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Emissions of ammonia, methane and nitrous oxide from pig houses and slurry: Effects of rooting material, animal activity and ventilation flow

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Abstract

Animal production is subjected to frequent public debate, because of environmental problems and increasing concern on animal welfare. European Union regulations about animal welfare stipulate that pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities. However, the use of rooting materials, such as straw or maize silage, in slatted systems may influence gaseous emissions from pig houses and slurry. The objective of this work was to evaluate the effects of different factors, including: animal activity, outdoor temperature, ventilation flow, number of heat production units (hpu, where 1 hpu is equal to 1000 W of total heat produced by the animals at 20 °C), time of day and type of rooting material provided to the animals as environmental enrichment; on ammonia, methane and nitrous oxide emissions, measured in a pig building for fatteners over 37 days. In order to obtain a better understanding of the effect of the rooting material on gaseous emissions, an additional laboratory test was performed with mixtures of slurry and rooting materials stored in enclosed flux chambers, simulating the conditions during storage of slurry. In the pig building, the three parameters that explained most of the variability of ammonia and methane emissions were type of rooting material, animal activity, and ventilation flow. The diurnal variations of ammonia and methane emissions were highly correlated with the diurnal variation of animal activity ($R^2 = 0.94$) and ventilation flow ($R^2 = 0.79$), respectively. The change of the rooting material, from maize silage to straw, caused an increase in the averaged ammonia emission from 1.68 to 2.22 g h^{-1} hpu^{-1}, and a decrease in the averaged methane emission from 3.05 to 1.70 g h^{-1} hpu^{-1}. In the laboratory test, ammonia emissions were significantly higher from pig slurry added maize silage (43 mg h^{-1} m^{-2}) than from pig slurry added straw (3.5 mg h^{-1} m^{-2}), while no significant differences were found concerning methane emissions. This work revealed that the use of rooting materials as environmental enrichment for improving the welfare of growing finishing pigs has an effect on ammonia and methane emissions from pig houses. The evaluation of this effect has to be done under normal housing conditions including presence of animals in the barn.

Keywords: Ammonia; Methane; Nitrous oxide; Pig; Rooting material; Animal activity

1. Introduction

Animal houses are an important source of ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O) gases that can have negative consequences for people, animals and environment. These gases are produced inside the buildings by direct emission from the digestive system of the animals or from the decomposition of the animal wastes. The produced gases are subsequently volatilized, and emitted to the outdoor environment by the ventilation.

Many different factors can influence gas formation and volatilization and so, gaseous concentrations and emissions from animal houses. These factors are mainly related to: animals (e.g. genetics, diet, number and weight, animal activity, and behaviour), wastes (e.g. handling, treatment, pH, temperature, and surface area), environment (e.g. indoor and outdoor temperature, ventilation flow, and air velocity over the manure surface) and other site-specific factors. Regarding these site-specific factors, the presence of certain

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materials inside of pig barns, used either as bedding material or for any other purpose, can have an effect on the emission of gases (Monteny et al., 2006; Sommer et al., 2006). This effect is partly due to the fact that during storage most organic solid materials (including the rooting materials that fall through the slats to the slurry pit in slatted houses) float to the surface of the slurry forming a crust layer. This crust layer can decrease the wind speed over the slurry, resulting in reduced transport by convection, higher levels of gases above the free surface of the slurry, and lower gas escape. It can also contribute to a reduction in pH in the surface of the slurry.

Within Europe, the presence of rooting materials in pig houses is regulated by the legislation about animal welfare (Commission Directive 2001/93/EC of 9 November 2001 amending Directive 91/630/EEC laying down minimum standards for the protection of pigs). In the directive it is required that ''pigs have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals.'' However, in another animal welfare legislation (Council Directive 2001/88/EC of 23 October 2001, amending Directive 91/630/EEC) it is stated: ''A balance must be kept between the various aspects to be taken into consideration, as regarding welfare including health, economic and social considerations, and also environmental impact.''

Therefore, the selection of suitable rooting materials implies considering not only ethological (e.g. behavioural priorities of the pigs among different materials), economical (e.g. increase of production cost) and practical issues (e.g. slurry handling, drainage, and availability), but also evaluating the consequences on the environment, such as its possible effect on the gaseous emissions from the animal house.

Ethological studies regarding the value of different materials as enrichment (rooting) materials have revealed that there are many materials that can be used for this purpose. In this sense, an extensive study (Bracke et al., 2006) showed that 29 out of 64 materials assessed by senior pig welfare experts, were considered to provide what they considered an 'acceptable enrichment' to pigs.

One of the rooting material most commonly used in pig farms is straw (Tuyttens, 2005; Scott et al., 2007). Straw has some practical advantages as rooting material (e.g. availability in farms, thermal isulation), but it has also important disadvantages (e.g. cost, labour, problems with the slurry handling, increased production of dust). Regarding the environmental impact of this material, several authors have evaluated gas emissions from deep-litter pig houses that used straw as bedding material (Groenestein and Van Faassen, 1996; Jeppsson, 2002). However, pig houses in Europe tend towards using partially slatted floors, essentially different from deep-litter houses, and the amount and handling of the straw used in deep-litter systems is different than when, in partially slatted pig houses, the straw is used exclusively for environmental enrichment. In this sense, Amon et al. (2006) evaluated NH_3, CH_4, and N_2O emissions from a straw flow system, obtaining lower gas emissions than default values for forced ventilated fully slatted floor systems.

Other materials than straw can be used as rooting material in pig farms. According to a recent Danish study, a suitable rooting material to pigs needs to reinforce appetitive foraging (i.e. the material should be chewable and ingestible), as a higher content of tasteful and chewable items may have further stimulated the pigs' motivation to interact with the material (Pedersen et al., 2006; Studnitz et al., 2007; Holm et al., 2007). Maize silage is an alternative material to straw that has these characteristics, being among the nine higher scored materials in the Bracke et al. (2006) study. However, according to our knowledge, the effect of the presence of this rooting material in pig farms, on gases emissions from the house has not been previously evaluated in literature.

The objectives of this work were:

(1) To evaluate the influence of animal activity, indoor, outdoor and slurry temperature, ventilation flow, number of heat production units (hpu, where 1 hpu is equal to 1000 W of total heat produced by the animals at 20 °C) and time of day (day or night) on NH_3, CH_4 and N_2O emissions, measured in a pig building for fatteners over 37 days.
(2) To study the effect of the type of rooting material provided to the animals on gaseous emissions, from data collected in two experiments: the 37 days field experiment in the pig building, and a laboratory test carried out with different types of rooting materials added to slurry in enclosed flux chambers, simulating the conditions during storage of slurry.

2. Materials and methods

2.1. Field experiment in the pig house

2.1.1. Experimental pig house

The investigation was carried out in an experimental building for fattening pigs (Fig. 1), at Research Centre Bygholm (University of Aarhus, Denmark). The pig house was provided with four pens with one third being slatted floor. The house was equipped with a neutral pressure mechanical ventilation system that consisted of one inlet unit and one exhaust unit, both located in ducts, at the roof of the house. Incoming air passed a circular slot in the inlet unit, and entered the house in a horizontal direction.

The duration of the experiment was 37 days, starting in November. Two products (maize silage and straw) were used as rooting materials for the pigs, during two successive periods (14 days with maize silage and 23 days with straw). The material was added daily, providing for each period: 0.53 ± 0.05 kg maize silage pig^{-1} day^{-1} or 0.22 ± 0.02 kg