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Effects of space allowance on behavioural and adrenocortical reactions to elevated temperatures in fattening pigs

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Abstract

To examine the effect of space allowance on behavioural and physiological reactions to high ambient temperatures, a total of four groups of growing finishing pigs were kept in pens with a lying area of 0.7 m^2 and 1.4 m^2 per animal for 23 days. Mean ambient temperatures ranged from 21.7 to 27.0 °C. Behaviour was video-recorded on days 1, 8, 18 and 23 and the number of pigs lying without contact with penmates and in the slatted dung area was determined. Cortisol concentrations were examined in saliva samples taken in the mornings and evenings on test days. Pigs kept in pens with a lying area of 0.7 m^2 tended to lie in the dung area more (P=0.052) and already at lower temperatures than pigs in the pen with 1.4 m^2 (P=0.12). These findings indicate that the resting behaviour of pigs kept with a lying area of 0.7 m^2 was more affected by elevated temperatures than pigs with a lying area of 1.4 m^2. We found no adrenocortical response to the temperatures tested. However, it seems to be possible to prevent the misuse of the dung area by providing the pigs with sufficient space to allow lying without physical contact with penmates.

Keywords: Cortisol, Heat, Lying Behaviour, Pen Size, Pig, Space Allowance

Zusammenfassung

Der Einfluss des Platzangebotes auf stressphysiologische und Verhaltensreaktionen bei Mastschweinen bei hohen Umgebungstemperaturen

Um den Einfluss des Platzangebotes auf ethologische und physiologische Belastungsreaktionen bei hohen Umgebungstemperaturen zu testen, wurden vier Gruppen von je 9 Mastschweinen in Buchten mit 0,7 m^2 bzw. 1,4 m^2 Liegefläche pro Tier gehalten. Die Versuchsdauer betrug 23 Tage. Die mittleren Tagestemperaturen lagen in dieser Zeit zwischen 21,7 und 27,0 °C. Das Verhalten der Tiere wurde an den Tagen 1, 8, 18 und 23 auf Video aufgenommen. Es wurde alle 15 Minuten analysiert, wie viele Tiere ohne Körperkontakt zu Buchtengenossen und wie viele Tiere im Kotbereich lagen. Zur Bestimmung des Cortisolspiegels wurden an den Versuchstagen morgens und abends Speichelproben genommen. Die Umgebungstemperatur hatte keinen Einfluss auf die Cortisolkonzentration. Die Schweine mit 0,7 m^2 Liegefläche lagen tendenziell mehr (P=0,052) und bereits bei niedrigeren Temperaturen (P=0,12) im Kotbereich als die Tiere in den grossen Buchten. Dies deutet darauf hin, dass das Ruheverhalten bei Mastschweinen mit einer Liegefläche von 0,7 m^2 je Tier durch hohe Umgebungstemperaturen stärker beeinträchtigt war. Ein Platzangebot von mehr als 0,7 m² Liegefläche pro Tier kann helfen zu verhindern, dass Schweine bei hohen Temperaturen im Kotbereich liegen.

Schlüsselwörter: Cortisol, Hitze, Liegeverhalten, Platzangebot, Schwein

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1 Introduction

For pigs, heat is a significant problem due to their limited capacity for physiological thermoregulation. Pigs react to heat by changing their behaviour. At high temperatures they lie on their sides to expose the maximum body surface to the floor, and they avoid contact with penmates (Götz and Rist, 1984; Quiniou et al., 2001). In addition, they prefer to lie on moist areas where heat dissipation is high due to conduction. Thus, at high temperatures pigs use the dung area for resting, and also often foul the lying area (McKinnon et al., 1989; Geers et al., 1990). This misuse of the pen areas entails hygienic problems and an impairment of air quality due to increasing emission of air pollutants, e.g. ammonia (Aarnink et al., 1997; Olsen, 2001). Heat can also lead to physiological stress reactions in fattening pigs as reflected by increased concentrations of cortisol (Becker et al., 1997). In sows, Bate and Hacker (1985) found that both heat and cold resulted in an increased daily mean level of cortisol, as well as affected the circadian pattern of cortisol release.

