The ear skin temperature as an indicator of the thermal comfort of pigs

Heidi Mai-Lis Andersen a,b,*, Erik Jørgensen c, Lise Dybkjær d, Bente Jørgensen d

a Department of Large Animal Sciences, Faculty of Life Sciences, Ridebanevej 12, 1870 Frederiksberg C, Denmark
b SKOV A/S, Hedelund 4, 7870 Roslev, Denmark
c Department of Genetics and Biotechnology, Faculty of Agricultural Sciences, University of Aarhus, P.O. Box 50, DK-8830 Tjele, Denmark
d Department of Animal Health, Welfare and Nutrition, Faculty of Agricultural Sciences, University of Aarhus, P.O. Box 50, DK-8830 Tjele, Denmark

Accepted 12 November 2007
Available online 26 December 2007

Abstract

The aim of the study was to investigate the relationship between the ear skin temperature and the behaviour of pigs. Fifty-four pigs weighing 75 ± 5 kg were used in three replications (18 pigs per replication) and housed in pens (six pigs per pen) in a controlled climate facility. The room temperature was changed by 2 °C from 18 °C down to 10 °C and up again to 22 °C. The ear skin temperature (EST) was continuously recorded and the activity, lying posture, location and contact with pen mates were scored by 12 min scan sampling for 24 h at the set point temperatures 18 °C, 10 °C and 22 °C. A diurnal rhythm in the EST, the posture and the lying behaviour was found. The EST was highest at night and lowest in the afternoon. During night the pigs had more physical contact to pen mates than during day time. For all three set point temperatures the predominant lying position during the night was the fully recumbent position. The room temperature affected the lying behaviour and the EST. With decreasing room temperature the pigs increased their contact to pen mates and fewer pigs were observed lying in the fully recumbent position. The EST decreased with decreasing room temperature, and the range in the EST’s at the three set point temperatures was larger during day than night (4 °C versus 2 °C). The results indicate that pigs adjust their behaviour to a higher EST when resting than when they are active, and they use behavioural adjustment (e.g. increased/decreased contact to pen mates) to bring their skin temperature into a preferred interval.

© 2007 Elsevier B.V. All rights reserved.

Keywords: Pigs; Skin temperature; Behaviour; Diurnal variation; Thermal comfort; Thermoregulation

* Corresponding author at: SKOV A/S, Hedelund 4, 7870 Roslev, Denmark.
E-mail address: hma@skov.dk (H.-L. Andersen).

0168-1591/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.applanim.2007.11.003
1. Introduction

The vital and productive processes in pigs require a relatively constant body temperature. Climatic conditions in pig housing, primarily ambient temperature are monitored and automatically adjusted based on a set point temperature. However, the thermal environment is not only determined by dry-bulb temperature, but is also influenced by wet-bulb temperature, radiant temperature and air velocity (Sällvik and Walberg, 1984). If the thermal environment does not satisfy the current thermal need of the pigs, it can lead to hygiene (Aarnink et al., 2006) and welfare problems (Hillmann et al., 2001). It is therefore of interest to identify a parameter which can give the climate controls system continuous information about the current thermal state of the pigs.

The thermal equilibrium in the body is achieved through a balance between the metabolic heat production and heat loss from the body. Pigs heat production has a diurnal rhythm depending on the feed intake and activity level, and is influenced by the ambient temperature (Henken et al., 1993; Pedersen and Sällvik, 2002). Storage of body heat will result in an increase in average body temperature. Therefore, to keep the body temperature relatively constant, a diurnal variation in heat loss may be expected. The pig can adjust the sensible heat loss by changes in lying behaviour, contact with pen mates and location in the pen (Mount, 1968; Riskowski et al., 1990; Hillmann et al., 2004), and the lying behaviour is used as an indicator of the thermal state of the pigs (e.g. Mount, 1968; Boon, 1981; Xin and Shao, 2004). The sensible heat loss is regulated by cardiovascular adjustments (Baldwin and Lipton, 1973; Collin et al., 2001), and it has been reported that humans have a certain skin temperature when feeling thermally comfortable (Gagge et al., 1938; Olesen and Fanger, 1973). In pigs, a relation between the lying posture and skin temperature has been found (Andersen and Nørgaard, 2006; Andersen, 2006) and Baldwin and Lipton (1973) reported that pigs activated a heater to bring their skin temperature into a preferred interval. Based on these results, it can be assumed that pigs, like humans, feel thermally comfortable at a specific skin temperature, and that the skin temperature, as well as the lying behaviour, can be used as an index of the thermal state of the pigs.

