5th International Conference of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Virtually from Québec City, Canada – May 11-14, 2021

IMPACT OF ENVIRONMENTAL CONDITIONS ON ACTIVITY PATTERNS IN GROWING PIGS

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CSBE21209 – Presented at the 5th CIGR International Conference

ABSTRACT Pigs in the EU are commonly reared in climate-controlled systems mainly dependent on air ventilation based on a single point (one sensor) temperature set value. These systems assume even spatial distributions of the indoor climate. Since pigs are sensitive to both temperature and other environmental aspects such as humidity and noxious gas concentration, adverse climate conditions can decrease animal welfare and consequently lead to economic losses. In an on-farm study, we measured temperature, relative air humidity, air velocity, ammonia and carbon dioxide concentrations continuously on five different measuring points in one room for a total of three consecutive batches (672 pigs per batch). Fresh air was supplied through ceiling diffuse inlet by a negative pressure ventilation system with two exhaust air ducts which were automatically controlled by the climate control unit The animals were continuously monitored using four network cameras (CCTV) during the whole batches (growing period). Deep learning techniques were developed to automatically detect the activity level of the animals in the recorded video data. Severe spatial differences (horizontal and vertical) in environmental conditions between the measurement points and temporal changes within and across batches were observed, which directly affected the animals' activity levels. The results demonstrate that environmental control based on single point measurements can have severe shortfalls. Furthermore, environmental information beyond air temperature need to be integrated into climate control to assure appropriate conditions for the animals' health and welfare.

Keywords: Climate control, deep learning, environmental monitoring, pig behaviour, sensor fusion

INTRODUCTION In pig farms, building control systems are usually based on room temperature set point which is a pre-defined value, with the speed of fans changing ventilation rate when the room temperature is higher than the set point of the climate control box. This cannot respond to extreme or rapid temperature changes (Jackson et al., 2017, 2020). In addition, design and equipment of pig building can be unadapted to extreme episodes of especially hot waves occurring more frequently in a context of global warming. Consequently, animals are sometimes living in suboptimal conditions, i.e. outside their thermoneutral zone, which result in a significant waste of energy and reduced performance (Le Dividich et al., 2018; Quiniou et al., 2019; Quiniou et al., 2020). There is a great need for optimisation of actual control settings relative to the demands of costs and animal welfare criteria.

The reaction of the animals to the changes in their living environment can be observed by their postural and social behaviours such as lying and mounting behaviours, social disruption and tail biting (Nasirahmadi et al, 2017, 2019a, 2019b). Visually and manually observing their behaviour is very subjective, time-consuming and limited by the sheer number of individuals. Further, this information is not accessible for integration into automated control systems. Therefore, there is a great need for systems that automatically monitor and evaluate the animals' behaviour, in order to actively control climate conditions of the livestock room, and give early warnings about unusual behaviour.

Furthermore, as described by numerous authors, noxious gas concentrations, particularly NH_3 and CO_2 can severely impact on animal health and welfare and in consequence on their performance. Clinical signs of elevated NH_3 concentrations include coughing, sneezing, salivation, lacrimation, black spots in the corner of the eyes (Stombaug et al 1969; Drummond et al, 1980; Donham et al., 1989). The size of the stains (so called tear tracks) are directly proportional to the ammonia concentration (Drummond et al., 1980). However, despite these impacts on animal performance and welfare and clear legal limits for noxious gas levels, their concentrations to date are rarely measured and even less likely to be included in climate control systems. A great need remains regarding the development of sensor networks measuring both environmental and animal related data and machine detectable indicators (Sturm et al. 2020).

The present work sets out to demonstrate the interdependency between environmental and animal related data as well as the need for a change in the design and operation of climate control systems in forced ventilation of pig barns.

MATERIALS AND METHODS

The observations for this study were undertaken on a commercial farm in Germany. Three batches of 672 weaned pigs (max. 28 per pen) each were studied between February and July 2020 in a single room. The pigs entered the room at an average weight of 7 kg and exited at an average weight of 23 kg. The average housing time was 40 days.

