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A NEW DESIGN FOR HIGHLY EFFICIENT PARTIAL PIT VENTILATION

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The study was conducted at an experimental farm with three sections with 32 growing finishing pigs, fully slatted flooring, diffuse air inlet and a maximum ventilation capacity of 100 m^3/hour/pig. The control section was equipped with room exhaust, and the two experimental sections with both room and pit exhaust. In both experimental sections, the openings of the slats in the fully slatted flooring were reduced by 40 per cent in order to improve the efficiency of the pit ventilation. Two suction points were studied, either underneath the dunging area or the resting area of the pen. During the summer 2009, measurements were made for two batches of pigs weighing 32-107 kg. Every week, the pit exhaust was switched between two fixed rates of either 10 or 20 m^3/hour/pig. Altogether, 120 odour and hydrogen sulphide measurements were made. Ammonia was measured continuously. Results showed that at a pit ventilation of 10 m^3/hour/pig, the concentration of hydrogen sulphide was reduced from 246 ppb in the control section to 87 ppb and 22 ppb in the experimental sections with suction point underneath dunging and resting areas, respectively ($P<0.001$). Comparing the control with the experimental section with suction point underneath the resting area, the room concentration of ammonia was reduced from 9.3 to 2.2 ppm and odour concentration from 480 to 200 OU_E/m^3 ($P<0.001$). Year-round, a partial pit ventilation rate of 10 m^3/hour/pig can be expected to collect more than 70 per cent of the ammonia emissions, more than 50 per cent of the odour emissions and more than 90 per cent of the hydrogen sulphide emissions.

Keywords: Ammonia, odour, hydrogen sulphide, emissions, working environment, pit ventilation, partly air cleaning, floor design.

INTRODUCTION

The exhaust air from animal houses contains gases that are harmful to the environment or a nuisance to neighbours. A solution to these problems is to clean the exhaust air by using biological or chemical air cleaners. A drawback of these techniques is expensive installations and high running costs. Annually, an air scrubber in a growing finishing pig house with 1700-1900 pig places costs 13-17 € per pig place depending on the type of air scrubber (KTBL, 2006).

An option for reducing the costs is to design the cleaners for partial air cleaning. In this technique, just part of the maximum ventilation capacity is cleaned while the rest is bypassed. To calculate the efficiency of partial air cleaning, 34 datasets were analysed in a Dutch study and a year-round ammonia emission model was established (Melse et al., 2006). Based on the dataset it was not possible to distinguish a seasonal effect on ammonia emissions.

The maximum ventilation capacity is dimensioned to maintain the desired climatic conditions in animal houses in periods with high external temperatures. Under Danish weather conditions, the maximum ventilation rate is only needed approx 15 % of the time (Kai et al., 2007 & Kai et al., 2008). In 40 % of the year's hours, the ventilation system operates at less than 20 % of maximum capacity. Assuming that ammonia emissions are not affected by seasonal effects, simulation of the air cleaning efficiency of partial air cleaning can be made in the computer programme StaldVent version 5.0 (Morsing et al., 2003). By cleaning 20 % of the maximum ventilation capacity with an air scrubber with 95 % ammonia reduction efficiency, more than 65 % ammonia reduction in total can be achieved.

Previous Danish research has demonstrated that it is possible to concentrate emissions from pig houses and enhance working environment by using slurry pit ventilation. The efficiency of the slurry pit ventilation very much depends on the floor and the slurry pit ventilation design (Pedersen 1979).

A study carried out in 2007 at a growing finishing farm equipped with partly slatted flooring and pit ventilation showed a high efficiency in concentrating odour and especially ammonia in the pit exhaust even at low ventilation rates during the winter period (Pedersen, 2008).

A computational fluid dynamic study on the airflow pattern and distribution of ammonia in growing finishing house with pit ventilation has shown that the efficiency of the pit ventilation can be improved by placing the suction point in areas with the highest concentrations (Bjerg et al., 2008). Taking advantage of the natural air flow pattern in the slurry pit - cold air entering the pit in the dunging area and leaving the pit in lying areas with the heat production from the pigs - an improved efficiency can be expected.

With these results and design criteria in mind, a new development project was set up. The aim of this study was to develop highly efficient partial pit ventilation for grower finishing pigs in order to improve working environment and create a cost-efficient solution to reduce ammonia and odour emissions from pig production units. The first step is developing a pit ventilation system that collects the major part of ammonia, odour and hydrogen sulphide emissions in as little exhaust air as possible.

