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### REDUCTION OF ODOUR EMISSIONS FROM SWINE BUILDINGS: COMPARISON OF THREE REDUCTION TECHNIQUES

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**ABSTRACT** Although several technologies have been developed to reduce odour emissions from swine housing, there is actually no official inventory that can be used to compare the reductions obtained with these technologies. The objectives of the present study were 1) to select from the literature the most promising technologies allowing odour emissions reduction; 2) to evaluate the selected technologies in an experimental barn and 3) to compare the emission reductions. A literature review listing all developed technologies was carried out. A list of criteria classified within six different categories (agronomic, economic, technical, environmental, use of resources and social & health) was used to assess the global potential performance of all those technologies. An experimental laboratory farm was then used to compare the selected technologies. The experiment involved five treatments: diet alterations, under slats separation system, a combination of diet alterations and under slats separation, biological air treatment and a control. Identical and independent chambers housing four growing-finishing pigs were monitored during seven weeks (3 weeks of accommodation and 4 weeks of testing). Odour concentration was evaluated weekly by olfactometry. Preliminary results showed that an appropriate diet can reduce odour emissions by 35% while in-barn separation system allowed a 33% reduction of the odour emissions. The combination of these two treatments allows a total reduction of 59% of the odour emissions. The biological air treatment can reduce the odour emissions by 81%. Results indicate that a biological air treatment is the most promising technology for odour reduction from swine buildings.

**Keywords:** Gas emissions, odours, diet, swine, in-barn separation, air cleaning

**INTRODUCTION** Livestock production in confinement facilities results in gas emissions such as ammonia (NH<sub>3</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and carbon

dioxide (CO<sub>2</sub>). Ammonia, CH<sub>4</sub> and N<sub>2</sub>O are products of manure decomposition while CO<sub>2</sub> is primarily a product of animal metabolism. Furthermore, odour from animal production represents an important concern. In pig production, manure is stored as a liquid beneath a slotted floor. Both the manure attached to the flooring material and as a stored liquid produces these odour and gases.

Several technologies have been developed to reduce odour and gas emissions from swine housing. Three techniques seem to be interesting that is to say the under-slat separation system, diet manipulation and the biological air treatment.

Literature has shown separating urine from feces under slats and frequently removing both fractions is suitable to reduce gas and odour emissions from buildings (Andersson, 1995; Arogo et al., 2001; Bernard et al., 2003; Jongebreur, 1981). On average, under-slat separation systems in piggeries can reduce ammonia and odour emissions up to 50% (Hendriks and Weerdhof, 1999; Kaspers et al., 2002; Koger et al., 2002; Kroodsma, 1986; van Kempen et al., 2003; Voermans and van Asseldonk, 1990; Voermans and van Poppel, 1993). Three major under-slat manure separations systems have been studied over the years, the conveyor net, the V-shape scraper and the conveyor belt.

A conveyor net made of chevron meshes placed under the slats drives the feces at one end; the liquid percolates throughout for storage in a conventional pit. The meshes are cleaned mechanically once a day using a brush (Marchal, 2002). The experiment conducted by Kroodsma (1986) demonstrates an odour reduction of 50% compared to a pull plug for a building equipped with such systems. According to Kroodsma (1980), using a conveyor net gives rise to a more pleasant smell in the building than the smell in a facility with conventional storage under the slats.

In the case of the V-shaped scraper, the feces stay on the inclined walls; urine is gathered into the middle trench and continuously drained out of the room. Voermans and van Asseldonk (1990) concluded that even with dirty floor, it is possible to get a 40% ammonia reduction with such a system in a grower-finisher building. Voermans and van Poppel (1993) obtained an 80% reduction in ammonia emissions in a nursery. Groenestein (1994) measured an NH<sub>3</sub> emission reduction from 12 to 27% with a similar system. Although no experiment was ever made on the potential reduction of odours, Bernard et al. (2003) maintain that a 45% reduction in odour emissions could be reached.