In a previous study, we found a diurnal variation in the skin temperature at a constant room temperature (Andersen and Nørgaard, 2006). Also, a diurnal rhythm in the ear skin temperature was reported by Bekkering et al. (2003). Ekkel et al. (2003) found a variation over day and night in the lying- and huddling behaviour of pigs. Both the lying behaviour and the skin temperature affect the sensible heat loss and it is of interest to see if there is a correspondence between the daily variations in the skin temperature and the lying behaviour. If so, it supports the use of the skin temperature as an index of the thermal state of the pigs. Results from Gagge et al. (1938), Stombaugh and Roller (1977) and Andersen and Nørgaard (2006) indicate that a change in the skin temperature in one part of the body results in a change in the skin temperature in another part of the body, but the level of the change will differ between body parts. Changes in skin temperature resulting from vasomotor responses are higher in the extremity regions than in the central body regions (Gagge et al., 1938; Stombaugh and Roller, 1977). Since the change is higher in the extremity regions, it can be assumed that the ear skin temperature (ETS) could be a good measure of the thermoregulatory response in pigs.

In order to elucidate the potential use of the skin temperature as an indicator of the pigs thermal state, the aim of this study was to see if the diurnal variation in the
EST is related to the diurnal variation in the behaviour of the pigs at different room temperatures.

2. Materials and methods

2.1. Animals and housing

Nine groups of six pigs (commercial crossbreed: 1/4 Landrace × 1/4 Yorkshire × 1/2 Duroc) grouped by an equal sex distribution were used in three replications (total 54 pigs). The mean start weights (±S.D.) of the pigs were 85.2 ± 7.1 kg in replication 1; 71.7 ± 5.5 kg in replication 2 and 72.8 ± 8.0 kg in replication 3. The pigs were housed in a room with three experimental pens place side by side. Each pen was 6.0 m × 6.0 m with 1/3 solid concrete floor in the back of the pen (lying area) and 2/3 slatted concrete floor in the front. A feed dispenser, with two feeding places, was placed about 2 m from the front of the pen, and at the opposite side a water nipple was placed about 3 m from the front. There was unlimited access to feed and water. The experiment was carried out together with another experiment aiming at assessing the effect of the floor softness in the lying area on the lying behaviour of pigs at different room temperatures (the results of this other experiment will be reported elsewhere). The lying area in each pen was therefore divided into two parts (each 2.0 m × 3.0 m) with a wall, one part with concrete floor and the other with a test floor. The lying area per pig in each part was 1.0 m² to ensure that the lying behaviour of the pig was not restricted by space conditions. The experimental design was made so that an influence of the different floor types on the EST could be analysed. No effect of the floor type on the EST was found. Two sprinkler systems were, in accordance with Danish regulations regarding cooling facilities, placed above the slatted floor area. The sprinklers started automatically each 45 min if the room temperature was 2°C above the set point temperature and were running for 2 min. The room was ventilated with a low-pressure system. Heating pipes were used for additional heating. The windows were covered and the artificial light was on from 7.00 a.m. to 7.00 p.m. Between replications the pen were washed and left empty for at least 7 days.

2.2. Experimental treatment

The room temperature was changed from 18 °C down to 10 °C and up again to 22 °C. For the statistical analyses each replication was split into six periods (one adaptation period and five treatments periods) based on the set point for the room temperature.

Period 0: The adaptation period (3 days), set point temperature constant at 18 °C.
Period 1: Set point temperature constant at 18 °C (3 days).
Period 2: Decreasing temperature in two degrees step from 18 °C to 10 °C (3 days).
Period 3: Set point temperature constant at 10 °C (3 days).
Period 4: Increasing temperature in two degrees step from 10 °C to 22 °C (6 days).
Period 5: Set point temperature constant at 22 °C (2 days).

