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# Innovative Ventilation Control in Fattening Pig Husbandry

## Part II - Indoor Air Quality and $NH_3$ Emissions

*Ventilation control, in combination with evaporative indoor air cooling, was tested during four fattening periods, using additional sensors for animal activity and $CO_2$ indoor concentration as control variables. A lower ventilation rate resulted in mean higher concentration levels of noxious gases. Using $CO_2$ controlled ventilation prevented frequently exceeding the 3000 ppm threshold level. In addition to the ventilation rate and indoor temperature, the fogging system also influenced $NH_3$ emissions.*

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### Keywords

Ventilation control, evaporative cooling, emissions

### Literatur

[1] *Häußermann, A., E. Hartung und T. Jungbluth* : Entwicklung innovativer Lüftungssysteme für Mastschweine, Teil I - Methode und erste Ergebnisse. ATF 10 (2004), H. 1, S. 7-15

The newly-developed ventilation control strategies were processed by a commercial control software (Möller GmbH Agrarklima-Steuerungen). They were tested randomly in the Hohenheim research pig facility during four fattening periods from February 2003 until July 2004 [1]. In order to investigate seasonal influences on the effects of the ventilation control, the results of two outside temperature ranges >T1< and >T2< with mean daily outside temperatures below and above 14 °C respectively, have been considered separately.

### Materials and method

The investigations were carried out in two separate compartments (54 pigs each, 0.9 $m^2$ $pig^{-1}$). In order to cool down and humidify the air, each compartment was equipped with two separately controllable high pressure water fogging lines (7 MPa). Four nozzles per compartment were placed in front of the air inlets and six nozzles were placed inside the compartments. The system was activated either when indoor humidity dropped below 50 % or for high indoor temperatures up to a maximum indoor humidity of 80%. Ventilation rate and water fogging were controlled by indoor temperature as well as by the additional sensors of the respective control strategy (*Table 1*). Using strat. C, the ventilation rate was controlled basically by the $CO_2$ indoor concentration, however, for high indoor temperatures, it was controlled by temperature and a dampened control range. Using strat. A, the ventilation rate was increased and water fogging was started additionally at times with high animal activity [1].

Outside and indoor temperature, relative humidity, ventilation rate, as well as $CO_2$ and $NH_3$ concentrations (NDIR spectroscopy) of indoor air, of incoming and exhaust air were logged continuously by the measuring and data acquisition system, integrated in the research facility. Measured $NH_3$ concentration values were corrected afterwards, according to the water vapour cross sensitivity of the gas analyser. The calculation of the $NH_3$ emission rate took into account the difference in the gas concentration in the exhaust and in theincoming air, the ventilation rate, as well as the animal weight, calculated as Livestock Units (1 LU = 500 kg). The strategies were compared by their mean values and mean percentile ranges, defined by the 25 %- and the 75%- percentiles of the measured mean daily values.

### Results

*Indoor air climate*

In >T1<, the indoor air temperature and ventilation rate at strat. R, strat. B, and strat. A did correspond largely with the settings of the ventilation controller (*Table 2; Table 3*). Using strat. C, mean ventilation rate was reduced by about 20 %, mean indoor temperature consequently increased by about 1°C. Water fogging was used mainly for increasing the relative humidity on a mean percentile range of 51 % to 61 % at strat. B and strat. A, compared to 44 % to 52 % at the reference strategy (strat. R). At strat. C, water fogging was in addition used to support indoor air cooling.

In >T2<, mean diurnal ventilation rate was reduced in average by about 22 % by using the fogging system (strat. B and strat. A) and by about 33 %, combining water fogging and $CO_2$ control (*Table 2*). Compared to >T1<, the indoor temperature in >T2< was approximately 1.5 °C to 5.3 °C higher, depending on the ventilation strategy (*Table 3*). Due to the fogging system and evaporative cooling, temperature peaks during the diurnal course were lowered in maximum by about 7 °C, in average in >T2< by about 4 °C to 5 °C. Furthermore, water fogging in >T2< resulted in an increase of the mean percentile range of the relative humidity at strat. B, strat. A, and strat. C on approximately 64 % to 82 %.

