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Research article

Hydrogen sulfide emissions from a swine building affected by dietary crude protein

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A B S T R A C T

Hydrogen sulfide (H_2S) is a toxic air pollutant at animal facilities; but the understanding of its generation and emission processes has been limited. This paper studied H_2S emissions during a complete cycle of wean–finish pigs from a research building, where 12 pig rooms were divided into three groups that were fed with standard feed (control), and 2.1–3.8% (T_1) and 4.4–7.8% (T_2) reduced dietary crude protein (CP) feed. The group cycle mean H_2S emission rates were 4.0 ± 2.9, 4.3 ± 3.2, and 5.4 ± 4.0 g d^{-1} AU^{-1} (Animal Unit = 500 kg live mass), respectively, for the control, T_1, and T_2 groups. Emissions of H_2S were promoted by 10.0 and 36.7%, respectively, for the T_1 and T_2 groups ($p < 0.001$), although large variabilities existed in the emissions from different rooms within the same groups. The enhanced H_2S emissions from the T_1 and T_2 groups were related to the reduced manure pH and were possibly affected through a number of pathways, which could involve volatile fatty acids and nitrogen concentrations, and microbial activities in manure.

1. Introduction

Hydrogen sulfide (H_2S) is a colorless and toxic gas that has the characteristic odor of rotten eggs. It occurs naturally in coal, natural gas, oil, volcanic gases, and sulfur springs and lakes, but is also a product of the anaerobic decomposition of sulfur-containing organic matter (Smith et al., 1979). Hydrogen sulfide is related to indoor air pollution. Exposure to low H_2S concentration leads to headache, fatigue, and irritation of eyes, nose, or throat (ATSDR, 2006). Repeated exposure could lead to increased susceptibility; and those symptoms could result from concentrations previously tolerated (NIOSH, 1978). Brief exposures to high concentrations of H_2S (greater than 500 ppm) can cause the loss of consciousness (ATSDR, 2006). Exposure to higher H_2S concentrations has been reported responsible for deaths of animals and human being in animal facilities (e.g., Oesterhelweg and Püschel, 2008; Riedel and Field, 2013). The emitted H_2S to the atmosphere can be oxidized to sulfuric acids, which could increase the potential risk of regional acid rain.

Different exposure limits of H_2S have been regulated or recommended by major occupational health organizations. The exposure ceiling concentration permitted by the Occupational Safety and Health Administration (OSHA), USA is 20 ppm. The National Institute for Occupational Safety and Health (NIOSH), USA recommended a 10-min exposure limit of 10 ppm. The threshold limit values recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), USA were 1.0 ppm and 5.0 ppm for the 8-h time weighted average and short-term exposure limit, respectively.

Hydrogen sulfide in animal building is either a product of bacterial sulfate reduction or the decomposition of sulfur-containing organic compounds in the manure, especially sulfates, which are originated from protein, minerals or the premix in the feed, and from the drinking and washing water. The H_2S concentrations in swine buildings were usually below 2 ppm (Ni et al., 2017a). However, concentrations as high as 5.7 ppm were also reported (Kafle and Chen, 2014). The rates of H_2S emissions from swine buildings were much lower compared with other gases, such as ammonia (NH_3), carbon dioxide (CO_2), and methane (CH_4). It was reported 6.3 g d^{-1} AU^{-1} (Animal Unit = 500 kg animal weight) from two 1000-head finishing buildings during a 6-month study (Ni et al., 2002). However, the number of studies investigating the H_2S emissions from swine building has still been very limited.

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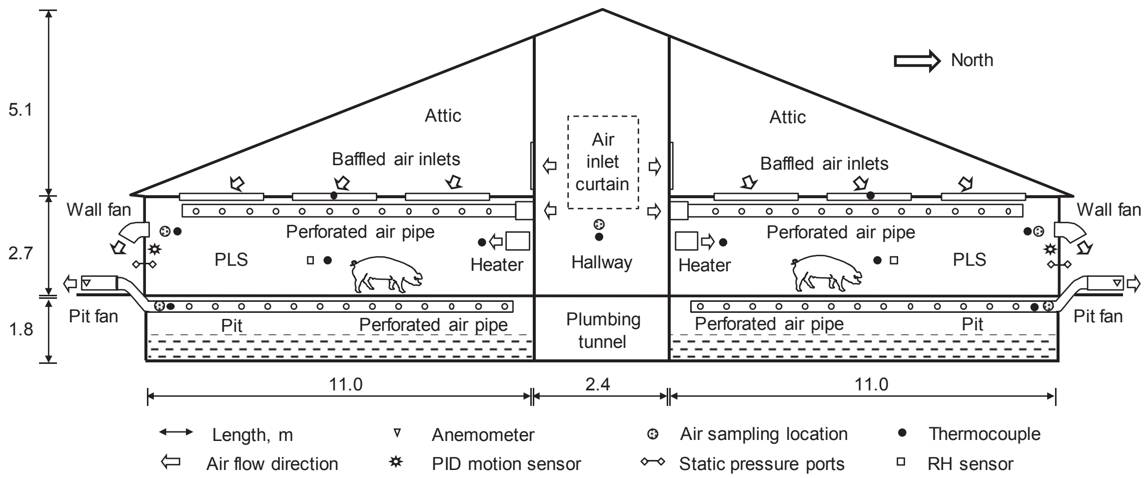

Fig. 1. East-side view of the swine experimental research building showing sampling and measurement locations (Liu et al., 2017).