All temperature changes were made at 8 a.m. The room temperature of 18 °C during the adaptation period was, based on a pilot study, considered as the thermoneutral temperature for the pigs under the given conditions as the pigs were lying next to each other, but not tightly together, in relaxed postures (Mount, 1968). Based on the pilot study 10 °C was considered as cold for the pigs as they were lying closely together and a higher proportion of them were lying in sternum position (Mount, 1968) and 22 °C was considered as warm under the given conditions as the pigs spread out and more pigs lied in a recumbent position (Mount, 1968).

In Table 1, the actual achieved room temperatures and the outdoor air temperature are shown for each period in the three replications. For period 3, it was not possible to achieve the wanted set point temperature
of 10 °C, because of high outdoor temperatures during replications 2 and 3. The mean room temperature only went down to 14.2 °C (replication 2) and 19.4 °C (replication 3), and period 3 in replication 3 was therefore not included in the statistical analysis.

2.3. Measurements

The ear skin temperature (EST) was measured using the computer system QSS2000. The pigs carried an ear tag with a temperature sensor covered in plastic material. The sensor had a temperature resolution of 0.02 °C (absolute accuracy: ±0.5 °C). The EST was measured every 3 min during the whole experimental period and a mean temperature on the basis of five 3-min values was automatically transmitted to a computer via wireless communication. Measurements from seven sensors were excluded from the statistical analysis, as the measurements were obviously wrong (below 0 °C and over 45 °C, probably caused by a leak in the plastic cover) and seven sensors were not transmitting.

For measurement of room air temperature and relative humidity a Testo 175-H1 mini logger was placed in the middle of each lying area at a height of 1.3 m and one in the middle of the pig house at a height of 2 m. The loggers had a temperature resolution of 0.1 °C (absolute accuracy: ±0.5 °C) and a humidity resolution of 0.1%RH (absolute accuracy: ±3% RH). The room air temperature and the relative humidity were logged each 5 min during the whole experimental period. To analyse if the temperature of the incoming air affect the behaviour and EST, recordings of the outdoor air temperature was taken from a climate station belonging to University of Aarhus and situated 1 km from the piggery. The outdoor air temperature was measured each 10 min, 2 m’s above ground level.

The feed intake was recorded over the last 2 days of periods 1, 3 and 5.

2.4. Behavioural observations

The behaviour of the pigs was continuously monitored throughout the test period by one web camera (Panasonic BB330) per pen. The camera was placed so high that it covered the entire pen. During the nights infra red light was used, to facilitate the behavioural observations. The pigs were marked with painted numbers on their backs for individual recognition. The dirtiness of the pen was registered and the lying areas were cleaned each morning. Within each replication, the behaviour was recorded by scan sampling at 12-min intervals for a 24 h period at set point temperature 18 °C, 10 °C and 22 °C (periods 1, 3 and 5). The definitions of the behavioural patterns recorded are given in Table 2.

3. Statistics

The statistical analyses were performed using the statistical computer program R Version 2.2.1. (R Development Core Team, 2005). The adaptation period “Period 0” was not included in the statistical analyses.
3.1. The mean EST

Effect of replication and period on the EST was tested using a mixed-effect model, the \textit{lme} function in the package \textit{nlme} (Pinheiro et al., 2004). The mean EST was aggregated for each combination of pig, replication, period and pen using the \textit{summaryBy} function in the package \textit{doBy} (Højsgaard, 2006). The following mixed-effects model was applied:

\[
Y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \upsilon_k + \gamma_l + \epsilon_{ijkl},
\]  

where \( Y \) is the EST, \( \mu \) is the overall mean of the observations, \( \alpha_i \) is the main effect of the replication \((i = 1, 2, 3)\), \( \beta_j \) is the effect of period \((j = 1, 2, 3, 4, 5)\), \( (\alpha\beta)_{ij} \) is the interaction term, \( \upsilon_k \) is the random replication/pen effect \((k = 1, 2, \ldots, 9)\), \( \gamma_l \) is the random pig effect \((l = 1, 2, \ldots, 39)\) and \( \epsilon_{ijkl} \) is the residual error.

