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INFLUENCE OF CLIMATE CONTROL ON THE AMMONIA EMISSION OF PIG HOUSES

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INTRODUCTION

Ammonia emission is one of the most important causes of soil and surface water acidification. More than 90% of the ammonia emission originates from agriculture. In a European context ammonia emission has to be reduced by 40% against 2010 in Belgium. Consequently, new feeding and building techniques are developed to satisfy the new regulations. Most of these measures require additional investments for the farmer. However, most modern mechanical ventilated livestock houses are equipped with climate controllers. In these controllers the setpoints of V_{min}, T_{opt} and P.B. can be varied. The hypothesis is that this low cost and simple variation of setpoints has a significant effect on NH_3 emission.

OBJECTIVES

The main objective of this study is to evaluate the influence of climate control parameters (indoor temperature, ventilation rate, control settings, ...) on ammonia emission by means of a dynamic simulation model.

METHOD

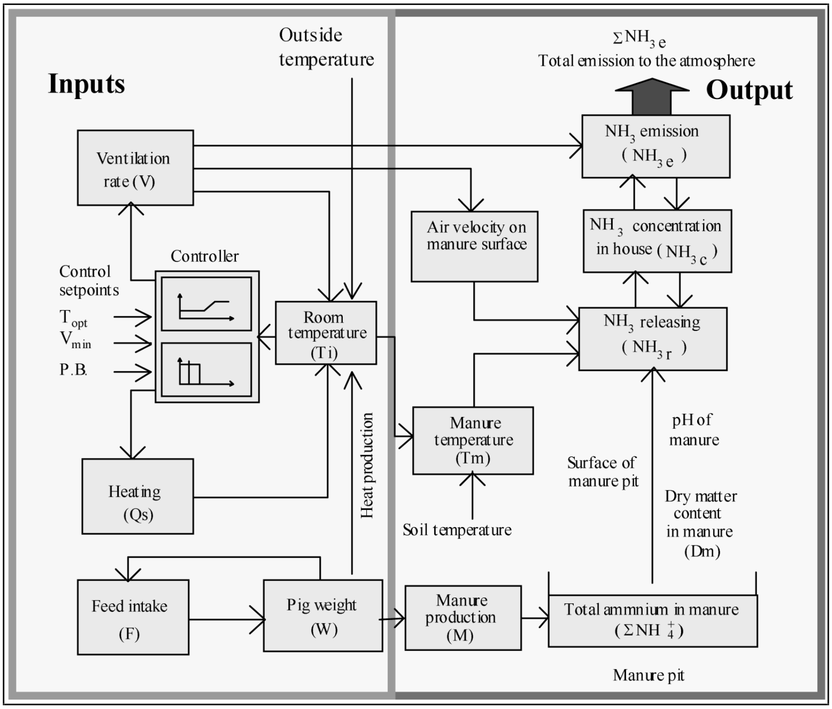
High frequent data of ammonia concentration, indoor and outdoor temperature and ventilation rate were measured in 2 commercial fattening pig houses in the period from 1992 till 1999 by using NO_x analyzers and accurate ventilation rate sensors (Berckmans *et al.*, 1991). The correlation matrix (Table 1) of these data demonstrates the important influence of ventilation rate on ammonia emission. Although, a decrease of ventilation rate increases ammonia concentration in the pig house, the total emission decreases. On the other hand, a decrease of ventilation rate causes an increase of manure temperature and indoor temperature, resulting in a higher emission. The inside temperature has also a positive correlation with the percentage of laying area covered with manure (defined as *floor factor*) (Aarnink and Elzing, 1998); (Ni *et al.*, 1996). This results in an additional source of ammonia emission.

Table 1: Correlation matrix between different variables measured in a commercial pig house based on half year measurements, 21000 samples (Ni et al., 1995).

	NH_{3e}	V	T_M	T_i	T_o	W	N	W_m	F_f
NH_3 emission rate (NH_{3e})	1								
Ventilation rate (V)	0.71	1							
Manure temperature (T_M)	0.57	0.68	1						
Stable temperature (T_i)	0.58	0.62	0.71	1					
Outside temperature (T_o)	0.56	0.83	0.73	0.84	1				
Total animal weight (W_t)	0.60	0.39	0.38	0.59	0.35	1			
Number of pigs (N_p)	0.47	0.17	-0.04	0.39	0.09	0.78	1		
Mean weight of pigs (W_m)	-0.28	0.004	0.28	-0.20	0.08	-0.45	-0.91	1	
Floor factor (F_f)	0.82	0.53	0.65	0.63	0.49	0.72	0.54	-0.30	1
Manure depth (D_m)	-0.15	0.08	0.2	0.07	0.09	-0.2	-0.15	0.10	-0.18

These findings demonstrate the potentials of ammonia emission reduction by means of ventilation control strategies. This could be further examined by using dynamic simulations. By linking a mechanistic ammonia emission model, total emission from pig house could be simulated when pigs were growing in 3 succeeding periods over a whole year. The dynamic climate simulation model (Figure 1, left side) exists of a main model and different sub models (Berckmans *et al*., 1992). The main model calculates for each time step the new values for the output variables (inside temperature, ventilation rate and pig weight) while the sub models describe the separate units of the ventilation system. This mechanistic model was validated with high dynamic measurement in pig houses in the field (Berckmans *et al.*, 1993).