Sensors and measurements The room was instrumented with four sensor groups to measure temperature and relative humidity (DOL 114), air velocity (SS 20250 Schmidt), carbon dioxide (CO_2, DOL 19) and ammonia (NH_3, Dräger Polytron C300) concentrations. The sensor groups were installed at five different measuring points in the room (fig. 1), two at pig level, two on 1.4 m height and one in the exhaust. Pigs were housed in 24 pens (2.0 x 5.0 m²) on fully slatted plastic floors and were fed *ad libitum* with a liquid feed. Fresh air was supplied through ceiling diffuse inlet by a negative pressure ventilation system with two exhaust air ducts, which were automatically controlled by the climate computer.

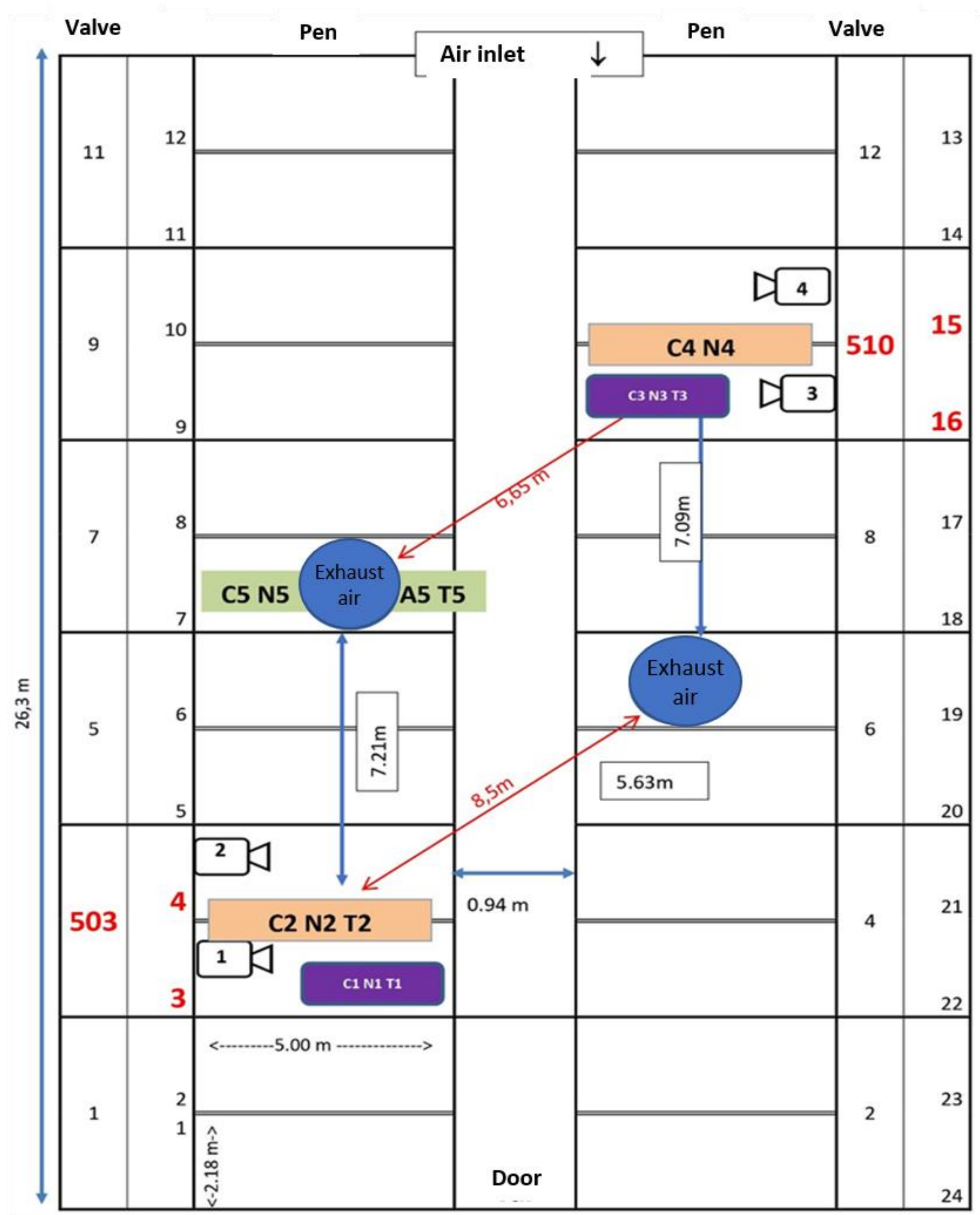

Figure 1. Schematic view or the room with indication of the dissemination and location of individual pens, cameras and sensor arrays (T= Temperature and humidity, A= Air velocity, N= NH_3, C=CO_2)

The animals were continuously monitored using four network cameras (CCTV, pens 3, 4, 15, 16) during the whole rearing period of on average 40 days. Cameras were placed over four pens to film the pigs during the study when the light was on. The footage was viewed using the S-Vidia client (version 6.0.12.220 MP IPPV8 TW). A total of 4900 snapshots distributed among the pens, at different times during the day and throughout the rearing period, light effects and disturbing factors (e.g. water drops on the lens) were saved.

