Air quality and reduction of slatted floor in growing-finishing pig units

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ABSTRACT

This study was carried out to establish the influence of partially slatted floors combined with the pen size on the air quality in growing-finishing rooms. Three rooms were compared: the control room with totally slatted concrete floor had six pens each with ten pigs. The second room with partially slatted concrete floor had six pens each with eight pigs, and the room with partially slatted concrete floor had two pens each with twenty four pigs. During the study, the ammonia concentrations in the ambience, the ammonia and the odour emissions were measured every 15 days between pig entry and first pig slaughterings, 96 days later. The type of floor appears to have a notable effect. Whatever the pen size, the ammonia concentration was multiplied by two in the partially slatted floor room compared to the control room. The average ammonia emission was 20% higher, and the odour emission was 80% higher. Whatever the pen size, the dirtiness of the solid floor appears to be the main source of ammonia and odour.

Keywords: Pig, Odour, Ammonia, Building, Type of floor.

INTRODUCTION

In order to increase the animal welfare, a European directive imposed on pig breeders to replace a significant portion of slatted surfaces by solid floors. In France, approximately 90% of all pig units have totally slatted concrete floors. In our country, the development of pig facilities is increasingly restricted by environmental parameters leading to a very small number of new buildings. The direct consequence of this new regulation would be the adaptation of existing buildings conceived with fully slatted floors. The aim of the study is to evaluate the effect of the reduction of slatted area in rooms initially conceived with fully slatted floors on environmental parameters as ammonia and odour emissions.

MATERIALS AND METHODS

In order to assess the impact of partially slatted floors on gaseous emissions, an experiment was conducted at the experimental farm of ITP in Britannia (France). The study was carried out on two batches of 156 growing-finishing pigs. Fattening pigs approximately 10 weeks old were used. Pigs were weighed at the beginning and at the end of each period. Their mean starting and finishing weights were 26.6 ± 3.5 kg and 107.8 ± 12.7 kg. The mean duration of the fattening periods was 95.3 ± 15.4 days and the average daily gain was 854.9 ± 140.9 g per day. Feed and water were available *ad libitum*.

Housing

For each batch, three rooms were compared: a control room with totally slatted floor and two rooms with partially slatted floors. The slats in the fattening rooms were made of concrete. The pen size was the only difference between the last two rooms. At the beginning of each fattening period, the slurry pits were empty and clean. The pit was completely emptied twice for rooms with partially slatted floor and just after departure of pigs for slaughtering for the control room.

Air was not heated before entering room via a ceiling of perforated plastic sheeting. The ventilation rate was controlled by sensing the room temperature. No heated system was installed to manage the temperature of the solid floor in pens. Temperature and exhaust ventilation rate are continuously recorded. Ventilation rate was measured with an anemometer with the same diameter as the fan channel. Every fan was calibrated before each pig entered the room. Ventilation rates were recorded every 15 minutes during the whole period of fattening. Average ventilation rates were 1740 ± 31.2,1749 ± 38.8 and 1720 ± 50.5 m^3/h, respectively, for the control, PS8 and PS24 rooms. For the control room, the extraction system was under-floor and over-floor for the other two rooms. Ambient temperature was measured 1.50 m above the floor in the middle of the room and recorded every 15 minutes. Outdoor temperature was 13.4 ± 4.0 during the study. Mean temperatures were 22.5 ± 0.8, 23.6 ± 0.6, 23.5 ± 0.8°C, respectively, for the control, PS8 and PS24 rooms. Surfaces per pig were 0.68 m^2 in the control room and 0.85 m^2 in the two rooms with partially slatted floor. The slatted floor areas were 47 and 42%, respectively, of the total floor area of PS8 and PS24. For the rooms PS8 and PS24, the solid floor was scraped each morning in order to condition the pig behaviour for the pigs to choose their lying area.

Measurements

Each two weeks, odorous air was sampling from the extracted duct in order to determine the odour concentration. Air samples were analysed by the CERTECH Laboratory (Seneffe- Belgium) for the determination of the odour threshold, which is defined as the dilution factor at which 50% of an odour panel can just detect an odour (CEN, 1999). Equipment and procedures are conformed to current recommendations (French Standard NF X 43-101, NFX 43-104 – AFNOR, 1986 and 1990 – European project standard prEN 13725 – CEN, 1999). Odour concentration is expressed as odour unit (OU or OUm^{-3}). The rate of emission from an odour source is the product of the concentration and the volumetric flow rate (m^3/s) of the emissions. Consequently, the units for the odour emission rate are $OU.s^{-1}$. In order to compare with literature, odour emission rate will be expressed in $OU.s^{-1}.LU^{-1}$ (1 LU = Livestock Unit = 500 kg live weight).