*Indoor concentrations of $CO_2$ and $NH_3$*

Corresponding to the lowered ventilation

| Strategy | Strat. R - Reference - | Strat. B - Humidifying - | Strat. C - Humidifying - | Strat. A - Humidifying |
|---|---|---|---|---|
| control parameter | temperature | temperature & humidity | $CO_2$-indoor concentration, temperature & humidity | temperature humidity & anim. activity |

*Table 1: Overview on ventilation concepts and integrated control parameters*

| | Strat. R | Strat. B | Strat. C | Strat. A |
|---|---|---|---|---|
| mean >T1< | $45^{b}$ | $46^{b}$ | $36^{a}$ | $46^{b}$ |
| 25 % - 75 % percentile | 31 - 51 | 34 - 55 | 29 - 40 | 34 - 56 |
| mean >T2< | $119^{c}$ | $93^{b}$ | $80^{a}$ | $92^{b}$ |
| 25 % - 75 % percentile | 120 - 131 | 65 - 127 | 57 - 100 | 67 - 117 |
| a, b, c means with different superscript letters differ significantly (p < 0,05) | | | | |

*Table 2: Ventilation rate [$m^3 h^{-1} pig^{-1}$] of control strategies at mean daily outside temperatures below [>T1<] and above 14°C [>T2<]*

| | Strat. R | Strat. B | Strat. C | Strat. A |
|---|---|---|---|---|
| mean >T1< | $19{,}2^{a}$ | $18{,}8^{a}$ | $19{,}9^{b}$ | $18{,}9^{a}$ |
| 25 % - 75 % percentile | 16,6 - 21,0 | 17,3 - 20, | 18,6 - 21,4 | 17,9 - 20,1 |
| mean >T2< | $24{,}5^{c}$ | $20{,}4^{a}$ | $21{,}8^{b}$ | $20{,}4^{a}$ |
| 25 % - 75 % percentile | 21,3 - 27,5 | 18,4 - 22,2 | 19,4 - 23,2 | 18,6 - 21,9 |
| a, b, c means with different superscript letters differ significantly (p < 0,05) | | | | |

*Table 3: Indoor temperature [°C] of control strategies at mean daily outside temperatures below [>T1<] and above 14°C [>T2<]*

| | Strat. R | Strat. B | Strat. C | Strat. A |
|---|---|---|---|---|
| mean >T1<strat. R | $99^{a}$ | $113^{b}$ | $109^{b}$ | $113^{b}$ |
| 25 % - 75 % percentile | 84 - 113 | 87 - 142 | 82 - 125 | 90 - 140 |
| mean >T2< | $114^{a}$ | $110^{a}$ | $113^{a}$ | $110^{a}$ |
| 25 % - 75 % percentile | 86 - 131 | 77 - 138 | 100 - 121 | 79 - 128 |
| a, b means with different superscript letters differ significantly (p < 0,05) | | | | |

*Table 4: $NH_3$ emission rate [$g\ d^{-1}\ LU^{-1}$] of control strategies of at mean daily outside temperatures below [>T1<] and above 14°C [>T2<]*

rate, mean indoor gas concentration was increased for strat. C in >T1<, in >T2< in addition for strat. B and strat. A. Altogether, >T1< featured a mean percentile range of the $CO_2$ indoor concentration of 1660 ppm to 2600 ppm, compared to 650 ppm to 1550 ppm in >T2<. For the $NH_3$ indoor concentration this was 8 ppm to 17 ppm and 4 ppm to 7 ppm respectively.

The main effect of strat. A, the transport of high loads of gases and dust to the outside, was reached mainly during indoor concentrations above 2500 ppm. In total, it took only a low percentage part of the whole data set, not the least due to the high frequent dynamics of the activity controlled ventilation rate.

