

Thermoregulatory Behaviour of Growing –Finishing Pigs in Pens with Access to Outdoor Areas

Pedersen S.¹, Sousa P.², Andersen L.³ and Jensen K.H.⁴

^{1,3} Danish Institute of Agricultural Sciences, Research Centre Bygholm, Department of Agricultural Engineering, Denmark. Soeren.Pedersen@agrsci.dk¹, Lga@Lro.dk³

² Agricultural Engineering College – State University Campinas - SP, Brazil. Patricia.Sousa@agrsci.dk²

⁴ Danish Institute of Agricultural Sciences, Research Centre Foulum, Department of Animal Health and Welfare, Denmark. KarinH.Jensen@agrsci.dk⁴

ABSTRACT

The aim of the studies was to evaluate the thermoregulatory behaviour of growing-finishing pigs in pens with access to outdoor areas. In addition, the effect of insulating the roof inside the pig house on the thermal comfort of the pigs was studied. Four pens with outdoor areas and natural ventilation were established and three replications were carried out for growers during the winter and three for finishing pigs during the summer, respectively. In two of the pens the roofs were uninsulated, and the other two pens were insulated. The outdoor activity area was covered with a simple roof, while the outdoor dung area was uncovered. Insulated walls separated the indoor resting areas. Each outdoor area included an activity area with rooting material, self-feeder and water bowl, and a dunging area with cooling facility. Pig behaviour observations were made via video recordings from a monitor placed in a separate room, so as to avoid disturbing the pigs. The pigs were observed simultaneously two hours in the morning and two hours in the afternoon. It was determined how many pigs were lying in resting area inside, in the activity and dung areas outside and how the pigs were lying; close together (huddling) or scattered without any physical contact with each other. The indoor and outdoor air temperatures were registered every 10 minutes. The results showed that insulated roofs stabilized the indoor climate both in winter and in summer, giving higher temperatures in winter and lower temperatures in summer compared to houses with uninsulated roofs. However, insulation of the roof did only lower the thermoregulatory response in finishing pigs significantly during the summer experiment at outdoor temperatures exceeding 15-20 °C, whereas no effect was observed on huddling behaviour in growers during the winter. This may be due to the use of plenty of straw as bedding material. Significant relationships were found between the outdoor temperature and thermoregulatory behaviours, like 'huddling', 'lying on the side', 'lying in the dunging area', and time spent inside, as well as the level of activity. In most cases also the group size and the body weight of the pigs affected the behaviour, probably reflecting an effect of the heat production mass.

In conclusion, climatic factors constitute a major challenge of the adaptability of the pigs in pens with access to outdoor areas. The indoor climate may, however, be stabilized by insulation of the roof, thereby reducing the thermoregulatory response of the pigs, especially during summer time in finishing pigs.

Keywords: Behaviour, environment, temperature, insulation, pigs, welfare.

INTRODUCTION

Access to outdoor areas is an important aspect in improving the animal welfare. Outdoor areas is one of the requirements to be fulfilled for growers and finishing pigs within organic farming. In naturally ventilated open barns, the indoor temperature will very much depend on the outdoor temperature, especially in houses without insulated roofs (Pedersen, 2000).

Pigs are highly sensitive to even small climatic changes, e.g. high/low temperatures, sunshine and draft, mainly due to their missing ability to sweat and their very thin fur.

In intensive pig production, the objective is to keep the animals in their comfort temperature, because within this temperature range, the potential growth will be maximal (Pedersen & Christensen, 1977 and 1979, Pedersen, 1982, Sallvik & Walberg, 1984). Under extensive conditions, pigs may compensate for variations in the climatic environment by altering their feed intake and their behaviour and physical activity and by seeking protection (Andersson, 2001, Blackshaw & Blackshaw, 1994).

Practice has shown that climatic problems in pens with more than one climatic zone often arise for small pigs in cold periods and for finishing pigs during the summer. In cold periods, the temperature can easily get too low for small pigs, thus involving risk for decreasing growth and more health problems. In the summer, finishing pigs often have problems with too high temperatures, which will result in fouled pens, bad hygiene and decreasing feed intake and performance.

One of the objectives for extensive pig production must be to enable the adaptation of pigs to environmental changes by offering them optimal facilities. The pigs should have access to zones that will fulfil their climatic demands, e.g. comfortable draft-free resting areas for growers in cold periods, or cooling facilities for finishers in hot periods.

The present experiment included an investigation of the thermoregulatory response of growers in the winter and of finishers in the summer, in respect to outdoor temperature and weight in an extensive housing system with access to outdoor areas. Furthermore, a comparison of the effects of insulated/uninsulated roofs on the pig behaviour was made.

MATERIALS AND METHODS

Experimental design

The experiments included three replications of growers (20-60 kg) during the winter period, November-March, and three replications of finishers (60-110 kg) during the summer period, May-September. The pigs in each pen were littermates, and in each pen there was an average of 10 pigs, varying from 7 to 14 pigs (Table 1). The body weight of grower littermates during the winter period was about 21 kg at the time where they were inserted in the pens, and at the start of measurements

their body weight was respectively 27, 27 and 24 kg in trials 1, 2 and 3. The body weight of finisher littermates during the summer period was about 54 kg when they were inserted in the pens, and at the start of measurements their body weight was respectively 75, 62 and 56 kg in trials 1, 2 and 3.

