REDUCING EMISSION FROM PIG PRODUCTION BUILDINGS BY VENTILATION CONTROL

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ABSTRACT

Odour, ammonia and green house gas emissions from pig buildings have been a major negative impact to atmosphere environment and the local society. However, how the emissions are dependent on air as transportation medium is far less investigated. Therefore, more comprehensive investigations on the effects of odour release of airflow patterns and ventilation airflow rates are needed. The objective of the project is to study the feasibility of reducing ammonia and odour emission by choosing ventilation control strategies.

At present the ventilation capacity of a pig production building is based on an absolute maximum ventilation rate which is determined according to the largest body weight of the animals during the production cycle. However, in modern batch production systems the maximum ventilation rate is only required when the animals reach end weight and the outdoor temperature exceeds a certain level. In this study, a ventilation control strategy using a restricted maximum ventilation rate according to the pig's actual weight in the building was investigated. According to computer simulations, limiting the maximum ventilation rate to the actual body weight is feasible in practical application to reduce odour emission. That is in agreement with a primary investigation performed in field measurements.

The studies on the correlation between emission and airflow characteristics have shown that choosing a right ventilation control strategy, emission can be also reduced. The investigations were performed in scale model experiments. Strategies such as constant inlet opening, constant inlet velocity and constant inlet momentum were studied. The proposed control strategy suggests that the ventilation rates in a pig production building should be controlled to maintain a low inlet air momentum to reduce emission.

KEYWORDS. Emission, ventilation control, air quality, pig buildings

INTRODUCTION

Modern pig husbandry is met by an increased public and political concern due to the issue of negative environmental impacts on water and air quality. Consequently, effective and practically applicable methods for reduction of the odour, ammonia and green house gas emissions from livestock buildings are highly desired. Exhaust ventilation air from livestock production buildings is a major source of pollution to the environment from agricultural operation. Indoor air quality in the building affects the well-being of both animals and workers.

In many cases, it is concluded that the odour and ammonia emission rates from a livestock building are dependent on the ventilation rates and the higher the ventilation rates, the higher the emission (Aarnink et al., 1995; Zhang et al., 2005; Lyngbye et al. 2006). However, there has been limited investigation reported in literature on the magnitude of these effects. Besides, there is very limited knowledge available on estimation of the air exchange rate in slurry pits in ventilated livestock buildings, even though this knowledge is crucial for emission estimation and reduction from a building (Sommer et al., 2006).

The effect of different airflow patterns created by floor type and slurry channel layout on ammonia emissions has been reported by Morsing et al. (2008). The objectives of this investigation are focused on the effects of using a restricted maximum ventilation rate control according to the pig's actual weight and of varying the ventilation rate using three different control strategies: constant inlet openings, constant inlet velocity and constant inlet air jet momentum.

MATERIALS AND METHODS

Simulation of restricted maximum ventilation

To estimate the ventilation control strategy using a restricted maximum ventilation rate according to the pig's actual weight in the building the computer program StaldVent version 5.0 (Morsing et al., 2003) was used. The program contains algorithms for the design of ventilation and heating systems based on performance data for ventilation equipment (Pedersen & Strom, 1995). Local weather data at middle of Jutland, Denmark, are used for the simulations. A maximum ventilation restricted according to actual weight of the pigs was compared with a maximum ventilation based the end-weight of the pigs, Figure 1. The simulated growing/finishing pig unit had 152.6 m^2 floor area and operated in negative pressure ventilation with diffuse ceiling air inlet. Numbers of the pigs were 192, start-weight and end-weight of 30 and 102kg respectively. Indoor temperature set point was 20°C.

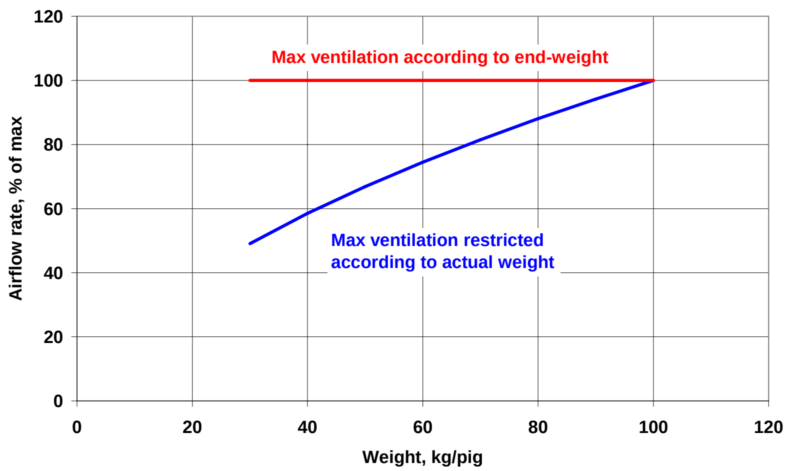


Figure 1. Two maximum ventilation control strategies used for estimating odour emissions.

