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COMPARISON OF AMMONIA AND GREENHOUSE GAS EMISSIONS FROM FATTENING PIGS KEPT EITHER ON PARTIALLY SLATTED FLOOR IN COLD CONDITIONS OR ON FULLY SLATTED FLOOR IN THERMONEUTRAL CONDITIONS

N. GUINGAND[1], N. QUINIOU[1], V. COURBOULAY[1]

ABSTRACT

Continuous measurements of ammonia and greenhouses gases were achieved on exhaust air from two fattening rooms differing by the type of floor (totally slatted floor vs. partially slatted floor) and the ambient temperature. Temperature was regulated at 18°C in the room with partially slatted floor (room PSF18) and 24°C in the room with fully slatted floor (FSF24). Pigs were fed ad libitum. Daily feed intake, growth rate and carcass backfat thickness were significantly higher for PSF18 pigs than for FSF24 ones, corresponding to a higher feed conversion ratio for PSF18 pigs. Under cold conditions (18°C), the N-NH_3, N-N_2O, C-CH_4 and C-CO_2 daily emissions per pig on partially slatted floor were similar to those on fully slatted floor under thermoneutral conditions (FSF24: 8.9–0.12-7.3 and 676 g, PSF18: 9.1–0.15-8.4 and 629 g/pig, respectively). A further reduction of ammonia emission from pig units on partially slatted floor would require a more pronounced reduction of ambient temperature. However, in such conditions, a deterioration of feed conversion ratio and carcass leanness may be expected. Thus, the extra-cost induced by the utilization of partially slatted floor in cold ambient conditions would not be acceptable with regard to the definition of Best Available Techniques given by the IPPC directive.

KEYWORDS. Pig housing, ammonia, greenhouse gas, floor, temperature

INTRODUCTION

In September 1996, the Directive 96/61/CE was adopted by the European Union Council and commonly called the IPPC Directive (Integrated Pollution Prevention and Control). The purpose of the Directive was to limit the pollution transfer by applying a global approach including the protection of air, water and soil. This Directive focuses mainly on ammonia emissions, water and energy consumptions. Among all industrial activities concerned, installation for the intensive rearing of pigs with more than 2 000 places for production pigs over 30 kg or 750 places for sows are considered under the scope of the Directive. Intensive poultry farming over 40 000 places are also concerned. Pig farmers have to take all appropriate preventive measures against pollution though the application of Best Available Technique (BAT) enabling them to improve their environmental performance. The 2001/81/CE, called the NEC Directive (National Emission Ceilings), was adopted in October 2001 and fixed national emissions ceilings to reach in 2010 for nitrogen oxides, Volatile Organic Compounds, sulphur dioxide and ammonia. In the NEC Directive, Best Available Techniques (BAT) are given as a tool to achieve ceilings in particular for ammonia.

The reduction of slatted floor, especially in fattening housing, is commonly presented in the BREF document (IPPC, 2003) as an efficient way to reduce ammonia emitted by building. Because of the reduction of manure surface area and frequent slurry removals, ammonia abatement between 15 and 35 % is expected. In France, 60% of sows and around 80% of fattening pigs are reared on fully slatted floor. Because a small number of new units will be built, existing buildings will have

[1] IFIP, BP 35104, La Motte au Vicomte, F-35651Le Rheu, France – nadine.guingand@ifip.asso.fr.

to be adapted. The main objective of studies conducted by our institute was to analyze the possibility of the adaptation of existing fully-slatted floor systems with the lowest cost for breeders. The easiest possibility was the obstruction of gaps and the adaptation of the ventilation system. First French studies were achieved on those adapted systems and the consequences on ammonia and odour emissions. In those studies, reduction of slatted floor area leads to an increase of the dirtiness of both the solid floor and the animals. The main consequence was the increase of ammonia and odours emitted by the room with partially slatted floor. The comparison between literature data obtained in other countries and those obtained in French conditions exhibits the great influence of ambient temperature in the process of ammonia volatilisation, probably connected to the lying and excreting behaviour of pigs (Aarninck et al. 2006).