Measurements: Pigs from two pens located left, front area in the room (pens 3 and 4) or right, rear area (pens 15 and 16, Figure 1) were weighed on a pen level on days 2, 14, 28 and 42 day after the arrival in the room. Daily feed intake per pen was measured at 2-pen level, with valves 503 and 510 delivering pens 3 & 4 and 15 & 16, respectively. Activity levels and patterns were determined using deep learning techniques. Pig health items were also noticed throughout the experimental period, e.g. treatments delivered, malting or dislocations, and ear lesions.

Data/images analyses using deep learning techniques were developed to automatically find the activity level of the animals in the recorded video data. On these images, each pig was categorized as "standing" or "lying" in Python (version 3.6) in LabelImg. Subsequently, a machine learning model was created with the dataset for further automatic image analysis. For this, 4500 of the images were used as a training dataset and 400 to validate the model (Nasirahmadi et al., 2019). The deep learning models were able to detect the number of standing and lying pigs which then used as inputs to find the activity levels of the animals (Figure 4)

Each data of the five ammonia sensors was analysed using the Bootstrap Forest analysis method with the batch, rearing day, daytime, temperature, air humidity as main variables (JMP® Pro 14.1.0, ©SAS Institute Inc., USA). For further investigations, the formula obtained from each bootstrap forest analysis was evaluated based on the data of other ammonia sensors to identify conformity between the measuring points. Likewise, the bootstrap forest analysis was also applied on the activity patterns with the variables being as those mentioned previously plus ammonia concentrations.

Statistical analyses: Testing of differences in posture and growth performance (average daily body weight gain (ADG), daily feed intake (ADFI), and feed conversion ratio (FCR)) were performed using a single factorial (ANOVA) and multiple variance analysis (proc GLM) with temperature in pen, carbon dioxide concentration, air velocity at exhaust fan, outdoor relative humidity, temperature and windspeed being used as independent variables in the model. Data was analysed using JMP® Pro 14.1.0 (©SAS Institute Inc., USA). For statistical testing of differences in ammonia concentrations and behavior between the two sensors (on pig level), the non-parametric Wilcoxon matched pairs test was used. For this purpose, the measurement repetitions were considered as replicates, since there is no independence of the data.

RESULTS AND DISCUSSION

Noxious gas concentration: Based on data collected on batch 1, Figure 2 exemplarily shows the time evolution of NH_3 concentration depending on of the location of the sensor in the room. Average, standard deviations, skewness and median of 17.6, 8.2, 0.5, 16.9 for sensor 1 and 5.2, 2.1, 0.5, 4.9 for sensor 3 were obtained, respectively. The average CO_2 concentration measured at the two places during batches 1 and 2 are compared in Figure 3. For batch 1 and sensor 1, average, standard deviations, skewness and median of 2586.39, 494, 0.34, 2636 were obtained while 2660.42, 502.12, 0.08, 2667 for sensor 3. In case of batch 2, 2458.15, 396.44, 0.18, 2467 and 2354.04, 389.62, 0.18, 2354 for sensor 1 and 3, respectively. The results clearly demonstrate the spatio-temporal variance in noxious gas concentration within and between batches.

