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Behaviour and performance of lactating sows housed in different types of farrowing rooms during summer

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ABSTRACT

Thirty mixed-parity Landrace × Large White sows were used to evaluate the effects of the type of farrowing room on 28-day lactation behaviour under tropical conditions during summer. The sows were allocated in a completely randomised design with three treatments with 10 replicates according to parity number and body weight, with each animal being considered an experimental unit. The treatments consisted of a conventional farrowing room (T1); a conventional farrowing room with floor cooling under the sow (T2); and a semi-outdoor farrowing room without a cage and with access to a fenced field (T3). The sows from T1 and T2 groups were exposed to mean maximum and minimum environmental temperatures of 25.7 and 21.0 °C, respectively, and the sows from the T3 group to average maximum and minimum environmental temperatures of 26.5 and 20.7 °C, respectively. The feed consumption of T3 sows was numerically higher than the T1 and T2 sows (+9.5% on average). The body-weight loss was influenced at 28 days ($P<0.10$) by treatment, being that the T3 sows gained weight (+4.7 kg) while the T1 and T2 sows lost weight (−11.9 and −3.7 kg, respectively for T1 and T2). The T3 sows showed a higher percentual litter mortality than the T1 and T2 sows (3.2% vs. 0% vs. 7.8%, respectively for T1, T2 and T3 sows). From farrowing until day 28 of lactation, the T2 and T3 sows showed higher lactation efficiency when compared with the T1 sows (72% vs. 87% vs. 88%, respectively for T1, T2 and T3 sows). The T1 sows showed higher ($P<0.01$) frequencies of visits to the feeder and drinker (+38% on average). The T3 sows spent more time ($P<0.01$) at the drinker than T1 and T2 sows (23 vs. 23 vs. 32 min, respectively for T1, T2 and T3 sows). The T3 sows showed a higher ($P<0.10$) frequency of nursing than the other treatments (+15% on average). T1 and T2 sows were found to spend more time ($P<0.01$) performing other postures during 24 h than sows maintained in T3 (50 vs. 51 vs. 22 min/d, respectively for T1, T2 and T3). It is concluded that cooling of the floor under the sow in the conventional farrowing room or the use of semi-outdoor farrowing rooms improves the thermal environment and the lactation efficiency of the sows housed in hot ambient temperatures at 28-day lactation in the summer period, indicating an improved welfare.

1. Introduction

Pig production in tropical and subtropical countries will rapidly increase as a result of increasing human population (Silva et al., 2009a). Although many factors are obviously involved, the combination of high temperatures and high

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relative humidity (RH) resulting in heat stress remains one of the major problems that affects the production efficiency and welfare of pigs in these regions (Silva et al., 2009a). In the specific case of the farrowing house, the challenge lies in attending to the different comfort temperatures for the housed animals, as the comfort temperatures for lactating sows, as described by Quiniou and Noblet (1999) and De Bragança et al. (1998) is between 16 and 22 °C, while the comfort temperatures for nursing piglets between 30 and 32 °C soon after the birth second is considered ideal (Black et al., 1993). The increase in environmental temperatures in the farrowing room can lead to a heat stress in the sows according to Renaudeau et al. (2001), and this results in a lower intake of food, which can compromise the performance of the litter.

In addition, heat stress can also cause alterations in lactating sow's behaviour and welfare due to thermal discomfort. These alterations include a reduction in the number and duration of nursing, higher time urinating and defecating and an increase in piglet mortality due to crushing (Martins et al., 2008; Silva et al., 2006). Thus, the lack of welfare may result in serious consequences for the productivity of the sows, compromising their reproductive cycle and piglet performance (Silva et al., 2006, 2009c).

In the attempt to improve performance and welfare under tropical conditions, the use of modified farrowing pens has been evaluated by several authors (Hötzel et al., 2004; Silva et al., 2006, 2009a,b,c). An alternative approach is to increase heat loss using a neck drip-cooling system (McGlone et al., 1988), chilled drinking water (Jeon et al., 2006) or a floor-cooling system (Silva et al., 2006, 2009c).

