Arch. Anim. Breed., 58, 185–191, 2015
www.arch-anim-breed.net/58/185/2015/
doi:10.5194/aab-58-185-2015

Open Access
Archives Animal Breeding

Time of day and season affect the level of noise made by pigs kept on slatted floors

M. Sistkova[1], A. Dolan[1], J. Broucek[2], and P. Bartos[1]

[1]University of South Bohemia, 370 05 České Budějovice, Czech Republic
[2]National Agricultural and Food Centre, Research Institute of Animal Production Nitra, 951 41 Luzianky, Slovak Republic

Correspondence to: J. Broucek (broucek@vuzv.sk)

Received: 26 May 2014 – Accepted: 17 April 2015 – Published: 18 May 2015

Abstract. The aim of this study was to prove the hypothesis that the noise emissions from pig housing varies according to the time of day and the season. The measurements were performed in a building for 1150 fattening pigs with a slatted floor during summer and winter. The pigs (average weight 95 kg) were kept in pens under a batch management system. Nine places were the focus of sound intensity measurements (one inside the stable in section 7; eight places outside the building). The measurements were performed during three sets of 5 consecutive days in summer and three sets in winter. On each day the data were obtained during three 30 min periods (before feeding, during feeding and after feeding). The measurement was made inside and outside the building at the same time. The level of noise depends very significantly upon the period of measurement (before feeding, during feeding, after feeding). The following values were recorded inside (place 1): 65.5 ± 1.6 dB before feeding, 72.0 ± 1.4 dB during feeding and 63.4 ± 0.7 dB after feeding ($P < 0.001$). The effect of seasonal noise levels can be seen only in outside measurements ($P < 0.05$; $P < 0.01$). The comparison of measurement place 1 (inside, pen with pigs) with the other places outdoors showed significant differences in both observed factors ($P < 0.001$). We can conclude that the noise in the pig housing depends significantly on the time of day. The season influences the noise outside the building, in particular.

1 Introduction

The negative effects of noise manifest themselves not only in relation to the human population (Babisch, 2003; Seidman and Standring, 2010), but many harmful effects – both auditory (hearing damage) and non-auditory (Peterson, 1980) – have also been observed in laboratory and farming animals (Morgan and Tromborg, 2007; Mihina et al., 2012). Noise is created by technical equipment, routine activities, animal activities and by animal vocalizations (Clough, 1999; Schäffer et al., 2001; Sistkova and Peterka, 2009). Vocalizations of animals are the result of emotional states in specific situations and relate to factors such as social pressure and fear (Von Borell, 2000a). Stress during management procedures with direct human interference might directly alter the response (Von Borell, 2000b; Von Borell and Schäffer, 2008), and distress calls of pigs can be used as indicators of impaired welfare (Tuscherer and Manteuffel, 2000; Manteuffel and Schön, 2004).

The impact of noise on animals and their productivity depends not only on its intensity or loudness, frequency, manner, and duration but also on the hearing ability, age and physiological state of the animal at the time of exposure. The impact also depends on the history of noise exposure, i.e. to which noise the animal was previously exposed (Burn, 2008). The noise contributes to the development of some psychosomatic diseases (Manteuffel, 2002; McBride et al., 2003; Morgan and Tromborg, 2007). The most obvious effect is a general stress reaction with a higher secretion of ACTH, leading to an increase in adrenocortical hormones in the blood (Manteuffel, 2002; Burrow et al., 2005). Other effects are changes in the glucose metabolism of the liver, changes in the enzymatic activity of the kidneys and immunosuppression (Algers et al., 1978). Prolonged exposure

Published by Copernicus Publications on behalf of the Leibniz Institute for Farm Animal Biology.

to intense noise is associated with an increased activity of the autonomic nervous system. Its prolonged activation is correlated with increased activity in the hypothalamic–pituitary–adrenal system (Otten et al., 2004; Kanitz et al., 2005; Morgan and Tromborg, 2007).

It has been recognized that acute and chronic stress such as noise has an impact on the neuroendocrine and immune system (Tuscherer and Manteuffel, 2000; Weber and Zárate, 2005). Regarding the assessment of animal welfare, especially in pigs kept in group housing, the greatest difficulties may arise from a high noise levels (Manteuffel and Puppe, 1997).

