Livestock Science 188 (2016) 166–173

Contents lists available at ScienceDirect

Livestock Science

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

Ammonia and greenhouse gas emissions from different types of deep litter used for pig rearing

Liping Zhang [a], Jing Sheng [a], Yuefang Zhang [b], Liugen Chen [b], Guofeng Sun [b], Jianchu Zheng [a,b,*]

[a] Institute of Agricultural Resources and Environment, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China
[b] Center for Sustainable Agriculture Research, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China

ARTICLE INFO

Article history:
Received 1 September 2015
Received in revised form
8 April 2016
Accepted 17 April 2016

Keywords:
NH_3
Greenhouse gas
Deep-litter
Pig rearing
Material flow analysis, MFA

ABSTRACT

Ammonia (NH_3) and greenhouse gas (GHG) emission during pig rearing on deep litter has been rarely reported. To evaluate the emission of NH_3 and GHGs according to the compositions of the deep-litter systems during pig rearing, we selected three different types of deep-litter systems: (a) RM, composed of 60% mushroom growth media and 40% rice husk; (b) RS, composed of 60% sawdust and 40% rice husk; and (c) RV, composed of 60% vinasse and 40% rice husk. Samples of the gases emitted were collected continuously using the static box method during one production cycle (150 d). The results showed that the patterns of NH_3 volatilization and CH_4 emission differed across the three deep-litter systems, but no significant differences were found in the pattern of N_2O and CO_2 emission. Further, the total quantity of NH_3 and GHG emission showed significant differences. Material flow analysis indicated that gaseous loss was the main pathway for escape of N or C. Thus, the use of RS could mitigate the emission of NH_3, N_2O and CH_4 (3.82 kg, 1.50 kg and 5.46 kg, respectively) and limit the effect of GHGs in terms of the emission equivalent carbon value (28% and 86% lower than that of RM and RV, respectively). Thus, the RS system was the most suitable with regard to reduction of environmental pollution.

1. Introduction

Biogeochemical cycling of carbon and nitrogen is a topic of interest globally, and is also the focus of environmental management research and strategies due to widespread concern about global warming. Agricultural ecosystems have been investigated and analyzed in detail in recent years. In the field of animal farming, the emission of carbon and nitrogen in the form of greenhouse gases (CO_2, CH_4 and N_2O) or ammonia (NH_3) has received much attention since the 1980s, especially the emissions from deep-litter systems. This is because it is believed that the deep-litter system for animal rearing can reduce livestock emissions and thus reduce environmental pollution. In addition, this system has been reported to improve pig welfare and production (Tuyttens, 2005) and reduce odor (Shilton, 1994; Kaufmann, 1997).

Nevertheless, the actual effect of the system on the environment remains to be assessed. There have already been some discussions, especially on the emission of ammonia and greenhouse gases (GHGs) (Olsson et al., 2014, 2016; Hassouna et al., 2005; Amon et al., 2007; Gilhespy et al., 2009; Groenestein et al., 2007). For instance, some authors compared gaseous emissions from the slatted floor with emissions from straw-based deep litter or sawdust-based deep litter. Their studies revealed that rearing weaned pigs or fattening pigs on straw-based deep litter releases nearly 20% more GHGs than rearing them on slatted floors (Philippe et al., 2013, 2007; Cabaraux et al., 2009). However, rearing gestating sows on straw-based deep litter reduces NH_3 and CH_4 emissions but results in greater N_2O emissions and thus greater emission of carbon equivalent of GHGs (CO_2eq) compared to rearing them on slatted floors (Philippe et al., 2011). Other authors found less ammonia and methane emission but more CO_2 and N_2O emissions from sawdust-based deep litter than that from straw-based deep litter (Nicks et al., 2003).

NH_3 is a well-known toxic gas that irritates the respiratory tract at concentrations exceeding 15 ppm (Banhazi et al., 2008) and plays an important role in acid deposition (Nicks et al., 2003; Webb et al., 2005). Furthermore, NH_3 emission contributes to indirect emission of nitrous oxide (N_2O) (IPCC, 2006). CO_2, CH_4 and N_2O are GHGs associated with livestock production (Groenestein et al., 1996; Nicks et al., 2004; Xiao et al., 2006; Mogensen et al., 2015). In the livestock sector, the contribution of CH_4 and N_2O to the greenhouse effect is more important than the effect of CO_2 because they are clearly the main sources of GHGs, with global warming potential indices that are 25 and 298 times higher that of CO_2, respectively, over a 100-year period (IPCC, 2007). These four

* Correspondence to: Institute of Agricultural Resources and Environment, No. 50, Zhong Ling Street, Nanjing, Jiangsu Province, 210014, China.
E-mail address: zhengjianchu@hotmail.com (J. Zheng).

http://dx.doi.org/10.1016/j.livsci.2016.04.012
1871-1413/

gases (CH_4, N_2O, CO_2, and NH_3) account for a large proportion of C or N conversion in the deep-litter system; therefore, it is important to evaluate their impact on the environment.

As the main component of deep litter, sawdust has higher economic value than crop residue or other materials such as mushroom growth residue and vinasse. Nowadays, research is being conducted on different materials that can be used as a substitute for sawdust, and the potential candidates are straw, rice husk, mushroom growth media residue, and vinasse. The use of these materials has several advantages with regard to nutrient recycling and cost reduction. However, NH_3 and GHG emission resulting from the use of these new materials have been seldom evaluated under field conditions in China. Therefore, the aim of this study was to compare the production of NH_3, N_2O, CH_4 and CO_2 from litter during rearing of fattening pigs with different types of bedding material, in order to identify litter components that are environment friendly and entail lower cost.