From a physiological, productive and reproductive perspective, the floor-cooling system has been proven that it can be a feasible strategy to attenuate the effects of heat stress, but there are some doubts about its benefits regarding the sow's welfare from an animal-behavioural perspective.

As an alternative to the conventional farrowing houses, outdoor housing systems or semi-outdoor housing systems (a farrowing room with access to a fenced field) have been suggested. The outdoor pig industry has grown quickly over the last decade, a factor that has been hastened by the high capital costs of indoor pig housing as well as public demand for a less intensive industry. Planning regulations have also made it more difficult to develop indoor pig production. Outdoor pig production is largely concerned with the housing of sows and the rearing of the young piglets for the first few weeks of their lives.

The outdoor farrowing systems have been extensively studied, and they have been proven to show no differences or has been best that concerning productivity in relation to the confined systems (Bracke et al., 2002a,b; Dalla Costa, et al., 1995). It is possible that the access of the lactating sows and their piglets to fields can contribute to improve animal welfare and lead to the reduction of abnormal behaviours. It has been verified that sows in intensive systems tend to develop abnormal behaviours, such as the act of staying longer at the water drinker, than sows in outdoor systems (Johnson et al., 2001).

Hence, based on these considerations, this study was realised to evaluate the behaviour and performance of lactating sows housed in different types of farrowing rooms during a 28-day lactation period in summer under Brazilian climatic conditions.

2. Materials and methods

2.1. Experimental design

The experiment was conducted during the summer period between January and April of 2008 at the farrowing houses of the pig breeding sector of the Department of Animal Science at Federal University of Viçosa, Viçosa, Minas Gerais, Brazil. The municipality is located in a tropical climatic region (20° 45′ 45″S and 4° 52′ 04″W, with an altitude of 657 m). Care and use of animals were performed according to the certificate of authorisation to experiment on living animals issued by the ethics committee of the Federal University of Viçosa.

Thirty multiparous Landrace × Large White crossbred sows were used in this experiment, distributed in a completely randomised design into three treatments (T1= conventional farrowing room; T2=conventional farrowing room with floor cooling under the sow; and T3=semi-outdoor farrowing room without a cage and with access to a fenced field) with 10 sows per treatment, each sow being considered as an experimental unit. The sows were distributed among the treatments according to body weight, backfat thickness (BFT) before farrowing and parity order. The sows remained in the experiment from farrowing to weaning at 28 days of lactation.

2.2. Animal management and installations

The sows from T1 and T2 groups were housed individually in cages with 2.0-m length and 1.60-m width and a floor of solid concrete. Each cage was equipped with a semiautomatic feeder, more a shell drinker for the sows. A juggler with an infrared light to provide supplemental heat for the piglets was attached to the cage. No bedding material was used. For the sows of T2, where the floor was cooled, the temperature of the water circulating in the cooled floors was maintained at 17 °C. A detailed description of the system to realise the floor cooling was previously given (Moreira et al., 2004; Silva et al., 2006).

The semi-outdoor farrowing pens used for T3 sows had 2.2-m length and 2.3-m width and the fenced field a total area of 55 m^2. These farrowing pens were equipped with a semiautomatic feeder and a nipple drinker for the sows and an infrared light to provide supplemental heat for the piglets. No bedding material was used. After the third day post farrowing, everyday in the afternoon for 2 hours, the T3 sows and their piglets were allowed access to the individual fenced fields.

At day 108 of gestation, the sows were moved to the farrowing houses, where they were allocated individually in farrowing housing until weaning. From day 108 until farrowing, sows were fed 3 kg day^{-1}, divided in two daily meals, of a lactation diet containing 17.8% crude protein (CP), 0.99% digestible lysine and 13.83 MJ kg^{-1} metabolizable energy (ME). The diet was formulated with maize, soybean meal and soybean oil and supplemented with synthetic amino acids, minerals and vitamins to achieve the requirements for this animal category defined by Rostagno et al. (2005). Sows were fed the same diet *ad libitum* after farrowing. Water was available *ad libitum* through a low-pressure bowl-type drinker of stainless steel for the sows kept in the T1 and T2 farrowing rooms, while the sows from T3 had free access to a low-pressure nipple drinker.