Table 1. Trials and number of pigs (littermates) during winter and summer

Trial No.	Winter (growers)			Summer (finishers)		
	1	2	3	1	2	3
Pen 1 – Insulated	10	7	10	9	9	10
Pen 2 – Insulated	14	11	11	14	8	12
Pen 3 – Uninsulated	7	8	11	7	11	8
Pen 4 – Uninsulated	8	9	10	8	9	8

Housing

Four full-sectioned pens with access to outdoor areas were established at The Organic Research Station, Rugballegaard, DIAS. The indoor areas were totally separated by insulated walls from floor to roof. The indoor areas were designed for resting with plenty of straw bedding. Flexible partitions permitted adjustment of the space allowance in the resting areas, so that the pigs could be housed in the same pens from weaning to finishing.

Each pen had access to an outdoor area. For pens with 8-12 pigs/pen, the total outdoor area was 15 m².

The wall and ridge heights were 2.3 and 4.5 m, respectively. In two pens, the roofs were insulated with 100 mm mineral wool, whereas in the other two pens the roofs were not insulated. All four pens were naturally ventilated (cross ventilation) with stationary horizontal ventilation openings, which were covered by nets. The ventilation openings in the wall toward the outdoor area were 0.6 × 1.6 m, and in the opposite wall they were 0.6 × 3.0 m. Because the openings were covered by windbreaker nets, the effective inlet areas toward the outdoor areas were 0.5 and 0.9 m², respectively. The outdoor area comprised an activity area with rooting materials on the floor (straw) and a self-feeder with one feeding place and a dunging area with water bowl and sprinklers for cooling. The dung area had open partitions to the neighbouring pens. A 40 mm downward step made a visible border between the activity area and the dunging area.

The outdoor activity area was covered with a simple roof, while the outdoor dunging area was uncovered. The feed dispenser was placed under the roof opposite the dunging area. Figures 1 and 2 show the plan and section for the house and pens.

Table 2 shows the space allowance in respect to the body weight in this experiment, together with the regulations for organically (EU Directive 91/630/EØF, revised in 2000) and conventionally produced pigs within the EU.

Table 2. Space allowance

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. “Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas”. *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*. Manuscript BC 03 002. May, 2003.

Weight (kg)	This experiment (m ² /pig ^{*)})		Organic EU regulation (m ² /pig)		Conventional EU regulation (m ² /pig)
	Indoors	Outdoors	Indoors	Outdoors	
20-30	0.6	1.5	0.6	0.4	0.30
30-50	0.8	1.5	0.8	0.6	0.40
50-85	1.1	1.5	1.1	0.8	0.55
85-110	1.3	1.5	1.3	1.0	0.65

^{*)} Based on 10 pigs per pen

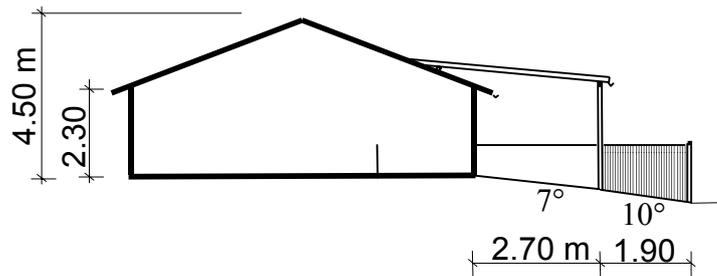


Figure 1. Sectional view of the experimental house (measure of length in m)

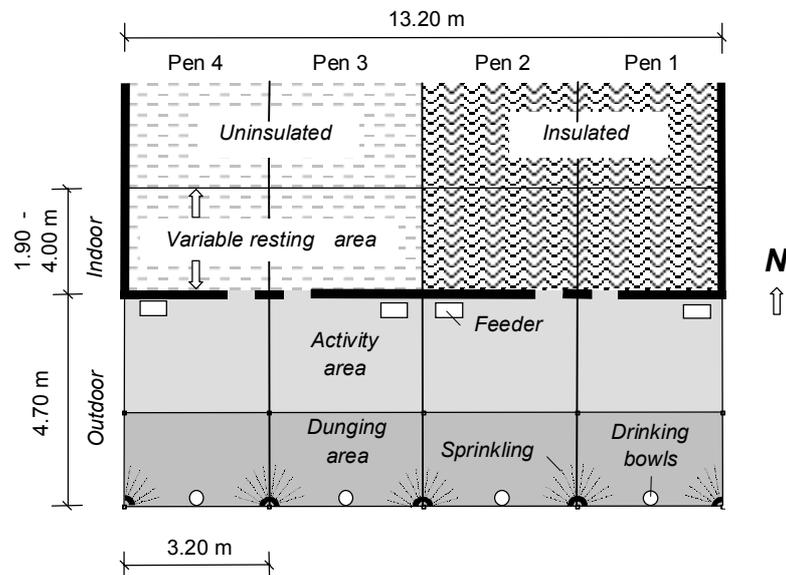


Figure 2. The experimental house with resting and activity areas (measure of length in m)

Animals

The animals were organically raised pigs of conventional Danish breed for outdoor pig production (sow: LYD [Landrace (Danish), Yorkshire and Duroc], boar: YD [Yorkshire and Duroc]). The herd

was declared free of *Actinobacillus pleuropneumoniae* serotypes 1, 2, 4, 5, 6, 8, 9, 10, toxigenic, *Pasteurella multocida*, *Brachyspira hyodysenteriae* (swine dysentery), *Haematopinus suis* (lice), and *Sarcoptes scabiei* (sarcoptic mange).

