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Effect of Slatted Floor Configuration on Air Quality and Floor Cleanliness in Sow Gestation Rooms

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ABSTRACT This study was part of a larger investigation of the effects of slat to slot ratio of slatted concrete floor on sow comfort and indoor environment for group housed gestating sows. Based on kinematic tests, two different designs of concrete slatted floor were installed in two gestation rooms: room #1 with 105 mm wide slats and 19 mm slots; and room #2 with 125 mm wide slats and 25 mm slots. The purpose of this paper was to compare air quality between these two different floor designs. Temperature and relative humidity were recorded continuously in each room for 9 weeks (test period) during each of two sow gestation periods. Ammonia concentrations were measured as an air quality indicator. Time-lapse cameras in each room took pictures of the pen floor hourly every Tuesday during the test periods, and the pictures were then analyzed to assess the cleanliness of the floors. Preliminary results showed that there were no significant differences in ammonia concentration and cleanliness of the floors between the two slat designs. The two floor configurations had the same performance in terms of manure drainage and air quality (ammonia level).

Keywords: Slatted floor, gestation sow, ammonia, manure

INTRODUCTION

The slatted concrete floors have been widely used in pig houses to promote manure handling, thus enhancing the indoor environment. The benefit of easy manure removal leads to cleaner floors, less manure accumulation on the floors, and lower emissions of manure gases such as ammonia.

On a typical slatted floor, part of manure can drop through the gaps of slatted floor, whereas some manure remains on the slats and between the gaps. Aarnink et al. (1997) assessed the wetted area of top surface of two concrete slatted floors (S1:10cm+2cm; S2: 7cm+1.8cm) after urination. No significant difference was found in the study. Ni et al. (1999) found that the ammonia emission rate had a high correlation coefficient (r=0.852) with floor contamination of manure. Ammonia mainly comes from the surface of wet fouled floor and the slurry pit under the floor (Aarnink et al., 1997). Hoeksma et al. (1992) estimated that floor emissions accounted for 30% of total ammonia emissions in pens with 62% of the floor area slatted. Aarnink et al. (1996) estimated floor emission was 40% of the total ammonia emission in pens with 25% of the floor area slatted and 23% in pens with 50% of the floor area slatted. Ammonia concentration is a key indicator of the indoor air quality. High concentrations of ammonia can irritate the skin and harm the eyes of animals and humans (Gerber et al., 1991) and as well as the respiratory tract (Urbain et al., 1994).

While large gaps and narrow slats may reduce manure accumulation on the floors, inappropriate slat and slot widths of slatted floor are usually considered as the main reasons for lameness and claw injuries of animals (Gjein, 1994; Ehlorsson et al., 2002; Olsson & Svendsen, 2002; KilBride et al., 2009). Gjein (1994) studied the influences of different floor conditions on claw health for sows and found that inappropriate design of slatted floor can lead to wounds and formation of cracks on claws of sows. Therefore, the optimal configuration(s) of slat width and gap width for slatted floor should not only minimize the impairment of pig gait but also accomplish effective drainage of manure. In the first phase of this study, sow gait characteristics on different slatted floors were investigated by using kinematics. Nine combinations of three slat widths (85, 105 and 125 mm) and three gap widths (19, 22 and 25 mm) were tested. The results showed that slat width of 105 mm and gap width of 19 mm were the best configuration. As a follow up, this study aimed to assess indoor air quality and floor cleanliness for the 105 mm slat and 19 mm gap configuration, and compare this configuration with the commonly used 125 mm and 25 mm configuration.

Material and methods

The experiments were carried out in the swine unit of the Glenlea Research Station, University of Manitoba. Two newly manufactured slatted concrete floors were installed in two identical rooms, but with different floor configurations. Room #1 was equipped with fully slatted flooring of 105 mm slats and 19 mm gaps and room #2 had fully slatted flooring with 125 mm slats and 25 mm gaps. Sows in each room were individually fed with an electronic sow feeder (ESF). The pen layouts are shown in Fig. 1. Each room housed 24 pregnant sows from 5 weeks to 15 weeks of gestation. Two gestations cycles were tested: one was from June 27th, 2016 to October 2th, 2016 and the other was from November 21th, 2016 to February 27th, 2017. For both cycles, due to the normal barn flow, the experiments in room #1 started (gestating sows entered into the room) 3 weeks earlier than room#2. Lights were set on timers to come on at 7 a.m. and off at 7 p.m.