3.2. Diurnal variation in the EST

For analysis of the diurnal variation in the EST, a linear mixed-effects model (Pinheiro et al., 2004), was used with sensor and pig applied as random effects. The
diurnal cycle was described by a linear combination of trigonometric functions (Diggle, 1990). There were an autocorrelation between the EST measurements, and therefore an exponential spatial correlation structure was applied (Pinheiro and Bates, 2000). The analysis was carried out separately for each period because of lack of computer power, using the mixed models:

\[ Y_{ijtsa} = \mu + \beta_1(\text{Replication})_i + \beta_2(\text{TempI})_t + \beta_3(\text{RH})_t + \beta_4(\text{TempI} \times \text{RH})_t + f(t) + \beta_5(\text{Time})_s + \beta_6(\text{TempII})_t + \beta_7(\text{Pen})_j + \kappa_s + \gamma_a + e_{ijtsa}, \]  

(2)

where \( Y \) is the EST, \( \mu \) is the overall mean of the observations, \( i = 1, 2, 3 \) (replication), \( t \) = time for observation and \( j = 1, 2, 3 \) (pen). In formula (2) TempI is the room temperature, TempII is the outdoor temperature and \( f(t) = \sum_{n=1}^{4} \alpha_n(\sin(n2\pi t)) + \beta_n(\cos(n2\pi t)) \), describe the diurnal variation, where \( \omega = 2\pi/24 \) h, \( t \) is the time for the observation and \( n \) is the number of cyclic components (Diggle, 1990). \( \kappa_s \) is the random sensor effect \((s = 1, 2, 3, \ldots, 16)\), \( \gamma_a \) is the random pig effect \((a = 1, 2, 3, \ldots, 39)\) and \( e_{ijtsa} \) is the residual error.

### 3.3. Behaviour

To determine the effect of period (1, 3 and 5) on the diurnal variation in the behaviour, each of the behaviour variables (general posture, lying posture, contact area, activity and location) was calculated as the proportion per hour. Data were then analysed separately for each behaviour variable, using the \textit{lme} function (Pinheiro et al., 2004), with a logit function applied to the proportions (Faraway, 2006). The diurnal cycle was described by a linear combination of trigonometric functions (Diggle, 1990). The posture “sitting” was observed less than 5% of the total observations, and was therefore added to the category ‘standing’. The lying posture ‘L0’ was very rare (between 3% and 4% of the observations in all periods) and was therefore added to the lying posture category ‘L1’. Based on a plot of the lying behaviour, it appeared that the number of observations and the distribution over day were alike for the lying behaviour categories ‘L2’ and ‘L3’. These two categories were therefore put together, ending up with three lying behaviour categories: Sternum position (L0 and L1); half recumbent position (L2 and L3) and fully recumbent position (L4). The following mixed-effect model was applied:

\[ \text{Logit} \ Y_{ijkl} = \mu + \text{replication}_i + \text{period}_j + (\text{replication} \times \text{period})_{ij} + f(t) + \kappa_k + \gamma_l + e_{ijkl}, \]  

(3)

where \( Y \) is the observed behaviour, \( \mu \) is the overall mean of the observations, \( i = 1, 2, 3 \) (replication), \( j = 1, 3, 5 \) (period), \( k = 1, 2, 3 \) (pen) and \( f(t) \) describe the diurnal variation, \( \kappa_k \) is the random pen/replication effect \((s = 1, 2, \ldots, 9)\) and \( e_{ijkl} \) is the residual.

If the systematic effect of an interaction was not significant \( (P > 0.05) \), the interaction was eliminated from the model and the analysis was repeated.

### 3.4. Feed intake

Effects of period (1, 3 and 5) on the daily feed intake was analysed by pairwise comparisons using \( t \)-tests (Dalgaard, 2002).
4. Results

4.1. The mean EST

For each period the mean EST and the standard error are shown in Table 3. Totally, the mean EST was significantly lower in the cold period, period 3 (31.8 °C), than in all the other periods except period 2. The mean EST was significantly highest in the warm period, period 5 (33.7 °C) \((P < 0.05)\). For the thermoneutral period, period 1, the mean EST was between the EST level in periods 3 and 5 and differed significantly from these periods \((P < 0.05)\).

In period 3, there was a significant difference in the EST between replications 1 and 3 \((P < 0.05)\). The other periods showed no significant differences between the replications.