MATERIALS AND METHODS

The study was conducted at Danish Pig Research Centre's experimental farm with a number of identical sections. The lay-out of three sections in this study was two pens with 16 pigs per pen, fully slatted flooring and diffuse air inlet with a maximum ventilation capacity of approx 100 m^3/hour/pig. Each pen was 4.8 m long and 2.4 m wide. The pigs were fed ad lib with dry feed. For further details see figure 1.

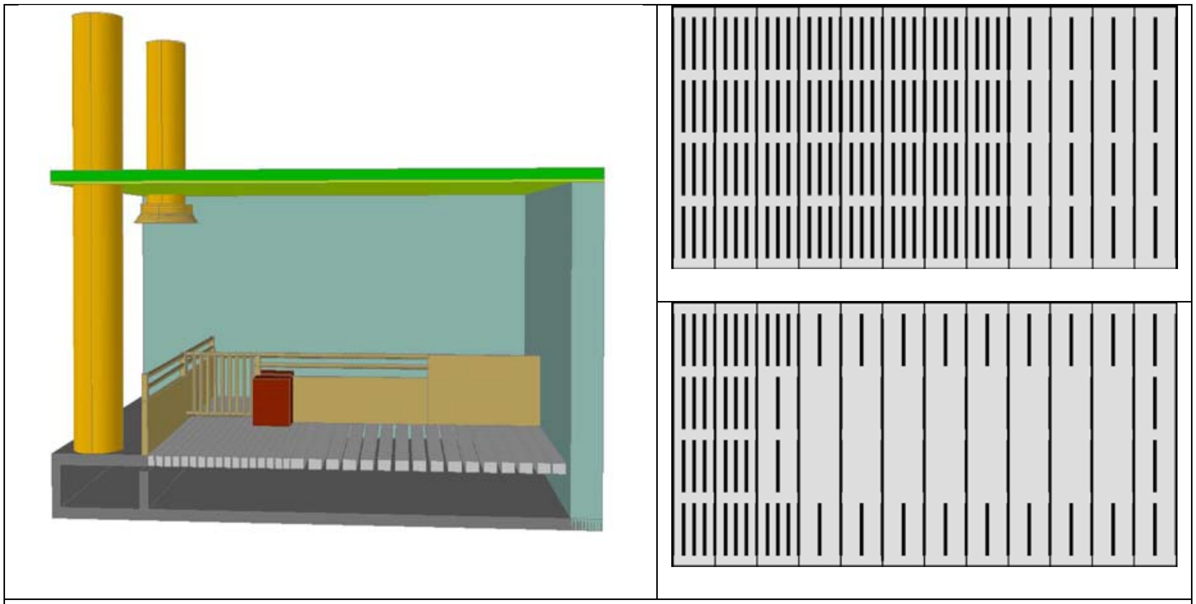

Figure 1: The lay-out of the three climate sections used in this study. The control section was equipped with only ceiling exhaust and fully slatted flooring. In both experimental sections shown in the lower right corner, the openings of the slats in the fully slatted flooring were reduced by 40 per cent in order to improve the efficiency of the pit ventilation. Two suction points were tried out in the experimental sections, either underneath the dunging area of the pen or underneath the resting area of the pen.

The study comprised three groups:

1. Control section: Room exhaust. Opening area of the slats: 0.091 m^2 per pig place.

2. Experimental section. Room and pit exhaust with suction point under the dunging area of the pen. Opening area of the slats: 0.054 m^2 per pig place

3. Experimental section. Room and pit exhaust with suction point under the lying area of the pen. Opening area of the slats: 0.054 m^2 per pig place

During the summer of 2009, measurements were made for two batches of growing finishing pigs weighing 32-107 kg. Every week, the ventilation rate for the pit ventilation was switched between two fixed rates of either approx. 10 or 20 m^3/hour per pig place. Ammonia, odour and hydrogen sulphide were measured in both room and pit exhaust air. Altogether, 120 odour and hydrogen sulphide measurements were made, evenly distributed on each batch.

On each measurement day, two odour samples were collected in each measurement point totalling 10 samples a day. The first sample was collected between 11-12 and the second sample after 12.30. The 10 samples were sent to the laboratory at Danish Meat Research Institute, Roskilde, where olfactometry odour analyses were performed the day after collection. The olfactometry used was an Ecoma TO 8.

