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The effects of slatted floors and manure scraper systems on the concentrations and emission rates of ammonia, methane and carbon dioxide in goat buildings

Liyuan Cai, Jiangkun Yu, Ji Zhang, Desheng Qi*

Department of Animal Nutrition and Feed Science, College of Animal Science and Technology, Huazhong Agricultural University, Wuhan, Hubei 430070, China

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ABSTRACT

This study was designed to quantify the concentrations and emission rates of ammonia (NH_3), methane (CH_4) and carbon dioxide (CO_2) and to evaluate their effects on the indoor environment of slatted floor and manure scraper systems in two goat buildings. One building had a slatted floor and a manure scraper system (building II); the other building did not, and manure removal was performed by workers (building I). This study was conducted from April 2014 until January 2015, with sampling during four seasons. The NH_3, CH_4 and CO_2 emission rates were highest in the summer and lowest in the winter in both buildings. However, in building II, these emission rates were significantly lower ($P < 0.05$) than those in building I in each season. In both buildings, the NH_3, CH_4 and CO_2 concentrations were highest in the winter and lowest in the summer, although the gas concentrations were significantly lower ($P < 0.05$) in building II than in building I. The results of this study suggest that the slatted floor and manure scraper systems substantially lower the emissions of harmful gases in goat buildings.

1. Introduction

Livestock buildings are the primary agricultural emission sources of harmful gases such as NH_3, CH_4 and CO_2 (Snell et al., 2003). NH_3 that comes from livestock accounts for 39% of global NH_3 emissions (Galloway et al., 2004). The negative effects of NH_3 emissions include acidification of soil and water, eutrophication, and loss of biodiversity and an indirectly contribute to the greenhouse effect (Steinfeld et al., 2006; IPCC, 2007). CH_4 and CO_2 are two of the highest contributors to global warming (IPCC, 2007) and livestock buildings account for 18% of anthropogenic GHG emissions (Steinfeld et al., 2006).

In livestock buildings, NH_3 emissions result from the hydrolysis of urea that is present in urine (Sommer et al., 2006; Cortus et al., 2008). The source of CH_4 is the anaerobic degradation of organic matter by bacteria in the digestive tract of the animals and in manures (Hellmann et al., 1997; Misselbrook et al., 2001; Monteny et al., 2006). CO_2 emissions have two sources: exhalation by livestock and release from manures. In manures, CO_2 is a key product of the aerobic decomposition of organic compounds and is a volatile by-product of urea hydrolysis (Møller et al., 2004).

Several factors that influence the emissions of NH_3, CH_4 and CO_2, such as the composition of the animal's diet, feed efficiency of the

Nomenclature

C_{NH_3}	Concentration of NH_3, ppm
E_{NH_3}	NH_3 emission rate, g day^{-1} $goat^{-1}$
C_{CH_4}	Concentration of CH_4, ppm
E_{CH_4}	CH_4 emission rate, g day^{-1} $goat^{-1}$
C_{CO_2}	Concentration of CO_2, ppm
E_{CO_2}	CO_2 emission rate, g day^{-1} $goat^{-1}$
C_{in}	Gas concentration in air inlet, mg m^{-3}
A	Area of air outlet, m^2
C_{out}	Gas concentration in air outlet, mg m^{-3}
v	Mean wind speed of the outlet, ms^{-1}
RH	Relative humidity, %
n	Number of goats
T	Air temperature, °C
VR	Ventilation rate, m^3 h^{-1} $goat^{-1}$

* Corresponding author at: Department of Animal Nutrition and Feed Science, Huazhong Agricultural University, Wuhan, Hubei 430070, China. Fax: +86 27 87281033.
E-mail address: qds@mail.hzau.edu.cn (D. Qi).

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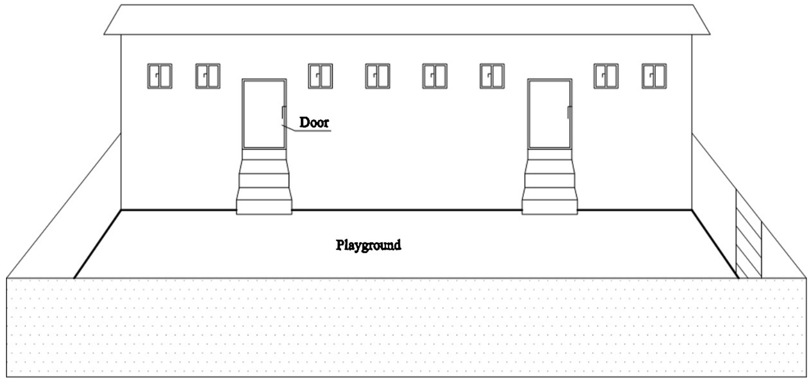

Fig. 1. Layout of the goat building.