Feeding and management

The pigs were fed *ad libitum* from a feed dispenser. The feed consisted of pelleted organic complete feed, and two kinds of mixtures were used. For growers (20-30 kg) there were 1.12 Scandinavian feed units (FEs) per kg feed, and for the finishers (from 30 kg) there were 1.05 FEs per kg. (1 FE = 12.4 MJ metabolizable energy) The feeding was made in accordance with Danish standards.

The indoor area was checked daily and kept strictly free of dung and wet straw, and there was plenty of straw bedding. Cleaning was only carried out on days when necessary. In the winter there was enough straw for the pigs to be half covered, and in the summer the layer of straw was somewhat smaller. The outdoor area was cleaned twice a week.

In the summer, when the outdoor temperature was above 20°C, the sprinkler was activated for 1 minute every 15 minutes.

Measurements

The pigs were weighed twice: 1) when they entered the pens, and 2) just before the end of the measurements, and a standard growth curve was used for calculation of the average day-to-day pig weight.

Video cameras were placed indoors and outdoors to enable the observer to survey the entire pen and all the pigs via a screen in a separate room. Thereby, pig behaviour observations could be made simultaneously without disturbing the pigs.

The pigs were video-observed for periods of two hours in the morning and two hours in the afternoon. The video recordings were carried out on a total of 24 days during the wintertime and 26 days during the summertime.

Each pen was observed for 15 min/h, after which the observer switched to another pen and so on.

During each 15-minute period, the observer made four behavioural scannings (t = 0 min, t = 5 min, t = 10 min, t = 15 min). It was noted how many pigs were lying in the resting, the activity, and the dunging areas, and whether they were lying close together with physical contact (huddling) or scattered without any physical contact. In addition, it was noted whether they were lying on the side. Finally, the number of active pigs and the number of pigs inside were registered.

The following climate parameters were measured every 10 minutes: Inside air temperature (1.5 m above the pigs), inside black globe temperature (2.0 m above the pigs), and outside air temperature.

Statistical analyses

Data collected during summer and during winter were analysed separately. The indoor temperature, the relative occurrence of thermoregulatory behaviour (huddling, lying on the side, and lying in the dunging area), the level of activity and the relative number of observation intervals spent indoor were subjected to analyses of variance by mixed model methods with multiple error terms using the MIXED procedure in the statistical package, SAS (SAS Institute Inc., 1995). To fulfil the assumptions for analysis of variance, behavioural variables (relative frequencies) were transformed by the logit transformation. The model included insulation and time of day (morning or afternoon) as fixed effects. Outdoor temperature, estimated weight at time of observation, and group size were used as covariates. Furthermore, the interactions between outdoor temperature and insulation as well as between group size and insulation were included. The dependency between observations introduced by the hierarchic experimental design was taken into account using random effects in the model. Replication and the interaction between replication and insulation were modelled with an additive random effect and the dependency between observations within pen with a random linear regression of the outdoor temperature within each pen of each repetition. If present, repeated daily measurements were taken into account by using a compound symmetry structure of the residual variance. Non-significant covariates and interaction terms were omitted from the model. However, due to the fact that insulated pens often contained more pigs in the groups than in uninsulated pens, group size was kept in the model, irrespectively of the level of significance, although the difference was non-significant. In the summer experiment (finishing pigs), means of the 15 minutes periods of observation in each pen in the replicate were used as experimental units, whereas means of morning and afternoon, respectively, were used as experimental units in the winter experiment. The difference between experiments was due to inconsistency in successful data collection on outdoor temperature at the level of observation periods in the winter experiment. In addition, it was analysed whether group size and growth rate, respectively, differed in accordance with insulation by use of analysis of variance by mixed model methods (SAS Institute Inc., 1995) including insulation as fixed effect and replication and the interaction between replication and insulation as random effect. Individual pens were used as experimental units.

The results of the statistical analyses are presented by the F-value and the degree of freedom for the investigated effect (df1) and of the error term in the denominator (df2). Degrees of freedom were calculated by using Satterthwaites approximation. All analyses were performed as two-tailed tests.

RESULTS AND DISCUSSION

Table 3 shows the production results for the experiments. The daily gain rates of 0.802 kg for growers and 1.089 kg for finishing pigs are 13 and 27%, respectively, above the Danish norm. The daily gain in pens with and without roof insulation were of the same size (growers: $F_{1,4} = 0.85$, $p > 0.05$; finishing pigs: $F_{1,4} = 0.09$, $p > 0.05$). Figures 3 and 4 show the effect of roof insulation on the air temperature in the resting area during the winter and the summer periods, respectively, based on two measurements in the morning and two measurements in the afternoon for each of the 24 observation days in wintertime and 26 observation days in sommertime.

Table 3. Production data for three replications for growers and three for finishing pigs

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. "Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Manuscript BC 03 002. May, 2003.