Physiological and behavioural studies have identified noise stress during housing (Schäffer et al., 2001; Kittawornrat and Zimmerman, 2011). Pigs exposed to 90 dB of prolonged or intermittent noise increased cortisol, ACTH and the noradrenaline-to-adrenaline ratios (Otten et al., 2004). Acute sound exposure was found to increase heart rate (Talling et al., 1996). This response was stronger for a frequency of 8 kHz than for 500 Hz and for an intensity of 97 dB than for 85 dB. Pigs respond with an increase in heart rate and plasma glucocorticoids when exposed to short-term noise stress (Talling et al., 1998). A single and short-term noise exposure of pigs at 120 dB was found to increase glucocorticoid concentrations but had no effect on plasma catecholamines (Kemper et al., 1976; cited by Venglovsky et al., 2007). The noise affects the behaviour of animals (Castelhano-Carlos and Baumans, 2009). During the exposure of sows to continuous noise, the communicative signals of mothers to their piglets were drowned out and milk production decreased (Algers and Jensen, 1985, 1991).

The auditory range of pigs is between 55 Hz and 40 kHz, and their sense of hearing is more sensitive in the range of 500 Hz to 16 kHz (Heffner and Heffner, 1993). Noise levels of approximately 40 dB are suggested as the appropriate level during the night (Algers et al., 1978). According to Lanier et al. (2000) and Venglovsky et al. (2007), one-time and short-term intensive noise has a harmful effect on the animals.

According to Weeks et al. (2008), sound levels varied between 85 and 110 dB in pig abattoir lairages. The mean sound levels due to vocalizations ranged from 80 to 103 dB, and vocalizations were the major source of loud noise. Algers et al. (1978) found the sound load produced by ventilation systems in pig housing in Sweden to be higher than 70 dB. McBride et al. (2003) reported that the sound intensity in a subsample of 60 New Zealand farms ranged from 84.8 to 86.8 dB. According to Talling et al. (1998), the average sound pressure level measured in mechanically ventilated pig buildings in Great Britain was 73 dB. In the Venglovsky et al. (2007) project, measurements were carried out on a pig farm in the house for weanlings (from 5–7 to 30–35 kg body weight). They recorded L_{eq} of 72.1 dB, and L_{peak} was 107.3 dB. In the farrowing house, values of 69.1 and 101.5 dB were measured. Before mating and during gravidity, there were noise levels of 83.1 and 113.8 dB in the sow section. The sources of harmful noise in animal production are varied: feeding (104–115 dB), mating (94–115 dB), high-pressure cleaning (105 dB) and feed mixing 88–93 dB.

Not only the animals are exposed to noise but the farmers are, too. Farmers are known to be exposed to intermittent intense noise from a variety of sources. As we often receive questions from the staff of the Ministry of Living Environment regarding the noise from big farms for finishing and fattening pigs during the day and during the year, we wanted to experimentally test the following hypothesis: the noise emissions created in pig housing varies according to the time of day and the season of the year. As most authors who have published on this subject evaluate the production of noise during transport and slaughter, there are no data for farms with large numbers of animals and for pigs that have reached their highest body weight before fattening and that are housed in buildings with slatted floors. Therefore, it was necessary to verify our hypothesis experimentally.

Talling et al. (1998), already cited, measured the noise L_{eq} 69 dB, L_{10} 71 dB and L_{90} 67 dB on a single pig farm with a slatted floor and mechanical ventilation, but the animals were in the lower weight category (over 30 kg) and there were only 70 pigs in the barn. Moreover, feeding was ad libitum. We found no information in the available literature on the impact of summer and winter on the noise from pigs. Therefore, new results would significantly enhance current knowledge in this area.

The objective of this study was to prove the hypothesis that the noise emissions created in pig housing varies according to the time of day and season of the year.

2 Material and methods

The measurements were performed in buildings with fully slatted floors during summer and winter. The pigs (average weight 95 kg) were kept in pens under a batch management system (12 sections, 18 pens in each section and about 8 animals in a pen). The pigs were fed four times a day: at 06:00, 10:00, 14:00 and 18:00. Wet feeding was used. Negative pressure ventilation was used: air was aspirated through the under-grid areas into a vertical shaft, which led 3 m up and ended above the roof of the house.

Nine places were identified by the digital rangefinder Bosch DLE 50 3 601 K16 000, where the sound intensity was then measured. Inside the barn the measurement point was placed in section 7; outside the building the points were placed at a distance of 7 and 11 m from the perimeter of the building, as shown in Fig. 1.

In order to minimize the influence of the weather on the results, the measurements were performed in three sets of 5 consecutive days in the summer and three sets in winter; within the three sets, climatic conditions were almost identical. On each day, the data were obtained during three half-hour periods: before feeding, during feeding and while