The piglets were handled (teeth clipping and tail docking, umbilical-cord treatment, labelling and antibiotic administration) up to 24 h after birth and the litter was not equalised, as the number of piglets was used as covariate. At day 7, males were surgically castrated. During the lactation period, piglets had no access either to creep feed or to the sow feed, but water was available *ad libitum* through a low-pressure nipple drinker. At weaning, the piglets were moved to the nursery of the farm, and sows were moved to a breeding facility.

2.3. Measurements and parameters analysed

The sows were weighed at the moment they were transferred to the farrowing houses (day 108), up to 24 h after farrowing, at day 21 and at weaning. BFT was measured at the same times by ultrasound (Model Microem MTU 100, Brazil). Two measurements were made 6.5 cm from the dorsal midline on the right and left side of the animal at the level of the 10th rib (P2), and the mean obtained for the two sides was considered for analysis. Piglets were individually weighed at birth, at day 21 and at weaning.

The thermal environment inside the farrowing house was monitored daily 5 times a day (07:00, 09:30, 12:00, 14:30 and 17:00 h) using minimum and maximum, dry and wet bulb and black-globe thermometers (Incoterm Ind. de termometros LTDA, Porto Alegre, RS, Brazil). These data were then converted to the black globe humidity index (BGHI), to characterise the thermal ambient of the sows, using the equation proposed by Buffington et al. (1981):

$$BGHI = tg + 0.36td + 41.5$$

where tg=black-globe-thermometer temperature and td=dry-bulb-thermometer temperature.

During the experimental period, all physiological parameters were obtained through the average of 18 measurements per sow obtained during nine stages of lactation (3, 6, 9, 12, 15, 18, 21, 24 and 27 days) at 09:00 and 15:00 h. The rectal temperature was measured twice a day (09:00 and 15:00 h) at three-day intervals using a digital thermometer. The respiratory rate was determined for 1 min on the same days and at the same times by counting the movements of the flank only on quiet animals. Floor temperatures and skin-surface temperatures (neck, hind thigh and chest) of the sows were also measured on the same days and at the same times with a laser thermometer (Model Raytec Minitemp MT4, São Paulo, Brazil). The skin-surface temperatures in contact with the floor and the floor temperature were measured immediately after the lying sow was got up.

The behavioural observations on the lactating sows were realised using four video cameras in each of the conventional farrowing rooms and eight video cameras in each of the semi-outdoor farrowing rooms. Four periods of observations per sow were realised at days 7, 14, 21 and 27 of lactation. The video recordings were realised during a continuous period of 24 h. Hence, behavioural activities were obtained from the average of four observations (at days 7, 14, 21 and 27 after farrowing) of each treatment and expressed in min, percentage and frequency per sow during a continuous 24-h period. The following sow behaviours were recorded: water drinking (time and frequency spent at the drinker), feeding (time spent and frequency of visits to the feeder), lateral recumbency nursing (time and frequency that the sows nursed; it was considered nursing the moment that the sow was in lateral recumbency and a minimum of two piglet were nursing) and other activities: lateral recumbency and/or lying on the udder (time spent on these positions; not considering the time in which sows were nursing), standing but not feeding or drinking water (time inactive, rail biting, etc.) and other postures (time spent sitting or kneeling down).