The aim of the present study was to determine whether the reduction of ambient temperature until 18°C with a system based on partially slatted floor leads to a reduced ammonia emission in comparison with a system based on totally slatted floor at 24°C or not.

MATERIAL AND METHODS

Animals and Housing

One batch of 108 crossbred (PP × LW) × (LW × LD) pigs was simultaneously fattened at the experimental farm of IFIP in Romillé (35 – France) from January to May (2009) in two housing conditions, that differed by the type of floor and the ambient temperature.

In the first room (called FSF24), 60 pigs were group-housed in 6 pens on fully slatted floor. Within each pen, equal number of barrows and gilts were studied. Slurry was stored in pit underneath (useful depth = 0.8 m) during the whole fattening period. The total pen area per animal was 0.7 m^2. Fresh air entered via a ceiling of perforated plastic sheeting and air exhaust was under-floor extraction with chimney The set-point temperature was fixed at 24°C during the whole period.

In the second room (called PSF18), 48 pigs were group-housed in 6 pens with 50% of the pen floor area slatted. Within each pen, equal number of barrows and gilts were studied. Slurry was stored in a pit underneath (useful depth=0.8m). The surface of the pit is equivalent to the surface of the slatted area. An intermediary emptying of the pit was necessary during the fattening period. The total pen area per animal was 0.85 m^2. Fresh air entered via side shutters and air exhaust was over-floor extraction. The set-point temperature was fixed at 18°C during the whole period of fattening.

Feeding conditions

In both rooms, feed and drinking water were available *ad libitum*. During the growing period (up to 65 kg BW on the room basis), the dietary protein and digestible lysine contents averaged 162 g/kg and 0.89 g per MJ of net energy. Afterwards, the corresponding values were 155 g/kg and 0.80 g/MJ. Other essential amino acids were provided according to the ideal protein concept (on a standardized digestibility basis) and the net energy content was 9.3 MJ/kg during the whole period.

Measurements

Pigs were individually weighed at the beginning of the growing period, thereafter every three weeks in order to organize the change of feed, and the day before slaughtering. The feed intake was recorded weekly on a pen basis. All pigs were slaughtered on the same day.

Temperature and hygrometry were continuously monitored inside and outside the two fattening rooms. The ventilation rate was continuously monitored by measuring the rotation speed of a full-size free-running impeller unit, coupled with the exhaust fan of the buildings.

For both rooms, the gas concentrations in the air of the experimental rooms and outside were continuously measured by photoacoustic infrared absorption spectrometry using a gas analyzer (Innova 1412) coupled to a sampler dosimeter (Innova 1303) able to sampling air from six different places (four in the ambience and two outside) during the whole fattening period. The duration of measurements per canal was 20 minutes. The gases analyzed were NH_3, N_2O, CH_4, CO_2 and H_2O.

Slurry samples (six sampling location per room)were achieved in pit at the feed change, just before the intermediary emptying of the PSF18 pit and just after the slaughtering. Dry Matter, pH, total nitrogen, ammonium nitrogen and total carbon were analyzed on each sample.

Dirtiness of pigs was evaluated using a scale of three modalities calculated per animal (Courboulay, 2005). Simultaneously, floor dirtiness was also quantified (Courboulay, 2005) in the partially-slatted room in order to determine the state of each area (i.e., solid and slatted floors).

Data analysis

In the calculation of mass balances for nitrogen (N), carbon (C) and water (H_2O), the inputs were the quantity of N, C or H_2O in the pig carcass at the entry, calculated by formulas established by CORPEN (2003) and consumed by pigs during the study, calculated by the feed quantities multiplied by the concentration of the considered parameter. The outputs were calculated on the base of the quantity of N, C or H_2O in the pig carcass at the end of the fattening period, in the slurry – calculated by multiplying the slurry volume by the concentration of the considered parameter, the volatilization in the ambience- recorded by continuous measurements of NH_3, N_2O, CH_4, CO_2 and water vapor. An analysis of variance (SAS 1998, proc GLM) was performed to test the effects of sex (X) and the combination between floor type and temperature (FT) on animal performance and only for temperature (T) on gas emissions.