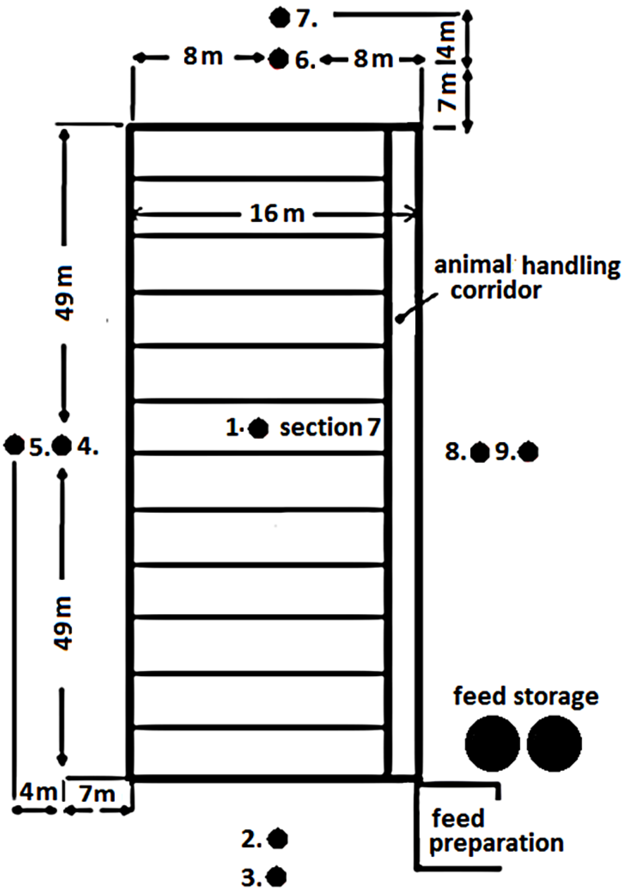

Figure 1. Schematic plan of monitored object with places of measurement (1–9).

the pigs were resting. The ventilation was turned on during measurements. The average daily air temperature and relative humidity in the housing facility during the individual 5 measurement days were as follows: 24.8 °C and 62.5 %, 23.7 °C and 66.0 %, and 24.2 °C and 70.5 % in summer; 19.3 °C and 81.0 %, 14.0 °C and 70.5 %, and 14.5 °C and 81.0 % in winter. Atmospheric pressures showed daily means of 1011.5, 1005.5 and 1000.5 hPa (summer) and 997.2, 997.0 and 997.4 hPa (winter).

The duration of all measurements was $T = 180$ s. The sound pressure levels were measured in decibels by two digital noise meters (Voltcraft Plus SL-300, EN 61672; accuracy class 2) while using the weight filter A and the dynamic characteristic "Fast". The microphone was placed in a camera stand 1.5 m above ground level and directed towards the barn, the source of noise. During the measurement inside the building, where the direction of noise was not identifiable (as every animal was a potential source of noise, there were many sources from different directions), the microphone was directed vertically upwards and placed in the middle of the manipulation passage of the section.

Measurements were taken inside and outside the building at the same time (to ensure this, researchers carrying out the measurements inside and outside the building communicated via Motorola TLKR T6 radio transmitters). Every day before the beginning of the measurements, the noise meter was calibrated (i.e. the adaptation of the noise meter to the existing pressure) using a Voltcraft 326 calibrator (IEC 60942; accuracy class 2).

Using the digital meteorological station Ws-1600 (accuracy class 2), the basic climatic and microclimatic conditions were investigated before every series of measurements.

From measured levels of sound pressure, the major evaluating descriptor (equivalent-level noise), the equivalent level of sound pressure, "$L_{A_{\mathrm{eq}},T}$", was consequently calculated by so-called energetic averaging according to the following relation:

$$L_{A_{\mathrm{eq}},T} = 10 \log \cdot \frac{1}{n} \cdot \sum_{i=1}^{n} 10^{L_{\mathrm{p}A_i}/10}, \qquad (1)$$

where $L_{A_{\mathrm{eq}},T}$ is the equivalent level of noise A in decibels measured at time T, $L_{\mathrm{p}A_i}$ is the ith measured level of sound pressure A in decibels and n is the total number of measured levels.

The data were analysed using a general linear model ANOVA of the statistical package STATISTIX 9 (Analytical Software, Tallahasee, FL, USA). The following factors were evaluated: place of measurement (1–9), time of day (1 – time before feeding; 2 – feeding time; 3 – time after feeding) and season (1 – summer; 2 – winter). The normality of the data distribution was evaluated by the Wilk–Shapiro/Rankin Plot procedure. All data conformed to a normal distribution. Significant differences between groups were tested by comparisons of mean ranks. Values are expressed as means ± SD.

3 Results

Average $L_{A_{\mathrm{eq}},T}$ (dB) values recorded inside the building (1) and outside the building (2–9) during observed times (periods 1, 2 and 3) are stated in Table 1. The results showed that the level of noise depends very significantly upon the time of measurement (before feeding, during feeding, after feeding). Differences $P < 0.001$ in all cases. $L_{A_{\mathrm{eq}},T}$ differences between individual periods for individual places of measurement are diagrammatized in Fig. 2. The biggest differences in all measurement places were found between periods 2 and 3 (7.7 and 9.5 dB, respectively). The differences in the levels recorded in periods 1 and 2 ranged from 5.9 to 6.9 dB. The smallest differences were discovered between periods 1 and 3 (1.5 and 3.3 dB, respectively).