Experimental investigations on inlet control strategies

A 1:12.5 scale model, Figure 2, made as a sub-section of a growing/finishing pig unit with double rows of pens, was used for the investigations.

Ventilation air was supplied through adjustable slats at two sides beneath the ceiling spanning the whole width of the model. The maximum opening height of each inlet was 45 mm. Room air was exhausted near the ceiling in the center of the model through a clear acrylic pipe, 35 mm in diameter, extending 38 mm downwards from the ceiling.

Ammonia water was circulated from a 50 l tank to the slurry pit of the scale model with a pump through a rubber hose. The liquid was drained back by an overflow pipe to the tank leaving a 160 mm deep reservoir of ammonia water in the bottom of the scale model. This gave a 70 mm head space between the water surface and the floor. A target pH value of 8.3 in the ammonia water was used to maintain a robust balance between ammonium and ammonia in the water with enough ammonia to be available for evaporation.

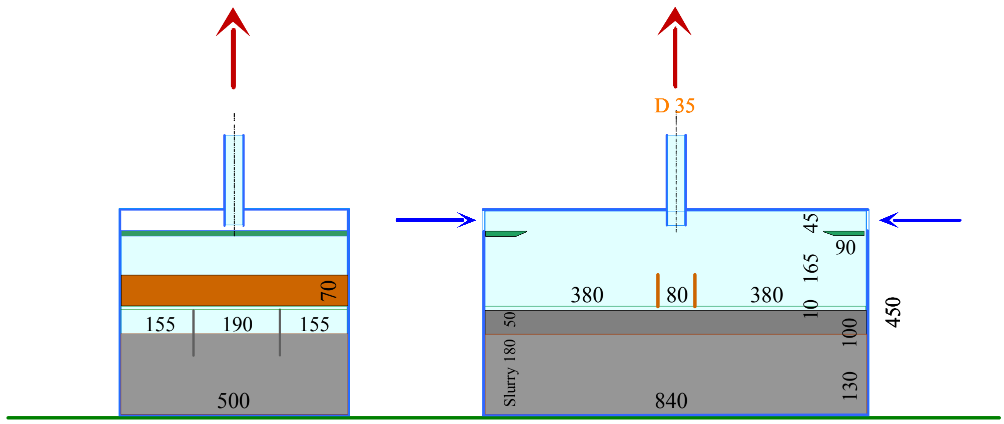


Figure 2. Dimensions (mm) of the 1:12.5 scale swine house section with double rows of pens

Three slatted floor types were investigated with various opening area: 100%, 33.3% and 16.7%. The 100% opening area meant that the head space was an integral part of the room air space and this configuration was used as the reference treatment. The slats for the fully slatted floor were 5.3 mm (±0.1mm) wide and 10 mm deep with 3 mm ((±0.1mm) slots between. The opening area 33.3% was with all slats open and 16.7% with every second slat sealed off with tape.

The experiment were conducted in four different ventilation airflow rates with three control strategies, namely fixed inlet opening area, inlet area adjusted to maintain constant supply velocity and inlet area adjusted to maintain constant inlet momentum, as described in Table 1.

Table 1. Inlet control strategies used in the experiments

Control strategies	Inlet opening height m	Ventilation rate m3/s
Constant inlet opening	0.005	0.005
	0.005	0.010
	0.005	0.015
	0.005	0.020
Constant inlet velocity	0.005	0.005
	0.010	0.010
	0.015	0.015
	0.020	0.020
Constant inlet jet momentum	0.005	0.005
	0.020	0.010
	0.045	0.015

The orifice plates designed according to the International Standard ISO 5167-1 were applied to measure the ventilation airflow rates. Airflow rate is computed based on the measured differential pressure using FC0510 Micromanometer (Furness Controls LTD, England). The inlet velocities were obtained based the ventilation airflow rates and the inlet opening area. Smoke was used in the experiments to indicate the direction of local airflow to provide a quick visualization of the path of the airstreams and pressure differentials. Ammonia concentration was measured with a 1312 Photoacoustic Multi-gas Monitor and a multiplexer 1303 (Innova