Figure 1: Overview of climate simulation model (left) and ammonia emission model (right).

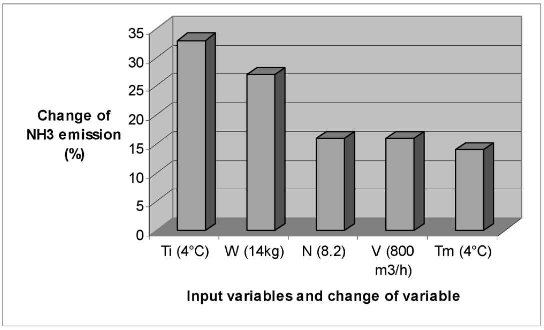


The main outputs of the climate model were used as inputs for the ammonia emission model (Figure 1 right side, Ni, 1998; Ni *et al.*, 1994).

The floor factor is estimated from the simulated inside temperature, number and weight of animals with an empirical model obtained from field measurements. The number and weight of pigs give information about the production of manure and thus the supply of nitrogen to manure. With pH, ventilation rate and manure temperature as inputs, the mass transfer coefficient between manure surface and inside air can be estimated (Ni *et al.*, 1996). The surface manure/air ammonia, concentration in air and manure top layer determines the release of ammonia from the manure pit. Ventilation rate maintains a continuous supply of fresh air and causes a continuous release of ammonia from manure.

RESULTS

Figure 2: Variance of ammonia emission.



A sensitivity analysis was executed to calculate the effect of the emission model inputs (T_i, W, N, V and T_m) on ammonia emission. In this analysis, one input variable was decreased/increased with a certain percentage. To make the effects of changing the inputs comparable, each input is increased/decreased with a certain percentage of the normal working range (minimum/ maximum). This kind of analysis demonstrates the relative importance of input variables on ammonia emission. Each time, only *one* variable is changed from -10% till + 10% of normal working range. Figure 2 shows that a variation from -10% to +10% (for Ti from 18 to 22°C) of inside temperature changes the emission with 33%. Normal emission is 12 mg/s as measured over 5 year field measurements

In second analysis some simulations on yearly base were done. In figure 3, two different control strategies of a frequently used algorithm in commercial pig houses are shown. The corresponding control setpoints (T_{opt}, V_{min}, V_{max}, P.B.) are given in table 2. Outdoor temperature was obtained from dynamic reference year.

Figure 3: Frequently used control algorithms for ventilation and heating (pig weight =100kg).

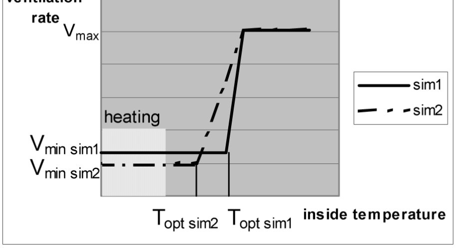


Table 2: Setpoints of control algorithm.

	W(kg)	Sim1	Sim2	
T opt	*20*	25	20	°C
	100	21	16	°C
Vmin	*20*	746	635	m3/h
	100	2165	1960	m3/h
Vmax	*20*	5800	5800	m3/h
	100	5800	5800	m3/h
P.B.		3	8	°C

In table 3, the simulation output of the two different control algorithms is compared. Mean ventilation rate, calculated over 1 year, increases with 22% in sim2 and inside temperature decreases with 12% without underspending the animal thermal comfort zone. The resulting ammonia emission decreases with 13 %.

Table 3: Simulation on yearly base

	Vent. Rate (m3/u)	Inside temp (°C)	NH3 emission (kg/year)	NH3 conc. (ppm)	Energy use heating (kWh)
sim1					
mean	1836	22.9	239	23.2	1677
				0%	
sim2					
mean	2237	20.1	208	16	1106
			effect:	**-13.0%**	

CONCLUSION

Field measurements and simulation analysis proved that inside temperature, animal weight, number of pigs and ventilation rate have a significant influence on the NH_3 emission. In a dynamic simulation on yearly base, the controller actions were considered and changing the control settings showed possibilities to reduce the emission by 13 %. Consequently emission can be reduced by decrease of ventilation rate and inside temperature without any additional costs.

List of symbols:

V: ventilation rate [m^3/h]
V_{min}: minimum V [m^3/h]
T_M: manure temperature [°C]
T_i: indoor temperature [°C]
T_o: outside temperature [°C]
W: total pig weight [kg]
N: number of pigs
P.B.: proportional band [°C]
W_m: mean pig weight [kg]
F_f: floor factor
T_{opt}: temp. setpoint [°C]

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