According to the control settings, the $CO_2$ indoor concentration of strat. C was shifted towards values between 2000 ppm and 3000 ppm, i.e. from 60 % at the reference towards approx. 80 %. Thereby, the central issue, around which the values were shifted, 2000 ppm, did correspond well with the $CO_2$ control setting. The threshold value of 3000 ppm was exceeded equally for all ventilation strategies at approx. 1 % of the measured values in >T1<, i.e. not more often for the $CO_2$ controlled strategy than for the other strategies.

The threshold for the $NH_3$ indoor concentration, 20 ppm, was exceeded in >T1< at approx. 1 % to 2 % of the measured values when using strat. R, strat. B, and strat. A. Using strat. C, however, the concentration was in a range between 20 ppm and 27 ppm at about 11 % and 0.6 % of the measured values in >T1< and >T2< respectively, mainly caused by the combination of the reduced ventilation rate and water fogging.

*$NH_3$ emission*

$NH_3$ emission rate was highest during the two fattening periods in spring, averaging at 130 g $d^{-1}$ $LU^{-1}$ and 120 g $d^{-1}$ $LU^{-1}$. In contrast, emission rates in the summer period as well as in the winter period were significant lower, in average 97 g $d^{-1}$ $LU^{-1}$ and 94 g $d^{-1}$ $LU^{-1}$ respectively. In >T1<, the mean percentile range of the measured $NH_3$ emission rate ranged between 82 and 142 g $d^{-1}$ $LU^{-1}$ over all ventilation strategies. The mean emission rate was significantly higher for strategies with water fogging compared to the reference strategy, in average by about 10 % to 14 % (*Table 4*). The higher emission rate was associated mainly with the increased indoor humidity and, for incomplete evaporation of fogged water, with wet and subsequently fouled surfaces.

Similarly to >T1<, the mean percentile range of $NH_3$ emission in >T2< was 77 to 138 g $d^{-1}$ $LU^{-1}$. Although both, ventilation rate, as well as indoor temperature, were lowered significantly by evaporative cooling and ventilation control, no significant differences in the $NH_3$ emission rate occurred between the ventilation strategies (*Table 4*). However, the effect of the reduced temperature and ventilation rate was sufficient to counteract an increase of the emission rate due to indoor humidity and pen fouling, but did not reduce $NH_3$ emission beyond it.

## Conclusions

A high potential for an efficient use of evaporative cooling systems was especially found for warm outside temperatures above 14 °C in daily mean. In this connection, the ventilation control strategies influenced the indoor air climate both, by the reduction of the ventilation rate due to indoor air cooling, as well as by directly controlling the ventilation rate.

Using additional control parameters enabled on the one side the specific increase of the ventilation rate at times with high animal activity. On the other side, ventilation rate was minimised due to the control by the $CO_2$ indoor concentration, avoiding at the same time more often exceeds of maximum $CO_2$ indoor concentrations. In conclusion, the combination of several control sensors and additional controlled actors has to be seen as a main basis for an intelligent, event-driven ventilation control.

The diurnal course of the $NH_3$ emission rate was influenced clearly by the level of the ventilation rate and the animal activity. Seasonally higher emission rate occurred mainly during spring and autumn. At mean daily outside temperatures below 14 °C with only small effects on indoor temperature and ventilation rate, $NH_3$ emissions were increased significantly by about 10 % to 14 % for ventilation strategies with humidifying. For warmer outside temperatures, this increase was counteracted by the reduction of the indoor temperature and ventilation rate. However, in order to reduce $NH_3$ emission by adiabatic indoor air cooling, an optimised fogging control, regarding complete evaporation of the water, has to be demanded. Mean measured $NH_3$ emission rate ranged at 5,1 kg $NH_3$ pig $place^{-1}$ $year^{-1}$ (330 fattening days).