



Effect of mechanical separation on emissions during storage of two anaerobically codigested animal slurries



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ABSTRACT

Emissions of ammonia and greenhouse gases from animal manure are an environmental concern and new techniques should be carefully examined to establish their effect on emissions across the whole management continuum, including storage operations. Biogas plants are becoming more common at farm facilities and the management of digestate raises some concerns regarding potential emissions to the air when mechanical separation is adopted. The aim of this study was to evaluate how mechanical separation affects ammonia and greenhouse gas emissions from the storage of different fractions obtained from separation of codigested pig and cattle slurries. A laboratory scale experiment was carried out in a temperature controlled room where 25 L of unseparated digestate and the relative solid and liquid fractions were stored in duplicates for 32 days at 17 °C. Each manure was sampled weekly for chemical analysis (total nitrogen, ammoniacal nitrogen, total solids, volatile solids and pH). Potential emissions from agitated samples were estimated twice a week using a dynamic chamber technique and acid traps for ammonia and a trace gas analyser for carbon dioxide, methane and nitrous oxide. Results from chemical analyses indicated that mechanical separation of digested manure increased nitrogen losses during storage when both separated fractions are taken into account, by 35 and 86% for the pig and cattle slurries, respectively. However, the flux measurements from the agitated samples showed that there was a lower potential for ammonia emissions during storage for the separated fractions than the digested unseparated slurry (9 and 23% reductions for the pig and cattle slurries, respectively), probably due to the lower TAN concentration of the liquid fraction. The treatment resulted in a significant reduction (40%) of GHG emissions for cattle slurries but had no consistent effect for pig effluents. The results of this study suggest that adoption of mitigation techniques should be considered for the management of the liquid and solid fractions of digestates in order to reduce the increased environmental impact during storage.

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1. Introduction

Globally, agriculture contributes significantly to both greenhouse gas (GHG) and ammonia (NH₃) emissions. In Europe and the US approximately 75% of NH₃ emissions derive from livestock production (Webb et al., 2005). Ammonia emissions are partly a local-regional environmental issue, because approximately 50% of the NH₃ may be deposited near the source (Sommer et al., 2013),

but there is also a contribution to trans boundary transport (EU, 2001). Deposition of NH₃ gas and particulate NH₄ can cause eutrophication of surface waters and acidification of ecosystems.

Enteric fermentation of organic matter by ruminants is the major source of methane (CH₄) emission, contributing 35–40% of atmospheric CH₄ (IPCC, 2006). The CH₄ losses from manure management are approximately 20% of total agricultural CH₄ emissions for most countries (IPCC, 2006). In addition, approximately 30–40% of the total global nitrous oxide (N₂O) emissions are caused by livestock production systems (Sommer et al., 2013).

To mitigate the effect of these emissions on the environment, many guidelines and regulations have been established by governments in various countries. Most of these regulations encourage manure recycling and a more efficient use of slurries by promoting the introduction of specific abatement strategies and

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technologies at the farm level. Among these, reducing emissions from storage is a relevant issue. The storage of effluents is strictly regulated and must be compatible with the time of spreading and with crop requirements. This often results in long slurry storage periods, leading to substantial organic matter degradation with subsequent uncontrolled release of CH₄, N₂O and NH₃. Storage accounts for 20–30%, ≈100% and 9–10% of the total respective NH₃, CH₄ and N₂O emissions produced during manure management (housing, storage and spreading) (Hutchings et al., 2001; EEA, 2013). Mitigation options during storage (e.g., cover, acidification) have been proposed, but they are not always easy to be implemented and their adoption in some areas, including Italy, is limited. The main barriers relate to costs and to technical difficulties in covering large outdoor slurry storage facilities. This means that changes in practices in response to the environmental guidelines and regulations have been slow.

Furthermore, the introduction of new treatment technologies brings new challenges that require a better knowledge of their effect on the emissions during subsequent storage of the treated manure. Over recent years, anaerobic digestion has been increasingly adopted as a treatment for energy production, especially at farm facilities, and the management of digestate is crucial to address concerns regarding possible negative impacts on the environment. In Italy during the last three years, the number of biogas plants (more than 1000 according to Piccinini, 2013) increased substantially as the result of incentive policies. Some authors (Amon et al., 2006; Clemens et al., 2006) have already shown that anaerobic digestion is an effective means to reduce GHG emissions. In contrast, slurries which have been codigested anaerobically in biogas production plants have a higher NH₃ volatilization potential than untreated slurries because pH and TAN (NH₃ + NH₄⁺) concentrations are higher (Sommer, 1996).

A common treatment scheme consists of anaerobic digestion followed by mechanical separation.

