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## A DYNAMIC MODEL OF AMMONIA EMISSION AND CONCENTRATION IN FATTENING PIG BUILDINGS

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**ABSTRACT:** The control of gas emissions from livestock buildings, especially ammonia, is important to limit the environmental impact, which depends primarily on the cumulated emission, and to improve the welfare and health of the animals and the stockmen, are affected by gas concentration inside the building. The model developed in this work aims at integrating the information and models already available in the literature in order to predict the ammonia emission and concentration inside the fattening rooms and in the exhausted air. The model includes the description of animals and feeding, housing and indoor climate, and processes involved in ammonia emission. Different housing designs are considered in the model including different types of slatted floors and ventilation systems. The effect of outdoor climate, including seasonal and diurnal variations, is also taken into account. The model predicts the indoor climate and the emission and concentration of ammonia. A sensitivity analysis has been performed in order to evaluate the effects of season, type of ventilation, and type and cleanliness of floor. These simulations indicated that ammonia emission and concentration are not well correlated and are highly dependant on the ventilation system and the temperature. The model was validated by comparison with ammonia concentration available from the literature, with different types of ventilation and slatted floor, and different indoor temperatures.

**Keywords:** ammonia, modelling, effluent, housing, swine

**INTRODUCTION:** The reduction of ammonia emissions from pig buildings is important because of the negative impact of this gas on the environment. These emissions contribute to acidification, eutrophication and the loss of biodiversity (Sutton et al., 2011). Moreover, high ammonia concentrations in pig buildings have adverse effects on animal's health and performance, and on health and wellbeing of stockmen (Portejoie et al., 2002). Ammonia emissions have also a major contribution to the formation of secondary small particulate matter which has been linked to public health issues in regions with high animal density (Sheppard et al., 2009).

In conventional piggeries for fattening pigs with storage of the slurry in a pit under a slatted floor, ammonia-N emission amounts 20 to 25% of total N excreted, corresponding to about 10 g/d per pig (Griffing et al., 2007; Rigolot et al., 2010). However, the level of these emissions varies widely according to different factors of variation including animal feeding and performance, type of floor, slurry handling, and ambient temperature and ventilation (Rigolot et al., 2010).

In this context the objective of the present work was to build a model for fattening pigs which predicts the effects of these different variation factors on ammonia emission toward the environment as well as its concentration in the building.

**1. MATERIAL AND METHODS:**

The model is composed with three modules representing (i) the animals, including feeding, growth, heat production, excretion, (ii) the building with indoor climate, and (iii) ammonia concentration and emission. These modules were partially built on the basis of already existing models (Aarnink et al., 1998; Schauberger et al., 2000; Rigolot et al., 2010a,b). Ambient temperature is calculated from the room enthalpy and depends on animal heat production, heat losses through the walls, floor and ceiling, outdoor temperature, ventilation rate, and possibly on heating (figure 1a). Ventilation rate is automatically regulated by the model according to a target ambient temperature, as in commercial conditions.

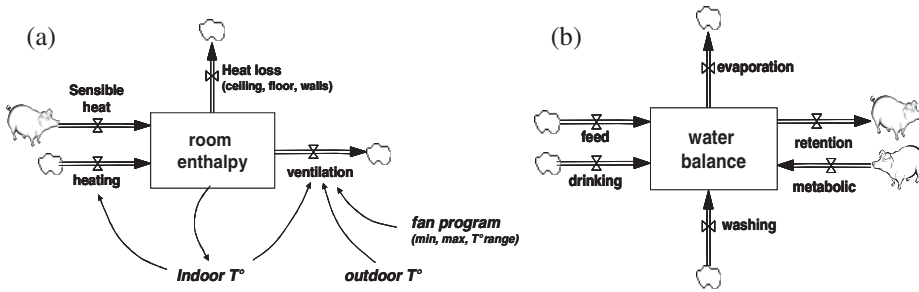


Figure 1. Modelling of heat exchanges, ventilation, temperature and water balance.

Animal's excretion and heat production are determined according to their performance, and the composition of the feed (Rigolot et al., 2010a). Heat production is partitioned among sensible and latent heat according ambient temperature (GIGR, 1984). Water balance is calculated considering water intake, evaporation, retention by the pigs and production by the metabolism, and water used for cleaning (Figure 1b).