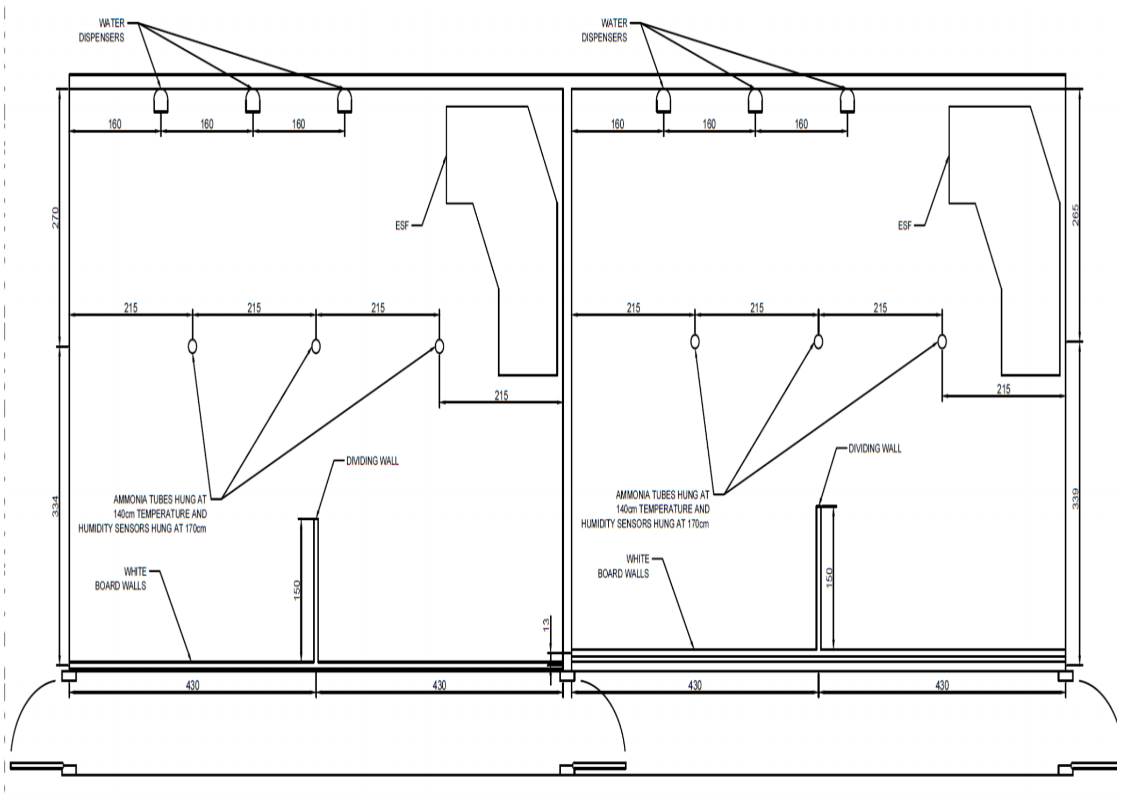


Figure 1. The pen layouts

Assess indoor air quality

Ammonia concentration

The ammonia concentration was measured with a Thermo NH3 17C Analyzer (Thermo Fisher Scientificby continuously sampling air at three sampling points for each room, one sampling point in the middle of the pen, one in the feeding area, and one at the other side of pen opposite to the feeder (Fig. 1). Air was drawn by a pump through sampling tubes mounted with their inlets 1.4 m above the ground level. Electric valves were used to alternate sampling between the two test rooms. A CR 1000 data logger (Campbell Scientific) connected to the NH3 Analyzer automatically recorded the data. The averaging time for the analyzer was set as 300 s (5 min), and the data logger recorded the averaged data every 30 min. In other words, the hourly average ammonia concentration was recorded for each room. The NH3 Analyzer was checked weekly with a 10 ppm NH3 calibration gas and clean air (tanked) for possible drift.

Temperature and relative humidity

Temperature and relative humidity were continuously recorded using 3 temperature sensors (T-Type Thermocouples, Honeywell) and 3 humidity sensors (Model HIH-4602, Honeywell) in each room. The sensors were mounted at the same locations as the ammonia sampling points, but 30 cm higher. The sensors were connected to a data logger (CR 1000, Campbell Scientific) with recordings at 5 minute intervals.