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Every two weeks, the ammonia concentration was measured by use of colorimetric gas detector tubes (ammonia 2/a Draeger tubes) in the ambient air 0.3 m and 1 m above the floor. Ammonia 2/a Draeger tubes have a measuring range of 2-30 ppm.

The ammonia concentration in extracted air was measured by a bubbling method. A known volume of air was sampled in the extracted duct and bubbled through a sulphuric acid solution. Chemical analyses permitted determination of the ammoniacal nitrogen content and the ammonia concentration in air samples. The ammonia emission is the result of the product of the concentration and the flow rate divided by the number of pigs per room. The unit used for the ammonia emission is g per day per pig (g/d/p).

The slurry was removed just after removal of pigs for slaughtering for the control room and three times (two intermediary emptyings) for both partially slatted floor rooms. Whenever the slurry was removed, samples were taken from each room and analysed. The slurry level was recorded at each pit emptying.

RESULTS

Ammonia concentrations

For both rooms, there was no significant difference between ammonia concentrations measured at 0.3 and 1 m above the floor. In our study, concentrations in the control room (Table 1) are slightly lower than values given in previous publications. GROOT KOERKAMP *et al.* (1998) reported values between 12.1 and 18.2 ppm for growing-finishing pigs reared on totally slatted floor in Northern Europe. GUSTAFSSON (1995) observed ammonia concentrations ranging between 10 and 45 ppm in finishing rooms during winter.

Table 1. Average ammonia concentrations

Ammonia concentration (ppm)	Control room	PS8 Partially slatted floor 8 pigs per pen	PS24 Partially slatted floor 24 pigs per pen
0.3 m above the floor	9.4 ± 7.1	21.0 ± 8.8	15.4 ± 11.2
Number of measurements	54	54	52
1.0 m above the floor	8.8 ± 6.1	21.6 ± 8.7	15.7 ± 11.6
Number of measurements	54	54	52
Average concentration	9.1 ± 6.6	21.3 ± 8.7	15.5 ± 11.3
Number of measurements	108	108	104

In our study, reductions of close to 50% of the slatted area increased the ammonia concentration by 70% for PS8 and 134% for PS24. Compared to results published by HENDRIKS *et al.* (1997) and GROOT KOERKAMP and UENK (1997), ammonia levels (between 18 and 20 ppm) measured in the winter period in rooms with partially slatted floor were similar to our results. In our study, until the 47th day, the ammonia concentration ranged within the upper 25 ppm, which is the limit value imposed for the respect of worker's health in pig facilities in France (INRS, 1986).

Ammonia emission rates

The ammonia emission rates measured in the control room (Table 2) were close to the previous values published in same conditions (GUINGAND, 1997). For KECK and BUSCHER (1994), the ammonia emissions obtained in the winter period for fattening pigs on totally slatted floor were 12.6 and 12.2 g/d/p, respectively, for under and over floor extraction. Those results are higher than those obtained in our study. In the winter period, the ammonia emission was 10.7 g/d/p in an experiment made on partially slatted floor (HENDRIKS *et al.*, 1997).

Table 2. Ammonia concentrations and emission rate

	Control room	**PS8 Partially slatted floor 8 pigs per pen**	**PS24 Partially slatted floor 24 pigs per pen**
Ammonia concentration (mg/m^3)	15.3 ± 5.1	16.5 ± 8.5	17.8 ± 8.6
Ammonia emission rate (g/d/p)	10.0 ± 3.1	12.2 ± 6.5	12.5 ± 6.2
Range (g/d/p)	4.7 – 13.6	3.9 – 19.3	4.6 –18.7
Ammonia emitted for the growing-finishing period (96 days) (g/p)	960	1171	1200

The standard deviations are significant for both rooms with partially slatted floors (Table 4). In order to explain this great variation, the evolution of this ammonia emission rate per measuring period is given in the following figure (Figure 1). The ammonia emissions were increased towards the end of the fattening period. The initial emission rates were about 5 g/d/p for both rooms, and the final emission rates were 13.6, 17.6 and 18.7 g/d/p, respectively, for the control room, PS8 and PS24. In our study, the ammonia emission increased slightly in the control room between the beginning and the end of the trial. This was already demonstrated by HOEKSMA *et al.* (1992).