The system studied at North Carolina State University (van Kempen et al., 2003) is a conveyor belt. The solids stay on the inclined conveyor rubber belt; the liquid flows off into a gutter positioned alongside the belt. Kaspers et al. (2002) measured a 65% reduction in ammonia emissions in comparison with values found in Arogo et al. (2001) and Aarnink et al. (1995). Kaspers et al. (2002) found no change in methane production, no matter the quantity of feces on the belt.

Nutrient management is a key to successful sustainable swine production (Honeyman, 1996). An effective way of reduction gas and odour emission would be to reduce manure and urinary nitrogen. In the past, dietary requirements of grower-finisher pigs for each of essential amino acids were met by including enough crude protein in diets to meet requirements for lysine, the first limiting amino acid in corn-soybean diets. Reduction of dietary protein combined with supplementation of synthetic amino acids in pig diets

might reduce total nitrogen excretion by 25 to 40% (Hartung and Phillips 1994; Kay and Lee 1997). Reduction of dietary protein by 29% results directly in a reduction of NH<sub>3</sub> emission by 52% (Kay and Lee, 1997). Moreover, concentrations of other major odour components responsible for pig odour were significantly lower in slurry from pigs fed low crude protein diets compared to a control diet (Hobbs et al., 1996).

An additional method to reduce emissions caused by excess nitrogen, in particular NH<sub>3</sub>, is alteration of the ratio of nitrogen excretion in urine versus feces (Mroz et al., 1993). Reduction of nitrogen excretion in urine as urea, the primary precursor for NH<sub>3</sub> volatilisation, combined with shifting nitrogen excretion into the feces, primarily as bacterial protein, will reduce NH<sub>3</sub> volatilisation and thereby NH<sub>3</sub> emission of swine barns. Inclusion of fermentable carbohydrates or non-starch polysaccharides (NSP) into diets stimulates bacterial fermentation in the hindgut and reduced urinary versus fecal nitrogen ratio by 68% (Canh et al., 1997a). In a subsequent study, NH<sub>3</sub> emission was reduced up to 40% by dietary inclusion of fermentable carbohydrates (Canh et al., 1997b). However, increased bacterial fermentation caused increased production of volatile fatty acids (for example: acetate, propionate, and butyrate), which are also part of the total odour. The decreased dietary electrolyte balance (expressed as mEq Na + K - Cl) in the diet reduced the pH of urine and subsequent slurry. Canh et al. (1998) and Mroz et al. (1996) showed that dietary calcium chloride and electrolyte balance significantly influenced urinary pH and subsequent pH and NH<sub>3</sub> emission from pig slurry.

The air treatment methods for odour control are classified into two broad categories, the non-biological treatment (physicochemical) and the biological treatment (Manuzon et al. 2007, Sheridan et al. 2002). Agricultural applications, such as livestock buildings, require solutions for the treatment of the air emitted. The air volume is high and the concentrations of pollutants are lower as compared from industrial applications. In addition, the systems must be simple and easy to operate and maintain (Devanny et al. 1999). In those applications, the main objectives of the air treatments are the reduction of odours, NH<sub>3</sub>, H<sub>2</sub>S and dust. The temperature and pressure of the air to be treated are similar to those of the ambient air. However, the climatic factor is sometimes an important element to consider. Removal efficiency for odour with a biological treatment can range from 29 to 100% depending of the operation conditions (Luo, 2001). The reduction of NH<sub>3</sub> and H<sub>2</sub>S emissions is also widely variable, going from 6 to 100% and 3 to 99%, respectively (Nicolai and Janni 2001, Armeen 2008, Iranpour et al. 2005).

Therefore, the objectives of the present study were 1) to test three techniques allowing odour and gas emissions reduction in an experimental swine barn and 2) to compare the emission reductions obtained from the diet, the V-shape scraper, the combination of both and from a biological air treatment.