RESULTS AND DISCUSSION

Growth Performances

At slaughter, pigs reared in PSF18 were significantly heavier than pigs reared in FSF24 (Table 1, P<0.001). During the growing period, no significant effect of temperature was observed on performances. At the opposite, Average Daily Gain (ADG) and Average Daily Feed Intake (ADFI) were significantly influenced by housing conditions and the Feed Conversion Ratio (FCR) tended also to be different. Indeed, the ADG and the FCR in PSF18 room were 139 g/d and 0.56 higher than in FSF24.

Table 1 – Growth performance.

Rooms		FSF24	PSF18	RSD	Stat.[1]
Live weight					
	At the beginning	21.4	20.9	2.2	T*
(kg)	At the feed change	67.0	67.1	5.9	
	At slaughtering	109.4	116.8	9.1	$X^{0.06}$, FT***
ADG	Growing period	878	907	95	$X^{0.06}$
(g/j)	Finition period	965	1104	138	$X^{0.07}$, FT***
	Total	917	999	88	X*, FT***
ADFI	Growing period	1.96	2.02	0.12	
(kg)	Finition period	2.88	3.44	0.09	FT***
	Total	2.38	2.68	0.09	FT***
FCR	Growing period	2.27	2.26	0.08	
	Finition period	2.94	3.08	0.11	$FT^{0.07}$
	Total	2.59	2.69	0.09	$FT^{0.09}$
Carcass weight (kg)		86.1	90.9	7.0	FT***
Muscle content (%) [2]		60.6	58.8	2.3	X***, FT*, W***
Backfat thickness (mm) [2]		13.3	15.8	2.9	X***, $FT^{0.05}$, W***
Muscle thickness (mm) [2]		56.3	56.7	4.4	X***, W***

[1] Analysis of variance including sex (X) and the combination floor type and temperature (FT) as main effects, ***: P<0.001 ** P<0.01 * P<0.05.

2 Slaughtering body weight (W) was included in the statistical model presented above as a covariable.

As indicated in the Table 1, the temperature significantly influenced ADG, ADFI and carcass parameters. The FCR tended to be higher in PSF18 room, which resulted both from an extra energy requirement for thermoregulation (Le Dividich et al., 1998) and a higher fatness of BW gain as indicated by the increased backfat thickness ($P<0.05$ – Table 1).

However, the increased backfat thickness might also result from a different partition of backfat tissue under cold conditions between subcutaneous fat and kidney fat (Rinaldo and Le Dividich, 1991).

Ambient parameters

For the whole fattening period, the average outside temperature was 8.4±4.7°C. The average ambient temperature was 25.0±0.8°C and 20.1±1.0°C inside FSF24 and PSF18 rooms, respectively. Average values measured were 1°C higher than the set-point temperature fixed for FSF24 and 2°C higher for PSF18.

In FSF24, the average ventilation rate was 28.7±9.5 m^3per hour per pig and 34.1±8.8 m^3 per hour per pig in PSF18 room. Despite of the smaller number of pigs in PSF18, an increase in air renewal rate was necessary to achieve the lower ambient temperature imposed (18 vs 24°C) when compared to FSF24, especially when outside temperature was high.

Slurry

In the PSF18 room, an intermediary emptying of the pit was achieved 53 days after the arrival of the pigs. At the end of the fattening period (96 days), pits of both rooms were emptied. Composition of the slurry produced by pigs reared in FSF24 was in agreement with literature (Levasseur, 2005 - Table 2). For slurry sampled in PSF18, composition values are very closed to those obtained by Aarnink (1996, 1997) with pH values between 7.4 and 7.6 and ammonium nitrogen around 5.5 kg per kg of slurry.

