BIOSYSTEMS ENGINEERING 122 (2014) 23–30

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Effects of acidification during storage on emissions of methane, ammonia, and hydrogen sulfide from digested pig slurry

Kaiying Wang[a,*], Dandan Huang[a], Hongchuang Ying[b], Haojie Luo[b]

[a] Department of Biosystems Engineering, Zhejiang University, Hangzhou 310058, China
[b] Environmental Monitoring Center of Zhejiang Province, Hangzhou 310012, China

ARTICLE INFO

Article history:
Received 21 August 2013
Received in revised form
9 March 2014
Accepted 10 March 2014
Published online 11 April 2014

Keywords:
Digested pig slurry
Gas emissions
Acidification
Reduction effects

The effects of acidification reduction on methane (CH_4), ammonia (NH_3) and hydrogen sulphide (H_2S) emissions from digested pig slurry during storage were investigated. Pilot-scale experiments designed with three different pH levels including one control and two acidified treatments were conducted. Digested pig slurry was stored and tested in nine mechanically ventilated reactors. An online and continuous monitoring system was used to acquire gas emissions data during the whole storage period. Temperatures and pH in digested slurry were continuously measured with sensors. Off-gas from the reactors and air from room environment were sampled alternately then supplied to gas analysers for CH_4 and H_2S determination. Headspace NH_3 from the 9 reactors were regularly sampled by an air sampling instrument and then determined for concentration by spectrophotometer. The study found that digested pig slurry characteristics still didn't satisfy the national standards after 95 days treatments. Both temperature and pH were crucial factors to influence CH_4 and NH_3 emissions from digested pig slurry. In the control group (Gn) CH_4 and H_2S emissions mainly occurred in the first 20 days and 12 days, respectively; while no predictable NH_3 emission patterns were found in the experiment. Comparing with Gn, adjustment of initial pH to 5.5 significantly reduced CH_4 emissions by 80.8% and NH_3 emissions by 40.2%, but increased H_2S emissions by 11,324% (average increasing emission flux was 4.1 $\mu g\ m^{-2}\ min^{-1}$). Acidification with pH adjusted to 6.5 reduced CH_4 emissions by 31.2%, but did not affect NH_3 and H_2S emissions significantly.

1. Introduction

Animal production is a major contributor to gas emissions in agriculture through methane (CH_4), ammonia (NH_3) and hydrogen sulphide (H_2S). Methane is known to be a major part of greenhouse gases and its global warming potential (GWP) is 25 relative to CO_2 for time horizons of 100 years (IPCC, 2007). Ammonia volatilisation not only represents a loss of the nitrogen content in organic fertiliser, but can also be a public concern for its adverse impacts on health and environment, e.g. respiratory diseases caused by particulate matter (PM 2.5),

* Corresponding author. Tel.: +86 571 86986442.
E-mail address: zjuwky@zju.edu.cn (K. Wang).
http://dx.doi.org/10.1016/j.biosystemseng.2014.03.002

Nomenclature

Gn	digested slurry with no acidification
G6.5	digested slurry acidified to pH = 6.5 using sulphuric acid
G5.5	digested slurry acidified to pH = 5.5 using sulphuric acid
TN	total nitrogen, mg l^{-1}
TP	total phosphorus, mg l^{-1}
COD	chemical oxygen demand, mg l^{-1}
NH_4^+-N	ammonia nitrogen, mg l^{-1}
TS	total solids, g l^{-1}
VS	volatile solids, g l^{-1}
E	emission of gases from the reactors, mg m^{-2} min^{-1} or μg m^{-2} min^{-1}
C_o	gas concentration at the outlet, mg m^{-3}
C_i	gas concentration at the inlet, mg m^{-3}
Q	airflow rate, m^3 min^{-1}
S	emitting surface, m^2