2. Materials and methods

The experiment was conducted from 3rd May to 30th September 2012 and repeated from 3rd May to 30th September 2013 in a room for pig rearing located at the field station of Jiangsu Academy of Agricultural Sciences, Nanjing, China.

2.1. Experimental housing for pig rearing

Three experimental rooms that were similar in space (100 m^3) and surface area (32 m^2) were used for pig rearing. In the interval between each experiment, the deep litter material was removed and the three pens were cleaned. The samples were analyzed to determine the total carbon (TC), total nitrogen (TN), ammonium nitrogen (NH_4^+-N), and nitrate nitrogen (NO_3^--N) levels; pH; and moisture content. Furthermore, natural ventilation was provided throughout the experimental period, and water mist sprayers were used to cool the room if the temperature exceeded 32 °C. Every pen had two water mist sprayers with a water flow rate 2.5 l/min, and opened 2 times one day, 30 min each time interval of 2 h. The water quantity of each pen was 150 l/d.

2.2. Animals and feed

We used Suzhong pigs for the experiments: 45 weaned pigs that were about 35 days old were used in each experiment. They were divided into three homogeneous groups of 15 animals each according to body weight. Each group was randomly allocated to a room: group 1 was reared on 40% rice husk +60% mushroom growth media residue (RM); group 2, on 40% rice husk +60% sawdust (RS); group 3, on 40% rice husk +60% vinasse (RV). The groups were fed from May to September 2012, and in the repeat experiments, the groups were fed from May to September 2013. At the start of each experiment, the baby pigs were given a transitional feed (baby starter) for 5–10 days, after which they were given the post-weaning feed (starter) ad libitum (Table 1). The pigs were weighed individually at the beginning and at the end of the experiment. The quantities of feed ingested and water consumed per group were determined.

2.3. Characteristics of the deep-litter systems used

The first room was equipped with an RM pen; the second room, with an RS pen; and the third room, with an RV pen. Each pen had enough room for 15 pigs, with a floor space of 2.13 m^2 pig^{-1}. Throughout the experiment, no fresh mixed material was supplied, but the deep litter was stirred weekly. Litters were sampled at the P0 phase (before the arrival of the animals) and P1 phase (after the departure of the animals). Before the experiments, a bed made of 50 cm of litter was provided in each pen: 8.29×10^3 kg of RM, 6.32×10^3 kg of RS and 8.02×10^3 kg of RV were used to make the corresponding beds. Pig wastes in the three groups were dispersed over all the area of each pen as a result of all the random activities of the pigs, and the wastes were also incorporated manually every 15 days during the experiments. Deep litter was sampled after homogenization at four spots (replicates) randomly at depths of 0–25 cm, 25–50 cm, and 50–70 cm. Each pen was sampled four times before the arrival of the animals and after their departure in each experiment. The mixed samples were divided into two parts: one part was air dried and passed through a 100-mesh sieve to determine the TC and TN contents, and the second part was a wet sample that was preserved at 4 °C for 2 days before the determination of NH_4^+-N and NO_3^--N concentrations (seal, AutoAnalyzer 3), water content (oven dried at 75 °C till to constant weight) and pH value (electrode method).

Table 1
Composition of the experimental diets.

	Growing diet	Finishing diet
Ingredients (%)		
Soybean meal	23	16
Corn	53	53
Fine rice bran	10.4	10.0
Fish meal	4.0	2.0
Fat	2.2	–
Salt	0.2	0.4
Mineral-vitamin complex[a]	2.0	2.0
Limestone	0.4	0.2
Dicalcium phosphate	1.1	1.5
L-Lysine	0.9	–
DL-Methionine	0.3	–
Copper sulphate	0.2	–
Wheat bran	–	5.0
Rapeseed meal	–	2.5
Chemical composition (%)		
Dry matter	89.6	88.9
Crude protein	18.6	17.3
Crude fat	4.0	2.9
Crude ash	5.6	5.6
Crude cellulose	2.4	2.8
Net energy (cal kg^{-1})	3908	3830

[a] Provided the following nutrients per 1 kg of premix: vitamin (Vit.) A, 1718 IU; Vit. D3, 197 IU; Vit. E,11 mg; Vit. B1, 1.1 mg; Vit. B2, 2.9 mg; Vit. B3, 18 mg; Vit.5, 10.8; Vit. B12, 15 μg; biotin, 0.1 mg; Vit. K, 2.9 mg; folic acid, 0.59 mg; cholic acid, 6.63 mg; Fe, 400 mg; Cu, 200 mg; Mn, 29.4 mg; Zn, 358 mg; K, 0.24 mg; Se, 0.85 mg.

2.4. Measurement of the emitted gases

Gases released from the deep litters were collected using the static box method. The concentrations of N_2O, CO_2 and CH_4 were simultaneously measured in situ using the static closed-chamber technique (Crill et al., 1988; Wang and Wang, 2003). The chamber was made of polyvinyl chloride (PVC) and covered an area of 0.25 m^2 (0.5 m × 0.5 m) and had a height of 0.62 m (chamber height and base height). Each chamber was equipped with two interior circulating fans to ensure complete mixing of the gases, and the chambers were wrapped in layers of sponge and aluminum foil to minimize changes in air temperature inside the chamber during sampling. For each measurement, four PVC frames were inserted in each replicate field plot (the floors were divided into four regions equally, with the center points of each region as the sampling plots). The top edge of the frame had a groove that could be filled with water to seal the rim of the chamber. To measure the N_2O, CO_2 and CH_4 fluxes, the four gas samples were