Table 2 – Slurry composition (all samples are included in the calculation of average parameters)

Rooms	FSF24	PSF18
pH	7.4	7.5
Dry matter (%)	4.9	8.7
Organic carbon (g/kg)	21.7	74.8
Total nitrogen (g/kg)	5.0	10.5
Ammonium nitrogen (g/kg)	3.4	5.2

Pigs reared on totally slatted floor produced around 24% more slurry than pigs on partially slatted floor, i.e. 423 vs 342 liters per pig. These volumes were in agreement with those measured by Guingand (2003) who observed a difference of 20% between pigs reared on totally vs. 50% slatted floor. The deposition of manure on solid floor and animals in PSF18 explained this difference of slurry volume between both rooms.

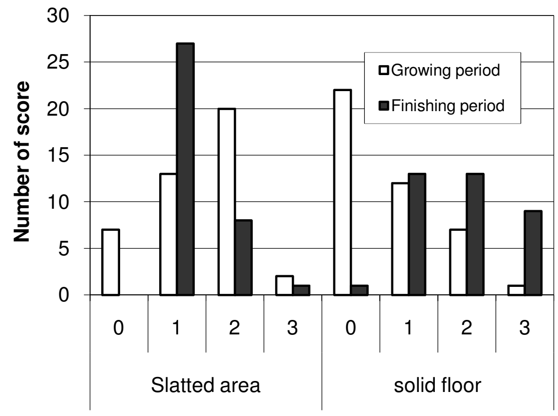
Dirtiness of pigs and floors

As a result of the fattening duration, a gradual deterioration of the animals' dirtiness score was observed during the study (Table 3). For PSF18 (Figure 1), the solid floor remained a clean area during the growing period, but became more and more dirty during the finishing period.

Table 3 – Percentage of pig per dirtiness score[1].

Room		**FSF24**			**PSF18**		
Note		0	1	2	0	1	2
Day	**21**	5	45	50	26	72	2
	49	73	24	3	69	14	17
	80	79	3	18	2	23	75

1. Score 0: less than 20%, score 1: between 20 and 50%, score 2: more than 50 % of the body surface is dirty.



Score 0: 0 % - 1: 25% - 2: 50% - 3: 75% - 4: 100%of the area is dirty

Figure 1: Dirtiness scores in relation with area and fattening period (only for PSF18 room)

Input-output mass balances

For nitrogen, the mass balance default per room is 1.4 and 1.5% of the input of nitrogen, respectively for FSF24 and PSF18 rooms. For carbon, the mass balance default is 5.9 and 15.7% of the input of carbon, respectively for FSF24 and PSF18 rooms. For water, it represents -5.6% of input of water for FSF24 and -6.8% for PSF18.

Gaseous emissions

Nitrogen emissions (NH_3 and N_2O) for FSF24 and PSF18 rooms continuously measured explained 110% and 88% of the nitrogen losses by volatilization calculated by the input-output mass balances, respectively. For the whole period of fattening, ammonia emission was 855 g N_NH_3 per pig in the FSF24 room and 878 g N_NH_3 per pig for the PSF18 room. Ammonia emissions represented 24 and 22% of the nitrogen excreted by pigs reared in FSF24 and in PSF18 rooms, respectively. Those values were in agreement with CORPEN (2003)'s recommendations. For the whole fattening period, average ammonia emission was 8.9 g N_NH_3 per pig per day in the FSF24 room, value in agreement with literature data (Hoeksma et al., 1992; Guingand and Granier, 2001; Philippe et al., 2007). In the PSF18 room, the ammonia emission was 9.1 g N_NH_3 per pig per day that was very close to value obtained for FSF24 room. A similar average value was published by Hoeskma et al. (1992, close to 9 g N_NH_3 with 25 % partially slatted floor and an ambient temperature of 20°C). In similar conditions, Guingand (2003) obtained an emission of 12.5 g $N\text{-}NH_3$ per pig per day with 50% partially slatted floor and 10 g N_NH_3 per pig per day with totally slatted floor. The ambient temperature of both rooms was close to 24°C. In comparison with this latter experiment, the reduction of ambient temperature applied in the present study on partially slatted floor room led to a 28% reduction of ammonia emission. The N_2O emission was 0.12 g $N\text{-}N_2O$ per pig per day for the FSF24 room vs 0.15 g $N\text{-}N_2O$ per pig per day for the PSF18 room. Those values were lower than those obtained by Philippe et al. (2007, around 0.3 g $N\text{-}N_2O$ per pig per day for totally slatted floor at 20°C). Osada et al. (1998) obtained values that ranged between 0.1 and 0.25 g $N\text{-}N_2O$ per pig per day with 25% slatted floor and an ambient temperature around 16°C.