Evaluate the cleanliness of the slatted floors

The entire floor of each room was visually inspected to identify the established dunging area(s) in the first two weeks and a floor map was then drawn to indicate the dunging area(s). Two time-lapse cameras were mounted on the ceiling in the corners adjacent to the walkway to take pictures of the pen floor area every hour. Cameras were set to automatically take time-lapse pictures every Tuesday from 7 a.m. to 7 p.m. On Wednesday of each week, the pen floor would be scraped clean of manure.

The time-lapse pictures were analyzed using MIPAR image processing software. The floor was divided in to four areas for analysis according to the observations of sow activities: sleeping, low traffic, high traffic and dunging areas. A rectangle on the exposed floor surface of each area was drawn for the image analysis by MIPAR. At first, the picture was cropped to the image of the area needing to be analyzed and set to grayscale color. The manured area of the floor was marked as red color by using the “adaptive threshold” function in “segmentation”. However, since the color of the gaps between the slats was close to black, which could be misidentified as the manured area. The gaps were removed from each rectangle manually by using “manual edit function”. Finally, the percentage of manured floor area including gaps blocked by manure were calculated by the “area fraction” function in “measurement” for the evaluation of floor cleanliness. The percentage of manured area of the whole floor was determined by averaging the four area fractions.

SAS 9.3 software (SAS Institute Inc) was used in this study for statistical analysis. The mean values and standard deviations were calculated by univariate analysis in SAS.

Results and Discussions

Indoor air quality

The average values and standard deviations of temperature and humidity for the two rooms during two gestation cycles are shown in Table 1. The average temperatures of the two rooms were similar in the two cycles, 23.39 ℃ in room #1 and 22.39 ℃ in room #2 for gestation cycle 1; 18.15 ℃ in room #1 and 18.91 ℃ in room # 2 for gestation cycle 2. Because the cycle 1 occurred in summer time (from June to October) with average outdoor temperature of around 20 ℃ and cycle 2 in winter time (from November to February) with average temperature of about -20 ℃, the indoor temperature for cycle 1 was higher than cycle 2. Moreover, the standard deviations for temperature data in cycle 1 were higher than cycle 2, which means the temperatures in cycle 1 varied more than those in cycle 2. For relative humidity, the two rooms also showed similar average values (Table 1).

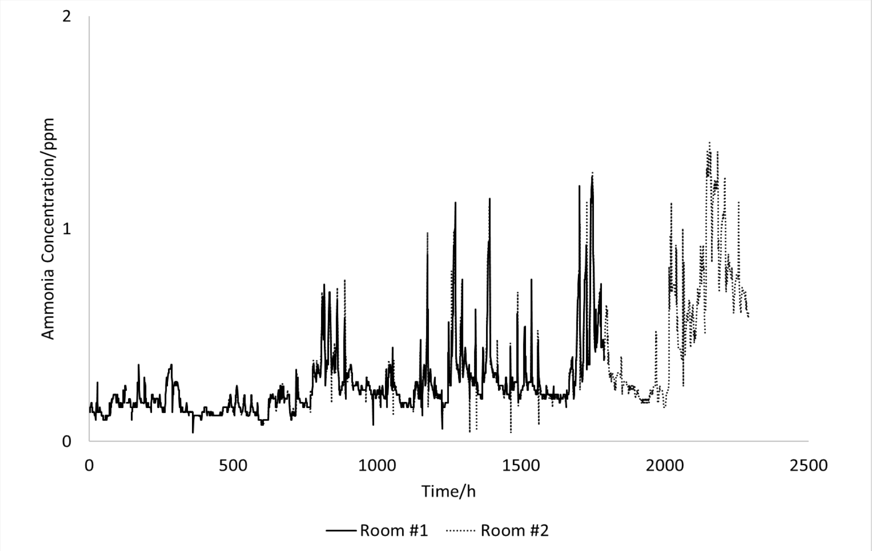
The ammonia concentration fluctuated from morning to night every day. Figure 1 shows the hourly ammonia concentration in each room during the two cycles. Since room #1 started the test 3 weeks earlier than room #2 in both cycles, the plot for room #2 started from 456 hours to keep the plots showing the same timeline for the two rooms. The ammonia concentration in cycle 2 was generally higher than cycle 1. This was related to the higher outdoor temperature and ventilation rate in cycle 1 (summer) than cycle 2 (winter).

