EFFECT OF FLOOR COOLING ON FARROWING SOW AND LITTER PERFORMANCE: FIELD EXPERIMENT UNDER DUTCH CONDITIONS

A. V. van Wagenberg, C. M. C. van der Peet-Schwering, G. P. Binnendijk, P. J. P. W. Claessen

ABSTRACT. *Lactating sows generally have problems dissipating their body heat to the environment. Cooling the floor under the sow's shoulder, called the cool-sow system, is a method to increase body heat removal by conduction, thereby contributing to the thermal comfort of the sow. In this study, the effect of the cool-sow system on the performance of the sow and her piglets in the farrowing room and on the position of the sow in the farrowing crate was determined. In total, 60 sows (parity between 2 and 5) were included in the study. One room with 12 pens was used during five batches in autumn, spring, and summer. During each batch, the floors were cooled in six randomly chosen pens, while the other six pens were used as reference pens. The sows on the cool-sow system had 0.6 kg higher average daily feed intake (P < 0.001). These sow's piglets grew 20 g per day per piglet faster (P < 0.001). There was no effect on the loss of bodyweight of the sow or on piglet mortality. The sows on the cool-sow system showed a higher feed intake during all five batches, not only during summer batches. Sow position and location in the crate was hardly affected by the cool-sow system. The cool-sow system removed on average 107 W of heat per pen, of which approximately 58 W was directly removed from the sow's body.*

Keywords. *Farrowing room, Feed intake, Floor cooling, Heat stress, Lying behavior.*

Excessively warm conditions for lactating sows can lead to a reduction in feed intake, causing reduced milk production and therefore lower piglet growth (Quiniou and Noblet, 1999). Furthermore, reduced feed intake can cause increased weight and condition loss, resulting in reduced reproductive performance of the sow in terms of an increased interval between weaning and first insemination and a reduced size of the next litter (Koketsu et al., 1996a; Prunier et al., 1997; Schoenherr et al., 1989). An excessively warm environment reduces thermal comfort, and thereby animal welfare (Bockisch et al., 1999), and in extreme situations can cause the death of the sow.

There are possibilities to cool the microenvironment of the sow without cooling the microenvironment of the piglets, which desire a warm microenvironment. Systems such as drip coolers and effective headspace ventilation are used to reduce the negative effects of excessively high temperatures in farrowing rooms (Raap et al., 1988; Dong et al., 2001; Barbari and Sorbetti Guerri, 2005). A disadvantage of drip cooling is that it causes restless sows (Barbari and Sorbetti Guerri, 2005). It is known that gilts prefer a cooling pad on the floor to drip coolers and snout coolers (Bull et al., 1997). Cooling of a partly solid floor in pens for growing finishing pigs at room temperatures above 25°C increased the number of pigs lying on the solid floor and increased feed intake (Huynh et al., 2004). This indicates that under warm conditions, an increase in body heat dissipation by conduction is comfortable for pigs.

An excessively warm environment for lactating sows is a problem not only in the summer. In insulated lactating rooms, as commonly used in the Netherlands, the room temperature in colder seasons is between 22°C and 26°C (Van Wagenberg et al., 2000a). Because of these relatively high room temperatures, a sow can have problems dissipating her body heat to the environment all year round. Cooling the floor under the sow's shoulder in a farrowing crate increases dissipation of the sow's body heat by conduction. In a preliminary study, no practical disadvantages were encountered, and the heat removal was found to be between 70 and 110 W per sow, about 20% to 30% of the sensible heat production of the sow (Van Wagenberg et al., 2000b). The preliminary study did not investigate if the sows were adapting their lying location in an attempt to avoid the cooled part of the floor. Phillips et al. (2000) found that farrowing sows preferred a warm floor at farrowing, and after seven days the preference changed to a colder floor. However, this was based on the floor temperature under the whole body of the sow. In the current study, the floor was only cooled under the shoulder of the lactating sow. This system is called the "cool-sow" system in this article. The first objective of this study was to determine the effect of the cool-sow system on animal performance in the farrowing room. The second objective was to determine the effect on sow lying behavior. The third objective was to determine the removal of sow body heat by the cool-sow system.