2.4. Calculations and statistical analyses

The daily maximum, minimum and mean values of ambient temperature, RH and BGHI were averaged for each replicate of sows and farrowing room. Changes in body weight (BW) and BFT during lactation were calculated from BW and BFT at weaning, at day 21 and farrowing. From these values, changes in body fat content (BFC) and body protein content (BPC) were calculated using the equations proposed by Clowes et al. (2003) and Whittemore and Yang (1989), respectively. The BPC (kg) considering weight and BFT at farrowing and weaning $= -2.3 + (0.19 \times \text{body weight, kg}) - (0.22 \times \text{BFT, mm})$ (Whittemore and Yang, 1989; in Clowes et al., 2003). The BFC (kg) considering weight and BFT at farrowing and weaning $= -20.4 + (0.21 \times \text{body weight, kg}) + (1.5 \times \text{BFT, mm})$ (Clowes et al., 2003). The milk production (MP) was estimated at day 21 and 28 from litter size and litter average daily BW gain (g day^{-1}), assuming that for each kilogram of litter gain the sow produces 4.27 l of milk. The MP was estimated based on litter average daily weight gain (g day^{-1}), the average number of piglets and the lactation length; MP (kg day^{-1}) $= ((4.27 \times \text{ADG}) \times \text{No. of piglets})/\text{No. of days of lactation}$ (Ferreira et al., 1988). The lactation energetic efficiency was estimated according to Whittemore and Elsley (1979), considering the energy value of 44.07 MJ kg^{-1} of BW loss of the sow, 25.87 MJ kg^{-1} of BW gain of the sow, 28.74 MJ kg^{-1} of litter gain and 14.52 MJ of digestible energy of the diet.

Feed intake was determined as the difference between feed allowance and the refusals collected on the next morning between day 1 after farrowing, day 21 and day 28 at weaning. Body-surface- and rectal-temperature measurement made at 09:00 h and 15 00 h were averaged per sow for the whole lactation period. Similar calculations were done for floor-temperature data. Behavioural activities of sows were obtained from the average of four observations (at days 7, 14, 21 and 27 after farrowing) of each replicate and expressed in frequency and min per sow during a 24-h period. The behavioural activities were verified for data normality using the Lilliefors procedure of SAEG (System for Statistical and Genetic Analyses, 2007). The parameters which did not show a normal distribution where compared by the non-parametric Kruskal–Wallis procedure. The data on daily feed intake, body weight and BFT variation, physiological parameters and MP of the sows, as well as the piglets' performance data were statistically analysed according to linear models using the SAS (SAS Inst. Inc., Cary, NC, USA) procedure associated to the Dunnet test, with replicate and treatments as main effects, having T1 as the control at an established significance of $P<0.10$. The litter size was used as covariate to analyse the effect of the experimental treatment on the performance parameters of sows, litter and piglet BW gain from day 1 to weaning.

3. Results

Because of small litter size (less than eight piglets) and health problems, three sows were removed from the study. In the experiment, sows of first to sixth parity were used in all treatments, three primiparous female being used in each treatment. The mean of parity order of sows was 2.8 for T1, 3.0 for T2 and 3.2 for T3.

The sows from T1 and T2 groups were exposed to average maximum and minimum environmental temperatures of 25.7 and 21.0 °C, respectively, and the sows from T3 to average maximum and minimum environmental temperatures of 26.5 and 20.7 °C, respectively. The average of dry bulb, maximum and minimum temperatures, RH and average of BGHI calculated for the experimental periods are shown in Table 1. It was observed that variations in both temperature and RH were higher for the semi-outdoor farrowing rooms.

The results of the performance parameters obtained for sows during the lactation period are shown in Table 2. According to the design of the trial, no difference ($P>0.10$) in postpartum BW, BFC and BPC, as well as BFT of the sows was observed among treatments.

Although the type of farrowing room had no significant influence ($P>0.10$) on feed intake, the feed consumption of T3 sows was numerically higher than the T1 and T2 sows (+9.5% on average). Lactation BW loss was influenced ($P\geq0.06$) by the treatments. During lactation, T3 sows gained weight (+4.7 kg) and T1 and T2 sows lost weight (−11.9 and −3.7 kg, respectively for T1 and T2). Lactation backfat losses were not affected by the treatments. The T2 and T3 sows showed numerically less backfat loss than T1 sows (1.0 vs. 2.0 mm; $P>0.10$). Body protein and lipid losses were not affected by the treatments.

Table 1
Mean maximum, minimum values and dry bulb temperatures (DBT), relative humidity (RH) and black globe humidity index (BGHI) during the trial according to farrowing room.