Carbon emissions (CO_2 and CH_4) continuously measured during the whole fattening period represented 90.8 and 70.2% of calculated emissions for FSF24 and PSF18 rooms, respectively. For CH_4, emission was 7.3 g C_CH_4 per pig per day in FSF24 room and 8.4 C_CH_4 per pig per day in PSF18 room. In the literature, available data vary ranged between 2 and 30 g C_CH_4 per pig per day. According to Gallman et al. (2003), CH_4 emissions ranged between 6 and 9 g C_CH_4 per pig per day for animals reared in winter on totally slatted floor with ambient temperatures between 19 and 23°C. In our study, C_ CH_4 emission for the PSF18 room was slightly higher than the one obtained for the FSF24 room. Osada et al. (1998) obtained emissions around 5 g C_CH_4 per pig per day with 25% partially slatted floor and an ambient temperature of 16°C. For CO_2, emission was 676 g and 629 g C_CO_2 per pig per day for FSF24 and PSF18 rooms, respectively. In the room with totally slatted floor, our values were lower than those obtained by Gallman et al. (2003) and Philippe et al. (2007) with values between 1.6 and 2 kg C_CO_2 per pig per day.

For nitrogen and carbon compounds, no significant effect of the housing conditions was established.

GENERAL DISCUSSION

In our study, under cold conditions, similar ammonia emission was measured on partially slatted floor and on totally slatted floor. For the others gas studied in this experiment, no significant effect was identified. The effect on ammonia of the reduction of ambient temperature in combination with the type of floor could be studied according to two directions :

Temperature acts on the chemical process responsible for the ammonia volatilization. Indeed, the temperature is one of the main factors influencing the ammonia volatilization (Groot Koerkamp and Uenk, 1997; Ni and al., 1995). Ammonia (NH_3) is a base which is, in liquid phase, constantly in balance with its combined acid (NH_4^+). This equilibrium is governed by the base constant K_B, which depends directly on temperature. The reduction of temperature moves the balance in discredit of ammonia, leading to the reduction of ammonia volatilization in the room under cold conditions.

Temperature acts on the pig behavior with regard to the identification on of lying and excreting areas inside the pen. According to Aarnink et al. (2006), above a certain temperature, called inflection temperature, excretion on the solid floor increases. This temperature is related to body weight. Thus, for 25 kg pigs, the inflection temperature is around 25°C and decreases to 20°C for pigs over 100kg. In our study, during the growing period, the ambient temperature is really lower than this inflection temperature cited by Aarnink et al. (2006), leading to a small excreting activity on the solid floor. This is confirmed by the dirtiness scores of pigs and floor during this period (Figure 1; Table 3). During the finishing period, the ambient temperature is similar or even higher than the inflection temperature that alters the pigs' excreting behavior. Indeed, during the finishing period, pigs and floor, especially solid floor, were dirtier than during the growing period contributing to the ammonia volatilization. Thus, the relation between ambient temperature and pig's behavior should be a main explanation of the difference observed between studies. The reduction of ambient temperature could be a solution to reduce ammonia emission with partially slatted floor.

In our study, the temperature effect on animal parameters was clearly highlighted. Temperature influences directly the feeding behavior of pigs as demonstrated by Quiniou et al. (1997) who observed a marked increase of ADFI and meal duration per day when temperature decreased below 25°C. In agreement with Massabie et al. (1996), the effect of the temperature reduction from 24 to 20°C on the ADG was not significant during the growing period while it was associated with an increase of ADG during the finishing period. Our results were in agreement with these observations (Table 1). The lower and upper limits of the thermo neutral zone both depend on body weight. The lower critical temperature is higher at the beginning of the fattening period. At this stage, the effect of the temperature interacts with the ingestion capacity (Quiniou et al., 1997). Thus, in our study, no significant effect on ADFI during the growing period was observed (Table 1) whereas the reduction of temperature was associated with a significant increase of ADFI during the finishing period. The increase of the ADFI allows the covering of the thermoregulation requirement induced by the cold exposure. However, the extra ADFI did not meet the extra energy requirement that would partly explain the increase of carcass backfat thickness (Table 1).