From 2008 the European Community Directives (2001/88/EC and 91/630/EEC) are required to be revised, taking into account the relationship between climatic conditions and flooring properties in particular. This means that the relationship between the ability of the pigs to cope with high temperatures, the space allowance, and hygiene issues becomes particularly relevant. Whereas it is known that space allowance affects performance, immune competence, and aggressive behaviour (Weng et al., 1998; Turner et al., 2000), less is known about the effect of space allowance on the ability of pigs to adapt to high temperatures. Ekkel et al. (2003) showed that at thermoneutral conditions, the floor area occupied by a lying pig is the estimated floor area for a semi-recumbent pig (eg. 0.7 m^2 for a pig of 100 kg). However, whether this space allowance is sufficient at high temperatures, when pigs lie fully on their sides, is unclear. In this study we used two different pens (0.7 m^2 and 1.4 m^2 per pig in the lying area) to examine the differences in the behavioural and adrenocortical reactions of fattening pigs (50-90 kg) to high ambient temperatures (22-27 °C). We hypothesised that providing the pigs with more space would reduce resting in the dung area as well as physiological stress responses to high temperatures. As a consequence, adrenocortical reactions were expected to be more pronounced in the smaller pen.

2 Methods

2.1 Animals and housing

We performed the experiments in two replicates between May and July 2001 at the Swiss Federal Research Station for Economics and Engineering (Taenikon, Switzerland) with a total of four groups of nine pigs each (Swiss large white), weighing 50-90 kg (see table 1 for details). Animals were grouped at 20 kg, and groups remained stable until slaughtering at approximately 100 kg. We balanced groups with regard to age, weight, sex (females and castrated males) and litters. Before the start of experiments, pigs were kept in pens comparable to the experimental pens in terms of pen size, structure, and climatic and management conditions. During experiments two groups were kept simultaneously in two pens. The STANDARD pen had a total area of 8.9 m^2 (lying area of 0.7 m^2/pig and dung area of 0.35 m^2/pig), while the LARGE pen had a total area of 18.5 m^2 (lying area of 1.4 m^2/pig and dung area of 0.7 m^2/pig). Both pens had partly slatted floors, and the solid lying areas were lightly bedded with straw (100 g/pig/day). The pens were located in two neighbouring rooms, but were visually and acoustically separated from each other. Pigs were fed with a commercial liquid diet at 0630 and 1630, and had access to water ad libitum. Pens were cleaned every day during the morning feeding. In addition to natural illumination, there was artificial light from 06:00 h to 17:00 h. From 17:00 h to 06:00 h there was dim light allowing video recordings. Every three days we individually marked the animals with a colour spray during feeding.

To adapt to the new environment, pigs were kept in the experimental pens for one week at 20.9 ± 3.7 °C (replicate 1), and 18.3 ± 1.6 °C (replicate 2). Each experimental period lasted four weeks. We selected four observation days within a period: days 1, 8, 18 and 23 after the week of adaptation. The exact temperatures in the pens are given in table 2. Although we strove to control the ambient temperature in the pen by using the stable heater and

Table 1:
Mean weight and mean daily weight gain (± s.d.) of groups during experiments

replicate	pen	mean weight at the start of experiments [kg]	mean weight at the end of experiments [kg]	mean daily weight gain [kg]
1	STANDARD	49.7 ± 3.0	79.7 ± 4.3	0.97 ± 0.1
	LARGE	52.3 ± 2.5	82.3 ± 5.8	0.97 ± 0.1
2	STANDARD	69.4 ± 4.2	95.6 ± 5.2	0.90 ± 0.1
	LARGE	69.4 ± 5.3	93.4 ± 7.3	0.84 ± 0.1

Table 2:
Mean, minimum and maximum daily temperatures during observation days; replicate 1: May/June, replicate 2: June/July

