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Impact of the Reduction of Straw on Ammonia, GHG and Odors Emitted by Fattening Pigs Housed in a Deep-litter System

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Abstract. *Straw systems are appreciated by consumers because it provides a better welfare for pigs and can reduce odour nuisances. Nevertheless, the development of this way of breeding pigs should be limited by the small availability of straw which is primarly used by beef and cattle productions. Reducing straw quantity per pig is a simple way to solve this problem of straw availability. The aim of this study was to determine the impact on ammonia, GHG and odours emissions from a 33% reduction of straw used for the bedding of fattening pigs. Two successive batches were grouped in three identical rooms which only differed in the quantity of straw used for the litter but also in the frequency of bedding. For the reference room (RR), the quantity of straw was 90 kg per pig for the whole fattening period. In the second and the third room (R33 and R33F), the quantity of straw per pig was 60 kg and in R33F, the litter was replenished weekly. The reduction of straw did not induce deterioration in animal performance and in carcase characteristics. Concerning ammonia and odours, the main effect of the reduction of straw was the increase in emissions and the degradation in the dirtiness of litter, especially for R33. The increase of ammonia and odours appears to be less important for R33F than for R33. Weekly bedding should be a good way to limit the negative effect of the reduction of straw used per pig.*

Keywords. Pigs, deep-litter system, ammonia, GHG, odour.

Introduction

Due to increasing awareness regarding animal welfare, deep-litter systems are being developed in France. However, this development could be restricted by the availability of straw which is primarily used in beef and poultry production. Generally, straw systems are appreciated because of its positive effects on pig welfare but also on the reduction of odor nuisance. The objective of this investigation was to determine the possibility of a new management of the litter by reducing the quantity of straw but also by modifying the frequency of bedding. But what will be the consequence on ammonia, GHG and odor emissions?

Materials and methods

Two successive batches (B1 and B2) of 120 pigs were grouped in three identical rooms, which only differed in the quantity and the frequency of straw used for bedding. Each room had a capacity of 40 pigs with an available floor space of 1.2 m^2 per pig. In the first room (Reference room noted RR), the total quantity of straw for the whole fattening period, was fixed at 90 kg per pig. In the second and third rooms (R33 and R33F respectively), the quantity of straw was reduced by 33% (60 kg per pig) in comparison with the RR room but added at the same frequency (every two weeks during the growing period and weekly after). For the R33F room, the bedding was replenished weekly during the whole fattening period. For the three rooms, 300 kg of wheat straw was used to constitute the initial deep litter before the pigs entered. During the fattening period, for each addition of fresh straw, the quantity of straw was weighed and recorded. In each room, ventilation was provided using an exhaust fan.

Animals and feeding

All the pigs were fed ad libitum with a commercial growing meal, followed after by a finishing meal (around 6 weeks). Crude protein content ranged between 16 and 16.5% for the growing meal and from 14.7 to 15% for the finishing meal. Feed and water intake were recorded weekly per room. Pigs were individually weighed at the beginning of the study, when the feed was changed from growing to finishing meal, and the day before slaughtering. At the slaughterhouse, individual carcass characteristics were recorded including carcass weight, muscle content,backfat and muscle thickness.

Measurements

During the whole fattening period both outside and inside air temperature and humidity were continuously recorded (every 5 minutes) with a temperature and humidity sensor (type VOLTCRAFT DL-120TH). The ventilation rate was continuously monitored (every 15 minutes); measuring the rotation speed of a full-size free running impeller unit (FANCOM ®), coupled with the exhaust fan in the fattening rooms. In all three rooms, the set-point temperature was fixed at 19°C (B1) and 22°C (B2). For each room, gas concentrations (NH_3, N_2O, CH_4, CO_2 and water vapor) were measured inside and outside, with a photoacoustic Multi-gas Monitor 1412 (Innova Air Tech Instrument) coupled with a sampler dosimeter 1303 (Innova Air Tech Instrument). Seven series of seven day-measurements were conducted simultaneously in each room. The air samples were taken successively and automatically every 2 minutes and analyzed during 15 minutes for each sampling location.