Moreover, fewer instruments are available for H_2S concentration measurement than those for NH_3. The major choices for H_2S monitoring instruments in swine buildings are gas tubes, Chem-cassette monitors, Jerometers, and sulfur dioxide analyzers (Xin, 2005). Other reported methods included Drager Pac III and Ion Chromatography (Ni et al., 2017a). The sulfur dioxide analyzer is the high-sensitivity and quick-response instrument that can be used for continuous H_2S monitoring.

In addition, H_2S exhibits a special behavior of Bubble Release and Reservoir Effect from liquid swine manure (Ni et al., 2009). Several studies have reported unexpected burst H_2S releases and sharp increases in H_2S concentrations at swine storage and buildings (e.g., Ni et al., 2002; Blanes-Vidal et al., 2012), especially at slurry removal events (Hoff et al., 2006).

Evidently, H_2S emissions from swine buildings are affected by different factors and one of them is the feed. Diet manipulation by reducing crude protein (CP) has been proven as one of the effective approaches to mitigate NH_3 emissions from swine production (e.g., Powers et al., 2007). Nonetheless, its effect on H_2S emissions was claimed not significant in an early work by Hansen et al. (1993), who studied 32 finishing pigs during the last 11 days of a 44-day experiment. Follow-up studies by Radcliffe et al. (2008) with low nutrient excretion diet for 1920 pigs, and Powers et al. (2007) with reduced CP and supplementing with amino acids (AA) for 48 pigs in eight animal chambers, all confirmed no effects on H_2S concentrations and emissions. However, the impacts of diet on H_2S emissions had not been sufficiently discussed (Powers et al., 2007).

A recent study in a 720-head swine research building demonstrated that CP-reduced diets supplemented with AA significantly reduced NH_3 emissions (Liu et al., 2017). However, in the same study, the diet effects on H_2S emissions were different from NH_3 emissions as well as from previous studies reported in the literature. The objectives of this paper are to present the research results and characterize the effects of the CP-reduced diets on H_2S emissions.

2. Materials and methods

2.1. Building description

The 12-room (R1–R12) research building is located at the Animal Sciences Research and Education Center, about 16 km from the Purdue University main campus at West Lafayette, Indiana. There are 6 rooms along each of the south and north walls of the building (Fig. 1). The room size is 11.0 m × 6.1 m × 2.7 m (L × W × H). Each room has two 1.8-m deep pits under the fully slatted floor of pig living space (PLS) with a capacity of housing 60 finishing pigs.

Fresh air from outdoor enters the building and is distributed to each pig room. Exhaust air is ventilated through four direct-driven fans: two 250-mm diameter variable-speed pit fans (Model P4E30, Multifan, Bloomington, IL, USA) and two single-speed wall fans, one of 356-mm diameter (Model V4E35, Multifan) and the other of 508-mm diameter (Model V4E50, Multifan). The ventilation in each room is controlled independently using a Fancom controller (Model FCTC, Fancom BV, Panningen, The Netherlands).

In this study, only the pit fans were kept on to maintain minimum ventilation during the nursery stage and the majority days during grower stage phase G1 due to low outdoor temperatures. The pit fans were in full performance starting from phase G2. The PLS ventilation rate increased drastically during G1 and G2 and maintained high ventilation in all rooms during the finisher stage after the wall fans were turned on starting from phase G1.

2.2. Experiment description

Sixty piglets, weighing from 4.5 to 13.0 kg each, were moved into each room in R1–R6 on Feb. 25, 2015 and into R7–R12 on March 4, 2015 (Table 1). The pigs were reared through three different growth stages: nursery (from weaned to 25 kg), grower (25–70 kg), and finisher (70 kg to market weight). The 12 rooms were divided into three 4-room groups to test the effects of CP-reduced diets in nine pig feeding phases on gas emissions. The control group was fed with a standard diet. The treated 1 (T_1) and treated 2 (T_2) groups were fed with diets of 2.1–3.8% and 4.4–7.8% reduced CP, respectively. Artificial AA and corn were added to the CP-reduced feed for the T_1 and T_2 groups. The diets also had different sulfur (S) concentrations (Table 2).

2.3. Data collection

The swine building is equipped with a comprehensive online air quality monitoring system, which includes analyzers for gas concentration measurement, sensors for fan operations and airflow rate monitoring, and sensors for indoor environment monitoring. The gas emission data were collected continuously for 155 days. All and partial data collection was temporarily interrupted on May 13 due to an unexpected problem with the computer, and on May 24 due to a pressure sensor failure, respectively.