Inside the building, in place 1, $L_{A_{\mathrm{eq}},T}$ of 65.5 ± 1.6 dB was recorded in period 1 (time before feeding). During this time, some pigs lay quietly, some were digging in the ground and some were playing with chains hanging from the barrier. In period 2 (time of feeding), the average noise level

Table 1. Effect of time of day on noise levels. The sample size, N, was 30.

Place of measurement	Sample period			Grand mean ± SD	Significance
	1 $\bar{x} \times \pm$SD	2 $\bar{x} \times \pm$SD	3 $\bar{x} \times \pm$SD		
1 (inside)	65.5 ± 1.6	72.0 ± 1.4	63.4 ± 0.7	66.9 ± 3.9	***
2 (outside)	43.7 ± 1.6	50.5 ± 2.6	42.5 ± 1.5	45.6 ± 4.1	***
3 (outside)	43.6 ± 1.6	50.3 ± 2.8	42.5 ± 1.4	45.5 ± 4.0	***
4 (outside)	47.0 ± 1.9	53.5 ± 2.8	45.1 ± 1.3	48.5 ± 4.2	***
5 (outside)	47.1 ± 2.2	53.7 ± 2.3	45.6 ± 1.1	48.8 ± 4.0	***
6 (outside)	46.0 ± 2.6	52.5 ± 2.3	43.8 ± 2.0	47.5 ± 4.4	***
7 (outside)	46.0 ± 2.8	52.0 ± 2.2	44.0 ± 1.9	47.3 ± 4.1	***
8 (outside)	48.0 ± 2.7	53.9 ± 3.0	45.1 ± 1.6	49.0 ± 4.4	***
9 (outside)	47.5 ± 2.8	53.7 ± 2.7	44.2 ± 1.5	48.4 ± 4.6	***

Place of measurement: 1 – inside; 2 – outside, distance of 7 m; 3 – outside, distance of 11 m; 4 – outside, distance of 7 m; 5 – outside, distance of 11 m; 6 – outside, distance of 7 m; 7 – outside, distance of 11 m; 8 – outside, distance of 7 m; 9 – outside, distance of 11 m; Period: 1 – time before feeding; 2 – feeding time; 3 – time after feeding; SD – standard deviation; Significance – calculated differences among the measurement times; *** $P < 0.001$.

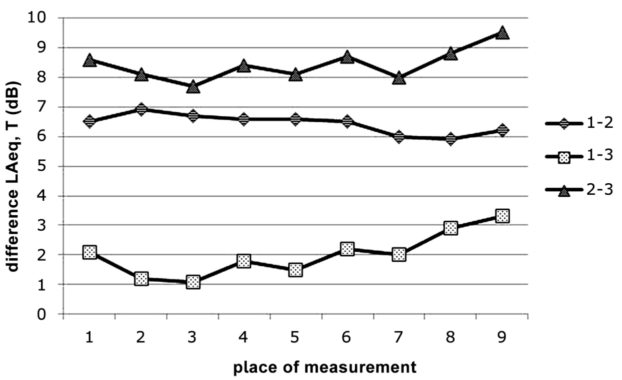

Figure 2. Difference in noise levels between different times and measurement places. Period: 1 – time before feeding; 2 – feeding time; 3 – time after feeding; 1–2 – difference between periods 1 and 2; 1–3 – difference between periods 1 and 3; 2–3 – difference between periods 2 and 3.

was 72 ± 1.4 dB, that is, 6.5 dB higher than before feeding. During period 3 (time after feeding), when almost all pigs were already lying down quietly, $L_{A_{eq},T}$ of 63.4 ± 0.7 dB was measured, which is 8.6 dB lower than during feeding.

The effect of season on the noise level can be seen only in outside measurements ($P < 0.05$; $P < 0.01$). Average $L_{A_{eq},T}$ values (dB) inside the building (1) and outside the building (2–9) in summer (1) and in winter (2) are given in Table 2.

In the noise values, interactions between daily period × season ($P = 0.0017$) were calculated. This interaction represents the associated effect of a combination of these factors on the dependent variable (intensity of noise). The measurements at individual times of day are influenced by season and vice versa.

