THE (RE)USE OF MECHANICAL SEPARATED SOLID FRACTION OF DIGESTED OR NOT DIGESTED SLURRY IN ANAEROBIC DIGESTION PLANTS

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1 INTRODUCTION

Treated effluent from anaerobic digestion (known as digstate) is mainly constituted from water (over 90%) and with a low content of residual substrate and inorganic compounds (Palm, 2008). It is generally stored in uncovered tanks and regularly land applied as organic fertilizer, or mixed with water for crop irrigation. Digestate management can cause problems as the volumes daily produced are high and, in some cases, storage tanks have insufficient capacity to hold the volumes produced over the required period. Moreover, digestate transport to fields sometimes far away from the farm centre can be very expensive. For these reasons, in many Italian anaerobic digestion plants, digestate is mechanically separated in order to obtain a solid and a liquid fraction (Balsari and Menardo, 2009). The liquid phase contains most of the potassium and ammoniacal nitrogen, whereas the solid fraction mainly contains the insoluble organic matter compounds and the phosphorus (Kaparaju and Rintala, 2005; Jorgensen and Jensen, 2009). Since the solid fraction still retains a high amount of volatile solids (Moller et al., 2007) it could be used as a feedstock for anaerobic digestion plants. The present study was carried out with the aim to assess the biogas and methane yield of five different mechanically separated solid fractions of co-digested slurry and of a solid fraction sample from the mechanic separation of raw pig slurry.

2 MATERIALS AND METHODS

Five solid fraction samples (labelled samples A, B, C, D and E) were collected from separators of the digestate following 3 biogas plants working in mesophilic conditions (~40°C) A sixth sample of (F) was taken from separated raw manure from a pig breeding farm (sample F).

The main biogas plants characteristics are listed below:

- samples A and B: from a biogas plant fed with cattle manure (70%) and energy crops (30%) and with an hydraulic retention time (HRT) of 100 days; sample A was taken during winter when the organic loading rate (OLR) was 1.09 kg VS/m^3 of digester per day and sample B in spring (OLR=1.17 kgSV/m^3 of digester per day).
- samples C and D: from a second plant fed with pig slurry (80%) and energy crops (20%) and with an HRT of 60 days; sample C was taken during winter (OLR=1.95 kgSV/m^3 of digester per day) and sample D in summer (OLR=2.47 kgSV/m^3 of digester per day).
- sample E: was from a plant fed with cattle manure (60%), energy crops (30%) and agro-industrial by-products (10%) and with an HRT of 100 days; the sample was picked up in spring (OLR=1.48 kgSV/m^3 of digester per day).

Samples A, B, D, E and F were obtained by screw press separators, whereas sample C was obtained by a one stage rotating separator. For both separator types a mean separation efficiency, in terms of mass, of about 20% (Moller et al., 2000) was used. Batch measurements for ultimate gas yield were carried out in laboratory according to Stardard VDI 4630 (2006), following the procedure described in Dinuccio et al. (2010). Glass digesters of two litres are connected to aluminium gas bags for the collection of the produced biogas (Figure 1) . All digesters were manually stirred twice a day. Each sample was made up of a mixture of biomass and inoculum (digested slurry collected from a co-digestion plant), in a 2:1 ratio calculated on the basis of volatile solids content. All samples were digested in triplicate. Control samples represented by inoculum alone were also digested in batch. The biogas volume produced by the control was afterwards subtracted from the solid fraction samples yield.

Incubations were carried out at 40°C over 60 days. Before the beginning of the measurements, each sample was analysed for pH, total solids (TS), volatile solids (VS), total nitrogen (N), neutral detergent fiber (NDF) and fats (EE) determination.

FIGURE 1 **Batch reactors used for the trials.**

The pH was measured by a *Hanna HI 9026* portable pH meter with a glass electrode combined with a thermal automatic compensation system. Total solids were determined by drying samples over 24 hours at 105°C. Volatile solids were determined after 4 hours at 550°C in a muffle furnace (AOAC, 2000). Nitrogen was determined by elementary analyzer. NDF was determined by Van Soest method (1991). Fats were determined through the Soxlet (AOAC, 2000). Biogas and methane yields were daily monitored during the whole period of the experiment. The biogas composition was analysed by a Draeger XAM 7000 analyser with infrared sensors, whereas biogas volume was determined by a Ritter Drum-type Gas Meter type TG05/5 volume meter. The daily biogas and methane yields were normalized to 0 °C and 1013 hPa. The specific yields of biogas and methane were afterwards expressed as NL/kgSV. In order to obtain the net biogas production of the tested samples, the biogas yield produced by the inoculum alone was subtracted from the total biogas yield measured from each replicate. The correlation between biogas yield and biomass main chemical parameters was determined by Pearson "r" correlation coefficient.