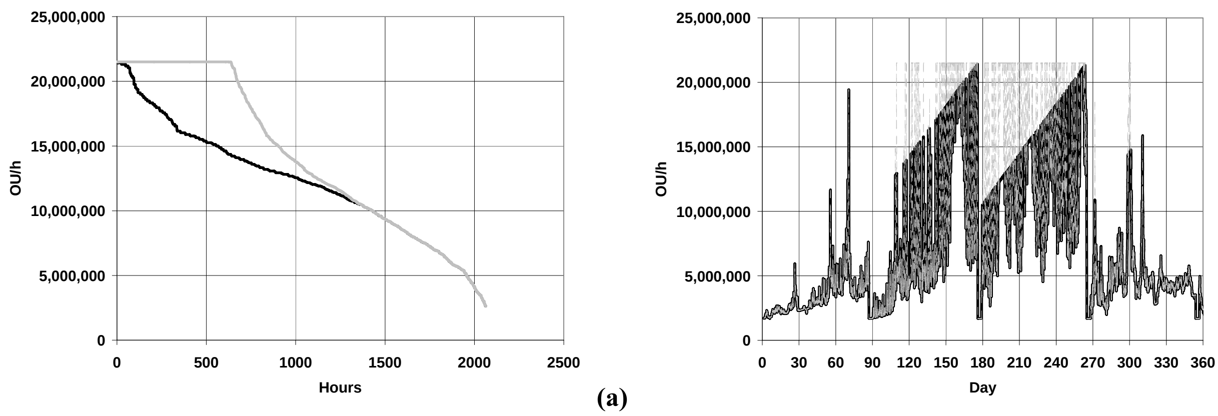
Air Tech Instruments A/S, Denmark). The concentration data at the exhaust, near the inspection alley and under the floor were sampled.

RESULT AND DISCUSSION

Effects of restricted max ventilation rate

The simulation results for using the restricted versus the conventional maximum ventilation are presented in figure 3.

The results show that using the restricted max ventilation, odour emission in about 1250 hours/year are lower than using the conventional max ventilation, figure 3(a), which is about 15% of total 8760 hours/year. It should be noticed that the effects of using the restricted ventilation occurred during the summer period, figure 3(b). The daily reduction in emission during this period can be up to 50%. In an investigation reported by Lyngbye et al. (2006), reductions in odour emission of 33% and 47% were achieved by limiting the ventilation capacity to 48% and 52% of the max ventilation in two batches of growing/finishing pigs. The measured results support the computer simulations. These results indicate that the restricted max ventilation can be a valuable approach to control ventilation system for pig production to reduce odour emission. It should be mentioned, however, the simulations are primarily based published odour measurements in pig buildings, with a general conclusion that odour concentration in pig buildings are independent of ventilation rates (Pedersen, 2004). To validate the simulations, both measurement in practices and modeling of odour emission are necessary.



(a)

(b)

Figure 3. Odour emission with conventional max ventilation (gray) and restricted max ventilation (black).

Inlet control strategies to minimize emission

In the studies a ventilation rate of 0.005m^3/s was used as the reference situation. The effect on the emission of higher ventilation rates is seen to be greatly dependant on the control strategy. The highest emission rate was found for constant inlet opening. The emission was reduced considerably when the inlet opening was adjusted to maintain constant inlet velocity, and when the inlet opening was adjusted to maintain constant momentum the emission was nearly independent of ventilation rate.

The effect of the control strategy may be explained by the airflow dynamics in the boundary layer of the emission surface and the gas transport in the building spaces. Without any floor the room ventilation air was in direct contact with the whole emitting surface. With the constant inlet opening strategy the inlet air velocity increases as ventilation rate increases. This resulted in a higher air velocity at the emission surface. A linear correlation between inlet air velocity and floor air velocity in a full scale room has been found by Strøm et al. (2002). The increased air velocity at the emission surface may explain the increased emission rate of ammonia. This is in accordance with Arogo et al. (1999); Zhang et al. (2005) who have reported that the higher the air velocity is at an emission surface, the higher emission rate will be.