	Growers	Finishing pigs
Number of pigs (total of three trials)	114	112
Initial body weight, kg	21	61
Final body weight, kg	52	104
Daily weight gain, kg	0.802	1.089
Feed conversion, FEs /kg weight gain	2.2	2.9
Use of bedding (straw), kg day ⁻¹ pig ⁻¹	0.6	0.5

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. "Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas". *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*. Manuscript BC 03 002. May, 2003.

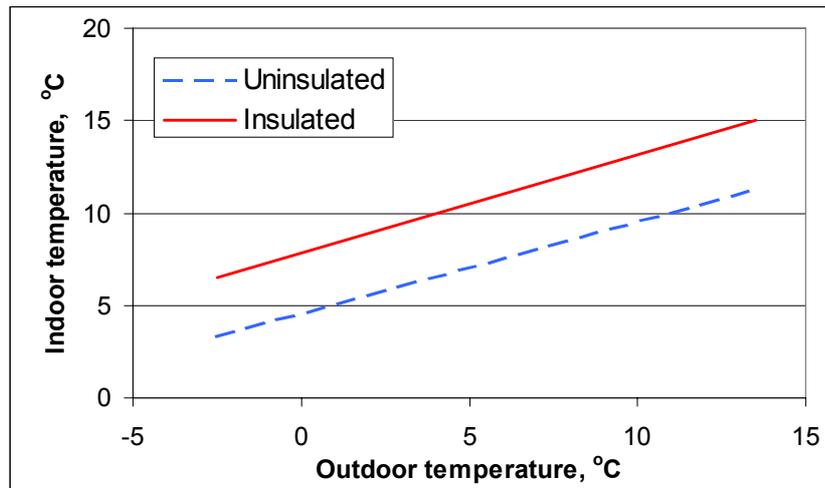


Figure 3. Relation between the temperature (°C) in the resting area with insulated/uninsulated roof and the outdoor temperature during the winter

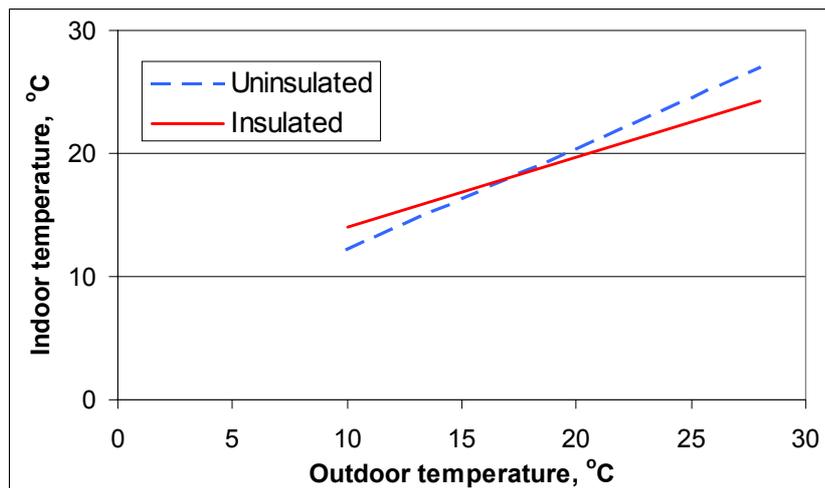


Figure 4. Relation between the temperature (°C) in the resting area with insulated/uninsulated roof and the outdoor temperature during the summer

In cold periods, the air temperature in the indoor areas with insulated roofs was in average 3.6°C higher than in the indoor areas with uninsulated roof ($F_{1,5.06} = 81.37$, $p < 0.001$). Whether or not insulated, the indoor temperature increased with increasing outdoor temperatures (0.5°C per 1°C, $F_{1,11.3} = 23.14$, $p < 0.001$), increasing group size (0.48°C per pig, $F_{1,10} = 15.89$, $p < 0.01$) and increasing weight of the piglets (0.15°C per kg, $F_{1,178} = 147.39$, $p < 0.0001$). In the summer period the indoor temperature depended on group size (increased with 0.21°C per pig, $F_{1,7.61} = 12.54$, $p < 0.01$). In addition, a significant interaction between the outdoor temperature and insulation was found ($F_{1,9.41} = 11.37$, $p < 0.01$) due to a steeper increase in indoor temperature with increasing outdoor temperature in uninsulated pens (0.81°C per 1°C) than in insulated pens (0.57°C per 1°C). This means that in periods with outdoor temperatures above 16.5°C, the temperature was higher in the

pens with uninsulated roofs than in the pens with insulated roofs. Both in winter and in summer, the insulated roofs stabilized the indoor temperatures. The figures also show that when it is hot outside, the indoor temperature is sometimes lower than the outdoor temperature. The reason for that can be explained by the heat accumulation capacity of the building mass. The high indoor temperatures in Figure 4 primarily refer to measurements in the daytime where the temperature of the building is delayed and much lower than the outdoor temperature. The stabilizing effect of roof insulation on the indoor temperature is shown on a diurnal basis in Figure 5.

