Ventilation System Requirements for Conversion to Group Sow Housing

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SUMMARY
Computer simulation was utilized to assess the performance of different ventilation system configurations needed for a sow gestation barn newly-converted to group housing. Various configurations of the ventilation system involving varying capacities and locations of exhaust fans as well as size, design and location of air inlets, were examined based on indoor air quality (i.e., air temperature, humidity, and air speed at the animal level) and ventilation effectiveness (i.e., air distribution and airflow pattern, inlet air velocity, and room static pressure). Based on the computer simulation results, horizontal flow ventilation system with air inlets on one side and exhaust fans on the opposite side showed the best simulated performance among all ventilation design configurations tested. The horizontal flow ventilation configuration was then selected for further evaluation in a group sow housing facility, where energy use, temperature and air quality, and sow welfare and performance were assessed.

INTRODUCTION
Ventilation affects many aspects of the animal environment as well as barn operating costs, specifically energy costs. Retaining the existing ventilation system in a converted group-housed sow barn leads to over-ventilation during winter because the existing minimum ventilation fans are designed for higher animal density, thereby using extra heating fuel, and most likely causing chilling of the animals and affecting its performance. According to Harmon et al. (2010), if ventilation is continued at the pre-remodeling level (prior to conversion to group housing), the building would be over-ventilated by about 33% higher than required.

An estimate of energy use for an over-ventilated facility indicated that over-ventilating by 30% can raise heating energy consumption by 75%. During summer, the impacts are less pronounced but over-ventilation will use extra electricity which translates to higher electricity cost (Harmon, 2013). In addition, the transitioning of the ventilation system design from stalls to group housing is not simply reducing the ventilation rate but requires careful reconfiguration to ensure proper air distribution throughout the room to eliminate dead spots (unventilated areas) and unwanted drafts.

Air exchange is critical to providing a healthy environment that fosters efficient pig growth by reducing humidity and noxious gases like ammonia and carbon dioxide. Since under-ventilation creates an unhealthy environment and over-ventilation wastes valuable heating and electrical energy, finding the right balance is the key to a healthy environment for both animals and workers as well as to energy savings and efficiency (Harmon et al., 2010). This balance can only be achieved by careful re-design of the existing ventilation system of a converted gestation barn.

MATERIALS AND METHODS
Assessment of ventilation system design using computer simulation
In this project, numerical computer simulation technique which utilized computational fluid dynamics (CFD) principles to numerically simulate fluid flow, heat and mass transfer, and mechanical movement, was used as a tool to examine various design configurations and determine the most effective design of the ventilation system for a converted group sow housing facility.
The ventilation system design parameters investigated included: (1). capacity and location of exhaust fans, and (2). size and location of air inlets. These two parameters were configured in such a way that the resulting ventilation system design followed the principles of either an upward airflow, downward airflow, or horizontal flow ventilation.

Barn implementation of the most effective ventilation system design
Two group-housed gestation rooms were used: one room designated as the Treatment room was modified to incorporate the horizontal flow configuration, while the second room's ventilation system was similar to those in pre-converted (stall) gestation barns (Control room). Eight replicate trials (4 winter, 4 summer) were carried out.
Figure 1 shows the ventilation design configuration of the two experimental rooms. In the Treatment room, air inlets were located at one end of the room and exhaust fans at the opposite end allowing air to flow horizontally through the entire length of the room (Figure 1A). In the Control room, inlets were located on the ceiling while the fans were on one of the external walls; this configuration represented a downward air flow direction which is typical in commercial sow barns (Figure 1B). Each room had inside dimension of 23.1 ft (w) x 65 ft (l), two electronic sow feeders, and four nipple drinkers and housed 40 sows, on average, throughout the study. With the exception of the ventilation system design, the management of the two rooms was as identical as possible throughout the test.

RESULTS AND DISCUSSION
Computer models of the sow gestation rooms with different geometries were generated in the simulation work. The developed models were used in simulations under winter and summer conditions. In general, with the group housing layout and new ventilation design, heat removal effectiveness (HRE) values increased particularly when the air inlets were located on the opposite side of the exhaust fans following the principle of a horizontal flow ventilation system (HFVS). HFVS had the highest HRE values among all the design configurations investigated. Also, for this configuration, all nine