This treatment separates slurry into a larger liquid and a minor solid fraction, with nutrients being more concentrated in the solid fraction (Dinuccio et al., 2008). This could improve nutrient management especially in areas with a high livestock density. Some studies have already investigated the effect of mechanical separation on untreated slurries. Fangueiro et al. (2008) reported higher NH₃ emission from separated cattle slurry, with the highest amount of NH₃ lost from the liquid fraction. Dinuccio et al. (2008) showed contrasting results depending on the origin of slurries: separation of pig slurry resulted in reduced NH₃ losses compared with storage of untreated pig slurry, while for cattle slurry the combined NH₃ losses from the storage of the liquid and solid fractions were higher than those from the untreated slurry. Greenhouse gas emissions from manure storage are predominantly as CH₄. Greater CO₂ and NO₂ emissions are observed during the storage of solid fractions and of liquid effluents with a high total solids concentration and a tendency to develop a crust (Misselbrook et al., 2005; Hansen et al., 2006; Fangueiro et al., 2008). However, few data concerning NH₃ and GHG emissions during storage of separated and unseparated digested slurry are currently available. A better knowledge of the effect of different management systems of digestate would help to minimise negative trade-offs of the introduction of environmentally favorable technologies.

The aim of this study was the comparison of emissions during storage of digested slurry with or without mechanical separation, considering both liquid and solid fractions. For this purpose an experiment was established to compare chemical composition and NH₃, N₂O, CH₄ and CO₂ emissions during the storage of two different untreated codigested slurries and their liquid and solid fractions generated after a mechanical separation process.

2. Material and methods

Two different digestates were investigated, one comprising pig and cattle slurries (P) and the other only cattle slurry (C):

- digestate P was derived from a cooperative biogas plant (1 MWe) located in Martinengo (BG), Italy, fed with 35% pig slurry, 50% cattle, 5% poultry and cattle manure, 10% other biomass (maize and sorghum silage, corn flour). Samples (60 L) were obtained from digested slurry (P_UN) and the liquid (P_LF) and solid fractions (P_SF) following mechanical separation (screw press);
- digestate C was derived from a farm installation (250 kWe) fed with 90% cattle slurry and 10% corn silage, located in Lodi Vecchio (LO), Italy. Samples (60 L) were taken of digested slurry (C_UN) and the liquid (C_LF) and solid fractions (C_SF) following mechanical separation (roller press).

In order to compare emissions from the untreated and separated digested slurries, the experiment was conducted in a temperature controlled room between September and October 2012. The temperature was set according to the annual average of maximum temperatures (17 °C) in Pianura Padana. For each digestate, the three fractions (UN, SF, LF) were stored in duplicate (total of 6 vessels for each digestate) inside 35 L plastic open vessels (operative volume: 25 L, open surface 0.096 m²) for a period of 32 days. The temperatures of the different fractions were recorded continuously using temperature sensors connected to a data-logger at 30 min intervals (HOBO U12, Onset Computer Corporation, Bourne, MA, USA). One sensor was used for each vessel, positioned at 15 cm depth.

The samples were analysed for total solid (TS), volatile solids (VS), total Kjeldhal nitrogen (TKN), total ammoniacal nitrogen (TAN) and pH, once a week and at the end of the investigation period, according to standard methods (APHA, 2005). The levels of uncertainty for these analyses, expressed as relative standard deviations, were 0.3%, 1.4%, 1.1% and 1.2% for TS, VS, TKN and TAN, respectively.

In order to compare the effect of separation on the nitrogen content of the digestates, differences in nitrogen loss were estimated from a mass balance of TAN and TKN analyses at the start and end of the storage period and expressed both as total losses and as a fraction of the TKN and TAN content at the beginning of the experiment. Losses from the two separated fractions were combined, considering the mass separation efficiency of the mechanical separators used. The total values obtained for the treated digestates (P_TR and C_TR) are thus comparable with the unseparated digestates. The variations in TKN can be considered losses to air as in the storage environment the nitrification process is practically absent (Patni and Jui, 1991).

Variations in TAN can be also considered losses, but in this case the concentration is also affected by the net mineralisation of organic nitrogen occurring during storage and therefore can underestimate emissions to the air (Patni and Jui, 1991).

Gas emissions were measured twice a week using a dynamic chamber method (Dinuccio et al., 2008; Petersen et al., 2012). As in Petersen et al. (2012), on each sampling day the vessels were gently stirred with a mixer for about 1 min and subsamples of one 1 L were transferred into 2 L plastic bottles (headspace: 1 L). An air flow of 1 L min⁻¹ across the headspace was established for at least 30 min before gas sampling to reach a steady state (Dinuccio et al., 2008) and then emissions were measured over a period of 3 h. The air outlet was connected to two serial acids traps filled with 1% boric acid. The quantity of NH₃ trapped was determined by titration (Curtis et al., 1975).

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