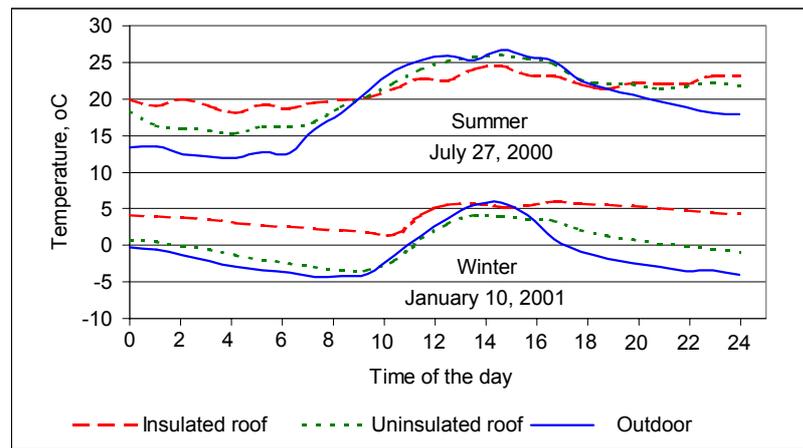


Figure 5. Outdoor temperature and temperature in the pen with insulated and uninsulated roof on a winter and a summer day, respectively

In addition to the indoor ambient temperature (t_a), the indoor black globe temperature (t_g) was measured at a height of 2 m and compared to the indoor ambient temperature (Table 4).

Table 4. Black globe temperature minus ambient temperature

	Winter (12°C) ($t_g - t_a$)	Summer (12°C) ($t_g - t_a$)
Insulated – morning	0.7	0.7
Insulated – afternoon	0.4	0.6
Uninsulated – morning	0.6	0.6
Uninsulated – afternoon	0.7	1.0

The advantage of including the globe temperature in the evaluation of the indoor climate is that the globe temperature will give additional information about the radiation from floor, roof and wall. As a rule-of-thumb, the black globe temperature is equal to the average of the radiant temperature and the air temperature when the air velocity is 0.15 m/s. Table 4 shows that the globe temperature in all cases will be 0.4 to 1.0°C higher than the ambient temperature, with a slight tendency towards a greater difference in the summer than in the winter, corresponding to a radiant temperature that is 0.8 to 2.0°C above the ambient temperature. The reason for the relatively high radiant temperature is probably the radiation from the pigs themselves.

Andersson *et al.* (1994) observed that the temperature inside the kennel in the case of uninsulated housing followed the outside temperature and always lying 5 to 10 °C above it. During the winter period, the pigs were not able to generate enough heat in the area at the beginning of the growing period, so the temperature only increased by about 2° C. The result is in accordance with measurements on indoor temperatures in houses with uninsulated and insulated roof for pregnant sows carried out by Pedersen (2000). He found that the indoor temperature in houses with uninsulated roofs varied closely with the outdoor temperature and that the temperatures in houses with insulated roof in average were 6° C higher than the outdoor temperature during the winter.

The relationship between the outdoor temperature and the thermoregulatory behaviour is shown in Figure 6 for the temperature interval that occurred during the experiments (winter: -2.7°C to 13.6°C; summer: 9.9°C to 28.3°C). The curves are based on the estimates of the effects arriving from the statistical analyses. For growers the calculations used the mean body weight for the winter experiment, 36.5 kg, a group size of 10 pigs and a mean lying frequency of 70%. For finishing pigs the comparable values were 82.5 kg body weight, group size of 10 pigs, and a mean lying frequency of 80%. The results from the statistical analyses are shown in Table 5.

Table 5. Results of the statistical analyses

	Age / time of year	Increasing outdoor temperature	Increasing body weight of piglets	Increasing group size	Time of day	Insulation	Interaction - outdoor temperature and insulation
Decrease in huddling	Growers / winter	F _{1,12.6} =8.55 p<0.05	F _{1,110} =106.2 3 p<0.001	F _{1,7.2} =9.42 p<0.05	NS	NS	-
	Finishing pigs / summer	F _{1,12.3} =10.77 p<0.01	F _{1,187} =9.83 p<0.01	F _{1,11.3} =3.83 p<0.08*	NS	NS	-
Increase in lying on the side	Growers / winter	F _{1,10} =19.68 p<0.05	F _{1,160} =17.37 p<0.001	F _{1,8.41} =5.97 p<0.05	NS	NS	-
	Finishing pigs / summer	NS	-	NS	F _{1,180} =10.75 p<0.01 ^a	NS	F _{1,10.2} =4.24 p<0.07
Increase in lying in dunging area	Growers / winter						
	Finishing pigs / summer	F _{1,10.2} =95.33 p<0.001	F _{1,85.5} =5.01 p<0.05	F _{1,14.2} =11.38 p<0.01	F _{1,186} =4.21 p<0.05 ^a	NS	F _{1,7.98} =3.71 p<0.1
Decreasing time spent indoor	Growers / winter	F _{1,8.26} =9.54 p<0.05	-	NS	F _{1,191} =42.23 p<0.001 ^b	NS	-
	Finishing pigs / summer	F _{1,12.1} =7.93 p<0.05	-	NS	NS	NS	-
Decreasing level of activity	Growers / winter	-	-	NS	F _{1,193} =54.01 p<0.001 ^a	NS	-
	Finishing pigs / summer	F _{1,9} =6.13 p<0.05	-	NS	NS	NS	-

a) Highest in the afternoon, b) Highest in the morning

*) Reverse relationship

1) The occurrence of the dependent variable was too infrequent for use in the analysis

