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The Effect of Pit Ventilation on the Emission of Odorants from Pig Production

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The aim of the present study was to investigate the effect of pit ventilation on the emission of odorants from pig production facilities. The study was conducted in four experimental facilities with 32 growing-finishing pigs (32–107 kg) in each. Facility A had partly slatted floor and only room ventilation, facility B had fully slatted floor and only room ventilation and facility C and D had fully slatted floor as well as room and pit ventilation. Over a period of six weeks in the middle of the production cycle four air samples were collected once a week from each outlet. The setting for the pit ventilation in facility C and D was alternated each week between 10 or 20 % of the maximum ventilation rate. The air samples were collected in 30 L polyethylene terephthalate (PET) bags. In one half of the samples the odour concentration was measured by dynamic olfactometry approximately 24 h after sampling and in the other half of the samples the concentrations of odorants were measured by Proton-Transfer-Reaction Mass Spectrometry (PTR-MS) approximately 4 h after sampling. The results showed that the emission of odorants such as reduced sulphur compounds, trimethylamine, butanoic acid and 4-methylphenol was higher from the pit ventilation compared to the room ventilation when the pit ventilation was set at 20 %. The results for acetic acid and propanoic acid demonstrated an opposite trend with higher emissions from the room ventilation compared to the pit ventilation. Furthermore, the emission of acetic acid and propanoic acid was higher from the partly slatted facility A compared to the fully slatted facility B and it seems that the surfaces in the facilities also contribute to the emission of carboxylic acids. In conclusion, pit ventilation can be used to concentrate most of the odorants found in pig production facilities in a small part of the ventilation air. More research is needed to study how the emission of odorants from room and pit ventilation is dependent on the pit ventilation rate and the design of the pit ventilation (fouling or resting area of the pen).

1. Introduction

Abatement technologies such as chemical and biological air cleaning can be used to lower the emission of ammonia and odour from modern intensive pig production (Melse and Ogink, 2005). However, air cleaning can be very costly when all the ventilation air (approximately 100 m^3 h^{-1} pig^{-1}) needs to be treated. The combination of pit ventilation and air cleaning may be a way to reduce the cost related to air cleaning. Pit ventilation has the advantage that ammonia and odour can be concentrated in a small part of the ventilation air (10–20 % of the maximum ventilation rate), while the remaining ventilation air contains lower concentrations (Pedersen and Jensen, 2010).
It has recently been demonstrated that biological air cleaning can be used to remove a large part of the odorants found in ventilation air from pig production (Feilberg et al., 2010a; Hansen et al., 2012).

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Although an air cleaner can remove the odorants emitted from the pit ventilation, it is also important that the emission of odorants from the untreated ventilation air is low. The effect of pit ventilation on the total emission of odorants from pig production facilities with both room and pit ventilation has not been investigated in previous studies. It is therefore of great interest to investigate the emission of odorants from the pit ventilation and the remaining ventilation air in order to evaluate the potential of pit ventilation in relation to air cleaning.

Proton-Transfer-Reaction Mass Spectrometry (PTR-MS) is an on-line measurement technique based on chemical ionization with protonated water (H_3O^+) that has been used in other studies to measure odorants from cattle production (Ngwabie et al., 2008; Shaw et al., 2007) and pig production (Feilberg et al., 2010b; Hansen et al., 2012). The PTR-MS has the advantage that it can measure most of the odorants found in pig production including the highly odorous sulphur compounds. In the present study a semi-field method was applied where air samples were collected in polyethylene terephthalate (PET) bags and analysed by PTR-MS. The aim was to investigate the effect of pit ventilation on the emission of odorants from facilities with growing-finishing pigs.

2. Materials and methods

2.1 Pig production facilities

Four experimental pig production facilities (Pig Research Centre, Danish Agriculture & Food Council, Grønhøj, Denmark) with 32 growing-finishing pigs in each were used. The facilities (A-D) were equipped with dry feeding and negative pressure ventilation with a diffuse air inlet through the ceiling:

- Facility A had partly slatted floor and only room ventilation.
- Facility B had fully slatted floor and only room ventilation.
- Facility C and D had fully slatted floor and both room and pit ventilation.