Time	DBT (°C)	RH (%)	BGHI
Conventional farrowing rooms (T1 and T2)			
07:00	21.0 ± 1.5	86 ± 6.2	70 ± 1.8
09:30	22.9 ± 1.7	80 ± 7.5	72 ± 2.0
12:00	25.5 ± 2.4	71 ± 9.6	75 ± 2.6
14:30	25.7 ± 2.5	71 ± 11.0	75 ± 2.7
17:00	25.3 ± 2.5	73 ± 11.1	75 ± 2.6
Daily temperature (°C)			
Minimum	21.0 ± 1.5		
Maximum	25.7 ± 2.5		
Semi-outdoor farrowing room (T3)			
07:00	20.7 ± 1.2	90 ± 4.1	70 ± 1.7
09:30	23.2 ± 1.8	82 ± 6.7	73 ± 2.1
12:00	26.1 ± 2.7	73 ± 12.4	76 ± 2.7
14:30	26.5 ± 2.7	71 ± 11.2	76 ± 2.9
17:00	25.4 ± 2.7	76 ± 10.4	75 ± 2.8
Daily temperature (°C)			
Minimum	20.7 ± 1.2		
Maximum	26.5 ± 2.7		

Table 2
Effect of the type of farrowing room on performance of the lactating sows during 28-day lactation.

Variable	T1	T2	T3	RSD[1]	Statistical analysis[2]
Number of sows	10	8	9		
ADFI, as fed					
At d 21, kg	6.1	5.6	6.5	1.0	ns
At d 28, kg	6.3	6.0	6.8	0.9	ns
Metabolizable energy intake, Mcal/d					
At d 21	21.3	19.6	22.6	3.3	ns
At d 28	22.0	20.7	23.5	2.9	ns
Digestible lysine intake, g/d					
At d 21	60.3	55.7	64.4	9.4	ns
At d 28	61.3	58.8	66.9	8.4	ns
BW, kg					
After farrowing	250.2	245.1	244.4	34.6	ns
Loss or gain of BW					
From d 1 to 21	−10.3	−3.7	+2.6	12.0	ns
From d 1 to 28	-11.9^a	-3.7^a	$+4.7^b$	13.1	0.06
Backfat thickness, mm					
After farrowing	17.3	15.1	14.9	3.1	ns
At d 28	15.3	14.0	14.0	3.0	ns
Loss during lactation					
From d 1 to 21	−1.8	−0.7	−1.1	1.2	ns
From d 1 to 28	−2.0	−1.1	−0.9	1.5	ns
Chemical composition of BW loss					
Protein, kg					
From d 1 to 21	−1.6	−0.5	0.7	7.1	ns
From d 1 to 28	−1.8	−0.5	1.1	7.1	ns
Fat, kg					
From d 1 to 21	−4.9	−1.8	−1.1	9.1	ns
From d 1 to 28	−5.5	−2.4	−0.4	9.1	ns

1 Residual standard deviation.
2 From an analysis of variance, where within a line, means with different superscripts are significantly affected by treatment ($P<0.10$). ns = not significant.

Table 3 shows the weight gain of piglets during the lactation period. Litter size was significantly ($P<0.04$) different at birth, but average piglet BW at birth was not. Piglets BW gain between birth and weaning and mean BW of piglets at weaning were not influenced by the treatments. The T3 sows showed a higher litter mortality rate (7.8%) than the other treatments (3.2% and 0%, respectively, for T1 and T2 sows). MP between days 1 and 28 was not influenced by the treatments (Table 3).

The lactation efficiencies from farrowing to day 21 and 28 of lactation are shown in Table 4. The sows submitted to T2 and T3 treatments showed a higher lactation efficiency from farrowing until day 21 than T1 treatment (93% vs. 93% vs. 72%, respectively for T2, T3 and T1). From farrowing until day 28 of lactation, the T2 and T3 sows also showed higher lactation efficiency when compared with control treatment (87% vs. 88% vs. 72%, respectively for T2, T3 and T1).