4.2. Diurnal variation in EST

A significant \((P < 0.05)\) diurnal variation in the EST was found for all five periods (Fig. 1) with the EST being highest at night and lowest in the afternoon. The EST decreased in the early morning, around 10 a.m., then increased slightly reaching a small peak around 12 a.m., then it decreased again until around 3 p.m. and then increased slightly until around 10 p.m. The diurnal variation for periods 1, 2, 3 and 4 was described by four cyclic components, whereas in period 5 it was described by three cyclic components. The first cyclic component describes the overall daily cycle ("day/night" variation), whereas the following cyclic components (maximum 12 in all) describe minor deviations from the smooth curve during the day, meaning that the less cyclic components included in the model the less is the variation in the diurnal rhythm. The amplitude was influenced by the set point temperature, the lower the set point temperature the larger is the amplitude in the EST (Fig. 1a).

The room temperature had a significant effect \((P < 0.05)\) on the diurnal variation in EST in periods 1 and 3. The variation in RH had a significant effect \((P < 0.01)\) on the diurnal variation in periods 2, 3 and 5, whereas in period 4 was there a significant effect \((P < 0.05)\) of the interaction between the room temperature and the RH. For the periods where the temperature was either decreasing (period 2) or increasing (period 4), there was a significant effect of the variation in the outdoor temperature on the diurnal variation in EST. The time within period 4 had significant effect \((P < 0.001)\) on the diurnal variation in EST in period 4.
4.3. Behaviour

A significant diurnal variation was found in the general posture ($P < 0.001$) and in the activity level among the pigs lying down ($P < 0.05$) for periods 1, 3 and 5 (Fig. 2a and b). Both diurnal variations were described by three cyclic components in all three periods. The highest proportion of lying down was observed at night and the lowest in the afternoon. During the early morning the proportion of lying down decreased, then increased around 10 a.m. and reached a small peak around 12 a.m. For the general posture there were no significant difference in the diurnal variation between the three periods and no significant difference in the proportion of lying down between the three periods. For each period was there no significant difference between the replications.

The diurnal variation in “other activity” among the lying pigs, was similar to the variation in general posture. The lowest level of “other activity” among the lying pigs was found during night, where there were no differences between the three periods. The highest level of “other activity” was observed at noon. The duration from the pigs began to “lie down” (Fig. 2a) to the activity level among the lying pigs (Fig. 2b) was a its lowest lasted longer in period 5 compared to the other periods. The diurnal variation differed significantly between periods 3 and 5 ($P < 0.001$), whereas there was no significant difference between periods 1 and 3 ($P = 0.20$). Periods 1 and 5 tended ($P = 0.07$) to differ with respect to “other activity”. Period 1, replication 3 differed significantly from replications 1 and 2 ($P < 0.05$). In period 5, replication 2 differed significantly from replications 1 and 3 ($P < 0.05$).

Also the location of the lying pigs varied significantly over the day ($P < 0.05$), see Fig. 2c. In periods 1 and 5, the diurnal variation was described by three cyclic components, whereas period 3, included two cyclic components. The overall daily variation differed significantly between the three periods ($P < 0.05$). The proportion of lying time spent on the slatted floor differed significantly between the three periods ($P < 0.001$), with the highest proportion in period 5 and the lowest in period 3. In all three periods, the proportion of lying on the slatted floor increased at noon.
The proportions of the three lying postures are shown for each period in Fig. 3. The overall diurnal rhythm for the sternum posture differed significantly between the three periods ($P < 0.01$). The overall diurnal rhythm of the half recumbent and the fully recumbent postures were significant different between periods 1 and 3 ($P < 0.001$) and periods 3 and 5 ($P < 0.001$). The diurnal rhythm was in periods 1 and 5 describe by three cyclic components, whereas only one cyclic component was included in period 3. As it appears from Fig. 3, the proportion of lying time spent in the fully recumbent posture was higher during night than during day and was predominant during night for all three periods. The proportion of time spent lying in the fully recumbent position differed significantly between the three periods ($P < 0.01$). It was highest in period 5 and lowest in period 3. Also lying in the sternum position and in the half recumbent position differed significantly between the three periods ($P < 0.01$), these lying posture were most common in period 3 and least common in period 5.

Regarding ‘lying in sternum position’ in period 1, there was a significant difference between replications 1 and 2 ($P < 0.05$) and between replications 1 and 3 ($P < 0.01$).

For the other lying postures and periods no significant differences were found between the replications.