nitrate contamination of drink water, soil acidification, etc. (Ndegwa, Hristov, Arogo, & Sheffield, 2008). Also, NH_3 and H_2S are both important odorous components emitted from animal manure and biosolids. High H_2S emission levels can even cause death. The production and release of gaseous emissions from livestock slurry under storage have been well investigated. Gas production is a complex process resulting from microbial and chemical reactions. The amount of gas emitted mainly depends on the characteristics of the slurry, management approaches and climatic conditions (Dinuccio, Berg, & Balsari, 2008; Martinez, Guiziou, Peu, & Gueutier, 2003; Park, Thompson, Marinier, Clark, & Wagner-Riddle, 2006). The effects of pH, temperature, covering and additives have been reported to affect and control gas emissions during slurry management (Berg, Brunsch, & Pazsiczki, 2006; Mukhtar, Samani Maji, Borhan, & Besedall, 2011; Sakamoto, Tani, & Umetsu, 2006; Sharpe, Harper, & Byers, 2002). Slurry acidification proved to be an effective method to reduce NH_3 emissions. Several technologies and approaches have been reported in the literature to reduce NH_3 emissions using acid scrubbers, using acid material as a cover and tubes with sulphuric acid flowing (Mukhtar et al., 2011; Sommer & Hutchings, 2001). In Denmark, slurry was acidified to pH = 5.5 and then pumped back to the livestock buildings in order to reduce NH_3 emissions. With this new technique, Kai, Pedersen, Jensen, Hansen, and Sommer (2008) succeeded in reducing NH_3 emissions by 70%. Ottosen et al. (2009) found that acidifying digested pig slurry to pH = 5.5 could restrain CH_4 emissions. Petersen, Andersen, and Eriksen (2012) showed that acidification of cattle slurry reduced the evolution of CH_4 by 67–87%, which suggested slurry acidification may be effective for CH_4 mitigation as well as NH_3.

Anaerobic digestion system can produce biogas (a combustible gas that contains CH_4) from animal slurry, recycle organic waste like energy crops and residues, also reduce greenhouse gas emissions compared to fossil fuels by utilisation of locally available resources (Weiland, 2010). More and more confined animal feeding operations (CAFO) have applied biogas engineering system to treat animal manure and wastewater in the world. However, its by-product of digested slurry continues to release CH_4 and NH_3 during subsequent storage. Higher CH_4 emissions were observed from digested slurry during storage period without full hydraulic retention time (HRT) than untreated slurry and fully digested slurry (Amon, Kryvoruchko, Amon, Béline, & Petersen, 2004; Sommer, Petersen, & Sogaard, 2000). For biogas digesters in livestock farms in central and southern China, where the use of upflow anaerobic sludge blanket (UASB) was encouraged, the HRT was only 2–5 days (Lei, Li, & Zhou, 2010). This could cause not only the release of considerable CH_4 and NH_3 during digested manure storage, but also loss of economic and environmental benefits.

Studies focussing on CH_4, NH_3 and H_2S emissions from digested slurry during storage are limited. Umetsu et al. (2005) found that CH_4 emissions from digested dairy slurry were correlated to temperature. Amon, Kryvoruchko, Moitzi, and Amon (2006) concluded that digested dairy and pig slurry emitted more CH_4 in summer than in winter. Sakamoto et al. (2006) studied the effects of a hydrophobic powder on CH_4 and NH_3 emissions of digested dairy slurry and found 97% NH_3 and 77% CH_4 were reduced respectively. Clemens, Trimborn, Weiland, and Amon (2006) found that co-digestion of cattle slurry with additives such as waste starch has a high potential with higher gas production with sufficient long HRT while not increasing greenhouse gas (GHG) emissions during subsequent storage and field application. However, knowledge of CH_4, NH_3 and H_2S emissions from digested pig slurry is still insufficient. The overall objective of this research was to investigate CH_4, NH_3 and H_2S emissions during digested pig slurry storage. It was implemented by the research on the effect of acidification with different initial pH adjustment on CH_4, NH_3 and H_2S emissions from digested slurry during storage.

2. Materials and methods

2.1. *Experimental setup*

The study was conducted in the School of Biosystems Engineering and Food Science, Zijingang Campus, Zhejiang University, China. Nine double-wall reactors were used to store digested slurry. Each reactor consisted of a 100-l and a 150-l container, both made of polyethylene (PE). The top of the 100-l container was open and was placed inside the 150-l container with top sealed through an air tight cap, thus forming a headspace for air sampling. Two openings were installed on either side of the centre on the cap, one for sampling gases, and the other for fixing a temperature sensor and a pH sensor. Both probes of the sensors located in the middle height of the stored digested slurry. An air inlet was installed on the wall of the 150-l container at 100 mm above the bottom. Another opening was installed in the opposite side of the container at 50 mm distance below the top, which was designed to remove extra gases outside the laboratory through an exhaust hood. This was to avoid exhaust gases re-entering the reactors.

Dynamic chambers were used for gas sampling and analysing. An air compressor continuously supplied fresh air to