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MATERIAL AND METHODS

The research was carried out in one farrowing room with 12 pens at the experimental farm in Sterksel, The Netherlands. There were five experimental batches, i.e., one group of sows managed all-in/all-out in the room. The experimental batches were in the autumn of 2004 and in the spring and summer of 2005. The average outside temperature during the batches varied between 11.7°C and 18.1°C, and is further specified in the Results and Discussion section of this article. All pens in the room were equipped with a cool-sow floor, but the cooling could be switched off for individual pens. The experimental treatments were: (1) no cooling of the floor in the farrowing room (reference), and (2) cooling of the floor in the farrowing room from the day the sows were transferred to the farrowing room until weaning (cool-sow).

DESCRIPTION OF THE COOL-SOW SYSTEM

The farrowing pens had a fully slatted floor under the sow made of coated steel (3 mm Plastisol coating). Under the sow's shoulder in the front of the pen, some parts of the floor were solid, and under these parts steel pipes (22 mm outside diameter) were installed (fig. 1). Only the front of the sow was cooled, preventing the sow's udder from being cooled, which is expected to be unpleasant for the sow (Phillips et al., 2000). When the cooling was on in a pen, water (3.3 L/min per pen) at approximately 17°C was pumped through the pipes in the floor. This water temperature was found to be suitable in a preliminary study (Van Wagenberg et al., 2000a). All the cool-sow floors received the same amount of water at the same temperature. The temperature difference between water flowing into a floor system and leaving a floor system was never more than 0.5°C. Water was recirculated in the room circuit until it reached a temperature higher than 17°C, when cool water of approximately 11°C (groundwater) was mixed into the water flowing towards the pens.

ANIMALS, FEED, AND WATER

In total, 60 sows (York × Dutch Landrace) inseminated with semen of a Topigs Tempo boar, were allotted to the experiment. For every batch, 12 were selected from a group of about 40 sows with the same expected day of farrowing. Sows were blocked by parity and bodyweight. Relatively young sows with parities 2 to 5 were selected because it was expected that these younger sows would show less undesired variation in feed intake than older sows. Experimental treatments were compared within the farrowing room. Cooled pens were randomly selected for every batch. The litters of all the sows were uniformed to equal litter size within 48 h after farrowing. Weak piglets (low survival chances) were removed from the experiment because they could influence the results undesirably.

The sows were fed twice a day in a trough. Until about 1 day before farrowing, sows were fed 3.4 kg per day. From 1 day before farrowing until 1 day after farrowing, the feed supply was about 1 kg/day. In the following 10 days, the feed supply was slightly increased to a maximum of 7 kg/day. During this 10-day period, a twice-daily check was made to see if there was any feed left in the trough half an hour before new feed was supplied. If any leftover feed was detected, the feed supply was not increased. This strict protocol was necessary during the first 10 days after farrowing to prevent the sows from overfeeding, which means that a sow has a very high feed intake during one day, after which the feed intake is quickly reduced and stays low for several days (Koketsu et al., 1996b). If the sow ate all the feed supplied, then the feed supply was kept at a maximum of 7 kg/day until weaning. This limitation had the possibility of influencing the results; however, it was necessary to maintain regular farm management practice at the experimental farm.

From an age of 10 days, the piglets received creep feed, the first days as mash and later as pellets, until weaning. Both sows and piglets had free access to drinking water. The sow had a drinker in the trough; the drinker for the piglets was located in the back of the pen.

HOUSING

The farrowing room contained two rows of six pens each. The pens were 2.4 m deep and 1.70 m wide (fig. 1). There was a piglet nest with a solid floor of 1.2 × 0.2 m. During the first 4 to 7 days after farrowing, a 150 W infrared heat lamp was used for local heating of the nest. There was a manure tray under all the pens to collect the manure. These manure trays