In facility C the pit ventilation was placed in the fouling area of the pen and in facility D it was placed in the resting area. In facility C and D 10 or 20 % of the maximum ventilation rate (3,200 m^3 h^{-1}) was ventilated through the pit ventilation, while the remaining ventilation capacity was ventilated through the room ventilation. During half of the experimental period the pit ventilation in facility C and D was set at 10 % and in the other half it was set at 20 %. The ventilation rate in each ventilation outlet was measured using a measuring fan (Fancom BV, Panningen, Netherlands).

2.2 Experimental setup

Air samples were collected from the outlets in the four facilities over a period of six weeks in the middle of the production cycle. Once a week four air samples were collected in 30 L PET bags (Nalophan NA, OLFAtec GmbH, Kiel, Germany) from each outlet. Half of the samples were sent to an odour laboratory (Danish Meat Research Institute, Roskilde, Denmark) for analysis of the odour concentration by dynamic olfactometry (CEN, 2003) approximately 24 h after sampling. The other half of the samples were sent to Aarhus University for analysis of odorants by PTR-MS approximately 4 h after sampling.

2.3 Analytical instrument

A high sensitivity PTR-MS (Ionicon Analytik, Innsbruck, Austria) was used to measure the concentrations of odorants in the PET bags. The PTR-MS is based on chemical ionization with protonated water (H_3O^+) and can measure compounds with a proton affinity higher than water. The PTR-MS was operated under standard conditions with a drift tube voltage at 600 V and a pressure between 2.1–2.2 mbar (E/N value 135 Td). Single ion monitoring was used and each ion was detected for 500 ms during each cycle. A total of 30 cycles was measured during the measurement on each PET bag. Permeation tubes (VICI Metronics Inc., Houston, TX) were used to calibrate the measurements of hydrogen sulphide (m/z 35), methanethiol (m/z 49), dimethyl sulphide (m/z 63), acetic acid (m/z 61+43) and 4-methylphenol (m/z 109; 3-methylphenol was used as a surrogate). The concentrations of trimethylamine (m/z 60), propanoic acid (m/z 75+57) and butanoic acid (m/z 89+71) were estimated based on the rate constants for proton-transfer, the estimated drift tube residence time and the mass specific transmissions factors as described by (de Gouw and Warneke, 2007). The concentrations of carbon dioxide and ammonia were measured in the ventilation outlets using Kitagawa gas detection tubes (Mikrolab Aarhus A/S, Aarhus, Denmark).

3. Results and discussion

In Table 1 the average climatic conditions in the pig production facilities during the collection of samples is shown. The measurements were performed in August and September and the outside temperature was 15.1 ± 4.2 ˚C during the measurements with 10 % pit ventilation, and 16.5 ± 1.4 ˚C during the measurements with 20 % pit ventilation. The ventilation rates in the four facilities were always below the maximum ventilation rate (3200 m^3 h^{-1}). It can be seen from Table 1 that the pit ventilation rate was close to the expected value at 320 m^3 h^{-1} (10%) and 640 m^3 h^{-1} (20 %). Table 1 clearly demonstrates that the concentration of ammonia was lower in the room ventilation in the facilities with pit ventilation compared to facility A and B. High concentrations of contaminants in pig production facilities can have a negative effect on the air quality, but it seems that pit ventilation is an effective method to improve the air quality.

Table 1: Average climatic conditions during collection of air samples (n=6).

Facility†	A	B	C		D	
Ventilation	Room	Room	Pit	Room	Pit	Room
			Pit ventilation: 10%			
Ventilation rate, m^3 h^{-1}	1,710	1,430	285	1,435	285	1,305
Temperature, ˚C	19.4	20.9	20.1	19.5	20.2	20.0
Relative humidity, %	72.9	72.8	82.5	73.4	79.9	76.1
Ammonia, ppm_v	5	8	29	3	19	2
Carbon dioxide, ppm_v	1,100	1,400	1,500	1,100	1,500	1,200
			Pit ventilation: 20%			
Ventilation rate, m^3 h^{-1}	1,860	1,573	595	1235	600	880
Temperature, ˚C	20.7	21.9	21.3	20.8	21.7	21.6
Relative humidity, %	70.2	67.8	79.2	70.3	76.1	70.3
Ammonia, ppm_v	5	7	18	1	14	1
Carbon dioxide, ppm_v	1,000	1,200	1,300	900	1,300	800

† A: partly slatted floor; B: fully slatted floor; C: fully slatted floor and pit ventilation in the fouling area of the pen; D: fully slatted floor and pit ventilation in the resting area of the pen.