The ammonia concentration of room #1 for test cycle 1 ranged from 0.04 to 1.24 ppm with the mean value of 0.26 ppm, and from 0.48 to 5.93 ppm with the mean value of 2.49 ppm for cycle 2

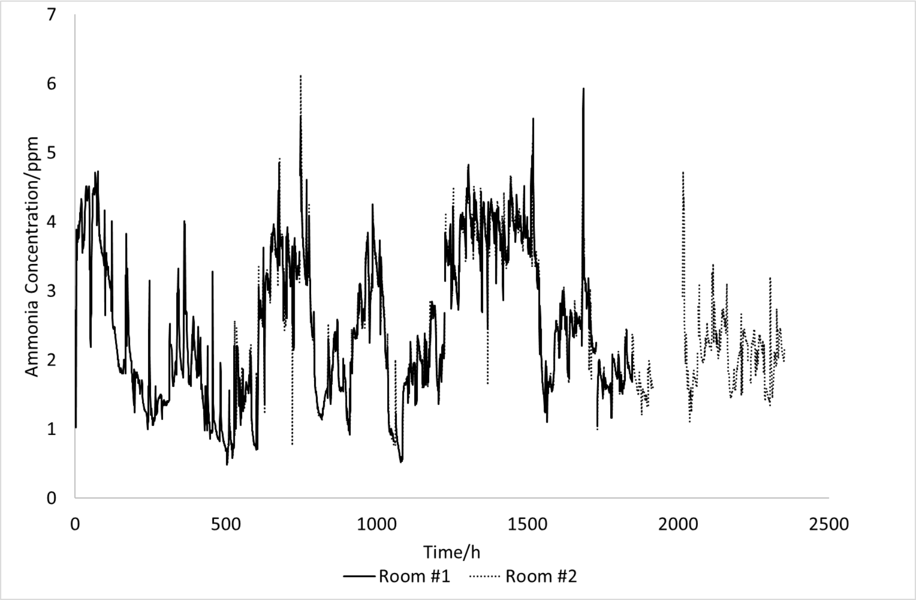
(Table 1). The ammonia concentration of room #2 for cycle 1 varied from 0.04 to 1.41 ppm with the mean value of 0.36 ppm, and from 0.50 to 6.13 ppm with the mean value of 2.46 ppm for cycle 2. Compared to the common threshold for ammonia in pig houses, which is 20 ppm (Commission Internationale de Genie Rural, 1984), both rooms during both test cycles had very low ammonia concentrations. The ammonia concentration in this study was much lower than that reported in the literature as well. Seedorf et al. (1999) investigated the ammonia concentrations in several German livestock buildings. They found the highest mean concentration of 15±9 ppm in fattening pigs and 13±4 ppm in sow buildings. Ni et al. (2000) observed that the average daily mean NH3 concentration at a mechanically ventilated swine barn was 5.6±0.41 ppm with a range from 2.8 to 10.6 ppm. The low ammonia concentrations in this study were most probably attributed to the low animal stocking density (24 sows in a room of 52 m^2).

Table 1. Average values and standard deviations of ammonia concentration, temperature and relative humidity in the two sow gestation rooms with different slat to slot ratio of slatted concrete floor.

Room	Ammonia (ppm)		Temperature (℃)		Relative Humidity (%)	
	Mean	SD	Mean	SD	Mean	SD
Room #1 (Cycle 1)	0.26	0.16	23.39	3.06	67.82	11.26
Room #2 (Cycle 1)	0.36	0.25	22.39	3.00	66.81	11.46
Room #1 (Cycle 2)	2.49	1.06	18.15	0.69	70.01	4.10
Room #2 (Cycle 2)	2.46	0.97	18.91	0.77	64.67	6.34



(a) Cycle 1



(b) Cycle 2

Figure 2. Variation of ammonia concentration with time in two test rooms with different slat to slot ratio of slatted concrete floor during two sow gestation cycles

The results illustrated that there was no significant difference in ammonia concentration between the two rooms. This observation was similar to that reported by Aarnink et al. (1997). They found that the ammonia emission for concrete floor with 10 cm slat and 2 cm gap was almost the same as concrete floor with 7 cm slat and 1.8 cm gap.