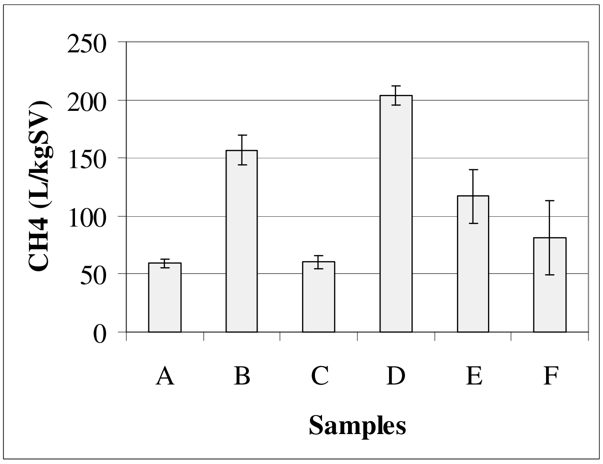
3 RESULTS AND DISCUSSION

The main chemical characteristics of the samples used in the trials are reported in table 1.

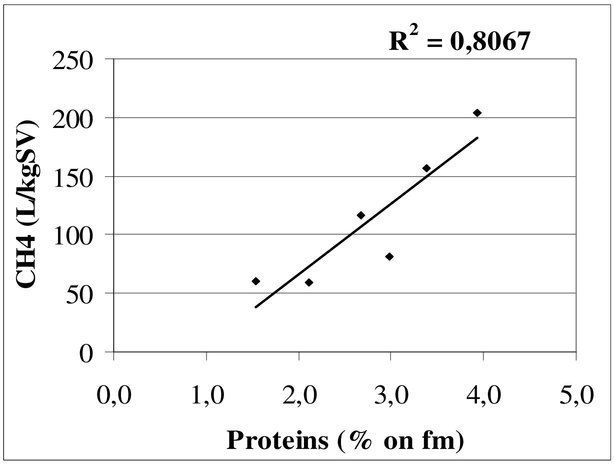
TABLE 1 **Main chemical parameters of the separated solid fraction of digested and not digested slurry ([1] data are expressed on dry matter).**

Parameter	A	B	C	D	E	F
pH	9.0	8.6	9.0	8.5	8.8	8.6
TS (%)[1]	21.6	28.8	18.4	22.1	21.6	25.8
VS (%)[1]	83.5	88.4	88.3	85.8	83.9	70.6
PROTEINS (%)[1]	9.8	11.7	12.4	17.7	11.6	12.4
N (%)[1]	1.9	2.5	3.1	3.1	2.8	2.9
NDF (%)[1]	76.7	75.7	76.8	73.0	69.7	63.3
EE (%)[1]	0.35	0.52	1.00	0.32	0.40	0.89

The specific CH_4 yields obtained from the samples were variable (Figure 2a). Samples B and D were the most productive ones: 156.9 L/kgSV and 203.8 L/kgSV respectively. The other biogas yields, in decreasing order, were 116.9 L/kgSV (sample E), 81.0 L/kgSV (sample F), 60.3 L/kgSV (sample C) and 59.3 L/kgSV (sample A). These latter were consistent with similar results obtained in other studies (Moller et al., 2004; Moller et al., 2007). There was no significant correlation between the CH_4 yields and the EE content, probably because the EE percentage was very low (<1.00%) in all samples. The NDF parameter, which represents the sum of fibre and lignin (organic compound not digestible by bacteria), was significantly and negatively correlated (α=0.01) with the specific CH_4 yields of the samples, as expected (Al-Masri, 2001). Conversely, the specific biogas and CH_4 yields were positively and significantly correlated (α=0.05) with proteins content (figure 2b). This indicates that the fraction of the organic compound digested was represented by protein fraction. This is consistent with the percentage of the volatile solids digested during the batch anaerobic process, which was included between 9.4 and 26.7%. The absence of correlation with the other parameters could confirm that the digested volatile solids fraction was mainly represented by proteins.



a)



b)

FIGURE 2 **a) Specific CH_4 yields of the separated solid fraction samples analyzed. b) Correlation between CH_4 specific yields of the separated solid fraction samples analyzed and the proteins, expressed as percentage on the fresh dry matter**