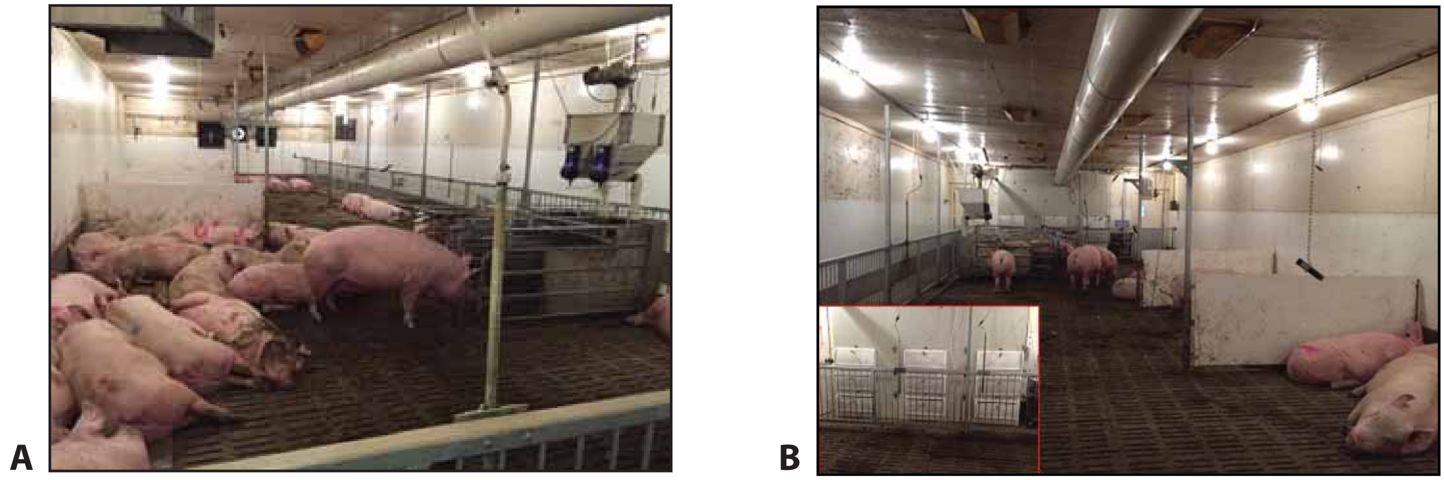

Figure 1. Photos of the control room with the existing (unmodified) ventilation system (A) and the treatment room with the air inlets on the opposite side (B) following the principle of a horizontal flow ventilation system. B – inset: wall air inlets installed in the treatment room.

monitoring points in the animal-occupied zone (AOZ) had HRE values greater than 1 which indicate that the air was homogeneously mixed. During winter period, in the model, all HRE values decreased which could be attributed mainly to the lower ventilation rates maintained in the rooms during the cold season. However, HFVS still had HRE values greater than 1 in all 9 monitoring points and the highest average HRE among all the designs tested for winter. Therefore, this ventilation system configuration (horizontal flow ventilation system) was selected for the subsequent in-barn evaluation.

Ventilation Effectiveness

Temperature and HRE

The set-point temperature in the rooms was 16.5°C which is the typical set-point temperature in gestation barns. During the summer trials, the average air temperatures in both the Control and Treatment rooms were uniformly distributed ranging from 20.4-21.0°C and 19.6-20.9°C, respectively. The inlet air temperatures were not much different between the rooms (Control; 16.0°C and Treatment; 16.1°C). However, a significant difference was observed at the exhaust with the average air temperature of 19.9°C and 20.4°C for the Control and Treatment rooms, respectively. This may imply that the ventilation system in the Treatment room was more effective in removing heat from the room.

The Control room had an average HRE value of 0.92 ± 0.05 (with only one point attaining 1.0) which generally implies that part of the fresh air coming from the inlets was directly removed from the room without mixing and without causing air displacement in the AOZ. This may result in accumulation of high contaminant levels in the AOZ because stale air is not being efficiently removed by the ventilation system. Conversely, the Treatment room had an average HRE value of 1.12 ± 0.15 indicating effective air displacement in the AOZ. Almost all the monitoring points in the treatment room had HRE values greater than one indicating that the fresh inlet air mixed well with the room air first before heading out to the exhaust.

Air Quality- CO_2

Carbon Dioxide (CO_2) levels are good indicators of air quality. In both the summer and winter trials the Treatment room had significantly lower concentrations of CO_2 than the Control room. In summer, the Treatment room had an average CO_2 concentration of 700.8 ppm compared to the average of 852.9 ppm, ranging from 806 ppm to 894 ppm in the Control room. In the winter trials the concentrations of CO_2 (Figure 2) in the Treatment room averaged 1904 ppm compared to 2158 ppm in the Control room. These levels indicate that the horizontal flow ventilation system in the Treatment room was better at removing contaminants from the room compared to the Control room which is consistent with the HRE values calculated in both rooms. Barn workers tending to the animals in these rooms during the trials also noted the much better air quality they experienced in the Treatment room compared to the control room.