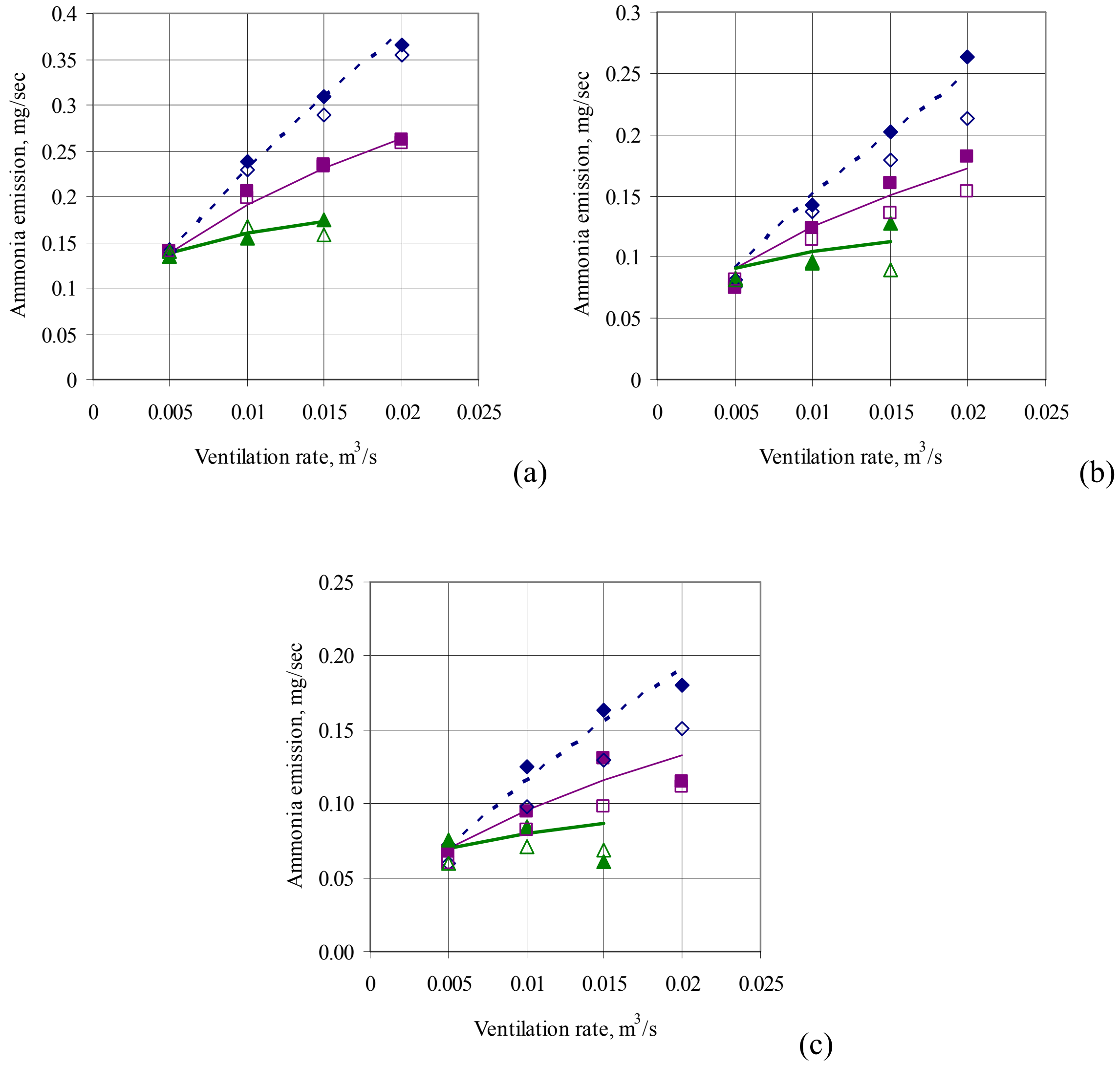


Figure 4. Ammonia emission versus ventilation airflow rate, (a), without floor; (b), with 33.6% floor opening and (c), with 16.7% floor opening: where, ♦, ◊ and ---, ■, □ and —, ▲, Δ and ▬, represent the results of the measurements, CFD simulation and non-linear model by using constant inlet opening, constant inlet velocity and constant inlet air momentum respectively.

Accordingly, with the constant inlet air velocity strategy, the increased ventilation rate increased the inlet air momentum and decreased the ammonia concentration in the room air space. However, variations of the air velocity at the emission surface were very limited due to the constant inlet air velocity according to the jet flow decay theory.

With the constant inlet air momentum strategy, the higher ventilation rate will result in a lower inlet air velocity and consequently a lower air velocity at emission surface. The size of the inlet opening becomes fast a limiting factor for compensation of higher ventilation rate, however.

Conclusion

According to computer simulations, limiting the maximum ventilation rate to the actual body weight is feasible in practical application to reduce odour emission.

The effect on the emission of higher the ventilation rate is seen to be greatly dependant on the control strategy. The highest emission rate was found for constant inlet opening. The emission was reduced considerably when the inlet opening was adjusted to maintain constant inlet velocity, and when the inlet opening was adjusted to maintain constant momentum the emission was nearly independent of ventilation rate. The maximum emission was found without slatted floor and the minimum emission was found for the slatted floor with the lower opening area.

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