The average emission of odorants and odour from the four facilities is shown in Table 2. The results are based on collection of air samples in PET bags and analysis by PTR-MS. It has previously been shown that the concentration of odorants is decreased during storage in PET bags (Koziel et al., 2005; Mochalski et al., 2009). The air samples in the present study were analysed approximately 4 h after sampling and the results can only be used to evaluate the relative emission from the four facilities. The results demonstrate that the emission of hydrogen sulphide was lower from the facility with partly slatted floor (A) compared to the facility with fully slatted floor (B), whereas the emission of acetic acid and propanoic acid was higher. However, it should also be noticed that the average ventilation rate was slightly higher in the facility with partly slatted floor (Table 1). In the facilities with pit ventilation (C and D) the emission of hydrogen sulphide was higher from the pit ventilation compared to the room ventilation both at 10 and 20 % pit ventilation, while the emission of acetic acid and propanoic acid was higher from the room ventilation. The higher emission of some carboxylic acids from the partly slatted facility and the room ventilation in the facilities with pit ventilation indicates that the surfaces in the facilities also contribute to the emission of carboxylic acids. This means that even though the pit ventilation is combined with an air cleaner there will be an emission of carboxylic acids from the untreated room ventilation. Carboxylic acids have relatively high odour threshold values compared to the concentration level found in pig production (Feilberg et al., 2010b; Hansen et al., 2012) and may only have a limited effect on the odour impression. The samples from 10 and 20 % pit ventilation cannot be compared directly because they were collected in different weeks. However, the results indicate that increasing the pit ventilation from 10 to 20 % decreases the emission of odorants from the room ventilation and increases the emission of odorants from the pit ventilation. The emission of acetic acid and propanoic acid at 20 % pit ventilation was also higher from the room ventilation, but compared to 10 % pit ventilation the emission was decreased from the room ventilation and increased from the pit ventilation. The odour emission based on the measurements by dynamic olfactometry also indicates that the emission was higher from the pit ventilation compared to the room ventilation in facility C and D at 20 % pit ventilation and in facility D at 10 % pit ventilation. In facility C at 10 % pit ventilation the odour emission was slightly higher from the room ventilation compared to the pit ventilation. In facility C the pit ventilation was placed in the fouling area of the pen and this indicates that the pit ventilation is less effective when it is placed in the fouling area of the pen. Further research is needed to investigate the optimum distribution between room and pit ventilation and the design of the pit ventilation (fouling or resting area of the pen) in order to have the lowest emission as possible from the room ventilation.

Table 2: Average emission (mg h^{-1}) of selected odorants from facilities with growing-finishing pigs (n=6).

Facility[†]	A	B	C		D	
Ventilation	Room	Room	Pit	Room	Pit	Room
			Pit ventilation: 10 %			
Hydrogen sulphide	183	1,060	410	215	389	86
Methanethiol	9	17	8	7	7	5
Dimethyl sulphide	11	14	5	9	4	8
Trimethylamine	15	18	9	10	7	10
Acetic acid	1,170	694	41	981	26	878
Propanoic acid	347	250	13	347	7	326
Butanoic acid	16	19	7	13	6	12
4-methylphenol	15	20	5	15	4	13
Odour (OU_E s^{-1})	320	419	119	165	195	125
			Pit ventilation: 20%			
Hydrogen sulphide	309	522	484	46	762	17
Methanethiol	18	15	12	3	11	2
Dimethyl sulphide	19	17	10	6	10	5
Trimethylamine	16	20	12	5	11	5
Acetic acid	1,530	941	212	469	176	445
Propanoic acid	498	357	91	178	80	173
Butanoic acid	26	24	15	8	14	7
4-methylphenol	17	13	9	5	8	5
Odour (OU_E s^{-1})	239	315	231	108	231	62

[†] A: partly slatted floor; B: fully slatted floor; C: fully slatted floor and pit ventilation in the fouling area of the pen; D: fully slatted floor and pit ventilation in the resting area of the pen.