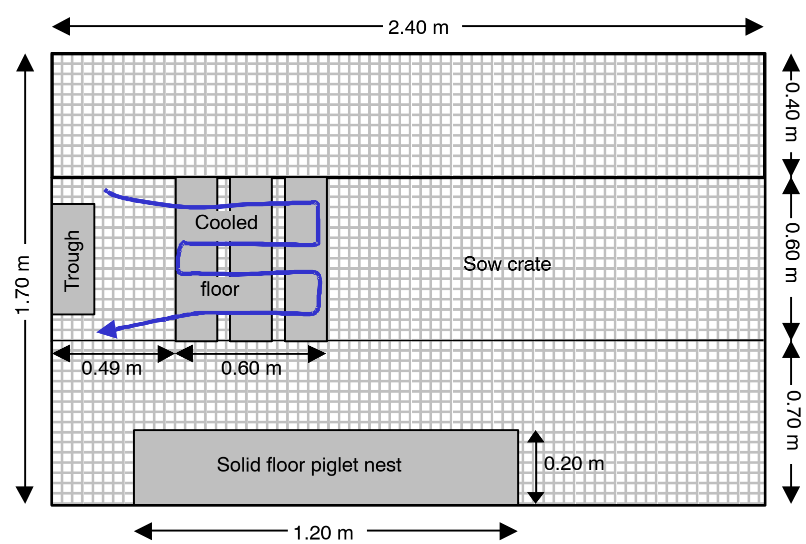

Figure 1. Plan of the farrowing pens.

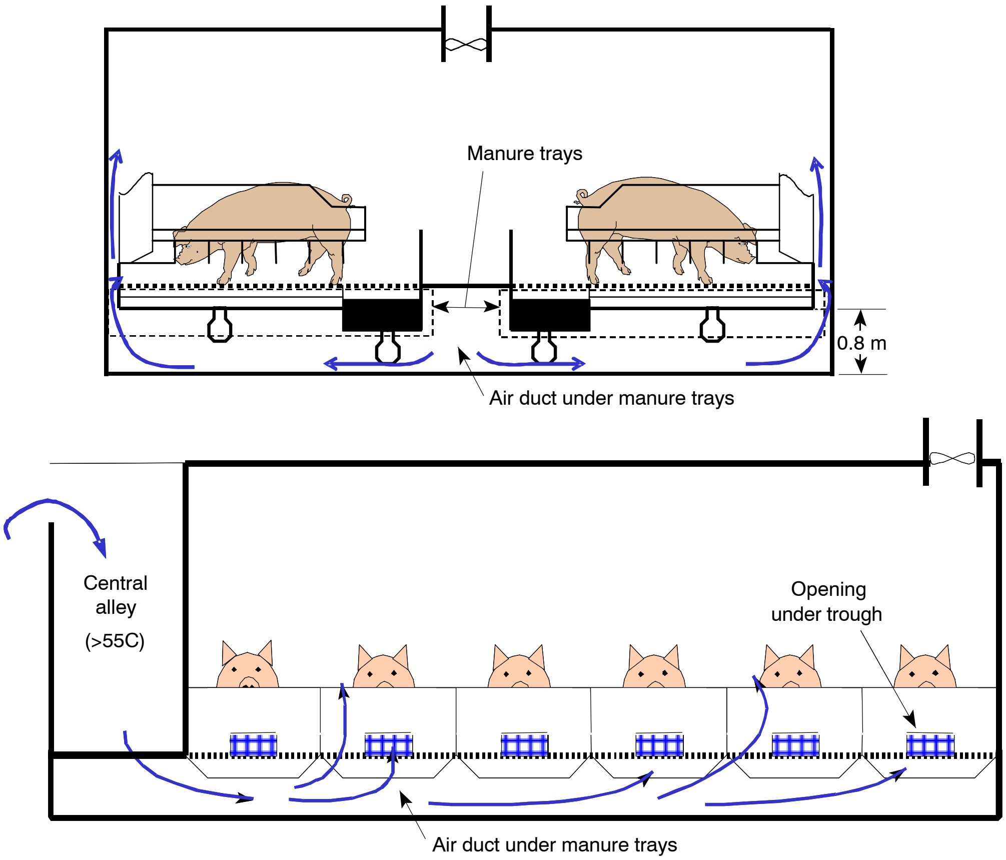

Figure 2. Schematic cross-sections of the experimental farrowing room showing the air duct under the manure trays.

are primarily used to maintain proper hygiene and to reduce ammonia emissions (Verdoes et al., 1998).