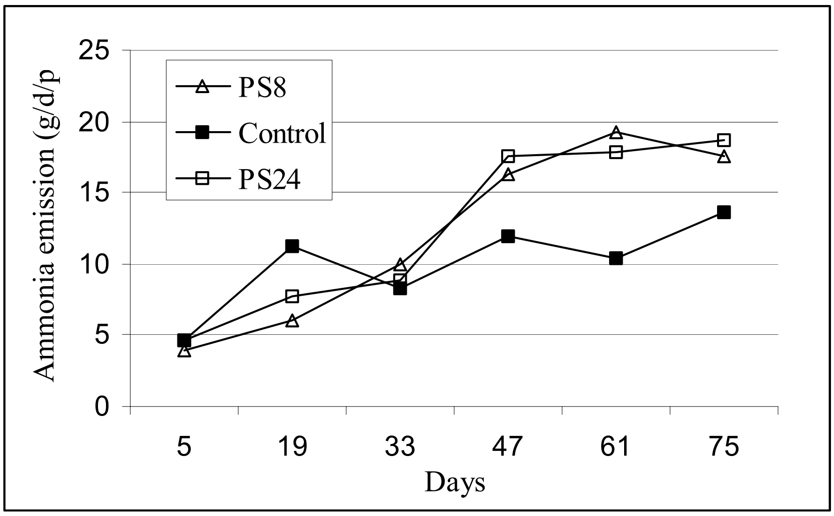

Figure 1. Evolution of ammonia emission rates during the study

Odour concentration and emission

The odour emission rates were 199.5, 352.4 and 339.7 $OU.s^{-1}$. LU^{-1}, respectively, for the control room, PS8 and PS24 rooms. The values obtained in our study (Table 3) were significantly higher than some of the values referred to in the literature (Table 4). Nevertheless, in both partially slatted rooms, the odour emissions increased by around 80% in comparison with emission from the control room.

Table 3. Odour concentrations and emission rates

	Control room	PS8 Partially slatted floor 8 pigs per pen	PS24 Partially Slatted floor 24 pigs per pen
Odour concentration (OU)	4986 ± 4413	6565 ± 3518	5932 ± 3066
Range (OU)	1200 – 16860	2000 – 14020	1900 – 12210
Odour emission rate ($OU.s^{-1}$)	2274 ± 2022	3239 ± 1996	2796 ± 1933
Range (OU/s)	440 – 6750	1038 –7726	1049 - 6846
Odour emission rate per pig ($OU.s^{-1}$)	39.9 ± 35.9	70.5 ± 43.9	67.9 ± 52.8
Range	7.3 – 118.4	22.6 – 164.4	21.9 – 190.2
Odour emission rate ($OU.s^{-1}.LU^{-1}$)	199.5 ± 197.7	352.4 ± 219.8	339.7 ± 263.9
Range ($OU.s^{-1}.LU^{-1}$)	36.7 – 592	112.8 – 821.9	109.3 – 850.9

1LU = Livestock Unit – 1 LU = 500 kg live weight

DISCUSSION

In the present study, the ammonia concentrations in the pig surroundings as well as the ammonia and odour emission rates increased significantly with the reduction of slatted floors. In this experiment, the ammonia emission rates from rooms with partially slatted floors are 20% higher than the emission from the control room. PFEIFFER *et al.* (1993) found higher emissions from a partially slatted floor than from a fully slatted floor. On the contrary, HOEKSMA *et al.* (1992) and AARNINK *et al.* (1996) observed reductions in the ammonia emission rate with decreasing slatted floor areas in houses for finishing pigs. In a study of AARNINK *et al.* (1996), the average ammonia emission was 6.4 ± 2.4 g/d/p in a finishing pig house with 50% slatted floor. This value is 50% lower than that measured in the two partially slatted floor rooms of our trial. Nevertheless, several differences can be identified between those studies. In the Dutch study, the solid floor was heated, thus generating a comfortable lying area for of pigs. That was not the case in our study. Differences between studies appear to be based on pig behaviour. In our study, the pigs considered both the solid and the slatted floor as excretory areas. It means that dejections were identically present on the solid and the slatted areas. This was confirmed by the dirtiness of pigs and pens in both partially slatted rooms. Towards the fattening period, both the pigs and the floor in the control room were cleaner than in the two others rooms. As described by AARNINK *et al.* (1997), the effect of slatted floors on the ammonia emission can be divided into two components: the emission from the slats and the emission from the solid floor. In our study, the positive effect of reducing the slatted area was cancelled by the increasing emission of the solid floor.