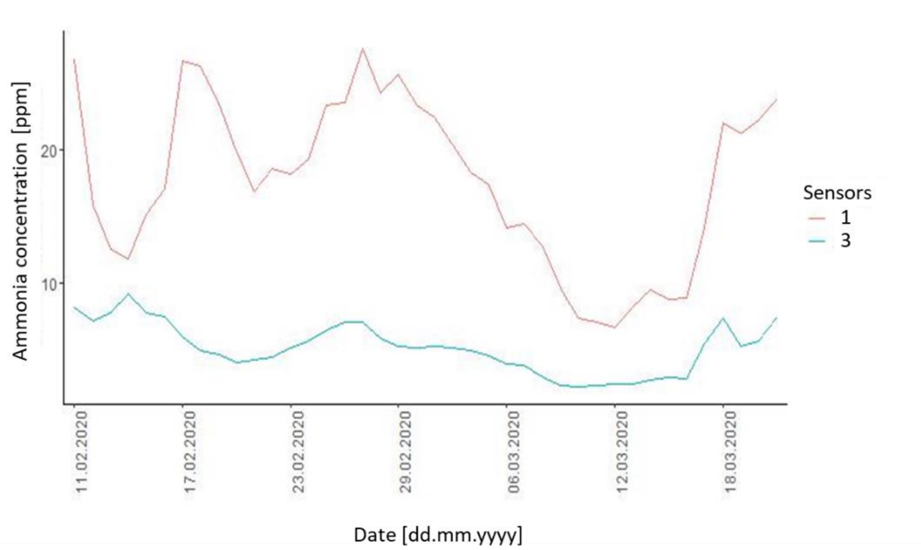

Figure 2. Temporal evolution of average NH_3 concentration during the 41 days of measurements for batch 1 at two sensor positions (1 data point per 10 minute)

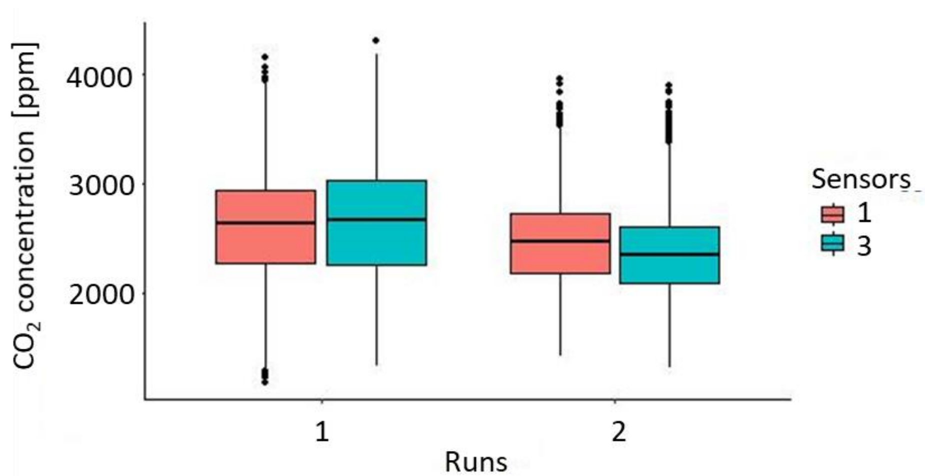

Figure 3. Average CO_2 concentration observed throughout the experimental period at two sensor positions (example from batches 1 and 2).

Table 1. provides the average values for the noxious gases for all three runs and over the whole period of investigation.

Table 1. Noxious gas concentrations at sensors 1 (left front) and 2 (right rear) for total observation period

Noxious gas	Sensor 1				Sensor 3			
	Mean	SD	skewness	median	Mean	SD	skewness	median
NH_3	15.7	7.9	0.71	14.3	6.6	4.8	1.98	5.3
CO_2	2350.79	516.37	0.01	2365	2424.80	501.39	0.30	2397.00

Activity pattern: Analysis of deep learning models detection datasets shows that on average, around 58% of pigs spend standing during the mid-day period followed with subsequent decline to about 11 % in the late afternoon. Figure 4 displays an example of the variation in standing behaviour of the pigs during a 12 h period in the two investigated zones, based on image analysis.