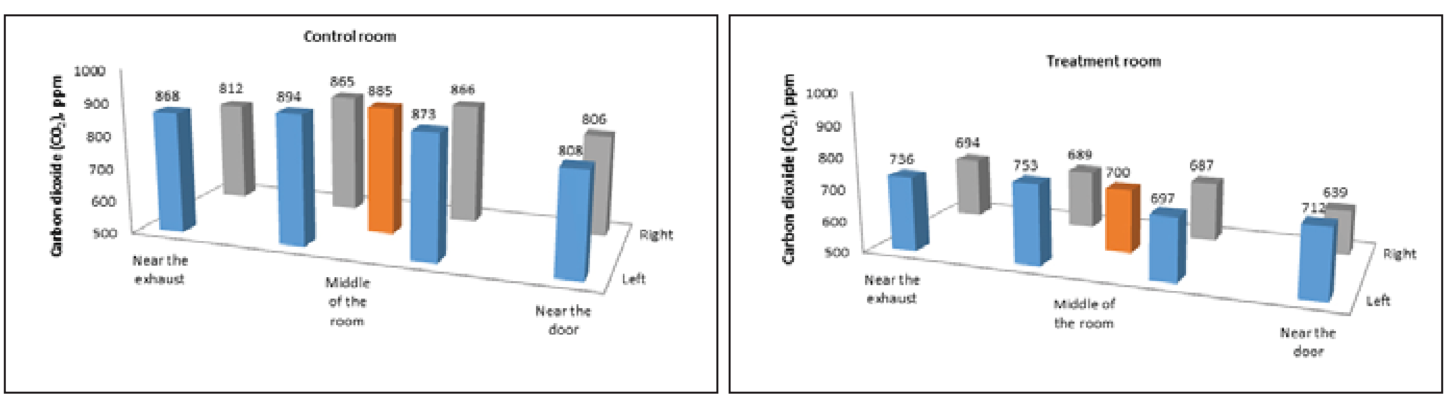

Figure 2. Average CO_2 concentrations measured at the animal-occupied zones in the Control and Treatment rooms in winter trials

Table 1. Percentage of sows in each posture.

Posture	Control room, %	Treatment room, %
Standing	13.78	14.75
Sitting	1.08	1.22
Lying ventrally	46.95	42.14
Lying laterally	38.28	41.92
Total Lying	85.23	84.06
Contacting*	74.87	68.08

*Percentage of sows lying and in contact with other sows.

Sow physiology, performance and condition

Monitoring of the performance of sows in terms of blood thyroxine levels, rectal temperature, average daily gain (ADG), backfat depth and condition score over four trials showed that there was little difference between the rooms with the only difference being higher blood thyroxine levels in sows in the Treatment room in the winter. This indicates that the sows in the Treatment room had higher metabolism in the winter compared to those in the Control room, but when taken together with the other performance indicators, this difference in metabolism level did not seem to lead to adverse impact on the performance of the sows.

Sow behaviour

Sow posture and location in the pen was monitored for 12 focal sows in each room on days 7, 14 and 28 of the trial using video recording. During that time, 85% of the sows were lying, 14% were standing and 1% were sitting (Table 1). A higher percentage of the sows in the Control room were observed lying in contact with other sows than in the Treatment room. The location of the sows in the room showed more sows in the Treatment room spending time in the enrichment area of the room implying that sow comfort was better in the Treatment room resulting in more exploratory behavior. In terms of sow aggression, sows in the Control room had more displacements (i.e., one sow forcing another sow at the feeder away) and attempted displacements at the feeder than the sows in the Treatment room.

Room and sow cleanliness

Dirtiness of sows as well as pens is a good measure of an effective ventilation system. Sow dirtiness was assessed weekly during each trial by following a 0 to 4 dirtiness score: 0 – completely clean to 4 – very dirty. Over the four summer trials, it was observed that sows in the Treatment room were relatively 'cleaner' than sows in the Control room. Sows in the Treatment room had an average dirtiness score of 2 which indicates that only their hooves and 20 % of their legs and body were soiled. On the other hand, sows in the Control room had an average dirtiness score of 3 which implies that their hooves and 50 % of their legs and body were soiled. Similar results were observed for the assessment of pen dirtiness. Consistently, the Treatment room had 25 to 50 % of its floor covered with manure while the Control room had about 50 to 75 % of its floor covered with faeces and urine. During winter, sows in both the Control and Treatment rooms had an average dirtiness score of 2 and both the Treatment and Control rooms had 25 to 50% of the floor covered with manure. These results imply that the horizontal air flow ventilation system in the Treatment room was relatively more effective than that in the Control room in the summer.

CONCLUSIONS

Results from the computer simulation work have confirmed the need to re-design the ventilation system of a newly-converted group sow housing facility. Among all the design configurations tested, horizontal flow ventilation system was the most effective in removing heat from the animal occupied zone (AOZ) in the room during both summer and winter seasons.

In-barn evaluation of the selected ventilation system design showed about 21% reduction in natural gas consumption during heating season and 14% reduction in electricity consumption in the room with the horizontal flow ventilation system relative to the control room with the unmodified ventilation system.

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