4 Discussion

The average level of 72 dB, recorded in period 2, was probably largely due to the loud noise that pigs emitted during food intake. This increase was not surprising for us and we would like to compare it to other studies. However, research on the effects of vocalization during feeding on pigs housed in groups is minimal. But to go back to our results, they raise the question of why we recorded lower-intensity noise overall than Algers et al. (1978), Talling et al. (1998) and McBride et al. (2003). A possible explanation for unexpectedly lower noise is as follows: from the literature it is known that both crowding at feeding, with possible aggression, and large-group housing negatively affect pig welfare. Both factors cause animals to make sounds. The issue of pig vocalization and aggression during feeding highlights one of the main advantages of small groups. In general, a small group can be relatively stable in comparison with a larger group (Morrison et al., 2007), and this was the case in our study. There were only eight pigs in a pen, with 0.84 m^2 per pig; these are comfortable conditions. Conventionally, pigs are housed in more confined systems, with fully or partially slatted floors and a liquid effluent system and with group sizes ranging from 5 to 50 pigs with a floor space allowance of approximately 0.65 m^2 per pig (Morrison et al., 2007). More space means that animals had good welfare, possibly better than recommend by the EU Commission Directive (2001). In addition, the link between animal vocalizations and the emotional state of an animal makes vocalizations useful tools for assessing the well-being of an individual (Weary and Fraser, 1995; Manteuffel et al., 2004; Von Borell and Schäffer, 2008).

Another explanation for lower noise levels in period 2 may be as follows. As the distribution of feed in the section is carried out gradually in individual pens, some pigs were still exploring or digging in the ground and moving around

Table 2. Effect of season on noise levels. The sample size, N, was 45.

Place of measurement	Season		Significance
	1 $\bar{x} \times \pm$SD	2 $\bar{x} \times \pm$SD	
1 (inside)	67.6 ± 3.9	66.3 ± 3.8	NS
2 (outside)	46.5 ± 4.1	44.6 ± 3.8	*
3 (outside)	46.4 ± 4.0	44.5 ± 3.9	*
4 (outside)	49.6 ± 4.3	47.5 ± 3.8	*
5 (outside)	49.9 ± 4.1	47.6 ± 3.6	**
6 (outside)	48.8 ± 4.2	46.1 ± 4.2	**
7 (outside)	48.7 ± 4.0	46.0 ± 3.8	**
8 (outside)	50.0 ± 3.8	48.0 ± 4.9	*
9 (outside)	49.9 ± 4.1	47.0 ± 4.7	**

Place of measurement: 1 – inside; 2 – outside, distance of 7 m; 3 – outside, distance of 11 m; 4 – outside, distance of 7 m; 5 – outside, distance of 11 m; 6 – outside, distance of 7 m; 7 – outside, distance of 11 m; 8 – outside, distance of 7 m; 9 – outside, distance of 11 m; Season: 1 – summer; 2 – winter; NS – not significant; SD – standard deviation; * $P<0.05$; ** $P<0.01$.

the pen while waiting for the feed, but some were already jostling during eating and pushing against each other at the mangers (mostly with a lot of noise). McBride et al. (2003) refer to the results of measurements in New Zealand, where noise, certainly in the short-term, reached levels of up to 105 dB in pig sheds at feeding time. This noise can, certainly in the short-term, reach levels of up to 105 dB in pig sheds at feeding time. According to Borberg and Hoy (2009), the social interactions between the group mates during feeding were stronger when they were given feed individually. More than 60 % of attacks and more than 40 % of fights were initiated by high-ranking pigs towards low-ranking pigs. Puppe (2003) reviewed basic mechanisms of coping with stress and related them to animal welfare and health, both generally and for the specific example of social stress in domestic pigs.

After feeding (period 3), noise was found to be lower than during feeding. Thus, this value ($L_{A_{\mathrm{eq}},T}$ 63.4 ± 0.7 dB) can be taken as a reference for further evaluation. Our measured sound levels are much lower than the EU limits. The regulation states that continuous noise levels above 85 dB should be avoided in the part of the building where pigs are kept. Constant or sudden noise should also be avoided (Commission Directive, 2001). Only Sweden has a maximum level for continuous noise that is lower than that recommended in the EU legislation (65 dB) (Mul et al., 2010).

$L_{A_{\mathrm{eq}},T}$ from all measurements inside the building (90 measurements) is 66.9 ± 3.9 dB and is lower than that stated by Algers et al. (1978) and Talling et al. (1998), who carried out measurements in pig housing that had a ventilation system. In contrast to McBride et al. (2003), who state that the noise level was very high at the time of feeding, the present work measured a maximum level of $L_{\mathrm{pA}\max}$ at 100.3 dB during feeding. The recorded noise load was not too intense and generally at a lower level than indicated by McBride et al. (2003); despite this, the effects of noise may cause hearing loss in staff.