Concerning odour emissions, a significant number of papers were found to report quantified odour measurements. However, emission rates are expressed very differently, thereby complication the comparison between values. In our study, odour emissions are expressed in odour units per second per livestock unit (1 livestock unit = 500 kg live weight). In order to compare our results with the literature, values obtained in different studies were converted to the same unit (Table 4). The first conclusion is that there is a great variation on odour emission levels from one paper to the other. Odour emissions range from 3.8 to 568.8 OU per second per livestock unit for finishing pigs. As shown by SMITH and DALTON (1999), there is a strong relation between odour emission rate and pen cleanliness. When pens are less clean, the odour emission rate increases. In our study, the pens in rooms with partially slatted floors are less clean than the pens in the control room. A significant quantity of manure stays on the solid floor, which is favourable for the volatilisation of odorous compounds.

Table 4. Odour emission rate in literature and the way of expression

References (authors, year)	Odour emission rate	Unit of expression	Information given in the paper	Odour emission rate converted in $OU.s^{-1}.LU^{-1}$ (1-3)
KLARENBEEK (1985)	1.33–6.50	DT_{50}/s/p	Fully slatted floor Season (summer/winter)	7.4–36.1
KLARENBEEK (1985)	0.69–4.25	DT_{50}/s/p	Partially slatted floor Season (summer/winter)	3.8–23.6
DALTON *et al.* (1997)	3.5–38.6	OU s^{-1} per pig	Finishing pigs Ventilation rate	19.4–214
MARTINEC *et al.* (1998)	38–495	OU $s^{-1}LU^{-1}$ (1)	Fully slatted floor Finishing pigs	38–495
WATTS (2000)	8–16	OU $s^{-1}SPU^{-1}$ (2)	Finishing pigs	100–200
SMITH & DALTON (1999)	1.3 – 45.5	OU $s^{-1}SPU^{-1}$ (2)	Finishing pigs	16.3–568.8
BOTTCHER *et al.* (2000)	19–45	OU $s^{-1}AU^{-1}$ (4)	Ventilation rate	19–45
MULLER (1994)	32.8–58.8	OU s^{-1} LU^{-1} (1)	Partially slatted floor	32.8–58.8
HARTUNG *et al.* (1998)	126	OU s^{-1} LU^{-1} (1)	Fully slatted floor	38–495
HEBER *et al.* (1998)	96	OU s^{-1} LU^{-1} (1)	Fully slatted floor	96

I. LU =Livestock unit = 500 kg live weight
II. SPU = Standard Pig Unit = 40 kg live weight
III. When pig weight is not specified, a pig weight of 90 kg has been considered.
IV. AU = Animal unit = 500 kg live weight

CONCLUSIONS

In our experiment, the reduction of the slatted area led to depreciate the air quality inside the building. The ammonia and odour emissions measured for partially slatted floors were higher than for fully slatted floors. In this trial, the positive effect of the reduction of slatted area observed by different authors appears to be cancelled by the dirtiness of the solid floor. No difference was observed between pen sizes. The cleanliness of the pens is mainly influenced by the pig behaviour. There is a strong correlation between the comfortable aspect of solid floors and the excretory behaviour of finishing pigs. This means that a simple reduction of slatted floors cannot be made in French pig units without a change of the ventilation systems and the heating systems for the solid area.

REFERENCES

Aarnink, A.J.A., Van den Berg, A.J., Keen, A., Hoeksma, P. & Verstegen, M.W.A., 1996. Effect of slatted floor area on ammonia emission and on the excretory and lying behaviour of growing pigs – Journal of Agricultural Engineering Research, 64: 299-310.

Aarnink, A.J.A, Canh, T.T. & Mroz, Z., 1997. Reduction of ammonia volatilisation by housing and feeding in fattening piggeries. In: Proceedings of the congress " Ammonia and odour control from animal production facilities",Vinkeloord, The Netherlands, October 6-10, 1997: 283-291.

Afnor, 1986. NF X 43 101. Méthode de mesurage de l'odeur d'un effluent gazeux. Détermination du facteur de dilution au seuil de perception. Qualité de l'air tome 2 : 253-271.

Afnor, 1990. NF X 43 104. Atmosphères odorantes : Méthodes de prélèvements – Qualité de l'air tome 2: 272-282.

Bottcher, R.W., Keener, K.M., Munilla, R.D., Williams, C.M. & Schiffman, S.S., 2000. Dust and odor emissions from tunnel ventilated swine buildings in North Carolina. In: Proceedings of the congress "Air pollution from agricultural operations", 2nd International Conference, October 9-11, Des Moines, Iowa: 196-203.

CEN, 1999. Air quality – determination of odour concentration by dynamic olfactometry. Draft European Standard, prEN 13725, Comité Européen de Normalisation, Brussel, Belgium.

