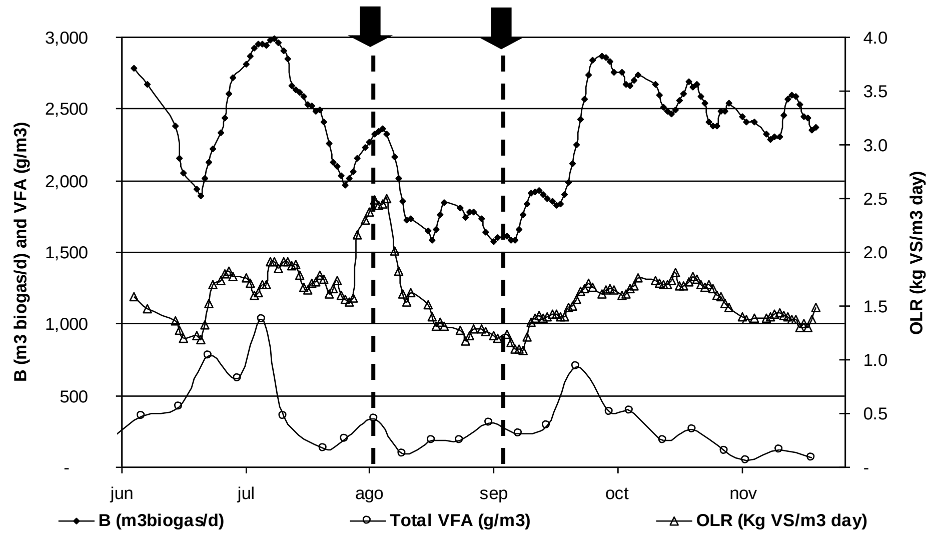

Figure 1. Evolution of B, OLR and VFA (June-November 2003)

Non-significant accumulation of *acetate* as an indicator of ammonia inhibition (Campos, 2001) and *iso-butyrate* as an indicator of overloading (Ahring *et al.*, 1995), and the

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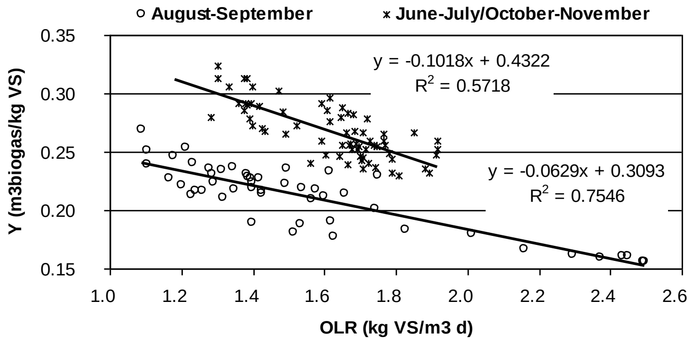

Figure 2. Correlation between Y and OLR

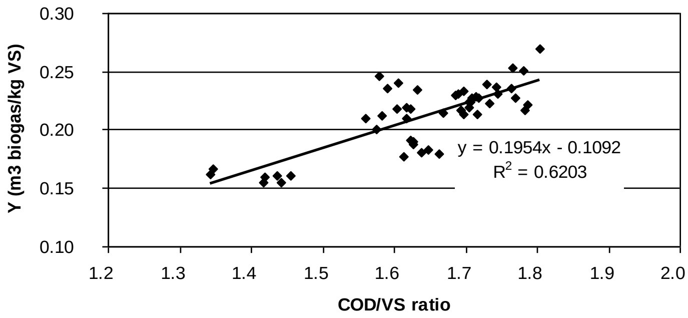

Figure 3. Correlation between Y and COD/VS ratio

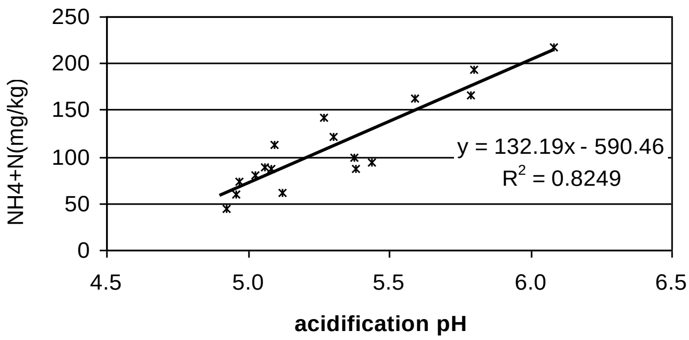

Figure 4. Correlation between NH_4^+-N in condensates and acidification pH.