During the whole fattening period, five series of air samples for olfactometric analysis were conducted in the extraction duct for each room. Odor concentrations were determined in accordance with the European standard (CEN 13725) and expressed in odour unit per m^3.Litter samples (twelve sampling locations per room) were achieved in each room at the feed change. The day after slaughtering, the whole litter was weighed and samples were taken in each room for chemical analysis (dry matter, pH, total nitrogen, ammonium nitrogen, total carbon). During the fattening period, the litter dirtiness was weekly quantified using a scale of five modalities calculated per room (Courboulay, 2005). During the study, the quantity of N, C or H_2O in the pig carcass at entry (formulas by CORPEN, 2003) and feed consumption per pig were added to calculate the input of nitrogen (N), carbon (C) and water (H_2O). Output was calculated by adding the quantity of N, C or H_2O in the pig carcass at the end of the fattening period, in the slurry (slurry volume x concentration), and the volatilisation in the exhaust air (recorded by continuous gaseous measurements). An analysis of variance (SAS 1998, proc GLM) was performed to test the effects of sex and treatment on animal performance and gaseous emissions.

Results

Ambient parameters

Table 1 lists temperature and ventilation rates recorded during the fattening of two successive batches. The differences observed between both batches are due to the variations of climatic conditions. B1, pigs entered in mid-March and the last departure for slaughter was in July. B2, pigs entered in mid-August and the last departure was at the end of November. For both batches, no significant difference in the temperature and ventilation rates was observed between the three rooms.

Table 1. Average temperatures and ventilation rates monitored per batch / per room.

	B1	B2
Temperature (°C)		
- RR	22.7±2.1	23.7±1.8
- R33	22.3±2.3	23.9±1.5
- R33F	22.5±2.2	23.7±1.8
- Outside	14.7±5.3	15.2±5.1
Ventilation rate ($m^3.h^{-1}$per pig)		
-Reference	56.4±48.8	45.1±17.6
-R33	50.3±24.3	46.2±16.9
-R33F	50.7±28.9	52.0±16.4

Animal performance

Table 2. Animal performance for both batches of pigs

Batch		R33	RR	R33F
B1	Average Daily Gain ($g.d^{-1}$)	859.3±51.8	809.1±66.0	807.7±116.0
	Feed conversion ratio	2.85	2.95	2.97
	Muscle content (%)	60.4±2.0	60.6±2.3	61.2±1.9
	Muscle thickness (mm)	63.3±5.7	63.3±6.9	60.2±12.3
	Backfat thickness (mm)	15.0±2.3	14.7±3.0	13.3±3.5
B2	Average Daily Gain ($g.d^{-1}$)	855.8±61.6	838.3±74.2	876.7±59.6
	Feed conversion ratio	2.82	2.91	2.96
	Muscle content (%)	60.3±2.2	61.1±2.8	59.7±3.1
	Muscle thickness (mm)	61.9±6.0	63.9±5.7	61.8±5.1
	Backfat thickness (mm)	14.8±3.0	14.1±3.7	15.6±3.9

The initial weight of the pigs was 24.5 kg for the three rooms. For B1 (RR, R33 and R33F), the slaughtering weight was 113.9±6.4, 115.7±4.7 and 112.2±9.7 kg. In B2 (RR, R33 and R33F), the slaughtering weight was 114.1±6.9, 116.2±5.3 and 117.8±5.0 kg. The performance obtained for pigs kept in RR (Table 2) are in accordance with the French average performance records for pigs kept on straw (Gaudré and al., 2008). In our experiment, the reduction of straw did not induce a significant difference in animal performance.

Litter characteristics

The total quantity of straw used for B1 (RR, R33 and R33F) was respectively 85, 49.8 and 59 kg per pig and 89.8, 58.5 and 59.9 kg per pig for B2 (RR, R33 and R33F). Table 3 presents the characteristics of the manure removed at the end of the fattening period.