The proportions of the four categories of contact with pen mates are shown in Fig. 4. With regard to the contact category “50%” was there no significant difference in the overall diurnal variation, whereas the overall diurnal variation for the three other categories differed significantly.
between the three periods ($P < 0.001$). The contact with pen mates was higher during night time as compared to day time for all three periods. In period 1 (Fig. 4a), the diurnal variation could be described by one cyclic component for the categories ‘0%’ and ‘75%’, and by two cyclic components for the categories ‘25%’ and ‘50%’. In period 3 (Fig. 4b), the diurnal variation was described by only one cyclic component for the category ‘50%’, whereas the rest of the categories include three cyclic components. In period 5 (Fig. 4c), the diurnal variation included only one cyclic component for all four contact categories.

For the contact category ‘0%’ in period 1, there was a significant difference between replications 1 and 3 ($P < 0.05$). For the contact category ‘50%’ there was a significant difference between all three replications ($P < 0.05$). For the category ‘75%’ in period 1 there was a significant difference between replications 1 and 2 ($P < 0.05$) and between replications 1 and 3 ($P < 0.05$). For period 5, a significant difference was observed between replications 1 and 2 and between replications 1 and 3 for the category ‘50%’ ($P < 0.05$).

### 4.4. Feed intake

Totally, the feed intake were (mean ± S.D.) 2.92 kg ± 0.21 in period 1, 3.14 kg ± 0.31 in period 3 and 3.27 kg ± 0.27 in period 5. Totally, the feed intake was significantly higher in period 5 than in period 1 ($P < 0.05$). There was no significant difference in the feed intake between periods within replications or between the three replications.
5. Discussion

For all periods a clear diurnal rhythm was found in the ear skin temperature (EST) reaching its maximum at night where the pigs were resting and a minimum in the afternoon. The diurnal rhythm of the EST was similar to the rhythm found in the general posture. When the proportion of ‘standing’ and the activity level among the lying pigs increased in the morning, the EST began to decrease. The heat production of pigs has a diurnal rhythm affected by the feed intake and the activity level (Henken et al., 1993; Pedersen and Sällvik, 2002). In this study, as well as in other studies (e.g. Pedersen and Sällvik, 2002), the activity level was highest during day time. It was therefore assumed that the heat production would be highest during day time in this study. Human’s are known to prefer a lower skin temperature when they are active as compared to when they are at rest (Olesen et al., 1972). A higher EST in lying pigs compared with standing pigs and in ‘lying not active pigs’ compared to ‘lying active pigs’ was also found by Andersen (2006).

The sensible heat loss is influenced by behavioural and by cardiovascular adjustment. If one of these adjustments results in a lower/higher change in the heat loss than needed, the opposite adjustment in the other parameter must be expected to maintain homeostasis. If pigs – as humans – prefer a higher skin temperature when they are at rest, then the behavioural adjustment during night must result in a decreased heat loss as compared to day time in order to compensate for the higher EST during night. However, the pigs were lying more in the fully recumbent position at night than during day time. Lying in the fully recumbent position increase the heat loss compared to the other lying
positions as the body surface exposed to the air is increased. The lying position at night therefore has the same influence on the heat loss as the higher EST, namely an increased in heat loss. One explanation why more pigs were observed lying in the fully recumbent posture at night as compared with day, could be the higher activity level among the lying pigs at day time. When lying pigs are active (e.g. have their heads lifted, root their snouts over the floor) they are usually lying on the bellies or partly on the side. The lying posture may therefore be related both to the thermal comfort and the activity level of the pigs. For all three periods, the contact area to pen mates was higher a night than during day time. By increasing the contact to pen mates, the sensible heat loss is decreased. A smaller part of the body is exposed to the air, and the radiant heat loss is decreased because the pen mates surface have nearly the same temperature as the pig itself, whereas the environment is usually colder. Also the proportion of lying time spend on the slatted floor was higher during day time. In this study, where the room temperature was relative constant over day and night and the floors in the lying areas were dry, it maybe assumed that the behavioural adjustments resulted in a higher heat loss during day time. In this way, there is an agreement between the expected heat production and the relation between the EST, lying position and the contact to pen mates.