Figure 3 shows the daily pattern of CH_4 production measured from the tested samples. Samples B, D and E showed a quick increase of CH_4 production within the first 5 days, whereas a slower increase was measured from the other ones. In detail, sample F, obtained from the fresh slurry, showed a very slow increase of the methane production and a peak only after 15 days from the beginning of the trial. The most productive samples showed a slow decrease of methane yield and a slight production was still observed in the very last days of the trial. The digestibility degree of organic matter for anaerobic microbial flora affected the increasing of the specific and the cumulative CH_4 yields of these samples. CH_4 yields measured from pairs of samples collected at the same AD plants (samples A & B, and C & D) also differed. . The CH_4 yield of sample B was almost 3 time higher than the one of sample A, whereas CH_4 yield of sample D was 3 time higher than the one measured from sample C. The HRT of these plants was similar for at each sampling time. This indicates that, the difference between these samples, in terms of CH_4 yields, was not strictly linked with the HRT of the plants. This difference was probably due to the plant specific organic loading rate which, instead, was changed at the two sampling times. The solid fractions with an higher CH_4 yield (B and D) were both sampled when the digester was fed with the upper OLR (1.17 $kgSV/m^3$ of digester per day, sample B and 2,47 $kgSV/m^3$ of digester per day, sample D), whereas the solid fraction with the lower yields were collected when the digester was fed with the lowest OLR (1.09 $kgSV/m^3$ of digester per day, sample A and 1,95 $kgSV/m^3$ of digester per day, sample C). Nevertheless, this correlation between the plant OLR and CH_4 yield of the solid fractions is only evident between samples collected at the same plant. This was probably due to the different feedstock used to feed the digesters. The comparison with a separated solid fraction of fresh pig slurry showed that its separated solid fraction had a quite high content in less digestible volatile solids, probably as the greater amount of easy digestable volatile solids remained as a soluble form into the liquid fraction. Moller et al. (2007) reported that, although the VS content of separated solid fraction of pig manure is higher than liquid one, the specific CH_4 yield is only a bit higher than liquid fraction, due to a small content of particles highly digestible in the separated solid fraction.

4 CONCLUSIONS

The re(use) of the separated solid fraction as a feedstock to produce methane through the anaerobic digestion of organic matter is an interesting possibility, but it needs a specific evaluation of the digestate. The organic loading rate and the feedstock used to feed the anaerobic plant greatly affects the residual CH_4 potential of the digested separated solid fractions.

In anaerobic digestion plants where the organic loading rate is high and the HRT is short, it is expected to obtain a digested solid fraction quite productive in terms of biogas and methane. Especially in this case, it could be economic advantageous the reuse the separated solid fraction as a feedstock to a biogas plant and to collect its residual CH_4 production. According to the results obtained from this study, the (re)use of the mechanically separated digested solid fraction into the digester can improve the total anaerobic digestion plant CH_4 production by between 4% and 8%.

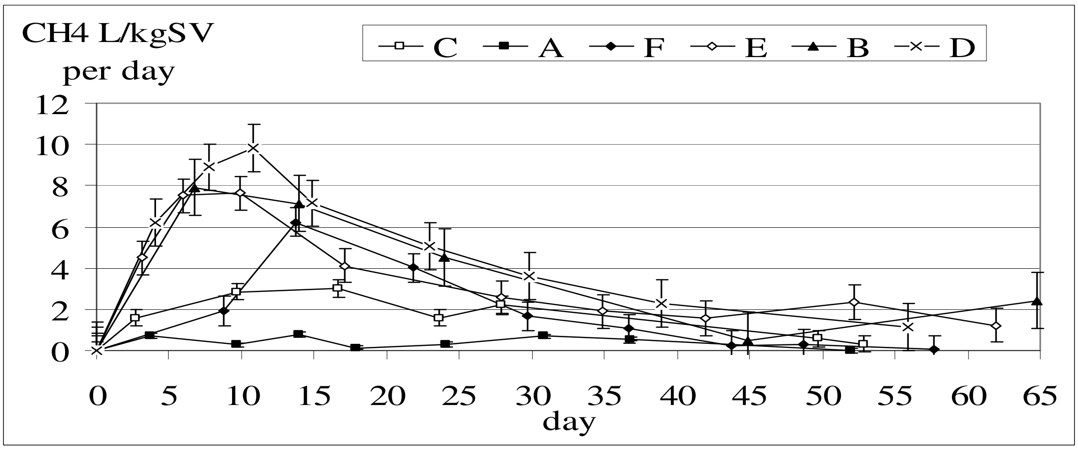


FIGURE 3 **Trend of the CH_4 daily gas production of the six separated solid fraction samples.**

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