DAY	1	8	18	23
period 1	19.8 °C	22.8 °C	27.0 °C	19.0 °C
min	15.2 °C	16.5 °C	24.5 °C	10.7 °C
max	22.9 °C	24.0 °C	27.5 °C	21.3 °C
period 2	19.0 °C	21.7 °C	25.9 °C	22.9 °C
min	13.2 °C	17.8 °C	21.7 °C	16.9 °C
max	21.4 °C	24.0 °C	26.4 °C	25.7 °C

ventilation the pen temperature depended to a large extent on outside temperature. Thus, temperatures in the LARGE pen were about 2 °C lower than in the STANDARD pen, and differed less than 3 °C between day and night. The temperature and humidity were recorded every five minutes with data loggers (HOTDOG©) fixed on the wall one meter above the floor, both in the lying and dung areas. Temperature was averaged separately for day (0800-2000) and night (2000-0600) on each day of observation, separately for each pen and both data loggers within a pen. Because the data loggers did not reliably record the humidity, we have had to omit the analysis of this parameter.

2.2 Behavioural analysis

On each of the four days of observation, behaviour was videotaped for 22 hours from 08:00 h to 06:00 h. Lying behaviour and lying places were analysed using scan-sampling at 15-min intervals, ie. we noted the number of pigs lying in the solid lying or in the slatted dung area, and if they had contact with penmates (more than 10 % of body surface in physical contact with at least one penmate). Other behaviours (standing, sitting, feeding or walking/running) were summarized as “standing”. For statistical analysis we calculated the mean proportion of animals showing the respective behaviour from 08:00 h-20:00 h (day) and 20:00 h-06:00 h (night).

2.3 Saliva sampling and analysis of cortisol

On the four days of observation we took individual saliva samples from all pigs in order to analyse the concentration of cortisol. Saliva samples ware taken at 19:00 h and at 05:00 h the next morning. In the LARGE pen, we took saliva samples immediately after saliva collection in the STANDARD pen. Each pig was allowed to chew on a cotton pad for approximately 30 s. Collecting the saliva samples from all pigs of one group took less than 20 min, and pigs were not restrained during the procedure. The pigs were well habituated to the sampling procedure.

The pads were stored in plastic tubes and frozen at –21 °C. Prior to analysis, the cotton pads were centrifuged (3000 rpm at 4 °C) to separate the saliva from the pad. Cortisol concentration was analysed using a double antibody RIA for quantitative measurement of cortisol in serum and urine (EURO/DPC®, Gwynedd UK), adapted to the analysis of cortisol in saliva in our laboratory. The saliva (150 µl each) was eluted with 150 µl cortisol antiserum. After incubation for 1 h at 37 °C, 160 µl of ^{125}I-labeled cortisol were added. After a second incubation (3 h at 37 °C) the second antibody was added, incubated for 10 min at 20 °C, and samples were centrifuged for 30 min at 4200 rpm and 4 °C. The supernatant was aspirated and the radioactivity in the tubes was counted for one minute (Cobra II, Canberra Packard S.A., Zurich). The intra-assay coefficients were 12.2 % (low concentrations) and 13.9 % (high concentrations), while the inter-assay coefficients of variance were 19.4 % (low concentrations) and 17.6 % (high concentrations), respectively.

2.4 Statistical analysis

Behavioural parameters and cortisol concentrations were analysed using a linear mixed effects model. We selected a model for the behavioural parameters “lying in the dung area”, “lying without contact” and “standing”, and the cortisol concentration as response variables. In the basic model for the behavioural parameters we tested pen size (STANDARD, LARGE), day of observation, their interaction, time of day (day, night) and temperature as fixed effects, and included the groups as random effects.

$$y = \mu + pen_i + day_j + \text{time of day}_k + \beta \times temperature_l + pen_i \times day_j + \varepsilon_{ijkl},$$
$$\text{with } i = 1,2;\ j = 1\text{-}4;\ k = 1,2;\ l = 1.$$