-: The effect was not included in the final statistical model

Overall, the main determinant of the thermoregulatory behaviours was the outdoor temperature. In addition, the group size and the body weight of the pigs affected the behaviours in most cases,

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. "Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas". *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*. Manuscript BC 03 002. May, 2003.

probably reflecting an effect of the heat production mass. The heat conserving behaviour (huddling) increased with decreasing temperature, and the heat emitting behaviours, 'lying on the side', and in finishing pigs also 'wallowing', expressed by 'lying in the dunging area', decreased. In addition, selection of the warmest environment, reflected by the time spent inside, increased with decreasing outdoor temperature. Furthermore, during the summer experiment the level of activity decreased with increasing outdoor temperature.

Growers – winter

Finishing pigs – summer

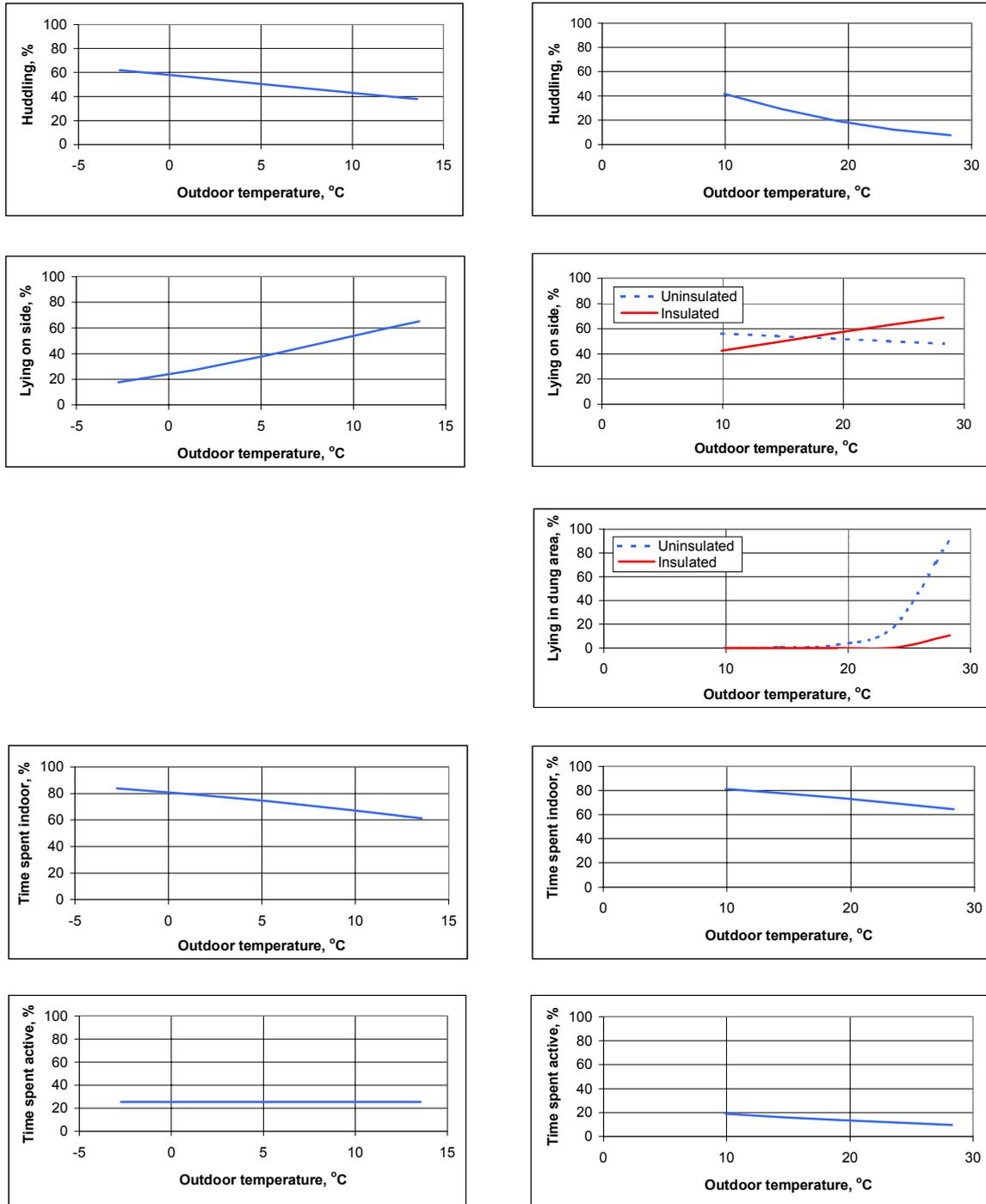


Figure 6. Relationship between outdoor temperature and thermoregulatory behaviour of pigs based on estimates from the statistical model. Due to a very low occurrence of ‘lying in the dunging area’ in growers, the relationship to outdoor temperature could not be analysed for this behaviour. For behaviours affected by an interaction between

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. “Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas”. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Manuscript BC 03 002. May, 2003.

outdoor temperature and insulation, the relationship is presented at the same graph for the insulated and uninsulated conditions, respectively

Comparable relationships between thermal environment and behaviour have previously been reported. Boon (1982) and Riskowski *et al.* (1990) reported that the heap of huddling pigs became denser and higher (i.e. pigs piled on top of one another) as the temperature decreased. Pigs huddled more at lower temperatures and high air velocities (Riskowski *et al.*, 1990; Botermans and Andersson, 1995). The physical contact between lying pigs and the level of activity decreased, whereas lying in the dunging area increased with increasing temperature (Sallvik *et al.*, 1984; Botermans and Andersson, 1993 and 1995; Andersson *et al.*, 1994; Olsen *et al.*, 2001). Pigs seem to select their environment in accordance with climatic factors (Botermans & Andersson, 1995; Blackshaw & Blackshaw, 1994; Olsen *et al.*, 2001).

