Journal of Environmental Management 200 (2017) 416–422

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Gaseous emissions and modification of slurry composition during storage and after field application: Effect of slurry additives and mechanical separation

Maxwell Yeboah Owusu-Twum [a,*], Adele Polastre [b], Raghunath Subedi [c], Ana Sofia Santos [a], Luis Miguel Mendes Ferreira [a], João Coutinho [d], Henrique Trindade [a]

[a] CITAB-Centre for the Research and Technology of Agro-Environment and Biological Sciences, Department of Agronomy, University of Trás-os-Montes and Alto Douro, 5000-801, Vila Real, Portugal

[b] Department of Soil Science, Escola Superior de Agricultura Luiz de Queiroz, University of São Paulo, Av. Padua Dias, 11, Piracicaba, SP, CEP 13418-900, Brazil

[c] Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095, Grugliasco, Italy

[d] Chemistry Centre, Department of Biology and Environmental Engineering, University of Trás-os-Montes and Alto Douro, 5000-801, Vila Real, Portugal

A R T I C L E I N F O

Article history:
Received 27 March 2017
Received in revised form
16 May 2017
Accepted 3 June 2017
Available online 10 June 2017

Keywords:
Manure management
Biological additives
Anaerobic storage
Structural carbohydrates
Gaseous emissions
Cattle slurry

A B S T R A C T

The aim of the study was to evaluate the impact of slurry treatment by additives (EU200® (EU200), Biobuster® (BB), JASS® and sulphuric acid (H_2SO_4)) and mechanical separation on the physical-chemical characteristics, gaseous emissions (NH_3, CH_4, CO_2 and N_2O) during anaerobic storage at ~20 °C (experiment 1) and NH_3 losses after field application (experiment 2). The treatments studied in experiment 1 were: whole slurry (WS), WS+H_2SO_4 to a pH of 6.0, WS+EU200 and WS+BB. Treatments for experiment 2 were: WS, slurry liquid fraction (LF), composted solid fraction (CSF), LFs treated with BB (LFB), JASS® (LFJ), H_2SO_4 to a pH of 5.5 (LFA) and soil only (control). The results showed an inhibition of the degradation of organic materials (cellulose, hemicellulose, dry matter organic matter and total carbon) in the WS+H_2SO_4 relative to the WS. When compared to the WS, the WS+H_2SO_4 increased electrical conductivity, ammonium (NH_4^+) and sulphur (S) concentrations whilst reducing slurry pH after storage. The WS+H_2SO_4 reduced NH_3 volatilization by 69% relative to the WS but had no effect on emissions of CH_4, CO_2 and N_2O during storage. Biological additive treatments (WS+EU200 and WS+BB) had no impact on slurry characteristics and gaseous emissions relative to the WS during storage. After field application, the cumulative NH_3 lost in the LF was almost 50% lower than the WS. The losses in the LFA were reduced by 92% relative to the LF. The LFB and LFJ had no impact on NH_3 losses relative to the LF. A significant effect of treatment on NH_4^+ concentration was found at the top soil layer (0–5 cm) after NH_3 measurements with higher concentrations in the LF treatments relative to the WS. Overall, the use of the above biological additives to decrease pollutant gases and to modify slurry characteristics are questionable. Reducing slurry dry matter through mechanical separation can mitigate NH_3 losses after field application. Slurry acidification can increase the fertilizer value (NH_4^+ and S) of slurry whilst mitigating the environmental impacts through a decrease in NH_3 losses during storage and after application.

1. Introduction

Slurry management contributes to global warming and environmental pollution through the release of air pollutants such as greenhouse gases (methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O)) and ammonia (NH_3) into the atmosphere which negatively affect the sustainability of livestock production (Merrington et al., 2002). Gaseous emissions from slurry are produced by microorganisms which are influenced by slurry composition such as organic matter and chemical compounds (Sommer et al., 2013). Therefore slurry management practices and treatment techniques which alters microbial processes or induces an unfavourable environment for these microorganisms are crucial in minimizing the environmental impacts associated with slurry management (Sommer et al., 2013).

Slurry additives (biological or chemical) are substances applied

* Corresponding author.
E-mail addresses: maxwell@utad.pt, pamax88@yahoo.com (M.Y. Owusu-Twum).

http://dx.doi.org/10.1016/j.jenvman.2017.06.004
0301-4797/

to slurry with the aim to reduce the problems associated with slurry management and may offer an alternative to some advanced treatment technologies since they appear to be feasible and economically viable to farmers (Matulaitis et al., 2013; McCrory and Hobbs, 2001). These additives can affect both chemical composition (especially N and C) and biological processes in slurries (Hjorth et al., 2015; Provolo et al., 2016) and may be expected to influence gaseous emission patterns when applied to slurries.

Biological additives are formulations of microorganisms and/or enzymes and are designed to improve biological degradation of organic materials in slurries (McCrory and Hobbs, 2001; Provolo et al., 2016). The microorganisms in the additives are separated from environmental samples and grown in a nutrient media which has the exact targeted organic chemical as the main energy source (McCrory and Hobbs, 2001). The selected microorganisms are grown by fermentation and concentrated by filtration or centrifugation, and preserved by lyophilization, freezing or drying (McCrory and Hobbs, 2001). Although several studies have shown positive impacts of biological additives in relation to decreasing pollutant gases (Kuroda et al., 2015; Lee et al., 2007; Wheeler et al., 2010) and enhancing degradation of organic materials in slurry during storage (Provolo et al., 2016), other studies (Van der Stelt et al., 2007; Wheeler et al., 2010) have shown that the use of these additives may lead to pollution swapping which may have negative repercussions on the sustainability of livestock production.

