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Research Note

Continuous in-house acidification affecting animal slurry composition

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The emerging slurry acidification technology affects gaseous emissions, fertiliser value, biogas production and solid–liquid separation; however, maximising the advantages is difficult, as the effect of acidification on the slurry characteristics resulting in those observations remains unclarified. A full-scale study was therefore performed, comparing pig slurry from normal in-house slurry management with pig slurry from housing with daily in-house acidification to pH 5.5. The effect on organic, inorganic and particles was evaluated. Increasing dissolved P, Mg and Ca contents indicated mineral dissolution in acidified slurry. Acceleration of carbohydrate hydrolysis was indicated, while deceleration of microbial acidogenesis, acetogenesis, methanogenesis and sulphate reduction was indicated. The particles were larger following acidification treatment causing a lower viscosity, likely due to acidification-induced aggregation. Overall, the acidified slurry was significantly different from untreated slurry; it had higher conductivity, more dissolved inorganic components, fewer small organic compounds, more large dissolved organic compounds, and larger particles.

1. Introduction

Animal slurry acidification minimises the societal problematic NH_3 emission (Kai, Pedersen, Jensen, Hansen, & Sommer, 2008; Wang, Huang, Ying, & Luo, 2014). National legislation therefore favours this technology (Danish Ministry of Environment, 2013). In Denmark below 2% of the slurry was acidified in 2008, while 10% was acidified in 2012 (Birkmose & Vestergaard, 2013). One solution is continuous in-house acidification, installable in new and existing housings. The pH targeted differs between available technologies (5.5–6.4), but depend on the intended NH_3 emission reduction and treatment duration.

Lower emissions of CH_4 (Ottosen et al., 2009; Petersen, Andersen, & Eriksen, 2012; Wang et al. 2014) and, in some studies, H_2S (Eriksen, Andersen, Poulsen, Adamsen, &

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Petersen, 2012) has been observed from stored acidified slurry than from untreated slurry. Increased plant growth has been observed upon fertilisation with acidified slurry (Petersen, Lemming, & Rubæk, 2013). Biogas production from acidified slurry has been observed to be lowered (Moset, Cerisuelo, Sutaryo, & Moller, 2012) and the solid products of solid–liquid separation have been observed to contain less nutrients (Fangueiro, Ribeiro, Vasconcelos, Coutinho, & Cabral, 2009). Hence, the slurry characteristics must be changed by the acidification.

Precipitation and dissolution of inorganic minerals are pH controlled. Anaerobic degradation is mediated by microorganisms and enzymes, which are sensitive to the media conditions including pH and conductivity. Particle sizes depend on the pH controlled slurry composition. The dominant reactions in complex chemical and biological mixture as animal slurry cannot be calculated, and the resulting slurry composition must therefore be assessed experimentally.

This study aimed to quantify the effect of in-house continuous acidification on the organic turnover, mineral dissolution and particle sizes under full-scale conditions. This was done by analysing the physical, organic, inorganic and emission characteristics of untreated slurry and in-house acidified slurry.

2. Materials and methods

Slurry was collected from two identical experimental sections, each housing 64 finishing pigs. The slurry in one section was acidified daily with H_2SO_4, while in the other section, the slurry was left untreated. The pig house was managed using Danish standard guidelines.

2.1. Slurry treatment

Slurry channels with non-acidified slurry were emptied to a storage container only twice during the period.

The equipment for acidifying slurry consisted of one external 14 m^3 treatment tank, to which 96% H_2SO_4 was added automatically until pH 5.5 (Infarm A/S, Aalborg). Slurry from the channels was flushed to the tank daily, and acid added. The duration of filling, treating and emptying was 1.5 min, 5–10 min and 2.5 min. Eight cubic meter acidified slurry was returned to the channel, and surplus slurry, approximately 5% by volume, was transferred to a storage container. Cleaning water was avoided.

Treatment (A) ran for 77 days from February 2012, and the pigs grew from 31 to 108 kg. In each section, 21 m^3 slurry was produced and a total of 8.4 L H_2SO_4 m^{-3} was added. A secondary treatment (B) ran under equivalent conditions for 70 days from September 2012, and the pigs grew from 33 to 104 kg. In each section, 21 m^3 slurry was produced, and a total of 9.5 L H_2SO_4 m^{-3} was added to retain pH 5.5.

By the end of each period, subsamples were collected from the storage container. Samples were stored a maximum of 3 days at 5C for physical analyses or at −18C for chemical analysis.

2.2. Physical and chemical analyses

Total sulphur, phosphorus, magnesium and calcium were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). The dissolved amounts were determined by ICP-OES in supernatant after 14,000 rpm-centrifugation. Dry matter (DM) and volatile solid were determined according to APHA (2005). Hemicellulose, cellulose and lignin were determined using a Fibertec 2010 (Foss, Höganäs, Sweden) (Van Soest, 1963). Free reduced carbohydrate content was measured at 540 nm in supernatant after dinitrosalicylic acid-derivatisation (Miller, 1959) using glucose standards. Total Kjeldahl nitrogen (N tot) and total ammoniacal nitrogen (TAN) were determined using a Kjeltec 2011 instrument (Foss, Höganäs, Sweden) (APHA, 2005). Volatile fatty acids were measured according to Moset et al. (2012). Total inorganic carbon (TIC) was determined by adding HCl, re-collecting the emitted CO_2 in NaOH, and titrating with HCl. Sulphide was quantified according to Eriksen et al. (2012). The pH and conductivity were measured using standard electrodes. Particle size distribution and zeta potential were measured with a Master sizer 2000 (Malvern Instruments Ltd, Worcestershire, UK), using tap water or 0.2 M KCl for dilution, respectively, after 1 mm sieving. Viscosity was measured using a Viscometer and a LV-1 spindle at 50 rpm (Brookfield, MA, USA); particle size distribution and viscosity were performed a rapidly as possible. Atmospheric NH_3 in ventilation air from housing sections was measured during the full period with an infrared analyser (INNOVA 1412 and INNOVA 1309, LumaSense, Ballerup, Denmark). In the laboratory, 200 ml slurry samples were stored for 35 days in N_2 flushed sealed 500 ml bottles. Gas volumes were measured by water displacement. The contents of H_2S, CH_4 and CO_2 in the gas were determined according to Moset et al. (2012).

Measurements of slurry dry matter, volatile solids, volatile fatty acids and particle sizes were performed to check for comparability between the two experimental periods A and B, and the periods proved comparable.

All analyses were performed in triplicate, except Mg, Ca, S tot, fibre analysis and TIC that were each performed in duplicate. With exception of soluble Mg, the coefficients of variance of the duplicate analysis were below 8% (Table 1).

2.3. Data analysis

The significance of the conversions was evaluated by balancing C, N, S, P, Mg and Ca (labelled X) amounts:

$$C_{reaction} = m(X_{product}) * m(X_{reactant})^{-1} \quad (1)$$

with product and reactant depending on the reaction, and m being mass expressed in g kg^{-1} DM.

3. Results

Addition of H_2SO_4 reduced pH in slurry, and increased tot-S in the slurry (Table 1). The NH_3 concentration in housing air was reduced by 70%, hence comparable with previous studies (Kai et al., 2008). The required H_2SO_4 addition varied by 11%