In the present study the exception from this pattern of thermoregulation was 'lying in dunging area' in growers. In contrast to the regular occurrence in finishing pigs during summer time, this behaviour did almost not occur in growers studied during the winter. Pig behaviour may vary greatly with age and with climate (Geers *et al.*, 1990). Thus, the tendency to cool by wallowing, reflected by lying in the dung area, seems to arise at relative high temperatures with low air velocity, and it increases with increasing body weight (Pedersen & Christensen, 1977 and 1979; Olsen *et al.*, 2001).

In consistency with that reported elsewhere (Xin & DeShazer, 1991), the thermoregulatory behaviour varied during the day. In finishing pigs the cooling behaviours, 'lying on the side' and 'lying in the dunging area', were significantly more common in the afternoon than during the morning observation. The result could not be explained by a time dependent difference in appropriate cooling behaviour, such as seeking of shade instead of 'lying in the dunging area', in that there was no uniform difference in exposure to sun at different areas and time of the day in the experimental pens. Thus, rather than reflecting different choices of thermoregulatory behaviour in morning and afternoon, the result reflects different demands of heat loss during the day. In growers the time spent indoor was lower and the level of activity higher in the afternoon compared to in the morning. In addition, the feeding activity is usually higher in the afternoon in pigs fed *ad libitum*, suggesting an increased heat production (Xin & DeShazer, 1991) and a lower heat demand in the afternoon (Swiergiel, 1998). The effect of the time of day may be amplified by the fact that the outdoor temperature was significantly higher in the afternoon, although the difference expressed as means was very low (18.1°C vs. 17.8°C).

Despite the fact that insulation stabilized the indoor temperature, it only lowered the thermoregulatory response significantly in finishing pigs during the summer experiment at outdoor temperatures exceeding about 15-20°C. In these circumstances the lowering effect of insulation on the indoor temperature implies that apparently, the heat loss demand is met by the early heat emitting behaviour, 'lying on side', which increases more at increasing outdoor temperatures in insulated pens than in uninsulated pens. Concomitantly, the outdoor temperature at which the more efficient cooling behaviour, 'lying in dunging area', arises is increased in insulated pens (Figure 6). The temperature at which wallowing increases in a comparable housing system as in the present study has been reported to be 15°C (Olsen *et al.*, 2001), thus corresponding to the increase in lying in the dunging area at an outdoor temperature about 15-20°C in the present study.

Surprisingly, the higher indoor temperature in insulated pens during the winter (3.6°C) did not reduce the thermoregulatory response to cold environment in the growers. The lack of effect on the huddling behaviour of the increased temperature in pens with insulated roofs may be due to the large amount of straw bedding available for the pigs. Lying in straw may be one of the pigs' ways of staying warm (Fraser, 1985). Hayne *et al.* (2000) demonstrated that pigs with plenty of straw were more inclined to lying alone burrowed in lateral position than pigs with less straw. The heat conserving properties of straw was also shown by Pedersen (1982). In addition, the increased temperature in pens with insulated roofs might have been accompanied by changes in the air currents, thus increasing the air velocity and thereby counteracting benefits of an increased temperature. In cold environment pigs huddled more at high air velocities (Pedersen & Christensen, 1977; Riskowski *et al.*, 1990).

Previous reports comparing the thermal comfort for finishing pigs in uninsulated and insulated pig houses (Botermans & Andersson, 1993 and 1995) showed that the thermoregulatory responses of the pigs were more pronounced in the uninsulated housing system, thus resulting in increased huddling behaviour and more activity as well as less time spent in the lying area, but on the other hand, in increased lying in the dunging area. The relationship between the outdoor temperature and the thermoregulatory behaviour in the present study confirmed the major significance of the thermal environment on the pig behaviour in pens with access to outdoor areas. The thermal environment may, however, be stabilized by insulation of the roof, which especially improves the thermal comfort in finishing pigs during the summer.

CONCLUSION

1. In pens with access to outdoor areas the thermoregulatory behaviour of the pigs reflects the outdoor temperature significantly, demonstrating that climatic factors constitute a major challenge of the adaptability of the pigs in these systems
2. Compared to uninsulated roofs, insulated roofs will stabilize the indoor climate both in winter and in summer, thereby giving higher indoor temperatures at outdoor temperatures lower than about 16°C and lower indoor temperatures at outdoor temperature exceeding 16°C
3. In accordance with the stabilizing effect on the indoor temperature of insulation of the roof, the thermoregulatory response in finishing pigs during the summer experiment was significantly lowered at outdoor temperatures exceeding about 15-20°C. The heat loss demand was apparently met to a larger extent by the early heat emitting behaviour, 'lying on side', increasing the outdoor temperature at which the more efficient cooling behaviour, 'lying in dunging area', was needed. On the contrary, when using plenty of straw as bedding material the increasing effect of insulation on the indoor temperature in winter may not be an essential factor for the welfare of weaning piglets as measured by huddling behaviour.
4. The study confirmed that behavioural thermoregulation in pigs includes huddling behaviour, lying on side, lying in dunging area, selection of pen area and adjustment of the level of activity, and the results emphasized the importance of the heat producing mass for the actual thermal demands.