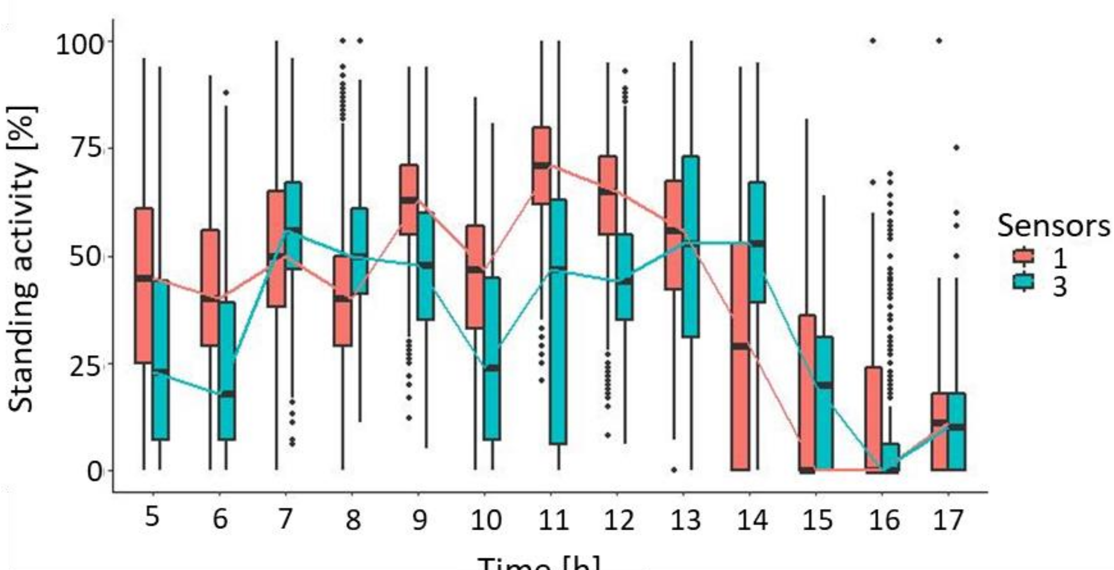

Figure 4: Circadian variation in hourly standing activity example: on February 27 2020 (batch 1).

Growth performance and health The growth performance of the pigs housed in the pens differed significantly between the both measurement locations. The animals in the left, front area on average had a 34 g/d lower average daily gain and 40 g/d lower feed consumption over the three runs than the animals raised in the right, rear area at the same time. No statistically significant differences in frequencies could be detected in the parameters characterizing animal health, such as treatments, malting or dislocations, and ear lesions,. A correlation with the quality of the air in the house during rearing is not excluded on the basis of the available literature findings (Lee et al. 2005; Whates et al., 2002).

Table 2. Average values for growth performance for total observation period

Growth Performance	left/front	right/rear	Mean difference
Initial body weight (kg)	7.7	8.0	
Final body weight (kg)	23.6	25.2	-1.6
Feed intake until day 10 (g/d)	173.5	191.8	-18.3
Feed intake until day 40 (g/d)	425.8	459.6	-33.8
Average daily gain (g/d)	426	460	-34

The pigs housed in pen 3, with the higher ammonia concentrations (17.6 ± 6.3 ppm NH_3), show 39% of standing animals, 3 percentage points more than in pen 16 (36%) with the relatively moderate ambient NH_3 content (5.2 ± 1.9 ppm NH_3). However the partly absent (on 5 of 11 days) to low to moderate (on 6 of 11 days) effect of the location must be taken into account. The estimation models established by random forest were stable without exception. The behavior of the pigs is determined by the same factors, which is why the previously created models are very similar for each sensor and time period. Although no model was able to predict the behavior of the pigs in the respective other period, the central importance of the pollutant gas concentration, as a total of NH_3 and CO_2 concentrations, on the behavior becomes apparent. The concentrations of both gases represented the most influential parameters on the proportion of standing animals in all cases. These results support the hypothesis that the pollutant gas concentrations can influence the performance and behavior of pigs.

CONCLUSION

The present work demonstrated that air quality particularly in terms of concentration of noxious gases, has a clear impact on animal activity and growth performance. Higher concentrations let to a higher proportion of standing animals and a lower average weight gain per day. It was furthermore demonstrated that temporal and spatial differences in minima and maxima within the compartment exist and significantly impacts on the performance of the ventilation control system. At a high temporary and localized NH_3 concentrations in the barn for example, the ventilation rate or air velocity had a significant influence on the barn air quality. Therefore, ventilation controlled according to real outdoor and target indoor temperatures is not sufficient in all cases to optimize pollutant gas concentrations in all areas within the room. The investigations confirm well-founded optimization potentials for the development of comprehensive sensor- and image-based climate control systems.

Before practical application, future work is needed to relate precisely standing –lying behavior to noxious gases concentration in order to determine threshold for alert system inducing correcting measures by climate control systems.

Acknowledgements. This research is part of the PigSys ERA-Net project, co-funded under EU Horizon 2020 RI program (SuSan, www.era-susan.eu, Grant Agreement n°696231) by the French ANR (grant n°ANR-16-SUSN-0003-02) and the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Office for Agriculture and Food (BLE) (grant number 2817ERA07D and 2817ERA08D).

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