Indeed, Van der Stelt et al. (2007) reported an increasing trend in NH_3 volatilization when effective-microorganism® (biological additive) was applied to slurry. Wheeler et al. (2010) observed some reductions in CH_4 emissions after using a biological additive for slurry treatment during storage. Nevertheless, such reductions in CH_4 emissions were accompanied by some increases in NH_3 losses. Therefore, further studies are required with more additives, to assess their relative benefits on the environment and slurry properties. A number of farmers already use biological additives like Biobuster®, EU200® and JASS® for slurry treatment. Although positive benefits are claimed by the manufacturers of these additives, little is known about their efficacy in reducing gaseous emissions and enhancing degradation of organic materials in slurry.

A wide range of chemical additives are utilized for the treatment of slurries or livestock waste and include acids, base precipitating salts and urease inhibitors (McCrory and Hobbs, 2001). In recent years, treatment of slurry with acids such as sulphuric acid (H_2SO_4) are being adopted on farms due to their effectiveness in reducing gaseous emissions during storage and after soil application (Fangueiro et al., 2015; Owusu-Twum et al., 2017). Although the impact of slurry acidification on gaseous emissions is known, there is limited information on its impacts on the transformation of organic compounds (lignin, cellulose, hemicellulose, organic matter) during storage of slurry.

Mechanical separation of slurry is done on farms to improve slurry management and results in two fractions, namely; a liquid fraction (LF) and a solid fraction (SF) (Hjorth et al., 2010). The LF is characterised by a lower dry matter (DM) and expected to infiltrate soil faster than the whole slurry (Jensen, 2013). This high infiltration potential of the LF minimizes its potential for NH_3 losses after application (Sommer et al., 2006). The SF has a high DM and nutrients content which is either transported to nutrient deficit regions or often composted on-farm prior to soil application (Jensen, 2013).

Earlier studies on slurry additives especially those with microbial composition have mainly been conducted using manure or whole slurry (Matulaitis et al., 2013; McCrory and Hobbs, 2001; Provolo et al., 2016; Wheeler et al., 2010) and have rarely considered the effect of these additives on the LF during storage and after soil application. As far as we know, no study has evaluated the impact of the treatment of slurry LF by acidification or biological additives on the infiltration of slurry into soil.

Our hypothesis were that: 1) The addition of biological additives to the effluents during storage will modify effluent characteristics; 2) The LF will increase slurry infiltration and consequently reduce NH_3 losses relative to the whole slurry; 3) The enhanced degradation of organic materials by the addition of biological additives will enhance soil infiltration of slurry and consequently reduce NH_3 losses; 4) Slurry acidification will reduce NH_3 losses and influence microbial degradation pathways in slurry during storage.

The overall aim of this study was to assess the effects of the treatment of slurry by separation (screw press) and additives (chemical and biological) on slurry characteristics and gaseous emissions during storage and after field application. In order to achieve these aims, 2 experiments were conducted with the following objectives: experiment 1 was performed to identify the impact of the additives on physical-chemical characteristics and gaseous emissions (NH_3, N_2O, CH_4 and CO_2) during storage; experiment 2 was conducted to assess the influence of the addition of slurry additives to the LF on NH_3 emissions and NH_4^+ concentration in soil layers (0–5, 5–10, 10–15 cm) after application.

2. Materials and methods

Cattle slurry used for the 2 experiments were obtained from the University of Trás-os-Montes and Alto Douro animal farm in Vila Real (North-West of Portugal) on June of 2013 and October 2014 for the first and second experiments respectively. Cows were mainly fed with maize silage and concentrate feed.

2.1. Experimental setup

2.1.1. Experiment 1- effect of slurry additives on gaseous emissions and physical-chemical characteristics

2.1.1.1. Experimental design and treatments. Experiment 1 was conducted as a completely randomised design with four treatments and three replicates each, making a total of 12 experimental units. The treatments were: whole slurry without an additive (control), whole slurry + sulphuric acid (H_2SO_4) to pH 6 (WS + H_2SO_4), whole slurry + Biobuster® (WS + BB) and whole slurry + EU200® (WS + EU200). The Biobuster® (a liquid formulation of microorganisms and enzymes, Biosystems Europe, UK) was applied at a rate of 0.40 L m^{-3} effluent whereas EU200® (a powder formulation of microorganisms, Biosystems Europe, UK) was applied at a rate of 0.17 kg m^{-3} effluent. Slurry acidification was performed by the addition of concentrated sulphuric acid (H_2SO_4) to the slurry until a pH of 6 was obtained. The pH of the acidification treatment (WS + H_2SO_4), was checked on days 1, 5, 11 and 22 after storage and more acid (average of 40 ml) was added each time to the effluent to keep the pH value around 6. The treatments (100 L each) were stored in 135 L container and kept constant at 20 °C in the incubation chamber for 85 days.

2.1.1.2. Measurement procedure and sampling. The effect of slurry treatments on gaseous emissions (NH_3, CH_4, CO_2, and N_2O) was investigated during the first 40 days of storage using acid trap technique (orthophosphoric acid (H_3PO_4) at 0.002 mol L^{-1}) and the measurement method described by Fangueiro et al. (2008). Briefly, each barrel was closed at the beginning of the experiment, leaving an open headspace between the surface of the slurry fraction and the barrel lid of ~35 L. The headspace atmosphere of each barrel was continuously washed using an air flow rate of 8 L min^{-1}. During each sampling period, NH_3 concentration in the inlet and outlet airflow was measured by passing a flow rate of 2 L min^{-1} through