After collection of odour samples in the trial period, hydrogen sulphide, ammonia and carbon dioxide concentrations were measured in the same measurement point as odour. The concentration of hydrogen sulphide was measured by Jerome 631 XE. The concentration of ammonia was measured by Kitagawa gas detection tubes 105SD, whereas the concentration of carbon dioxide was measured by Kitagawa gas detection tubes 126SF.

Ammonia and carbon dioxide, temperature and ventilation rate were also measured continuously by using VE 18 Multipoint Sensors, VE 10 temperature sensors and Fancom AT(M) unit 40 measuring fans. Data were logged every five minutes by a VE PC log programme.

Statistics

Ammonia concentrations and emissions, hydrogen sulphide concentrations and emissions and the logarithm transformed odour concentrations and emissions from pit and room exhaust in each climate section were subject to an analysis of variance with the MIXED procedure in SAS, taking into account repeated measurements per day. The percentage differences of ammonia and odour emissions between test and control sections were also subject to an analysis of variance with the MIXED procedure in SAS, taking into account repeated measurements per day.

RESULTS AND DISCUSSION

Results in table 1 shows that the pit ventilation was efficient even at a capacity of only 10 m^3/hour per pig.

Table 1. Odour, hydrogen sulphide and ammonia concentrations and emissions measured at a desired pit ventilation rate of 10 m^3/h per pig. Emissions of hydrogen sulphide and ammonia are calculated per pig in climate chamber with 32 pig places. Altogether 60 measurements of odour and hydrogen sulphide are included in the table. Continuous ammonia measurements from the days with a desired pit ventilation rate of 10 m^3/h per pig are included.

Group	1	2		3	
Measuring point	Room	Pit	Room	Pit	Room
Ventilation rate, m^3/h/pig	52	10	49	10	48
Odour concentration, OU_E/m^3	480	890	170	1230	200
- 95 % confidence interval	300-780	540-1470	110-290	740-2030	120-340
Odour emission, OU_E/s/1000 kg	99	31	33	47	38
- 95 % confidence interval	66-148	20-48	21-51	30-73	25-59
H_2S-concentration, ppb	246	485	87	777	22
- 95 % confidence interval	137-354	359-610	0-212	652-902	0-148
H_2S-emission, mg H_2S/h/pig	4.8	2.0	1.4	3.0	0.3
- 95 % confidence interval	4.1-5.7	1.1-2.9	0.5-2.4	2.0-3.9	0-1.2
Ventilation rate, m^3/h/pig	50	10	43	11	39
NH_3-concentration, ppm	9.3	20	2.6	27	2.2
- 95 % confidence interval	8.3-10	19-21	1.4-3.8	25-28	1.0-3.3
NH_3-emission, g NH_3-N/h/pig	8.2	3.6	2.0	4.7	1.5
- 95 % confidence interval	7.8-8.6	3.1-4.0	1.5-2.4	4.3-5.1	1.1-1.9

The pit ventilation efficiency could be evaluated by using hydrogen sulphide concentration as indicator, because hydrogen sulphide is nearly exclusively emitted from the slurry. It can be concluded that suction point underneath the pigs' lying area was the most efficient pit ventilation design in improving the working environment. Hydrogen sulphide in the room exhaust was reduced from 246 ppb in the control section to 87 ppb and 22 ppb in the experimental sections with suction point underneath dunging and lying areas, respectively ($P<0.001$).

Comparing control with experimental section with suction point underneath lying area, the concentration of ammonia in the section was reduced from 9.3 to below 2.2 ppm and odour concentration from 480 to 200 OU_E/m^3 ($P<0.001$).

Table 2. Odour, hydrogen sulphide and ammonia concentrations and emissions measured at a desired pit ventilation rate of 20 m^3/h per pig. Emissions of hydrogen sulphide and ammonia are calculated per pig in climate chamber with 32 pig places. Altogether 60 measurements of odour and hydrogen sulphide are included in the table. Continuous ammonia measurements from the days with a desired pit ventilation rate of 20 m^3/h per pig are included.