## **MATERIAL AND METHODS**

**The experimental laboratory barn** consisted of 12 identical and independent chambers laid out side-by-side (figure 1). Each room is equipped with a fully concrete slatted floor and has its own manure handling system. Four growing-finishing pigs were housed per chamber during seven weeks (3 weeks of accommodation and 4 weeks of testing). All animal-related data (feed and water consumption, weight gain, volume of manure) as well as manure samples were taken weekly.

The chambers were provided with uniform heating and ventilation rates, and with instrumentation to continuously measure temperature and relative humidity. Relative humidity and temperature in the chambers were measured by a combined temperature and relative humidity probe (Model CS500, Campbell Scientific, Logan, UT). The temperature probe was calibrated by a mercury thermometer ( $\pm 0.4^{\circ}\text{C}$ ). The relative humidity probe was calibrated with a saturated aqueous salt solution (magnesium chloride: 32.5% RH; magnesium nitrate: 52.9% RH). The dew point of the incoming air was available from the inlet ambient temperature and relative humidity values. The output from temperature and relative humidity probe and the pressure differential transducer were recorded every 10 min by an acquisition system (Model CR-10, Campbell Scientific, Edmonton, AB).

The ventilation system consisted of an inlet and exhaust fan mounted in the ceiling of each chamber. The exhaust fan was able to vary its capacity from 14 to 75 L/s. The exhaust air was directed through a 204-mm iris orifice damper (Model 200; Continental fan manufacturer inc., Buffalo, NY). Its accuracy was rated at  $\pm 5\%$ . A differential pressure transducer measured the pressure across the orifice plate.



Figure 1. A picture of the experimental chambers.

**Experimental design** The experimental design used in this experiment involved four treatments: 1) C: control (no technology implemented, manure handled with a pull plug system emptied every week); 2) D: dietary manipulation; 3) S: under slat separation system (V-shaped scraper); 4) D+S: a combination of the treatment D and S. Three replicates per treatment were completed each trial, for a total of six replicates per treatment.

**Treatments** A standard commercial diet was used as control and the treatment diet is a special diet formulated to reduce odour emissions (Table 1).

Table 1: Composition of the control and treatment diets

Ingredients	Quantity (%)	
	Control diet	Treatment diet
Corn	67.690	54.240
Tourteau soya	15.000	8.000
Wheat	15.000	15.000
Animal fat	0.000	5.000
Soybean hulls	0.000	15.000
Limestone	0.850	0.700
Dicalcium. Phosphate	0.400	0.400
Calcium chloride	0.000	0.150
Lysine-HCL	0.150	0.350
DL-Methionine	0.000	0.030
L-Tryptophan	0.000	0.030
L-Threonine	0.000	0.150
NatuPhos5000 liquid (phytase)	0.015	0.015
Porzyme9310 granular	0.000	0.040
Choline 60	0.095	0.095
Premix (Vitamin et minerals)	0.500	0.500
NaCl	0.300	0.300
<b>TOTAL (%)</b>	100.0	100.0
<b>Total protein contain (%)</b>	15	12

The in-barn manure management system separates urine from feces using a V-shaped scraper and a V-shaped gutter (figure 2). Feces stay on the inclined walls while urine is gathered into the middle trench and stored under the gutter. A mobile squeegee-type scraper is used to remove feces once every two or three days.



Figure 2. A picture of the V-shape scraper system.

Using the information available in the literature, three air treatment units (ATU 1, 2 and 3) were thus designed to meet the air treatment required for the three small-scale swine chambers (Figure 3). Each unit has a treatment volume of  $0.80 \text{ m}^3$  fabricated from synthetic material and a continuous recirculation of liquid was used to moisten them.



Figure 3. A picture of the air cleaning system.