Table 3. Manure characteristics

Parameter	R33	RR	R33F
Manure removed (kg/pig)	196±51	258±25	199±30
pH	8.5±0.3	8.6±0.1	8.2±0.6
DM (g/kg)	299±110	363±25	265±70
Total N (g/kg DM)	27.0±6.8	25.5±4.4	33.9±4.5
Ammo N (g/kg DM)	8.7±0.4	8.8±0.4	7.1±1.0
Total C (g/kg DM)	295±85	348±55	272±65

Gaseous emissions

In B1 and B2, the reduction of straw induced an increase in ammonia emissions compared to the levels measured in RR (table 4). In B1, ammonia emission was increased by 46% in R33 and reduced by 12% for R33F, compared to the emission of RR. This dramatic rise in ammonia emitted by R33 is due to an omission of 10 kg of straw per pig. In B2, ammonia emission was increased by 13% and 33%, respectively for R33 and R33F compared to RR. N_2O emissions in R33F were multiplied by 3 compared to RR and R33. The reduction of straw by 33%, in R33 and R33F, led to a decrease in CH_4 emissions compared with RR (-40% and -20% respectively for R33 and R33F), however, no significant effect of the treatment is observed on CO_2 emissions.

Table 4. Gaseous emissions (per pig per day per batch) measured during the fattening period

Batch		R33	RR	R33F
B1	NH_3 (g)	21.9±12.4	15.0±8.4	13.1±7.3
	N_2O (g)	1.5±1.6	1.3±0.9	3.0±3.1
	CH_4 (g)	5.2±8.5	9.9±14.2	7.1±9.5
	CO_2 (kg)	880.6±435.9	829.9±303.0	789.2±308.6
B2	NH_3 (g)	13.0±8.6	11.5±7.0	15.4±12.1
	N_2O (g)	0.3±0.6	0.3±0.6	1.0±1.8
	CH_4 (g)	11.2±5.9	18.9±17.0	16.8±14.8
	CO_2 (kg)	748.4±304.2	827.4±302.1	933.2±488.3

Mass balance

For nitrogen, the mass balance default per room was -1.8, -1.9 and 1.9% of the input of nitrogen for B1 and 3.3, 10 and -2.8% for B2, respectively for RR, R33 and R33F.The mass balance default of carbon was 2.4, 3.9 and -13.2 % of the input of carbon for B1 and 3.4, 11.4 and -3.2%

for B2, respectively for RR, R33 and R33F rooms. The mass balance default of water was 15.8, -10.9 and -14% for B1 and 19.8, 23 and -26% for B2, respectively for RR, R33 and R33F.

Odor emissions

For B1, the average odor emissions were 4.9 10^5±2.5 10^5, 5.0 10^5±2.2 10^5, 4.2 10^5±1.9 10^5 odor units per pig per day, respectively for the RR, R33 and R33F. In B2, the average odor emissions were 7.9 10^6±2.1 10^5, 1.1 10^6±6.5 10^5, 1.0 10^6±5.8 10^5 odor units per pig per day, respectively for the RR, R33 and R33F. B1 and B2 pigs housed in R33 emitted 22% more odors than pigs housed in the Reference room. The difference between R33F and RR is only 8%.

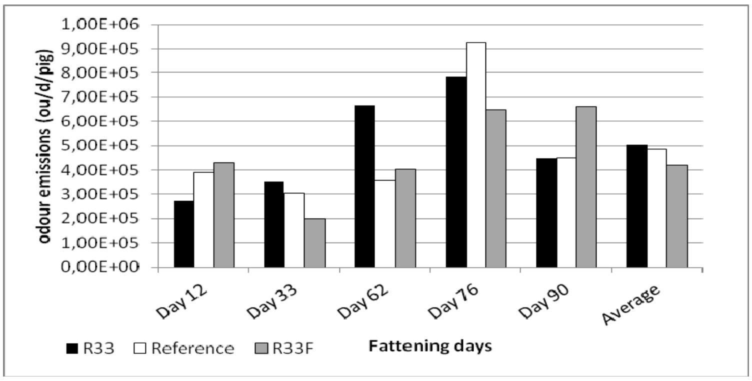

Figure 1. Odor emissions per room during the fattening period (only B1)

Dirtiness of litter

In both batches of our study, the litter in R33 was always dirtier than the litter in RR. For B1, the percentage of scores over 3 (>50% of the area was dirty) was 25, 67 and 61% respectively for the RR, R33 and R33F. In B2, this percentage was 66, 68 and 64% respectively for the RR, R33 and R33F.

