PERSTRUP PIG HOUSE WITH PARTIAL UNDER-FLOOR AIR EVACUATION AND IN-HOUSE SEPARATION OF FAECES AND URINE

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ABSTRACT

This paper deals with a newly developed Perstrup pig house with partial under-floor air evacuation and in-house separation of faeces and urine. The under-floor air evacuation was very efficient in reducing ammonia concentration in the room and improved the air quality and the working environment significantly. The ammonia concentrations in the room were very low compared with the exhaust air beneath the slats due to a very efficient under-floor evacuation. On average, the ammonia concentration was below 0.5 ppm in the room and more than 10 times as low as the under-floor outlets. The odour concentration was also higher in the exhaust air beneath the slats compared with the concentration in the room, but only with a ratio of 1.6 in the control room and 1.8 the room with in-house separation.

Odour emissions were 16% higher in the room with in-house separation due to higher odour concentrations in the outlets from the under-floor air evacuation.

The in-house separation has shown high separation efficiencies, but the in-house separation still needs to be improved to increase the dry matter content and reduce the amount in the solid fraction.

INTRODUCTION

Intensive pig production is associated with a significant flow of nutrients such as nitrogen and phosphorous. For farmers, the loss of nitrogen via ammonia emission from animal houses, manure stores and applied manure will reduce the fertilizer value of animal manure, and, as a result of these losses, livestock animals are the most important source of gaseous ammonia in the atmosphere in regions with significant livestock production (ECETOC, 1994).

In countries with significant pig production, slurry-based manure management is state-of-the-production. However, because of a high water content, pig slurry is low in nutrients and is produced in large quantities per produced animal unit and thus adds costs to the production due to bulk storage, transportation, and field application. In areas with a high pig population, sustainable utilization of pig slurry causes farmers to transport slurry over long distances, and thus incentives are present to reduce bulk manure volumes.

This paper deals with the development of an environmentally and economically sound pig facility; the focus is on natural separation of the manure inside the pig house, low ammonia and odour emissions, and partial evacuation of the ventilation air directly from the manure channel. The purpose of the study was to investigate the pig house with respect to ammonia concentrations and emission, odour concentrations and emissions, and separation efficiency of the pig manure.

MATERIALS AND METHODS

Experimental design

The pig house contained two rooms, each with a capacity of 384 growing-finishing pigs. The pens had partially slatted floors. One room served as control and was equipped with a slurry channel. In the other room, faeces were collected in a manure channel established with a 3% downwards slope towards a gutter for urine drainage (figure 1). The gutter was equipped with 110 mm drain pipes for every 240 cm. The manure was removed using a scraper four times a day during the trial.

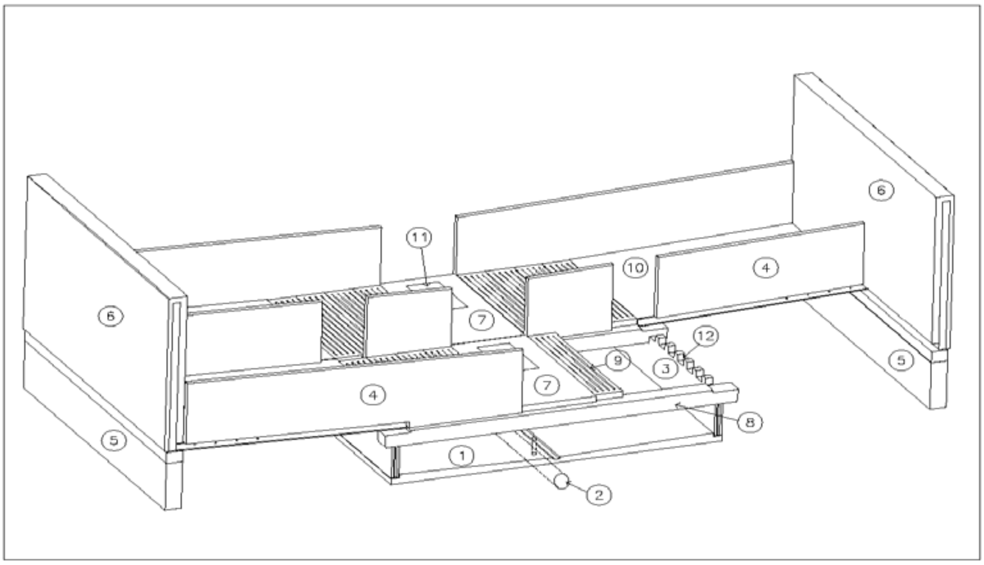

Figure 1. Drawing of the Perstrup pig house with pens with partially slatted floor, sloped manure channel with a gutter for urine drainage and partial air evacuation directly from the manure channel through a ventilation channel under the solid part of the pen floor.