The locations of the measurement places, outside or inside, are important; all comparisons between measurement place 1 (inside, pen with pigs) and the other places, positioned outdoors, showed significant differences (66.94 ± 3.89 vs. 47.57 ± 4.44 dB; $P<0.001$). The greatest factor in lowering noise levels was represented by fixed obstacles. This factor is related to the ability of noise to permeate various barriers. Lendelova et al. (2013) researched this ability regarding various wall partitions used in barns. They found that, at a noise load of 80 dB, the noise level was reduced by 37.5 % when a 10 mm thick wooden barrier was used. However, when a 50 mm soundproof plate with 12.5 mm plasterboard (total thickness 62.5 mm) was used, the ability of noise to permeate this barrier was reduced by 58.3 %. In our case, the obstacle to the propagation of noise (wall) was sufficiently strong.

From the results shown it is evident that the noise inside is not as significantly influenced by season as the noise measured outside the barn ($P<0.05$; $P<0.01$). Higher noise levels in summer recorded outside the stable building were caused by increased demands on ventilation, resulting in more opened windows and doors. Moderately elevated noise values inside the building could be caused not only by a greater need for ventilation but also by a probable change in activity on the part of the pigs.

It has been tested whether the vocalization of pigs can be used to assess their adaptability to ambient temperatures (Hillmann et al., 2004b). Pigs adapt to extreme ambient temperatures mainly by changing their behaviour, e.g. they avoid contact with pen mates and lie in the dung area at high temperatures to increase conductivity and huddle together at low temperatures to reduce heat loss (Hillmann et al., 2004a). However, the mean temperatures recorded during the measurements in summer and winter (24.2 and 15.9 °C) do not support the theory of increased activity of pigs in the summer. As Harris (1966) reports, the propagation of noise through the air depends not only on the distance but also on relative humidity. Of course, it is also effected by wind, turbulence and temperature. However, there is very little information on this issue, and individual cases cannot be compared.

Some authors have measured noise generated in the animal housing (Schäffer et al., 2001; Otten et al., 2004; Weeks, 2008; Kauke and Savary, 2010), but there is a lack of sources about noise transmittance from the barn to outdoors. It is likely that nobody has dealt with this problem except for us. Husbandry procedures cause the loudest sounds, especially if metallic equipment is involved or if the work is performed in a hurried manner (Broucek, 2014). However, we studied the emissions of noise from pig housing, i.e. the noise created inside a barn under controlled conditions. The results of our long-term measurements are a new contribution to the study of the influence of environmental factors on the welfare of animals and people. We have gained valuable insights useful for determining levels of hygiene in modern pig farming. However, the results obtained cannot, in our opinion, be generalized. Using the example of fattening pig husbandry, the usefulness of physiological, immunological, pathological, ethological and technical criteria of husbandry conditions has been discussed (Weber-Jonkheer and Zárate, 2009). In order to generalize, measurements would have to be made in more barns with different technologies. Therefore, the results are only valid for this type of housing.

In the present work, noise levels inside the pig building were influenced primarily by the regime (time of day), but there was no excessively high noise load caused by animals or service workers. In the surroundings of the building, the dependence of noise on season was ascertained. Noise levels were higher during the summer than in the winter.

Noise in pig housing should be reduced, but noise protection of workers should not be forgotten. Generally, noise emissions from the barn can be reduced by the use of different noise barriers, a limitation of ventilation speeds, attaching fabric to the wall or altering the texture of the wall. An important factor is applying management strategies in order to create calm in pig housing.

Acknowledgements. The contribution was created from data measured within the framework of the project QH 72134 "Research of principal environmental aspects in breeding of livestock from the point of view of greenhouse gases, smell, dust and noise, supporting the welfare of animals and BAT creation". The work has been supported by the BAT centrum JU. This article was also made possible through project APVV-14-0806 of the Slovak Research and Development Agency Bratislava.

Edited by: A.-E. Freifrau von Tiele-Winckler
Reviewed by: two anonymous referees

References

Algers, B. and Jensen, P.: Communication during suckling in the domestic pig. Effects of continuous noise, Appl. Anim. Behav. Sci., 14, 49–61, 1985.

Algers, B. and Jensen, P.: Teat stimulation and milk production during early lactation in sows: Effects of continuous noise, Can. J. Anim. Sci., 71, 51–60, 1991.

Algers, B., Ekesbo, I., and Stromberg, S.: The impact of continuous noise on animal health, Acta Vet. Scand., 67, Suppl. 1–26, 1978.

Babisch, W.: Stress hormones in the research on cardiovascular effects of noise, Noise and Health, 5, 1–11, 2003.

Borberg, C. and Hoy, S.: Analysis of agonistic interactions between sows with different rank position during mixing, Arch. Tierz., 52, 603–612, 2009.

Broucek, J.: Effects of noise on performance, stress, and behaviour of animals: A review, Slovak J. Anim. Sci., 47, 111–123, 2014.