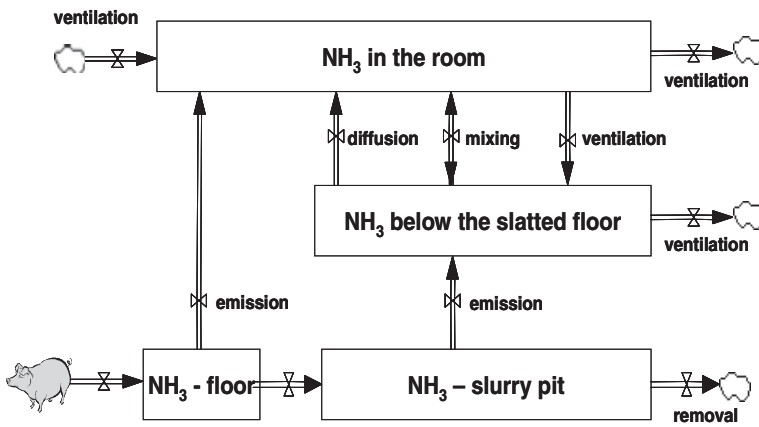


Figure 2. Modelling of ammonia emission and concentration.

Ammonia is present in four compartments: excreta on the floor, slurry in the pit, in the air below the slatted floor, and in the air of the room (Figure 2). In liquid compartments ammonia is present in the form of ammonium ( $\text{NH}_4^+$ ) and dissolved or gaseous ammonia ( $\text{NH}_3$ ). The chemical equilibriums between these different forms are represented in the model as well as the effects of slurry pH and temperature. Ammonia volatilisation depends on slurry gaseous  $\text{NH}_3$  concentration, slurry temperature and air velocity. The model was built using Vensim<sup>®</sup> modelling platform

with a time step of one minute. Different types of housing were considered with different floors (total or partial slatted floor), different locations of air extraction (under the slatted floor, in the room). A note of floor cleanliness was also considered in order to estimate the amount of excreta remaining on the floor.

## 2. RESULTS AND DISCUSSION:

**2.1. Simulation and validation:** The model was used to simulate the effect of slatted floor type (total, partial), season (summer, winter), and location of air extraction (under the floor, in the room) on average  $\text{NH}_3$  concentration in the room and total emission during the fattening period. The main results are presented in table 1. With totally slatted floor, the highest emission (1.05 kg N- $\text{NH}_3$ /pig) is obtained during summer for an under-the-floor air extraction, whereas in that situation  $\text{NH}_3$  concentration in the room is the lowest (4 ppm). Conversely, during winter with in-the-room air extraction, total  $\text{NH}_3$  emission is the lowest (0.54 kg N- $\text{NH}_3$ /pig) and  $\text{NH}_3$  concentration the highest (22 ppm). For the same rate of air renewal the in-the-room air extraction resulted in a higher  $\text{NH}_3$  concentration and a lower emission, the ammonia emitted from the slurry pit being transferred through the room before being exhausted. When it was clean, the use of partial slatted floor resulted in lower  $\text{NH}_3$  emission compared to totally slatted floor, because of the reduction of the pit emitting surface. This was not the case when the concrete area was dirty.  $\text{NH}_3$  concentration was always higher with partial slatted floor because of the increased proportion of  $\text{NH}_3$  being emitted from the floor for this system. These different results indicate that total ammonia emission and concentration may be not well correlated and are highly dependant on the ventilation system and the temperature.

*Table 1. Simulation of the effect of type of slatted floor (total or partial), of season and localisation of air extraction (under-the-floor, in-the-room) on ammonia emission (kg N- $\text{NH}_3$ /pig) and ammonia concentration (ppm)<sup>1</sup>.*

Season & air extraction	Totally slatted		Partially slatted			
			Dirty		Clean	
Summer						
under -the-floor	1.05	(3.5)	1.10	(7.1)	0.91	(6.0)
in-the-room	0.94	(14.0)	1.03	(15.7)	0.85	(13.2)
Winter						
under -the-floor	0.64	(7.9)	0.68	(15.0)	0.57	(12.6)
in-the-room	0.54	(22.1)	0.67	(28.0)	0.56	(23.6)

<sup>1</sup>concentration between brackets (ppm)

The model was validated by comparing model predictions with experimental results. Many studies were available for amounts of slurry and its N content and the comparison showed that they were well predicted by the model ( $r=0.95$  and  $0.77$ , respectively). Much less literature data were available for  $\text{NH}_3$  concentration and emission. The effects of ventilation rate and type of floor on  $\text{NH}_3$  concentration in the room were in agreement with the study of Guingand et al. (2001) and the effect of ambient temperature on  $\text{NH}_3$  concentration below the stated floor or in the room was in agreement with Granier et al. (1996).

**CONCLUSION:** The proposed model allows predicting in a coherent way the cumulated ammonia flow and ammonia concentration. However, some lacks in knowledge were identified, in particular concerning the estimate of the pH of the liquid manure and the qualification of the floor's dirtiness. Likewise, it appeared that the air transfer between the air located above and below the slats must also be better

specified, because it strongly influences ammonia concentration in the room. The results from the simulations indicated that total ammonia emission and concentration may be not well correlated and are highly dependant on the ventilation system and the temperature. Thus, in practice, there may be some antagonism between the reduction ammonia emission and the improvement of air quality inside the building. The proposed model should contribute to identify optimal practices and techniques to reach the best compromises between these two objectives.

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