The room was mechanically ventilated. Ventilation and heating were controlled by a computer based on a room temperature measurement above the third pen, 2 m from the side wall and at 1.2 m height. Ventilation air entered the building via a central alley, where the minimum temperature was kept at 5°C; from there it entered an underground air duct between the manure trays and the concrete floor. From this duct, the air flowed into the room through small air inlets in the front of the pens on both sides of the room (fig. 2), resulting in effective heat removal from the animal-occupied zone (Van Wagenberg and Smolders, 2002). A large amount of fresh air could enter the pens directly through an opening under the trough. The underground air duct heated the air by several degrees when the inlet temperature was lower than 15°C, and cooled the air by several degrees when the inlet temperature was higher than 20°C (Van Wagenberg et al., 1999). The climatic settings are listed in table 1.

Table 1. Climatic settings (temperature range between minimum and maximum ventilation was 5°C; setpoint room heating was 2°C lower than setpoint ventilation).

	Setpoint Ventilation (°C)	Minimum Ventilation per Pen (m^3/h)	Maximum Ventilation per Pen (m^3/h)[a]	
			Batches 1 and 2	Batches 3, 4, 5
Before farrowing	20	42	217	178
During farrowing	23	42	217	178
After farrowing	23 – 20	42	217	178 – 198[b]

[a] There was some difference in maximum ventilation between batches caused by the farm management. In The Netherlands, with this air inlet system, normally 175 m^3/h per farrowing sow is advised as the maximum ventilation.
[b] Slight reduction in seven days.

Data Collection and Analysis

To document animal performance, the litter size at birth (live born piglets, stillborn piglets, and mummies), the number of weaned piglets, and the litter weights at birth and at weaning were recorded. Each sow was weighed after farrowing (within 24 h) and at weaning. The total feed intake of the sow and the piglets during the lactation period were also recorded. The growth of the piglets, the feed intake of the piglets, the sow's loss of bodyweight, and the feed intake of the sow were analyzed with an analysis of variance using the following model (Genstat, 2000):

$$Y_{ijk} = \mu + \mathit{parity\ number\ of\ sow}_i + \mathit{batch}_j + \mathit{experimental\ treatment}_k + \mathit{error}_{ijk} \quad (1)$$

where Y_{ijk} is one of the items mentioned above, μ is the overall mean, *parity number of sow*$_i$ is the effect of parity of the sow (i = 2 to 5), *batch*$_j$ is the effect of batch (j = 1 to 5), *experimental treatment*$_k$ is the effect of experimental treatment (k = 1 or 2), and *error*$_{ijk}$ is the error associated with an individual measurement. The veterinary treatments of the sows and piglets were also recorded, as was any piglet mortality (with reason for death). These data were analyzed using the chi-squared test.

During all batches, room temperature (controller sensor) and outside temperature were measured. Ventilation rate was measured with a two-bladed ventilation rate sensor in the

Figure 3. Examples of sow positions and locations in the farrowing crate as distinguished during the study: (a) lying on belly at the back of the crate, (b) lying on side in the middle of the crate, and (c) standing in the front of the crate.

ventilation shaft (part of the climate control equipment). These data were recorded every hour and were used to characterize outside and inside conditions during the experiment.

Eight cameras were used to observe the position of the sows in the crates during the first three batches; each could record a picture of one sow every 20 min (24 h per day). Due to unclear images and failure of the recorder, pictures of only two pens were usable from batch 2, and pictures of seven pens were usable from batch 3. The following positions were distinguished: standing, sitting, lying on belly, and lying on shoulder. Three locations in the crate (front, middle, and back) were distinguished for each position. A location in the front meant that at least a part of the sow's nose was under the trough. When the back of the sow touched the back of the crate, this was scored as "back," and locations in between were scored as "middle." Figure 3 shows some examples of observed sow positions and locations. Weekly and batch averages of sow position and sow location were determined and analyzed using a logistic regression.