The peak in the diurnal rhythm of the EST found in this study is in accordance with the results from Andersen (2006), but not with the results reported by Bekkering et al. (2003). They also found a typical daily rhythm in the EST, but the EST dropped between 3 a.m. and 5 a.m. and there was a peak between 3 p.m. and 5 p.m. One explanation for this difference could be that the pigs were kept in groups in the present study and in the study by Andersen (2006), whereas in the study by Bekkering et al. (2003) the pigs were singly penned. The single pigs had no possibility to increase the contact to pen mates at night but could only adjust their heat loss by changing their lying position and/or by physiological changing the EST. Unfortunately, the behaviour of the pigs was not observed in the study by Bekkering et al. (2003).

An interesting question is whether the skin temperature causes the behaviour to change, or whether is it the opposite way around. The difference in the EST level between the periods, can to some extent be explained by the differences in the air temperature between the five periods. But as it appears from Fig. 1, the differences between the three curves for EST varied over day, even though the temperatures in each period were kept relatively constant.

Based on the behavioural observations we conclude that the climate in period 1 was thermally comfortable for the pigs, as the pigs were lying in relaxed postures next to each other but not tightly together (Mount, 1968). If we assume a correlation between the skin temperature and the thermal comfort, then the change in the lying behaviour in the cold and warm period (periods 3 and 5) may indicate attempts to bring the skin temperature into a preferred interval. At all three temperature levels the pigs predominate lying position at night was the ‘fully recumbent’ position, which has also been reported by Ekkel et al. (2003). The fully recumbent position therefore seems to have a high priority at night. In period 3, the cold period, the level of lying in the fully recumbent position at night was much lower than in the other periods, which may be interpreted as the pigs attempting to cope with a low environmental temperature. If pigs only have limited opportunities for behavioural adjustments, then their skin temperature decreases with decreasing temperature (Stombaugh and Roller, 1977; Loughmiller et al., 2001). Had the pigs made no behavioural adaptations to the low temperature, then a decrease in the skin temperature in order to reduce the sensible heat loss would have been expected. The purpose of the behavioural change was likely to bring the surface temperature into a preferred zone. The EST level found at night in period 3 may then indicate that the room temperature was below the pigs thermal comfort zone.
At night the highest EST was found in the warm period, where about 80% of the pigs were lying in the fully recumbent position and the contact to pen mates was low. The duration of time from the pigs began to ‘lie down’ and until the activity level among the lying pigs was at its lowest lasted longer as compared to the other periods, indicating the pigs had severe difficulties adjusting to the high temperature. The EST level found at night in the warm period may therefore indicate that the room temperature was above the pigs thermal comfort zone.

The highest EST level during day time was found in the warm period. In this period, there was nearly no contact between the animals during the day time and the highest proportion of ‘lying on the slatted floor’ was observed here, indicating that the pigs experienced the climate as being too warm and trying to cool themselves (Hillmann et al., 2004; Aarnink et al., 2006). During day time in the cold period, the main part of the pigs was observed ‘lying in sternum position’, indicating that they were feeling cold (Mount, 1968), and correspondingly the contact with pen mates was high. In the thermoneutral period, there was a small increase in the proportion of lying on the slatted floor, indicating that the environmental temperature was above the comfort level. However, the lying posture and contact area was in agreement with, what is normally considered to indicate thermoneutral comfort; they pigs were lying next to each other, but not tightly together, in relaxed postures (Mount, 1968; Boon, 1981). Our results indicate that pigs, like humans, feel comfortable with a lower skin temperature when active as compared to when they are at rest, and that they use behavioural adjustments to bring the skin temperature into the preferred zone.

Based on the results of the present study, we assume that when the pigs feel thermally comfortable, the EST level will be above the level found in the cold period and below the level found in the warm period. Both the EST and the lying behaviour were influenced by the daily variation in the general activity level of the pigs, which should be taken into account if the EST or the lying behaviour is used as an index of the thermal comfort.

6. Conclusion

A diurnal rhythm in the EST was found, with the EST being highest at night and lowest in the afternoon. The overall diurnal variation in the EST was related to the diurnal rhythm in the general posture. The pigs seemed to prefer a higher EST when they were resting as compared to when they were active, and they used the behaviour to bring their skin temperature into a preferred zone. Both the EST and the lying behaviour were affected by the daily variation in the general activity of the pigs, which should be taken into account if the EST or the lying behaviour is used as an index of the thermal comfort. The EST level was influenced by the indoor temperature and the behavioural adjustment. When the pigs feel thermal comfortable, the EST level should be somewhere between the levels found in the cool and warm period.

References