REFERENCES

- Andersson, M., J. Botermans, & J. Svendsen. 1994. Slaktsvin i oisolerad byggnad. Growing-fattening pigs in uninsulated houses (In Swedish and English). Report 94, Swedish University of Agricultural Sciences. Department of Agricultural Biosystems and Technology.
- Andersson, M. 2001. Uninsulated housing for finishing pigs. Pens with sloped flooring. Proceedings of the International Symposium of the CIGR, Szklarska Poreba, Poland: 521-529.
- Blackshaw, J.K. & A.W. Blackshaw. 1994. Shade-seeking and lying behaviour in pigs of mixed sex and age, with access to outside pens. *Applied Animal Behaviour Science* 39, 249-257.
- Boon, C.R. 1982. The lower critical temperature and group postural behavior of pigs. Proc. of second Int. Livestock Environment Symp. April 20-23: 509-514.
- Botermans, J. & M. Andersson. 1993. Pen function and thermal comfort in an uninsulated stable for growing-finishing pigs. *Livestock Environment IV. Proceedings of a conference held in Coventry, UK, 6-9. July: 851-858.*
- Botermans, J. & M. Andersson. 1995: Growing-Finishing Pigs in an Uninsulated House. Part 2. Pen function and thermal comfort. *Swedish J. agric. Res.* 25: 83-92.
- Fraser, D. 1985. Selection of bedded and unbedded areas by pigs in relation to environmental temperature and behaviour. *Applied Animal Behaviour Science.* 14 (2): 117-126.
- Geers, R., V. Goedseels, G. Parduyns, P. Nijns, & P. Wouters. 1990. Influence of floor type and surface temperature on the thermoregulatory behavior of growing pigs. *J. Agric. Eng. Res.* 45: 149-156.
- Hayne, S.M., T. Tennessen, & D.M. Anderson. 2000. The responses of growing pigs exposed to cold with varying amounts of straw bedding. *Can. Jour. Anim. Sci.* 80 (4): 539-546.
- Olsen, A.N.W., L. Dybkjær & H.B. Simonsen. 2001. Behaviour of growing pigs kept in pens with outdoor runs. II. Temperature regulatory behaviour, comfort behaviour and dunging preferences. *Livestock Production Science* 69, 265-278.
- Pedersen, P. 2000. Drægtighedsstalder med og uden isoleret tagflade. Erfaring nr. 1. (Gestation stalls with and without insulated roof. First experience). (in Danish). The National Department of Pig Production, Axelborg 3, Copenhagen, Denmark.
- Pedersen, S. & B. Christensen. 1977. Lufthastighedens indflydelse på slagtesvineproduktionen. (Influence of air velocity on fattening pig production) (in Danish). SBI-Landbrugsbyggeri 52/DLU-Beretning 19. De Landbrugstekniske Undersøgelser, Otterup, Denmark.
- Pedersen, S. & B. Christensen. 1979. Lufthastigheds- og temperaturvariationers indflydelse på slagtesvineproduktionen. (Influence of air velocity and temperature variations on fattening pig production) (in Danish). SBI-Landbrugsbyggeri 58/ DLU-Beretning 22, De Landbrugstekniske Undersøgelser, Otterup, Denmark.
- Pedersen, S. 1982. Lufthastighedens, temperaturens og stroelsens indflydelse paa slagtesvineproduktionen (The influence of air velocity, temperature and bedding on pig production) (in Danish). DLU-Beretning nr. 11. De Landbrugstekniske Undersøgelser, Otterup, Denmark.
- Riskowski, G.L., D.S. Bundy & J.A. Matthews. 1990. Huddling behavior and hematology of weanling pigs as affected by air velocity and temperature. *Transactions of the ASAE* 33 (5) 1677-1685.
- Sallvik, K. & K. Walberg. 1984. The effect of air velocity and temperature on the behavior and growth of pigs. *J. Agric. Eng. Res.* 30, 305-312.

S. Pedersen, P. Sousa, L. Andersen, and K.H. Jensen. "Thermoregulatory Behaviour of Growing—Finishing Pigs in Pens with Access to Outdoor Areas". *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development.* Manuscript BC 03 002. May, 2003.

- SAS Institute. 1995. SAS Users Guide, Version 6.11, SAS, Cary, NC.
- Swiergiel A.H. 1998. Modifications of operant thermoregulatory behaviour of the young pig by environmental temperature and food availability. *Physiology and Behavior*. 63 (1): 119-125.
- Xin H. & J.A. DeShazer. 1991. Swine responses to constant and modified diurnal cyclic temperatures. *Transactions of the ASAE*. 34 (6): 2533-2540.