We checked which parameters showed group-to-group variability, but only a random effect of the intercept needed to be included. For the analysis of cortisol concentrations, data were logarithm-transformed, and we tested the fixed effects of pen size, time of day, day of observation, temperature (as covariate) and interactions. In addition, we tested random variation of the temperature parameters in groups and individuals:

$$\log(\text{cortisol}) = \mu + \text{pen}_i + \text{day}_j + \text{daytime}_k + \beta \times \text{temperature}_l + \text{pen}_i \times \text{day}_j + \text{day}_j \times \text{time of day}_k + \text{temperature}_l \times \text{time of day}_k + \text{pen}_i \times \text{day}_j \times \text{time of day}_k + \varepsilon_{ijkl},$$
$$\text{with } i = 1,2;\ j = 1\text{-}4;\ k = 1,2;\ l = 1.$$

Again, only random variation of the intercept needed to be included. In addition, group-to-group variation was negligible in comparison to interindividual variation and was thus omitted. A first analysis showed that the saliva concentration of cortisol was significantly lower in STANDARD as compared to LARGE pigs ($F_{1,2}$ = 33.2, *P<0.05), and this difference depended on the time of day and the day of observation (pen×day×daytime: $F_{4,211}$ = 6.1, ***P<0.001). We therefore analysed the morning and evening samples separately by using the same model without the fixed effects of time of day, day×time of day, temperature×time of day, and pen×day×time of day.

All statistics were computed with S-Plus 2000 Professional© Release 3 software.

3 Results

3.1 Lying behaviour

Long-term high temperatures clearly affected the lying behaviour of the animals. Both lying without contact and lying in the dung area increased with increasing temperatures, and decreased when ambient temperature went down (figures 1 a, b).

The mean proportion of pigs resting without contact with penmates was significantly affected by both day ($F_{3,20}$ = 4.0, *P<0.05) and temperature ($F_{1,20}$ = 149.2, ***P<0.001). Resting without contact increased from 28 % (STANDARD) and 34 % (LARGE) on day 1 to 55 % (STANDARD) and 53 % (LARGE) on day 8, and 63 % (STANDARD) and 70 % (LARGE) on day 18 (figure 1 a). On day 23, 45 % of the STANDARD pigs and 52 % of the LARGE pigs lay without contact. Lying without contact was additionally affected by the time of day, with higher values during the day than the night ($F_{1,20}$ = 10.6, **P<0.01). Pen size had no effect on lying without contact ($F_{1,2}$ = 2.0, P=0.2)

Lying in the dung area increased from 6 % on day 1 to 27 % on day 8, to 43 % on day 18 in STANDARD pigs (figure 1 b). In the LARGE pen, 3 % of the pigs lay in the dung area on day 1, with this figure increasing to 8 % on day 8 and 39 % on day 18. On day 23, 23 % of the STANDARD and 15 % of the LARGE pigs lay in the dung area. The effects of both day and temperature on the number of pigs lying in the dung area were significant (day: $F_{3,24}$ = 3.6, *P<0.05; temperature: $F_{1,21}$ = 177.3, ***P<0.001). LARGE pigs showed a tendency to lie less often in the dung area than STANDARD pigs ($F_{1,2}$ = 17.6, *P=0.052; figure 1 a,b); however, on each day of observation, a higher mean number of STANDARD pigs lay in the dung area at lower temperatures (i.e. on days 8 and 23) as compared to LARGE pigs (figure 1 b), but the difference failed to reach level of significance (pen × day: $F_{3,21}$ = 2.1, P= 0.13).