The results of the physiological parameters and surface temperatures obtained from sows during the lactation period are shown in Table 5. Except for the rectal, neck and chest (without contact with floor) temperatures checked, all other physiological parameters studied were influenced by the treatments. Sows submitted to floor cooling had lower

Table 3
Effect of the type of farrowing room on performance of the litter during 28-day lactation[1].

Variable	T1	T2	T3	RSD[2]	Statistical analysis[3]
Number of sows	10	8	9		
Litter size	9.5	10.1	11.6	1.7	0.04
At d 1	9.3	10.1	10.7	1.6	ns
At d 21	9.2	10.1	10.7	1.6	ns
At d 28					
Mortality rate from d1 to 28,%	3.2	0.0	7.8	-	-
Piglet BW, kg					
At d 1	1.48	1.48	1.40	0.161	ns
At d 21	6.13	5.87	5.82	0.700	ns
At d 28	8.15	7.65	7.70	0.855	ns
Piglet BW gain, g/d					
From d 1 to 21	232	220	221	32.0	ns
From d 1 to 28	247	229	233	29.0	ns
Litter BW gain, kg/d					
From d 1 to 21	2.038	2.084	2.125	0.331	ns
From d 1 to 28	2.270	2.277	2.356	0.320	ns
Sow milk production, kg/d					
From d 1 to 21	9.151	9.343	10.152	1.528	ns
From d 1 to 28	9.602	9.725	10.720	1.433	ns

[1] The piglets had no access to creep feed.
[2] Residual standard deviation.
[3] From an analysis of variance, ns = not significant.

($P<0.01$) values of respiratory frequency ($P<0.01$) compared with T1 and T3 sows. Significantly lower surface temperatures measured in the different regions of the sow's body were observed in sows submitted to floor cooling ($P<0.01$). The floor-cooling sows (T2) and semi-outdoor sows (T3) had, on average, lower floor temperatures in the morning ($P<0.01$) when compared with the T1 sows (i.e., 35.3 vs. 29.3 vs. 33.7 °C, respectively for T1, T2 and T3 sows); this effect was also was observed for the afternoon (i.e., 36.5 vs. 30.9 vs. 35.1 °C, respectively for T1, T2 and T3 sows; $P<0.01$).

Table 4
Effect of the type of farrowing room on lactation energy efficiency during 28-day lactation.

	T1[1]	T2[1]	T3[2]
Energy efficiency from farrowing to d 21			
Number of sows	10	8	9
BW change until d 21, kg	−10.4	−3.7	+2.6
Energy in BW loss or gain, kcal/kg	109.5	38.9	16.1
Total feed intake d 21, kg	123.0	113.0	130.5
Energy in feed intake, kcal/kg	426.4	391.8	452.4
Litter BW, kg	56.4	58.4	58.8
Energy in produced litter BW, kcal/kg	387.1	400.9	403.6
Lactation efficiency,%[1]	72.2	93.1	93.0
Energy efficiency from farrowing to 28			
Number of sows	10	8	9
BW change until d 28, kg	−11.9	−3.7	+4.7
Energy in BW loss or gain, kcal/kg	125.2	38.9	29.0
Total feed intake until d 28, kg	169.1	160.9	183.0
Energy in feed intake, kcal/kg	586.3	557.8	634.5
Litter BW, kg	74.9	76.1	77.8
Energy in produced litter BW, kcal/kg	514.1	522.4	534.0
Lactation efficiency,%[1]	72.2	87.5	88.2

[1] Lactation efficiency (%) = Energy in produced litter BW/(Energy in feed intake + Energy in BW loss).
[2] Lactation efficiency (%) = Energy in produced litter BW/(Energy in feed intake - Energy in BW gain).

Table 5
Effect of the type of farrowing room on average respiratory rate, cutaneous temperatures (neck, thigh and chest) and rectal temperature of the sows, and temperature of the floor under the sow.