During all batches, the heat uptake of the cool water in the water circuit was determined every 15 min by an energy meter (Raab Karcher type Q 2,5 EC) based on a water flow measurement and on water temperature measurements before and after the cool-sow floors. In addition, between batches (without animals), the heat uptake of the water (e.g., caused by convective heat exchange between floor and air) was measured. These data were subtracted from the measurements during batches to calculate the amount of body heat removed by the cool-sow floor.

Results and Discussion

Animal Performance

Table 2 shows sow and litter performance. Two sows were removed from the experiment, both in batch 4. One sow died directly after birth (in a cool-sow pen); the other had a serious uterus infection (in a reference pen). The results of these two sows and their litters have been omitted.

The sows on the cool-sow floors ate 13.6% more during the lactation period. The average daily feed intake per sow was 0.6 kg higher (in total, 17.4 kg per sow per batch) than in the reference pens. Reducing the ambient temperature from 25°C to 18°C resulted in a similar increase in total feed intake (Quiniou and Noblet, 1999). Indicative weekly registration of the feed intake during batch 3 showed that the difference in feed intake between the two experimental treatments was found in all weeks of the lactation period.

The piglets of those sows grew 22 g per day per piglet (9%) faster, resulting in 0.6 kg extra weight per piglet at weaning (6.5 kg higher litter weight at weaning). The intake of creep feed by the piglets was comparable between the cool-sow and reference pens, and there was no significant difference between the weight losses of the sows. The extra feed intake by the sows was therefore used to produce extra milk. If the maximum feed supply of the sows had been above 7 kg/day from day 10 until weaning, then the difference between the two experimental treatments could have been bigger.

Veterinary Treatments and Piglet Mortality

The veterinary treatments of the sows, the piglets, and the mortality of the piglets are listed in table 3. The number of veterinary-treated sows did not differ between experimental treatments. In addition, there were no differences in the number of veterinary treatments per reason. There was no difference in piglet mortality or in the number of veterinary treatments of the piglets. It could be expected that the piglets

Table 2. Sow and litter performance in farrowing pens with cooled floors (cool-sow) and in reference pens.

	Ref.	Cool-sow	SEM[a]	Signif.[b]
No. of sows	29	29		
Parity	3.0	3.1		
Total piglets born per litter:	12.8	13.5		
Live born piglets	12.1	12.7		
Stillborn piglets	0.4	0.6		
No. of piglets after fostering	11.2	11.4		
Birth weight after fostering (kg)	1.53	1.55	0.042	n.s.
Length of lactation period (d)	26.4	26.5		
No. of piglets at weaning	10.6	10.7		
Piglet weaning weight (kg)	7.9	8.5	0.12	**
Growth per piglet (g/d)	242	264	4.6	***
Creep feed intake:				
Mash (kg/litter)	1.65	1.68	0.010	n.s.
Pellets (kg/litter)	2.54	2.62	0.190	n.s.
Total (kg/litter)	4.19	4.30	0.270	n.s.
Total (kg/piglet)	0.39	0.40	0.024	n.s.
Bodyweight of sows (kg):				
After farrowing	251	251		
At weaning	223	226	2.0	n.s.
Weight loss	28	25	2.0	n.s.
Feed intake sows (kg):				
From farrowing till weaning	128.2	145.6	2.85	***
Average per day	4.9	5.5	0.10	***

[a] SEM = pooled standard error of mean.
[b] ** = ($P < 0.01$), *** = ($P < 0.001$), and n.s. = no significance.

Table 3. Number and type of veterinary treatments of the sows and piglets, and mortality of the piglets in farrowing pens with cooled floors (cool-sow) and in reference pens.