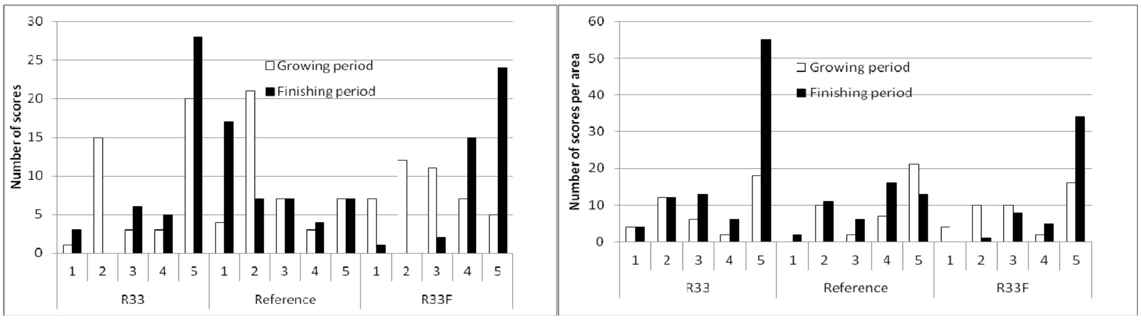

Figure 2. Dirtiness scores per room per batch (left=B1 and right=B2 - score 1:0% - 2:<25% - 3:25-50% - 4:50-75% - 5: 75-100% of the area is dirty)

For B1 and B2 (RR) there was no degradation in the dirtiness of the litter between the growing and the finishing period. In R33 and R33F the litter was always dirtier during the finishing period than during the growing period (figure 1). However, the litter in R33F was slightly cleaner during the finishing period than the litter in R33.

Discussion

In our study, the reduction in the quantity of straw did not have any significant effect on animal performance or in carcass characteristics. The main effect of the treatment was the increase in ammonia and odour emissions and the degradation in the dirtiness of litter, especially for R33. Increasing the frequency of bedding led to a slight rise in ammonia and odour emissions than simply reducing the quantity of straw. In our experiment, the total quantity of straw used per pig was 90 kg for RR, 60 kg for R33 and R33F. In literature, the current use of straw is around 4 kg per week, which is almost 64 kg of straw per pig for a 16 week-period (Philippe and *al.*, 2007 a,b – Gilhespy and *al.*, 2009), similar to R33 and R33F. Mean ammonia emissions measured by Philippe and al. (2007 a, b), i.e; 13 g per pig per day, were close to the levels measured in R33 and R33F. In his experiment, Gilhespy and al. (2009) studied the effect of the quantity of straw combined with the way the straw is added. In his study, the quantity of straw per pig was only 64 kg, for the reference treatment, similar to R33 and R33F. At the opposite of his results, our data show a decrease of ammonia emitted by RR compared to R33 and R33F. The main explanation should be the highest frequency of bedding, contributing to the lower dirtiness of litter and then, the reduction of ammonia and odorous compounds volatilization. In both cases, the increase of odour and ammonia emissions is the result of the degradation of the dirtiness of the litter which is the direct consequence of the reduction of the quantity of straw used for bedding. In both batches, there was a gradual degradation in the dirtiness of litter between the growing and the finishing period in the rooms with less straw. This degradation was less important for R33F compared to R33, contributing to reduce the rise of odors emitted by R3FF compared to RR. Adding straw more frequently could contribute to reduce the airflow across surfaces soiled by urine. New investigations have to be done, coupling weekly bedding with an increase of the quantity of straw used during the finishing period.

Conclusion

Generally, rearing pigs on straw has a good brand image for consumers because straw systems provide a better level of welfare for pigs and reduce odour nuisances. In the future, the non-availability of straw for pigs could limit the development of this production. Our study has shown that it's not possible to reduce the quantity of straw without increasing ammonia and odour nuisances, however, new investigations into the management of litter, including the frequency of bedding, are necessary in order to meet consumer demands.

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