**Gas and odour measurements** The concentration of methane ( $\text{CH}_4$ ), carbon dioxide ( $\text{CO}_2$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ) were measured with a gas chromatograph (Varian 3600, USA) equipped with a flame ionization detector (FID) for detection and quantification of

CH<sub>4</sub> and an electron capture detector (ECD) for detection and quantification of CO<sub>2</sub> and N<sub>2</sub>O. Ammonia (NH<sub>3</sub>) was measured with a non-dispersive infra-red (NDIR) analyzer (Ultramat 6E, Siemens, Germany) and the semi-quantitative evaluation of hydrogen sulphide (H<sub>2</sub>S) is done with a UV fluorescence analyzer (M101E, Teledyne API, USA). Every two days, the analyzers would monitor ambient air and certified calibration gas.

Odour samples were collected weekly. Odour concentration was evaluated by dynamic olfactometry and odour intensity was evaluated in-situ by nasal rangers (BSI, 2003; Feddes et al., 2001). Two trained odour assessors evaluated the ambient odour intensity at the intake and the exhaust of each room with a 9-point n-butanol scale as described in the Standard Practices for Referencing Suprathreshold Odour Intensity Standard (ASTM 544-99, 1999). During the same time periods, air samples at the air room intake and exhaust were collected in 60-L flushed Nalophane bags for odour concentration evaluation. These olfactometry tests to measure the concentration was carried out in a 24 hours period from the sampling period.

## **RESULTS AND DISCUSSION**

The initial and final average pig weights were 60.4 kg and 90.25 kg, respectively. The average daily gain for all treatments and control ranged from 1.03 to 1.06 kg/day-pig for an overall average of 1.05 kg/day-pig showing no significant difference between treatments. Consequently, the experimental diet did not have any detrimental effect on animal performance.

The V-shaped and the combination Diet-V-shaped scraper treatment reduced odour emissions by 20% in comparison with the control (Table 2) but that difference was not statistically significant. A significant odour reduction of 60% was achieved by the air cleaning treatment.

Except for the air cleaning system, all treatments had no impact on CO<sub>2</sub> and N<sub>2</sub>O emissions (Table 2) and these results are in agreement with the literature. The air cleaning treatment increased significantly (by more than three times) the N<sub>2</sub>O emissions. Only the diet treatment increased (by 120%) significantly the CH<sub>4</sub> emissions.

The NH<sub>3</sub> emissions were significantly reduced by all treatments (Table 2). The best reductions were obtained by the air treatment and the treatment combination reaching 77 and 66% in comparison with the control, respectively. A reduction of 63 and 48% was obtained with the diet and V-shape scraper, respectively. These results are within the same range than the literature (from 40 to 65% of reduction).

Table 2. Gas and odour emission results.

Treatments	CO <sub>2</sub>	mg/hr-kg <sub>pig</sub>			Odour OU/hr-kg <sub>pig</sub>
		CH <sub>4</sub>	N <sub>2</sub> O	NH <sub>3</sub>	
Control	701.00	1.28	0.07	3.33	140.65
Diet	652.00	2.82	0.07	1.20	150.12
V-Shaped	617.98	1.71	0.08	1.71	113.50
Diet + V-Shaped	600.25	1.64	0.07	1.10	112.83
Air treatment	684.50	1.30	0.31	0.76	58.08

**CONCLUSION** The objectives of the present study were 1) to select from the literature the most promising technologies allowing odour emission reduction; 2) to test the selected technologies in an experimental barn and 3) to compare the measured emission reductions.

Three different techniques (dietary modification, in-barn separation system and air cleaning system) have been identified as the most promising options to reduce gas and odour emissions from a pig barn. The diet tested in this study reduced NH<sub>3</sub> emissions by 63%, increase significantly CH<sub>4</sub> emissions and had no impact on odour emissions. In comparison with the control, the in-barn separation system reduced both NH<sub>3</sub> and odour emissions by 48% and 20%, respectively and increased CH<sub>4</sub> emissions by 34%. The air cleaning system tested allowed a significant reduction of odour (60%) and NH<sub>3</sub> (77%) emissions. However, N<sub>2</sub>O emissions were higher than the control. Therefore, more research has to be done on biological air cleaning systems to minimize side effects as the increase in N<sub>2</sub>O emissions.

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