	Reference	Cool-sow	Significance[a]
Number of sows	29	29	
Number of treated sows	13	7	n.s.
Reason for treatment:			
Birth assistance	7	3	n.s.
Uterus infection	0	3	--[b]
Udder infection	2	1	--[b]
Lameness	3	0	--[b]
Various	1	0	--[b]
Number of litters	29	29	
Number of piglets[c]	326	338	
Mortality (no. of piglets)	21	30	n.s.
Reason for mortality:			
Crushing	5	7	n.s.
Biting	4[d]	0	--[b]
Congenital defects	1	9	*
Not viable	4	4	n.s.
Backward development	3	7	n.s.
Various	4	3	n.s.
Number of treated piglets	15	11	n.s.
Reason for treatment:			
Lameness	8	9	n.s.
Respiratory diseases	0	1	--[b]
Streptococcus	6[e]	0	*
Various	1	1	--[b]

[a] * = ($p < 0.05$), and n.s. = no significance.
[b] Too few data to test for significance.
[c] The numbers are different between the two experimental treatments because some piglets died before the fostering of the litters.
[d] All four piglets were bitten by the same sow.
[e] Five of the six treated piglets were from the same litter.

Table 4. Positions of the sow in the crate as percentage of the total number of observations in farrowing pens with cooled floors (cool-sow) and in reference pens.

	Batch Avg.	Weekly Avg.	Reference	Cool-sow	Signif.[a]
Number of sows			7	10	
Standing					
Total[b]	x		9.0	8.8	n.s.
Front	x		6.4	7.0	**
Sitting					
Total[b]	x		3.5	3.0	n.s.
Front	x		0.1	0.1	n.s.
Lying on belly					
Total[b]	x		22.3	22.4	n.s.
Front	x		14.6	13.8	*
Lying on shoulder					
Total[b]	x		65.2	65.8	n.s.
Front	x		60.3	58.8	***
Lying on shoulder in front					
Week 1		x	42.4	55.0	***
Week 2		x	64.4	63.1	n.s.
Week 3		x	67.2	57.8	***
Week 4		x	59.6	58.1	n.s.
Week 5		x	51.0	55.5	**

[a] * = ($P < 0.05$), ** = ($P < 0.01$), *** = ($P < 0.001$), and n.s. = no significance.
[b] Total = front, middle, and back of the crate.

would avoid the cooled floors, thereby reducing the risk of crushing. However, this was not found to be the case; the surface temperature of the cooled floor was not so low as to keep the piglets away.

Sow Location and Position

Table 4 shows that there was hardly any difference in batch-average sow positions between the two experimental treatments. The batch average for standing in the front of the crate is significantly higher for the cool-sow system than for the reference, possibly because these sows ate more, which took longer. The batch average for lying in the front of the crate, both on the belly and on the shoulder, is a little lower for the cool-sow system. For the middle and back locations, there were no significant differences.

Weekly averages show that in the first week after farrowing, the sows were lying more often on their shoulder in the front of the pen in the cool-sow pens than in the reference pens. This indicates that the sows preferred the colder floors during the first 7 days after farrowing, which seems contradictory to the results found by Phillips et al. (2000). However, the cool-sow system only cools the shoulder of the sows and not the floor at the back of the sow where the piglets are born. As suggested by Philips et al. (2000), the sow preferred a warm floor at and directly after farrowing because her piglets were born in a warmer environment. The cool-sow system has no effect on the microclimate behind the sow. In weeks 2 and 4 after farrowing, the differences in lying locations were very small. Surprisingly, in week 3 after farrowing, the sows in the reference pens were more frequently lying in the front of the pen than the cooled sows. This difference cannot be explained by the level analysis.

Table 5. Batch average room indoor climate characteristics (standard deviations in parentheses), sow feed intake, and heat removal by cool-sow floor.

	Climate Characteristics				Sow Weight after Farrowing (kg)		Feed Intake (kg/day)			Heat Removal by Floor (W/pen)	
Batch	N[a]	Room Temp. (°C)	Ventilation Rate per Sow (m^3/h)	Outside Temp. (°C)	Ref.	Cool-sow	Ref.	Cool-sow	Diff.	Total	Corr.[b]
1	684	24.2 (0.7)	151 (28)	12.2 (3.5)	257	261	4.38	5.57	1.19	86	37
2	835	24.0 (1.8)	140 (43)	11.7 (4.7)	264	261	5.44	5.59	0.15	87	38
3	666	25.7 (2.1)	162 (34)	17.1 (6.2)	230	236	5.36	5.86	0.50	109	59
4	669	26.0 (2.1)	173 (28)	18.1 (4.5)	243	250	4.59	4.98	0.39	130	81
5	763	25.4 (1.6)	164 (33)	17.2 (5.4)	261	246	4.16	5.48	1.32	123	74

[a] N = number of measurements.
[b] Correction was based on measurements in pens in warm room but without animals, which resulted in average heat removal of 49 W per pen.