Burn, C. C.: What is it like to be a rat? Rat sensory perception and its implications for experimental design and rat welfare, Appl. Anim. Behav. Sci., 112, 1–32, 2008.

Burow, A., Day, H. E., and Campeau, S.: A detailed characterization of loud noise stress: intensity analysis of hypothalamo-pituitary-adrenocortical axis and brain activation, Brain Research, 1062, 63–73, 2005.

Castelhano-Carlos, M. J. and Baumans, V.: The impact of light, noise, cage cleaning and in-house transport on welfare and stress of laboratory rats, Lab. Anim. Sci., 43, 311–327, 2009.

Clough, G.: The animal house: Design, equipment and environmental control, in: The UFAW Handbook on the Care and Management of Laboratory Animals, edited by: Poole, T., 7th Edition, Blackwell Science Ltd, Oxford, UK, 97–134, 1999.

Commission Directive: 2001/93/EC of 9 November 2001 amending Directive 91/630/EEC laying down minimum standards for the protection of pigs, Official Journal of the European Communities, L 316/36, Issued 1 December 2001, 3 p., 2001.

Harris, C. M.: Absorption of Sound in Air versus Humidity and Temperature, J. Acoust. Soc. Am., 40, 148–159, 1966.

Heffner, H. E. and Heffner, R. S.: Auditory perception, in: Farm Animals and the Environment, edited by: Phillips, C. J. C. and Piggins, D., CAB International, Wallingford, UK, 159–184, 1993.

Hillmann, E., Mayer, C., Schön, P. C., Puppe, B., and Schrader, L.: Vocalisation of domestic pigs (Sus scrofa domestica) as an indicator for their adaptation towards ambient temperatures, Appl. Anim. Behav. Sci., 89, 195–206, 2004a.

Hillmann, E., Mayer, C., and Schrader, L.: Lying behaviour and adrenocortical reactions as indicators for the thermal tolerance of pigs of different weights, Anim. Welf, 13, 329–335, 2004b.

Kanitz, E., Otten, W., and Tuchscherer, M.: Central and peripheral effects of repeated noise stress on hypothalamic–pituitary–adrenocortical axis in pigs, Livest Prod. Sci., 94, 213–224, 2005.

Kauke, M. and Savary, P.: Lärm und Vibrationen im Melkstand – Auswirkungen auf das Tier [Effect of noise and vibration in milking parlour on dairy cow], Agrarforschung Schweiz, 1, 96–101, 2010.

Kemper, A., Wildenhahn, V., and Lyhs, L.: Der Verlauf der Plasmakonzentrationen an Katecholaminen und Kortikosteroiden sowie des plasmagebundenen Jods (PBJ) bei Schweinen unter Einwirkung von Geräuschen beiverschiedenen Haltungsformen, Archiv für Experimentelle Veterinärmedizin, 30, 309–315, 1976.

Kittawornrat, A. and Zimmerman, J. J.: Toward a better understanding of pig behavior and pig welfare, Anim. Health Res. Rev., 12, 25–32, 2011.

Lanier, J. L., Grandin, T., Green, R. D., Avery, D., and McGee, K.: The relationship between reaction to sudden, intermittent movements and sounds and temperament, J. Anim. Sci., 78, 1467–1474, 2000.

Lendelova, J., Plesnik, J., and Zitnak, M.: Účinok použitia STEREDU k zvukovej izolácii pracovného priestoru [Effect of STERED using on sound isolation of workspace], Zbornik recenzovanych vedeckych prac na CD, Nitra, Slovakia, 132–136, 2013.

Manteuffel, G.: Central nervous regulation of the hypothalamic–pituitary–adrenal axis and its impact on fertility, immunity, metabolism and animal welfare, Arch. Tierz., 45, 575–595, 2002.

Manteuffel, G. and Puppe, B.: Is it possible to judge the subjective perception of internal state in animals? A critical analysis from a scientific point of view, Arch. Tierz., 40, 109–121, 1997.

Manteuffel, G. and Schön, P. C.: STREMODO, an innovative technique for continous stress assessment of pigs in housing and transport, Arch. Tierz., 47, 173–181, 2004.

Manteuffel, G., Puppe, B., and Schön, P. C.: Vocalization of farm animals as a measure of welfare, Appl. Anim. Behav. Sci., 88, 163–182, 2004.

McBride, D., Firth, H., and Herbison, G.: Noise Exposure and Hearing Loss in Agriculture: A Survey of Farmers and Farm Workers in the Southland Region of New Zealand, J. Occup. Env. Med., 45, 1281–1288, 2003.

Mihina, S., Kazimirova, V., and Copland, T. A.: Technology for farm animal husbandry, Slovak Agricultural University, Nitra, Slovakia, 99 pp., 2012.