The pigs were offered feed ad libitum from a dry feed dispenser mounted in the pen partition between two adjacent pens. The feed dispenser also supplied the pigs with water. Straw was allocated daily to each pen in the room with in-house separation. The amount of straw added was restricted to 70 g/pig*day, which was the amount that did not clog the slots in the slatted floor. Fresh air was taken into the rooms through a diffuse ceiling (mineral wool with cement bonded wood wool plate beneath) during hot periods supplemented with ceiling inlets. Outlets consisted of two outlets taking the used air from beneath the slats and one supplementary outlet in the ceiling.

Measurements

The data collection was based on two consecutive batches in each room. The pigs entered the pig house at 32 kg and were housed until delivery for slaughter at 108 kg. The ammonia concentrations in each room as well as the background concentrations were measured continuously using an electrochemical detector (Polytron 1, Dräger). The odour concentration was measured 10 times in each batch in duplicates using the European standard method for odour concentration measurements by dynamic olfactometry (European Committee for Standardization - CEN standard 13725, 2003). The ventilation rates were measured continuously using measuring fans (Fancom). Every time odour samples were collected the ammonia and carbon dioxide concentrations were also measured using gas detector tubes (105SD and 126 SF, Kitagawa) for control measurements.

The effect of the in-house separation system on the characteristics of the solid and liquid manure fractions was based on three measuring days per batch. On each measuring day, the solid and liquid manures were collected individually and quantitatively. The following manure parameters were analysed using standard methods: Dry matter (DM), volatile solids (VS), total nitrogen, total ammoniacal nitrogen (TAN), and phosphorous (P). The separation efficiency was calculated as the amount of a specific parameter collected in the solid manure fraction in per cent of total amount of the parameter.

RESULTS AND DISCUSSIONS

Production results and ammonia emissions

The production results and ammonia emissions are shown in table 1. The statistical analysis showed no differences in ammonia emission between the control room and the in-house separation room. However, the room ammonia concentrations were very low compared with the exhaust air beneath the slats due to a very efficient under-floor evacuation. On average, the ammonia concentration was below 0.5 ppm in the room and more than 10 times as low as the under-floor outlets ($p<0.001$). In conclusion, the slurry surface below the slats is the major source to ammonia emissions. Relatively high room ammonia concentrations were only measured for a short period with pen fouling in august 2007.

In figure 2, ammonia concentrations are depicted as a function of under-floor ventilation rate. As shown, even at ventilation rates below 20% of maximum capacity, i.e. 20 m^3/h per pig place, the under-floor air evacuation is very efficient. Former Danish studies have shown that n average air velocity of 0.1-0.2 through the slats is crucial to obtain efficient under-floor air evacuation (Pedersen, 1979). At a ventilation rate of 20 m^3/h per pig place, the air velocity can be calculated to 0.14 m/s in the Perstrup pig house.

These findings can be utilized to reduce the cost if an air scrubber is needed for ammonia reduction. With an efficient under-floor air evacuation more than 90% of the ammonia emission can be collected in just 20% of the maximum ventilation capacity.

Table 1. Production, climate, concentrations and emissions of ammonia

	Control unit	In-house separation	Significant
Number of batches	2	2	
Number of measuring days per batch	79	79	
Number of pigs produced	673	672	
Weight in, kg	31.8	31.6	
Weight out, kg	107.8	108.6	
Daily gain	968	984	
Meat percentages	59.6	60.0	
Mortality rate	3.3	2.0	
Climate			
Ambient temperature, °C	13.9	13.9	
In-house temperature, °C	19.3	18.7	
Under-floor temperature, °C	17.1	16.6	
Room ventilation rate, m^3/hour	9100	9200	
Under-floor ventilation rate, m^3/hour	20200	20500	
Room carbon dioxide concentration, ppm	770	710	
Under-floor carbon dioxide concentration, ppm	920	880	
Ammonia			
Number of measurements	1724	1724	
Room ammonia concentration, ppm	0.3	0.3	NS
Under-floor ammonia concentration, ppm	5.6	5.5	NS
Ammonia emission per section, g NH_3-N/h	59	60	NS