Dalton, P.A., Harris, T.R., Smith, R.J. & Hancock, N.H., 1997. Odour emissions from piggery buildings. In: Proceeding of the congress "National Workshop on odour measurement standardisation", August 20-22, Sydney, Australia: 1-9.

Gustafsson, P.J.G., 1995. Abatement and control of air pollutants in and from buildings. FEZ Pragues: 1-12.

Groot Koerkamp Ir., P. W.G. & Uenk, G.H., 1997. Climatic conditions and aerial pollutants in and emissions from commercial animal production systems in the Netherlands. In: Proceedings of the congress "Ammonia and odour control from animal production facilities", October 6-10; Vinkeloord, The Netherlands: 139-144.

Groot Koerkamp, P.W.G., Metz, J.H.M., Uenk, G.H., Phillips, V.R., Holden, M.R., Sneath, R.W., Short, J.L., White, R.P., Hartung, J., Seedorf, J., Schroder, M., Linkert, K.H., Pedersen, S., Takai, H., Johnsen, J.O. & Wathes, C.M., 1998. Concentrations and emissions of ammonia in livestock buildings in Northern Europe. Journal of Agricultural Engineering Research 70: 79-95.

Guingand, N., Granier, R., Massabie, P., 1997. Characterization of air extracted from pig housing: effects of the presence of slurry and the ventilation rate. In: Proceedings of the congress"Ammonia and odour control from animal production facilities", October 6-10; Vinkeloord, The Netherlands: 49-55.

Hartung, E., Martinec, M., Lais, S. & Jungbluth, T., 1998. Testing Measures to improve the ammonia reduction of bioscrubber and biofilters. Eur Ag Eng Paper No. 98-E-008, AgEng 98, Oslo, Norway.

Heber, A.J., Bundy, D.S., Lim, T.T., Haymore, B.L., Diehl, C.A. & Duggirala, R.K., 1998. Odour emission rates from swine finishing building- In the proceedings of the congress ”Animal Production Systems and the Environment”, International conference on Odour, Water Quality, Nutrient Management and Socioeconomic Issues, July 19-22, Des Moines, Iowa, USA: 305-310.

Hendriks, J., Berckmans, D. & Vinckier, C., 1997. Field test of bio-additives to reduce ammonia emission from pig houses. In: Proceedings of the congress “Ammonia and odour control from animal production facilities”, October 6-10, Vinkeloord, The Netherlands: 707-714.

Hoeksma, P., Verdoes, N., Oosthoek, J. & Voermans, J.*A.M.*, 1992. Reduction of ammonia volatilization from pig houses using aerated slurry as recirculation liquid. Livestock Production Science 31: 121-132.

INRS, 1986. Valeurs limites pour les concentrations des substances dangereuses. Cahier de notes documentaires n°125 4ème trimestre 1986.

Keck, M. & Buscher, W., 1994. Influence on the ammonia emission by under-and overfloor extraction in a pig house. Eur Ag Eng Paper No. 94-C-027, AgEng Milano 94, Italia : 7 pp.

Klarenbeek, J.V., 1985. Odor emissions of Dutch agriculture – In “Waste utilization and management”, 5th International Symposium on Agricultural Wastes, Chicago, USA: 439-445.

Martinec, M., Hartung, E. & Jungbluth, T., 1998. Odour emissions data from animal housing. KTBL Arbeitspapier 260, ISBN 3-7843-1998-2.

Muller, H.J., 1994. Rates of odour and pollutant emission from animal housing: measurements and analysis. Landtechnik 49(6): 360-371.

O’Neill, D.H. & Phillips, V.R., 1991. A review of the control of odour nuisance from livestock buildings: Part 1, Influence of the techniques for managing waste within the building. Journal of Agricultural Research 50: 1-10.

Pfeiffer, A., Arends, F., Langholz, H.J. & Steffens, G., 1993. The influence of various pig housing systems and dietary protein levels on the amount of ammonia emissions in the case of fattening pigs. In: Proceedings of the congress “Nitrogen flow in pig production and environmental consequences”, First international symposium, June 8-11, Wageningen, The Netherlands: 313-317.

Smith, R.J. & DALTON, P.A., 1999. Factors affecting the rate of odour emissions from Australian piggery building . Australasian Environmental Engineering Conference: 257-262.

Watts, P.J., 2000. Modelling odor emissions from Australian piggeries. In: “Air pollution from agricultural operations”, 2nd International Conference, October 9-11, Des Moines, Iowa, USA: 353-360.