Group	1	2		3	
Measuring point	Room	Pit	Room	Pit	Room
Ventilation rate, m^3/h/pig	53	20	43	19	39
Odour concentration, OU_E/m^3	360	820	140	910	170
- 95 % confidence interval	230-570	480-1370	80-230	540-1530	100-290
Odour emission, OU_E/s/1000 kg	80	64	22	71	27
- 95 % confidence interval	53-120	39-103	14-36	44-114	17-43
H_2S-concentration, ppb	197	505	70	475	30
- 95 % confidence interval	85-309	377-634	0-198	347-603	0-159
H_2S-emission, mg H_2S/h/pig	4.3	3.8	1.1	4.0	0.4
- 95 % confidence interval	3.1-5.4	2.5-5.1	0-2.4	2.7-5.3	0-1.7
Ventilation rate, m^3/h/pig	50	22	33	18	31
NH_3-concentration, ppm	7.4	14	1.5	18	1.1
- 95 % confidence interval	6.4-8.4	13-16	0.4-2.7	17-20	0.2-2.3
NH_3-emission, g NH_3-N/h/pig	7.3	5.2	1.0	6.4	1.1
- 95 % confidence interval	6.8-7.7	4.6-5.8	0.5-1.6	5.8-7.1	0.5-1.7

The results of a required pit ventilation of 20 m^3/hour per pig are shown in table 2. Hydrogen sulphide in the room exhaust was reduced from 197 ppb in the control section to 70 ppb and 30 ppb in the experimental sections with suction point underneath dunging and lying areas, respectively ($P<0.001$).

Comparing control with experimental section with suction point underneath the lying area, the concentration of ammonia in the section was reduced from 7.4 to below 1.1 ppm and odour concentration from 360 to 170 OU_E/m^3 ($P<0.001$).

Partial pit ventilation was able to substantially improve the working environment. Comparing the control section with the experimental section with suction point placed underneath the lying area, the room concentration of ammonia was reduced by 76 and 90 % at a pit ventilation rate of 10 and 20 m^3/hour/pig, respectively ($P<0.001$). Hydrogen sulphide was reduced by 91 % and 85 % at a pit ventilation rate of 10 and 20 m^3/hour/pig, respectively ($P<0.001$).

Partial pit ventilation was also able to reduce the emissions from the room exhaust in the experimental sections significantly. Comparing the control section with the experimental section with suction point underneath the lying area at a pit ventilation of 10 m^3/hour/pig, the odour, hydrogen sulphide and ammonia emissions were reduced by 62 %, 94 % and 82 % respectively ($P<0.001$). At a partial pit ventilation rate of 20 m^3/hour/pig, odour, hydrogen sulphide and ammonia emissions were reduced by 66 %, 93 % and 85 %, respectively ($P<0.001$).

Comparing a partial pit ventilation rate of 10 with 20 m^3/hour per pig, the working environment was slightly improved as were the reductions of emissions from the room exhaust. This indicates that a pit ventilation rate of 10 m^3/hour per pig is close to having the same efficiency as 20 m^3/hour per pig, but from this study it is not possible to make a final conclusion on optimum pit ventilation rate. Further measurements on concentrations and emissions in relation to pit ventilation rate are needed.

The conclusions in this study are based on measurements in the summer period from April to October 2009. Year-round measurements of ammonia and hydrogen sulphide concentrations and emissions are needed to draw the final conclusions on the effectiveness of pit ventilation. Because odour mainly is a problem in the summer period, conclusions can be made on odour on the basis of this study. Although year-round measurements are not performed yet, it is expected that the pit ventilation efficiencies found in this study will be of at least same scale in the winter period, because then the overall ventilation rate will be much lower compared with the summer period.

CONCLUSION

This study has shown that a partial pit ventilation rate of only 10 m^3/hour/pig substantially improves working environment and reduces the emissions from the room exhaust. From this study, a partial pit ventilation rate of 10 m^3/hour/pig can be expected to collect at least 70 per cent of the ammonia emissions, 50 per cent of the odour emissions and 90 per cent of the hydrogen sulphide emissions.

As of now year-round partial air cleaning with a capacity of 20 % of maximum ventilation capacity, a 65 % ammonia reduction can be expected by cleaning room exhaust with an air cleaner with 95 % ammonia reduction efficiency. From this study it can be concluded that at least the same ammonia reduction can be achieved by cleaning only 10 % of maximum ventilation by connecting the air cleaner to a highly efficient pit ventilation system instead of cleaning on air from a room exhaust.

The next step of this development process is full-scale implementation of the technique. The first challenge is to design a central pit ventilation system that will ensure an identically and uniform pit ventilation in a large-scale pig production unit. The second challenge is connecting partial pit ventilation with an efficient air cleaner to create a cost-efficient solution to reduce emissions of ammonia and odour. New types of air cleaners might be needed for this purpose, because of the very high concentrations of odour, hydrogen sulphide and ammonia.

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