Although the combination of room and pit ventilation can concentrate the emission of odorants in the pit ventilation it still requires an efficient air cleaner that can remove the odorants emitted from the pit ventilation. It has previously been demonstrated that a biological air cleaner can remove odorants such as carboxylic acids, aldehydes, ketones, phenols and indoles to a high extent (80–99 %) (Feilberg et al., 2010a; Hansen et al., 2012). The study by Hansen et al. (2012) also demonstrated that the biological air cleaner could remove approximately 75 % of hydrogen sulphide, whereas only ~ 0–15 % of methanethiol and dimethyl sulphide was removed. Reduced sulphur compounds such as hydrogen sulphide and methanethiol have relatively low odour threshold values compared to the concentration level found in pig production and are considered to be important odorants (Feilberg et al., 2010b; Hansen et al., 2012). In Figure 1 it is shown how much the total emission of hydrogen sulphide from facility C and D can be decreased if the air cleaner removes 75 % of hydrogen sulphide. An air cleaner with a removal efficiency at 75 % decreases the total emission of hydrogen sulphide with 49–61 % at 10% pit ventilation and 68–73 % at 20 % pit ventilation. Even though 75 % of hydrogen sulphide is removed from the pit ventilation in facility C and D the total emission is at the same level as the partly slatted facility (A). Furthermore, methanethiol is only removed to a low extent in a biological air cleaner and may still have a large influence on the odour impression. This underlines that the combination of pit ventilation and biological air cleaning requires that the cleaning efficiency is improved in relation to the highly odorous sulphur compounds.

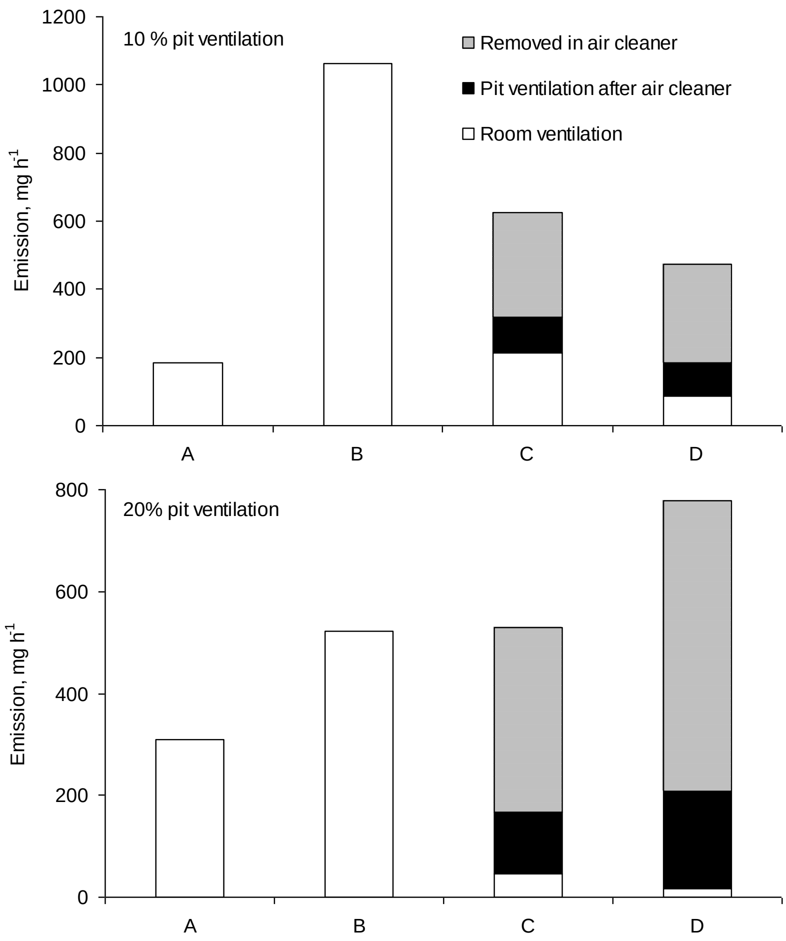

Figure 1: Effect of an air cleaner with a removal efficiency at 75 % on the emission of hydrogen sulphide from pig production facilities with room and pit ventilation. A: partly slatted floor; B: fully slatted floor; C: fully slatted floor and pit ventilation in the fouling area of the pen; D: fully slatted floor and pit ventilation in the resting area of the pen

4. Conclusions

It can be concluded that pit ventilation can be used to concentrate the emission of odorants in a small part of the maximum ventilation rate, whereas the emission from the room ventilation is lower for most of the odorants. For some carboxylic acids the emission from the room ventilation is higher compared to the pit ventilation which is ascribed to emission from surfaces in the room. More research is needed to investigate how the emission of odorants from room and pit ventilation is dependent on the pit ventilation rate and the design of the pit ventilation (fouling or resting area of the pen).

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