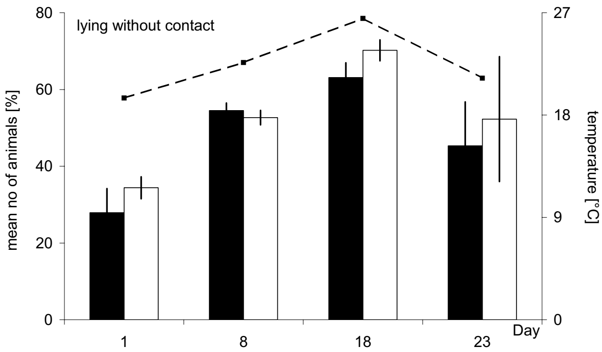

Figure 1 a:
Mean proportion (± s.d.) of STANDARD (filled bars) and LARGE subjects (open bars) lying without contact, and mean daily temperature (line) on days of observations

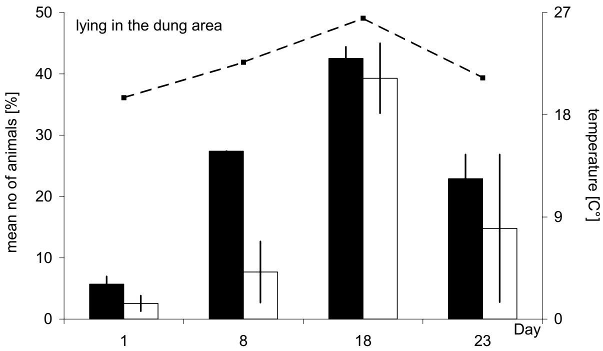

Figure 1 b:
Mean proportion (± s.d.) of STANDARD (filled bars) and LARGE subjects (open bars) lying in the dung area, and mean daily temperature (line) on days of observations

There was no difference in standing between STANDARD and LARGE pigs (pen: $F_{1,2}$ = 2.7, P=0.2).

3.2 Cortisol

The cortisol concentration of LARGE pigs was higher than that of the STANDARD pigs (figure 2 a,b). This effect of pen size interacted with temperature and day of observation (temperature: day:pen size ($F_{4,78}$ = 3.37, *P<0.05). With increasing temperatures, the concentration of cortisol in morning samples increased in STANDARD as well as in LARGE pigs (temperature: $F_{1,78}$ = 10.14, **P<0.01; day: $F_{3,78}$ = 6.22, ***P<0.001; temperature:

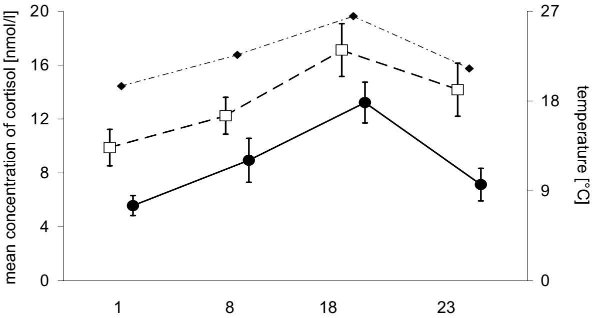

Figure 2 a:
Mean saliva concentration (± s.e.) of cortisol in STANDARD (filled circles) and LARGE pigs (open squares) at 0500, and the mean daily temperature on days of observations

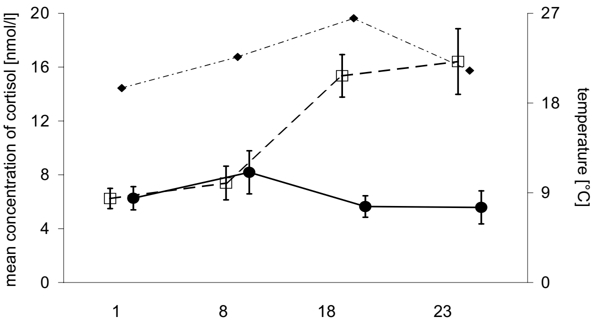

Figure 2 b:
Mean saliva concentration (± s.e.) of cortisol in STANDARD (filled circles) and LARGE pigs (open squares) at 1900, and the mean daily temperature on days of observations

day: $F_{3,78}$ = 8.75, ***P<0.001, figure 2 a). On day 23, the cortisol titre decreased again. On day 18, morning cortisol was highest in all animals (13.2 nmol/l in STANDARD, 17.1 nmol/l in LARGE pigs).