Morgan, K. N. and Tromborg, C. T.: Sources of stress in captivity, Appl. Anim. Behav. Sci., 102, 262–302, 2007.

Morrison, R. S., Johnston, L. J., and Hilbrands, A. M.: A note on the effects of two versus one feeder locations on the feeding behaviour and growth performance of pigs in a deep-litter, large group housing system, Appl. Anim. Behav. Sci., 107, 157–161, 2007.

Mul, M., Vermeij, I., Hindle, V., and Spoolder, H.: EU-Welfare legislation on pigs, Report 273, Wageningen UR Livestock Research, P.O. Box 65, 8200 AB Lelystad, 34 pp., 2010.

Otten, W., Kanitz, E., Puppe, B., Tuchscherer, M., Brüssow, K. P., Nürnberg, G., and Stabenow, B.: Acute and long term effects of chronic intermittent noise stress on hypothalamic–pituitary–adrenocortical and sympatho-adrenomedullary axis in pigs, Anim. Sci., 78, 271–283, 2004.

Peterson, E. A.: Noise and laboratory animals, Lab. Anim. Sci., 30, 422–439, 1980.

Puppe, B.: Stressbewältigung und Wohlbefinden – verhaltensphysiologische Ansatzpunkte einer Gesundheitssicherung bei Tieren [Coping with stress and animal welfare – behavioural and physiological approaches of health management in animals], Arch. Tierz., 46, Special Issue, 52–56, 2003.

Schäffer, D., Marquardt, V., Marx, G., and Von Borell, E.: Noise in animal housing. A review with emphasis on pig housing, Deut. Tierarztl. Woch., 108, 60–66, 2001.

Seidman, M. D. and Standring, R. T.: Noise and Quality of Life, Int. J. Environ. Res. Publ. Health, 7, 3730–3738, 2010.

Sistkova, M. and Peterka, A.: The exposure of working environment noise in the agricultural service workplaces, Res. Agr. Eng., 55, 69–75, 2009.

Talling, J. C., Waran, N. K., Wathes, C. M., and Lines, J. A.: Behavioural and physiological responses of pigs to sound, Appl. Anim. Behav. Sci., 48, 187–201, 1996.

Talling, J. C., Lines, J. A., Wathes, C. M., and Waran, N. K.: The acoustic environment of the domestic pig, J. Agric. Eng. Res., 71, 1–12, 1998.

Tuscherer, M. and Manteuffel, G.: Die Wirkung von psychischem Stress auf das Immunsystem. Ein weiterer Grund für tiergerechte Haltung (Übersichtsreferat) [The effect of psycho stress on the immune system. Another reason for pursuing animal welfare (Review)], Arch. Tierz., 43, 547–560, 2000.

Venglovsky, J., Sasakova, N., Vargova, M., Ondrasovicova, O., Ondrasovic, S., Hromada, R., Vucemilo, M., and Tofant, A.: Noise in the animal housing environment, Proc. 13th Cong. Intern. Soc. for Anim. Hygiene, Tartu, Estonia, 995–999, 2007.

Von Borell, E.: Stress and coping in farm animals, Arch. Tierz., 43, 144–152, 2000a.

Von Borell, E.: Mechanismem der Bewältigung von Stress [Coping strategies during stress], Arch. Tierz., 43, 441–450, 2000b.

Von Borell, E. and Schäffer, D.: Tiergerechte Nutztierhaltung – Eine Feldstudie auf der Basis von Kritischen Kontrollpunkten in der Schweinehaltung [Welfare conform farm animal housing – a field study based on Critical Control Points from pig farms], Arch. Tierz., 51, 57–65, 2008.

Weary, D. M. and Fraser, D.: Signalling need: costly signals and animal welfare assessment, Appl. Anim. Behav. Sci., 44, 159–169, 1995.

Weber, R. E. F. and Zárate, A. V.: Der Begriff Wohlbefinden in der Nutztierhaltung – Diskussion aktueller Definitionsansätze als Grundlage für praxisorientierte Forschung am Beispiel Mastschweinehaltung [Welfare in Farm Animal Husbandry – Current definitions and concepts as basis for practical oriented research with focus on fattening pig husbandry], Arch. Tierz., 43, 475–489, 2005.

Weber-Jonkheer, R. E. F. and Zárate, A. V.: Bewertung von Wohlbefinden in der praktischen Nutztierhaltung – Diskussion der Kriterienauswahl am Beispiel Mastschweinehaltung [Evaluating welfare in practical farm animal husbandry – discussion of criteria selection using the example of fattening pig husbandry], Arch. Tierz., 52, 378–394, 2009.

Weeks, C. A.: A review of welfare in cattle, sheep and pig lairages, with emphasis on stocking densities, ventilation and noise, Anim. Welf, 17, 275–284, 2008.