INDOOR CLIMATE

The average room temperature was above 24°C during all batches, resulting in a relatively high ventilation rate, which is characteristic for a room with a high internal heat load (table 5). Because the room had effective ventilation (effective heat removal from the animal-occupied zone; Van Wagenberg and Smolders, 2002), it is known from earlier research that the air around the head of the sow was approximately 6°C cooler than the room temperature (Van Wagenberg et al., 2000a) for both experimental treatments.

In all batches, sows on the cool-sow floors ate more than sows in the reference pens (table 5). The difference in feed intake was highest in batches 1 and 5. This was surprising, as it was expected that the biggest difference in feed intake would be found during the batches with the highest room temperatures (batches 3 and 4). The explanation for this is that factors other than room temperature alone varied between batches. For example, the sow weight after farrowing was lowest in batch 3; the relatively high room temperature in batch 3 probably had less effect on the feed intake of these relatively light sows. The difference in feed intake of the sows is not only due to some warmer batches. The results indicate that the critical temperature for sow performance is below 24°C, which is lower than the 25°C reported by Quiniou and Noblet (1999).

The heat removal by the floor varied and was highest during the warmest batches. It was on average 107 W per pen. Not all of this heat was removed from the sow's body; the heat removal of the cool-sow system in an empty room was measured (between batches) as 49 W per pen. The heat removal from the sow's body was estimated by subtracting the empty room heat removal, resulting in approximately 58 W, which is between 10% and 25% of the sensible heat production of a lactating sow (at room temperatures of around 25°C). Theoretically, subtracting all of the empty room heat removal can lead to a slight underestimate of the sow's body heat removal, since the presence of the sow in the crate will interfere with the convective and radiative heat gain of the plate from sources such as the ceiling, heat lamp, and convective airflow. Figure 4 shows the course of the daily average heat removal by the floor during all five batches.

Most of the piglets were born on day 9 of the batch. Figure 4 shows that the heat removal by the floor varied per day. This variation does not seem to have been affected by the day number of the batch. It may have been due to the outside temperature or to some other factors. This was also found in the preliminary study (Van Wagenberg et al., 2000b).

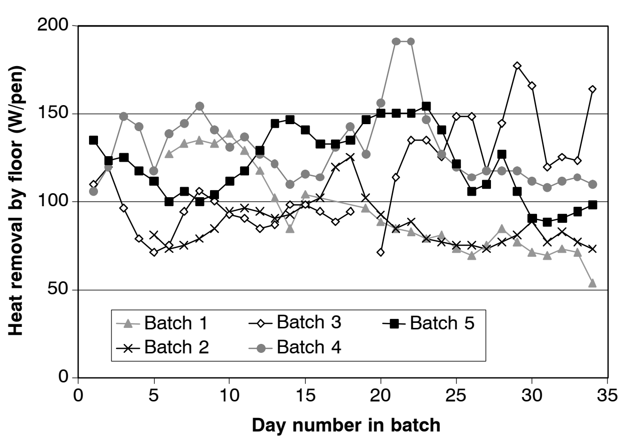

Figure 4. Course of the daily average heat removal by the floor during all five batches.

CONCLUSION

In a field experiment under Dutch conditions, lactating sows on a cool-sow floor, with cooling under the shoulder and neck, ate 0.6 kg/day per sow more than sows on a floor without cooling. This difference was not due only to summer batches.

The piglets of lactating sows on the cool-sow floor grew 20 g/day per piglet faster, resulting in an 8% higher weight at weaning. The cool-sow system did not affect the mortality of the piglets.

The positions and locations of the sows in the farrowing crates were hardly changed by the cool-sow system.

The cool-sow system removed on average 107 W of heat per pen, of which approximately 58 W was directly removed from the sow's body.

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