livestock, the animal's growth cycle, the climatic conditions inside the buildings, the season, the time of day, the design of the building, the ventilation system, the flooring system and the manure removal system (Philippe et al., 2011; Philippe and Nicks, 2015). Among these factors, the flooring system and the manure removal system are easily overlooked. Slatted floors have been used for decades in livestock buildings worldwide, and the main purpose of slatted floors is to gain a sanitary indoor environment. It can be made of different materials, such as wood, bamboo, plastic, concrete or metal (Svennerstedt, 1999). In a naturally ventilated dairy cattle house, NH_3 emissions were lower with slatted floor systems compared to solid floor systems at all temperatures, but the different floor systems did not significantly differ in terms of CO_2 or CH_4 emissions (Pereira et al., 2011). A manure scraper system is another way to lower gaseous emissions. In livestock buildings, the pollutant gases are mainly released from the manure pit or manure storage area. As the manure is removed timely by manure scrapers, the emission of gases is decreased. However, whether a manure scraper system is useful for lowering gas emissions is disputed. Some authors have argued that the standard flat scraper seems to have no positive effect on NH_3 emissions (Predicala et al., 2007; Kim et al., 2008). In contrast, other authors have reported that a V-shaped scraper system is effective in redu$_{cin}$g NH_3 emissions from livestock buildings (Lachance et al., 2005). However, the effects of manure scrapper on CH_4 and CO_2 emissions have been poorly studied.

In recent years, goat production has continued to expand rapidly in China. Therefore, goat production is facing environmental challenges and public concern regarding the health and welfare of goats and workers. The aim of this study was to evaluate the effects of a slatted floor and a manure scraper system on the indoor environment of buildings that house goats. To do so, we compared the emission rates and concentrations of NH_3, CH_4 and CO_2 over the course of all 4 seasons in one year from two types of goat buildings. This study will provide information that will help environmental researchers and animal producers understand the effects of a slatted floor and manure scraper systems in improving the indoor environment of goat buildings so that they can make informed decisions regarding the further selection and implementation of mitigation strategies for harmful gases in these buildings.

2. Materials and methods

2.1. Study area and buildings

The study was carried on a commercial goat farm where located in Hefei City, Anhui province, China. The latitude and longitude are 31°5′N and 117°18′E, respectively and the climate of this area is characterized as a subtropical monsoon climate (Sun et al., 2008).

This study was conducted in two naturally ventilated grower-finisher goat buildings. The two buildings are the same size and of similar construction. Each building was connected to an outside yard for exercise. The two buildings were located next to each other, and each building was $29.8 \times 7.5 \times 3.0$ m (L × W × H, 670.5 m^3). There were two pens in each goat building, one on each side of a central aisle. And each pen was 26.70×3.00 m (L × W, 80.1 m^2), providing 1.3 m^2 per goat. In building I, the goats were kept on a solid floor, and the manure was removed by workers once a week. In building II, the goats were kept on a fully plastic slatted floor, and the manure was removed by a manure scraper once a day. The layout of goat building is shown in Fig. 1 and a sectional view of building II is shown in Fig. 2.

2.2. Slatted floor and manure scraper systems

The slatted floor made of plastic (polyethylene) (Fig. 3) and was manufactured by the Golong Company (Beijing, China). The modules of the slatted floor were 0.8 m (long) × 0.5 m (wide) × 0.05 m (thick) and the width of the gaps was 10.0 mm. The height of each bed was 0.6 m, and it was elevated by 3 supporting walls. There were 17 vents (0.50 × 0.10 m, each) in each supporting wall (Fig. 4). Two manure scraper units were installed in building II; each unit included 2 horizontal steel scrapers whose width and thickness were 1.0 m and 0.2 m, respectively. The manure scrapers were manufactured by the Golong Company (Beijing, China). The scrapers were connected to a stainless steel cable looped through several pulleys. An electric motor (1.5 kW) provided the driving force for the manure scrapers. The layout of the manure scraper system is shown in Fig. 5. The manure scraper system was manipulated using a control panel with a LED screen, and a single removal cycle was 6 min long.

2.3. Goats, diet and feeding

In this study, each building housed 120 Anhui white goats, each with an initial body weight of 18.0 ± 0.5 kg. The goats were fed the same diet twice daily (8:00–9:00 and; 16:00–17:00), with free access to water. Goats were fed daily with a 900 g/day maintenance diet, including 500 g alfalfa. The ingredients and nutritional composition of the diet are given in Table 1.

2.4. Measurements

The present study were conducted within the guidelines of and approved by the Animal Care and Use Committee of Huazhong Agricultural University. This study was conducted from April 2014 to January 2015, over four seasons. The air temperature (T), relative humidity (RH) and ventilation rate (VR) and the concentrations