In our experimental conditions, the reduction of the set-point temperature from 24 to 18°C tended to increase the FCR by 0.1 unit between pigs reared on totally slatted floor at 24°C vs. partially slatted floor at 18°C. The effect of temperature on FCR is well-known (Massabie et al., 1996). According to Le Dividich et al. (1985), the FCR increased by 0.017 unit per degree between 28 and 20°C and by 0.052 between 20 and 12.5°C.

Pigs reared on partially slatted floor were heavier at slaughter than pigs reared on totally slatted floor. A theoretical calculation of the FCR was achieved on the basis of a similar slaughter weight for both rooms (based on the weight of FSF24 pigs). For 109 kg body weight at slaughter (Table 1), the fattening duration of PSF18 would be reduced by 6.7 days. In such conditions, the estimated FCR would be 2.63 vs 2.59 for FSF24 pigs, taking into account the reduction of feed intake resulting from the reduced duration of fattening. Corresponding ammonia emission would be 815 grams per pig for PSF18 room, corresponding only to a reduction of 5% when compared to previous presented values. For a similar fattening BW range, the combination type of floor-temperature would have a smallest effect on FCR, without reducing notably ammonia emissions.

Results obtained with this first batch conducted at 18°C have to be confirmed with a second batch conducted in the same cold conditions. In fact, difficulties to reach an average ambient temperature close to 18°C are expected for batches conducted during summer. Nevertheless, the reduction of ambient temperature appears to be the best solution to reduce ammonia emission in French housing adapted to partially-slatted floor. But, in the definition of BAT given by the IPPC directive, the economic viability is clearly stated. In our experimental conditions, the significant difference on carcass fatness combined with a FCR that tended to be higher in PSF18 leads to different economic return per pig. Amongst possible solution toward reduction of ammonia emission, the implementation of partially slatted floor will need to be associated with a reduction of set-point temperatures. The application of a 16°C set-point temperature, for example, would probably directly deteriorate growth performance, especially FCR. In addition, the reduction of ambient temperature would require a perfect management of room climate especially to limit the generation of high air speed on animals. Indeed, the alteration of climate could have very negative effects on animal' performances and could induce respiratory diseases.

CONCLUSIONS

Because mainly French housing systems are based on fully slatted floor, the implementation of partially-slatted floor will need an adaptation of existing housings. Previous French studies based on the comparison of adapted system with partially-slatted floor and French classical system with fully slatted floor have shown no positive effect on ammonia and odor emissions when the set-point temperature was around 24°C. The aim of this study was to compare ammonia levels emitted by pigs reared in adapted housing with 50% partially slatted floor with a low temperature to levels emitted by pigs reared in housing with totally slatted floor under thermal comfort conditions. Indeed, with a set-point temperature fixed at 18°C, ammonia emitted per pig on partially slatted floor was equivalent to the amount emitted per pig on totally slatted floor with a set-point temperature of 24°C. No effect was highlighted on other gas. In adapted housing with partially-slatted floor, temperature appears to have a consequent influence on the volatilization process both by its chemical effects than its action on pig behavior. These results were obtained with a difference of 6°C between set-point temperatures applied. With a set-point temperature close to 16°C, it could be possible to increase the effect on ammonia reduction between the two types of housings. Nevertheless, Best Available Techniques integrate the notion of economic viability in relation with the efficiency on environmental parameters. A consequent reduction of temperature would have a great influence on FCR and on carcass quality. The implementation of this technique would generate an extra-cost for pig breeders which could not be acceptable in agreement of the definition of BAT as given by the IPPC Directive.

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