The concentration of cortisol in the evening samples was low on days 1 and 8 for all pigs (fig 2 b). However, the cortisol concentrations measured on the following days of the test clearly differed between pens (pen:day: $F_{3,95}$ = 11.1, ***P<0.001). On day 18 the cortisol concentrations increased in LARGE pigs, but decreased in STANDARD pigs. On day 23, when mean temperature was 5 °C lower than on day 18, the concentrations of cortisol remained high in LARGE pigs (14.2 nmol/l) and low in STANDARD pigs (5.6 nmol/l; temperature: $F_{1,95}$ = 17.9, ***P<0.001; day: $F_{3,95}$ = 18.8, ***P<0.001).

4 Discussion

4.1 Lying behaviour

When exposed to high ambient temperatures, more pigs lay without contact to penmates and in the slatted dung area. We found the tendency that STANDARD pigs lay in the dung area more and at lower temperatures compared to LARGE pigs. Although the dung area offered enough space for all pigs (0.68 m^2 per animal), LARGE pigs seemed to lie more often in the solid lying area (even at higher temperatures), resulting in less fouling of the lying area in the LARGE pen (personal observation). These behavioural adaptations are assumed to correspond to heat stress in pigs (Götz and Rist, 1984; Sällvik and Walberg, 1984; Aarnink et al., 2000; Mayer and Hauser, 2000). We therefore conclude that at high temperatures the pigs prefer to lie spread out on the solid floor rather than use the dung area, when there is enough space, as was the case in the LARGE pen. Consequently, it may be possible to prevent the use of the dung area and, thus, pen fouling at high temperatures, by offering a lying area of more than 0.7 m^2 per growing finishing pig. These findings support the results of Ekkel et al. (2003), who found that the space occupied by a 100-kg lying pig corresponds to 0.76 m^2 at thermoneutral temperatures. At high temperatures, space requirements are even higher. However, when temperatures rose above 25 °C, LARGE pigs also lay in the dung area. This indicates that at long-term high ambient temperatures, additional possibilities for the pigs to cool down (eg showers) should be offered.

4.2 Cortisol

Saliva concentration of cortisol was clearly affected by the ambient temperature. In fact, morning cortisol values increased with prolonged high temperatures, and decreased again with falling temperatures in both STANDARD and LARGE pigs. The concentrations of cortisol obtained at 05:00 h are assumed to reflect the reaction of the HPA (hypothalamo-pituitary-adrenocortical) axis to night time temperatures and seemed to be a reliable indicator for heat challenge, given that we found a clear relationship between cortisol concentrations and ambient temperature.

On day 18 (long-term heat exposure), evening cortisol concentrations had increased in LARGE pigs but had decreased in STANDARD pigs. Whether this reflects changes in the diurnal course of cortisol release and/or indicates higher heat stress in the LARGE pigs remains unclear. For gilts subjected to intermittent stress for 34 days, no change in the circadian rhythm of cortisol release was found, although pigs showed no behavioural habituation to the stressor (Jensen et al., 1996). In contrast to our hypothesis, cortisol levels were generally higher in LARGE pigs than in STANDARD pigs. Similar results were obtained by de Jong et al. (1998) and Klont et al. (2001), who found that baseline cortisol during the light period was higher in enriched housed pigs (with a large space allowance and straw bedding) as compared to barren housed pigs (with little space allowance and no straw). Possible reasons for these findings are still unclear, however.

5 Conclusion

Our findings indicate that in pens with concrete floor the ability of pigs to cope behaviourally with high ambient temperatures rises with increasing space allowance. In addition, with a space allowance of more than 0.7 m^2 in the lying area, it was possible to prevent the use of the dung area to a certain degree, and fouling of the lying area was not observed in the large pen. However, at temperatures above 25 °C, all growing finishing pigs used the dung area for lying, even in the large pen. Thus, at such high temperatures, an additional means of cooling down (e.g. showers or wallows) should be provided.

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