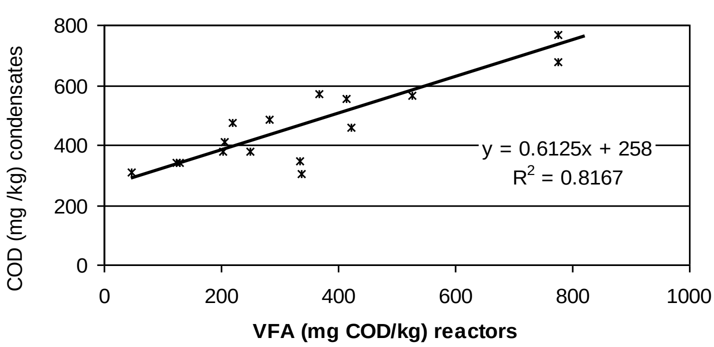

Figure 5. Correlation between COD in condensates and VFA in anaerobic reactors

results of the IAT, experiments carried out on September 2003 (data not shown), suggest that the most probable reason for the low productivity was the low biodegradability of the substrate. To check this hypothesis an ABT experiment was performed in September 2003. A relatively low biodegradability index (*46.34%*) was reported, in comparison with previous ABT assays on TRACJUSA inflow (*59.8%* biodegradability reported in 2001). This low biodegradability tested implies low potential biogas production, *10.77* m^3 *biogas/ton* (from ABT), which is consistent with the low productions reported.

Based on the results from the tests performed and the correlation shown in Figure 2, it was concluded that differences in behaviour observed from one period to another were not due to the OLR, but rather to the characteristics or biodegradability of the inflow. Summer 2003 was one of the hottest in *Garrigues* and farm storage remained at maximum levels until November, with a retention time of over 4-5 months. These circumstances provide optimal conditions for transforming long-term manure storages into anaerobic digesters (Husted, 1994). Literature decreases of *75%* in Y from pig slurries stored for long periods have been reported (Bonmatí *et al.*, 2001). A correlation between Y and the COD/VS ratio (from August to September 2003) was found to be an indicator of the inflow degradation state (Figure 3).

A correlation between concentration of NH_4^+-N in the condensates and pH reduction during acidification was derived from the plant analyses for July to November 2003 (Figure 4). As expected, the higher levels of slurry pH produced higher concentrations of NH_4^+-N in condensates.

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Other components present in pig slurry that could be responsible for producing poor quality condensates (organic matter contamination) include VFA, which are a result of a non-stabilized anaerobic digestion (Ahring *et al., 1*995). Furthermore, reducing pH to avoid free ammonia (NH_3-N) losses increases the un-ionised VFA fraction, which is more volatile. As expected (Figure 5), the higher VFA concentration in the digested outflow, the greater the level of organic pollution in condensate.

The condensates were analysed to determine their composition. About *55%* of total COD in the condensates was BOD, which corresponded to the VFA content of the anaerobic digestion outflow. The main compounds of the remaining fraction were aromatic compounds: *1 H-Indole 3-methyl* (*Skatol*) and *Diethyl Phthalate*, which explained the BOD/COD ratio.

CONCLUSIONS

After 2 years of full-plant operation, a stabilized anaerobic digestion and acidification before evaporation have been shown to be the keys factors involved in plant operation. The low biodegradability of the inflow must be taken into account in order to adapt manure management at the farm level and to design the appropriate slurry supply logistics for the centralized plant. Good farm management correlated highly with successful plant performance. It is necessary to maintain a stabilized anaerobic digestion process, not only for successful biogas production, but also for the evaporation process. The consumption of organic matter during anaerobic digestion and the fixing of ammonia nitrogen during acidification reduce its volatilisation during evaporation and therefore produce higher quality condensates, that can be reused in plant operations.

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