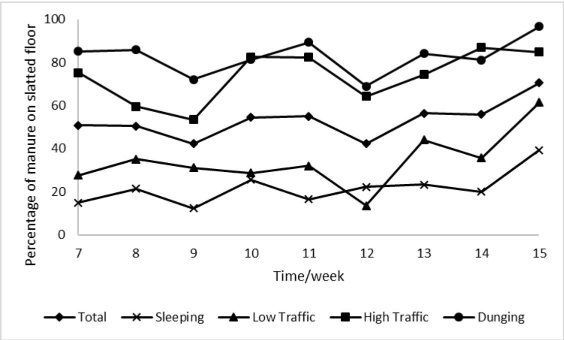
Cleanliness of slatted floor

The percentages of floor area covered by manure (dry and wet) are summarized in Table 2. The average percentages of manured floor area in room #1 were 53.14% in gestation cycle 1 and 51.34% in cycle 2, respectively. In room #2, 50.92% of the floor area and 55.83% of the floor area were covered by manure in cycle 1 and cycle 2, respectively. There was no significant difference in the percentages of floor area covered by manure between the two rooms ($P>0.05$). Aarnink et al. (1997) did not find any significant difference in wetted surface of the slats after urination for a floor with 10 cm slat and 2 cm gap compared to a floor with 7 cm slat and 1.8 cm gap.

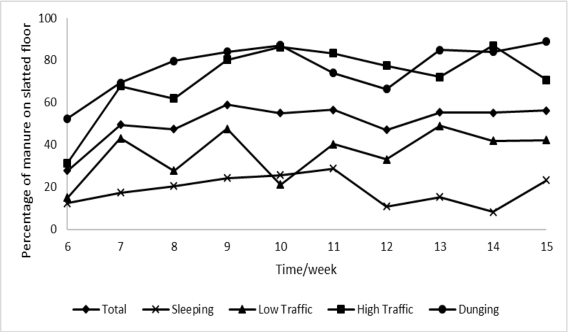
Table 2. Average percentage of manure soiled area on slatted floor in two sow gestation rooms with different slat to gap ratios of slatted concrete floor.

Room	Average percentage of manured floor area (%)									
	Total		Sleeping		Low Traffic		High Traffic		Dunging	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Room #1 (Cycle 1)	53.14	8.50	21.75	7.87	34.39	13.01	73.70	12.01	82.73	8.37
Room #2 (Cycle 1)	50.92	9.12	18.65	6.91	36.12	11.49	71.82	16.41	77.10	11.51
Room #1 (Cycle 2)	51.34	6.07	23.66	6.36	47.80	8.07	61.72	8.51	72.19	12.60
Room #2 (Cycle 2)	55.83	5.23	30.40	12.48	45.40	12.91	71.98	6.70	75.54	5.01

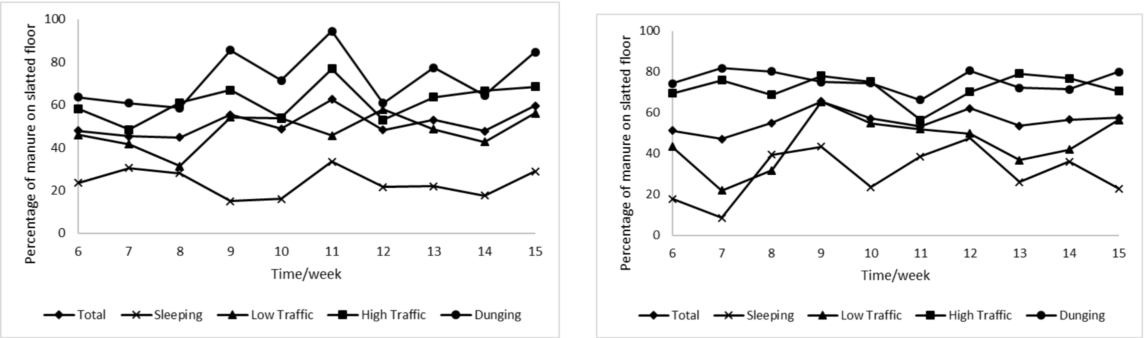
Manure-coverage was the lowest for the sleeping area and the highest for the dunging area (Fig. 3). On some occasions, the high traffic area appeared to have more manure coverage than dunging areas. A close examination revealed that the high traffic area was close to the waterers, so some of the wet area was from drinking water instead of urine. Fig. 3 also showed the upward trend of every plot, thus, the floor was covered by more manure with increasing time. Even though the floors were scraped clean once a week some manure remained on the slatted surface.



(a) Room #1 (Cycle 1)



(b) Room #2 (Cycle 1)



(c) Room #1 (Cycle 2) (d) Room #2 (Cycle 2)

Figure 3. The percentage of manured area on the slatted floor

Conclusion

In this study, ammonia concentration and befouled floor conditions were evaluated on two different slatted floor configurations during two gestation periods under the same condition of climate and stocking density. The two floor configurations had the same performance in terms of manure drainage and air quality (ammonia level).

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