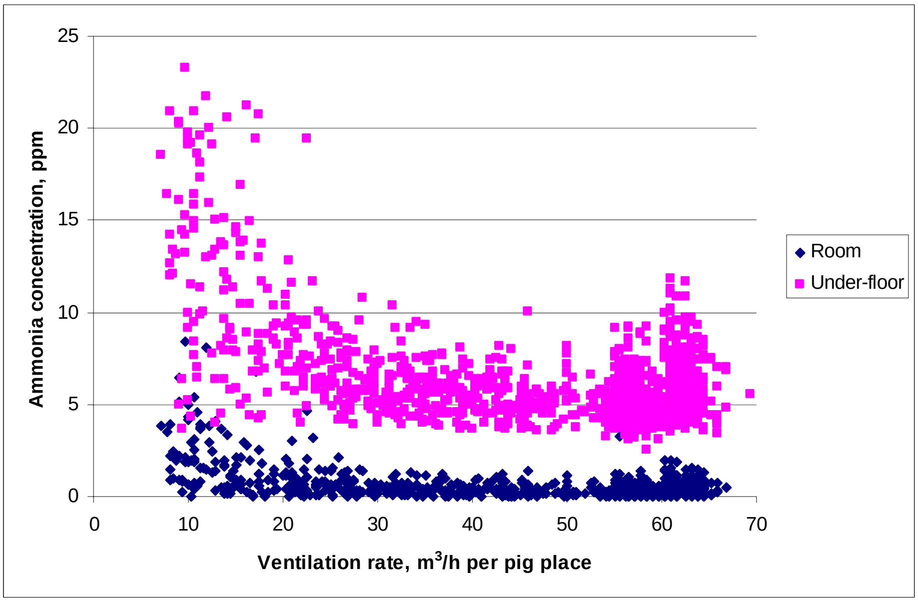

Figure 2. Measurements of ammonia concentrations in the room and under-floor respectively depicted in relation to the under-floor ventilation rate. The measurements originate from the first batch in the control unit April to June 2007.

Odour emissions

The odour concentrations and emissions are shown in table 1. The statistical analysis showed no difference in the room odour concentration between the control room compared with the in-house separation room, but the under-floor odour concentrations were 24% higher in the section with in-house separation compared with the control unit (P=0.011). The higher under-floor concentrations also resulted in a 16% higher odour emission from the in-house separation compared with the control unit with traditional slurry system (P=0.023). In comparison, the odour emissions from the control unit are close to the Danish standard figure at 300 OU_E per 1000 kg of animal weight for this particularly system (Riis, A.L, 2006).

The odour concentrations were also higher in the exhaust air beneath the slats compared with the concentration in the room, but only with a ratio of 1.6 in the control room and 1.8 the room with in-house separation ($p<0.001$).

Separation efficiency

The collected solid manure contained on average 22% DM or 93% of the total amount of DM (Table 3). Of dry matter, 80% was organic, i.e. VS, thus indicating that the solid manure would be an excellent source of biogas. The solid manure also contained 69% of the total nitrogen, 49% of TAN, and 96% of the total amount of phosphorous in the manure. The latter strongly indicates that the liquid manure was little contaminated with faeces. On the same account, the large amount of total nitrogen found in the solid manure strongly indicates that the solid manure was contaminated with urine.

Even though this research has shown high separation efficiencies, the dry matter content in the solid fraction was too low and the amount was too large to make the system economically feasible. The in-house separation needs to be improved. This is the goal of a new project, aiming at reducing the amount of manure in the solid fraction to less than 25% of the total amount, but still obtaining high separation efficiencies.

Table 2. Concentrations and emissions of odour			
	Control unit	In-house separation	Significant
Ambient temperature, °C	15.6	15.6	
In house temperature, °C	19.4	19.0	
Number of pigs produced	341	16.7	
Average weight, kg	59	60	
Room ventilation rate, m^3/hour	12000	11600	
Under-floor ventilation rate, m^3/hour	22400	22300	
Odour			
Number of measurements	20	20	
Room odour concentration, OU_E/m^3	483	474	NS
- 95% confidence interval	388-601	381-589	
Under-floor odour concentration, OU_E/m^3	737	913	P=0.011
- 95% confidence interval	609-890	757-1102	
Odour emission, OU_E/s per 1000 kg[1)]	313	363	P=0.023
- 95% confidence interval	266-368	309-426	

Table 3. Separation parameters observed in the room with in-house separation. Average of 6 measuring days.			
		Manure fraction	
Manure parameter	**Unit**	**Solid**	**Liquid**
Amount of manure	Kg/day	991	868
Separation efficiency	%	53	
pH		6.5	8.7
Dry matter (DM)	%	22	2
Separation efficiency	%	93	
Volatile Solids (VS)	% of DM	80	54
Separation efficiency	%	96	
Total Nitrogen	g/kg	8.7	4.5
Separation efficiency	%	69	
TAN	g/kg	2.8	3.3
Separation efficiency	%	49	
P	g/kg	2.2	0.10

CONCLUSION

The under-floor air evacuation was very efficient in reducing ammonia concentration in the room. The room ammonia concentrations were very low compared with the exhaust air beneath the slats. On average, the ammonia concentration was below 0.5 ppm in the room and more than 10 times as low as the under-floor outlets. The odour concentration was also higher in the exhaust air beneath the slats compared with the concentration in the room, but only with a ratio of 1.6 in the control room and 1.8 the room with in-house separation.

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