Variable	T1	T2	T3	RSD[1]	Statistical analysis[2]
No. of sows	10	8	9		-
Respiratory frequency (breaths/min)					
Morning	43.7^a	28.0^b	38.2^a	10.1	0.01
Afternoon	61.7^a	33.7^b	53.1^a	16.2	0.01
Rectal temperature (°C)					
Morning	38.7	39.0	38.9	0.334	ns
Afternoon	39.1	39.0	39.2	0.323	ns
Neck temperature (°C)					
Morning	35.1^a	34.8^a	34.3^b	0.749	0.06
Afternoon	36.9	36.2	36.2	1.019	ns
Thigh temperature in contact with the floor (°C)					
Morning	34.9^a	30.6^b	33.8^a	1.536	0.01
Afternoon	36.4^a	32.6^b	35.6^a	1.029	0.01
Thigh temperature without contact with the floor (°C)					
Morning	36.0^a	35.6^a	35.2^b	0.653	0.04
Afternoon	37.8^a	36.9^b	37.3^a	0.706	0.03
Chest temperature in contact with the floor (°C)					
Morning	36.3^a	32.1^b	35.4^a	1.270	0.01
Afternoon	37.6^a	33.5^b	36.9^a	1.038	0.01
Chest temperature without contact with the floor (°C)					
Morning	37.2	37.0	36.8	0.485	ns
Afternoon	38.6^a	38.0^b	38.2^a	0.468	0.03
Floor temperature under the sow (°C)					
Morning	35.3^a	29.3^b	33.7^b	1.095	0.01
Afternoon	36.5^a	30.9^b	35.1^b	1.152	0.01

[1] Residual standard deviation.
[2] From an analysis of variance whereas, within a line, means with different superscripts are significantly affected by treatment ($P<0.10$). ns = not significant.

The results of the sows' behavioural activities during the lactation period are shown in Table 6. The treatments influenced the behaviour of the sows, where the T1 sows showed higher ($P<0.01$) frequencies of visits to the feeder (26 vs. 21 vs. 12 times, respectively for T1, T2 and T3) and drinker (34 vs. 27 vs. 22 times, respectively for T1, T2 and T3). The time spent at the drinker was also influenced ($P<0.01$) by the treatments, whereas T3 sows spent more time than T1 and T2 sows (32 vs. 23 min, respectively). The T3 sows showed a higher ($P=0.07$) frequency of breast feeding than the other treatment sows (39 vs. 33 times). Regarding the other activities evaluated, T1 and T2 sows were found to spend more time ($P<0.01$) performing other activities during 24 h than sows maintained in T3 (50 vs. 51 vs. 22 min, respectively for T1, T2 and T3).

4. Discussion

The effect of high ambient temperature on the performance of lactating sows is well known in the literature (De Bragança et al., 1998), with negative effects on performance and behaviour when ambient temperature rises above the

Table 6
Effect of the type of farrowing room on the time and frequency of behavioral activities during a 28-d lactation.

Variables	T1	T2	T3	CV(%)	RSD[1]	Statistical analysis[2]
Number of sows	10	8	9			
Feeder						
Feeding (min/d)	94	94	108	29.4	29.0	ns
% time spent	6.5	6.5	7.5	-	-	-
Frequency (N°. of times)	26[a]	21[a]	12[b]	50.2	9.6	0.01*
Drinker						
Water drinking (min/d)	23[a]	23[a]	32[b]	45.2	11.6	0.01
% time spent	1.6	1.6	2.2	-	-	-
Frequency (N°. of times)	34[a]	27[b]	22[b]	38.1	10.3	0.01
Nursing						
Nursing (min/d)	217	216	231	21.1	46.7	ns
% time spent	15.1	15.0	16.1	-	-	-
Frequency (N°. of times)	33[a]	33[a]	39[b]	24.2	8.5	0.01
Lateral recumbency (min/d)	986	999	999	7.1	87.3	ns
% time spent	68.5	69.5	69.5	-	-	-
Standing (min/d)	70	54	45	71.2	39.7	ns*
% time spent	4.9	3.8	3.9	-	-	-
Other postures (min/d)	50[a]	51[a]	22[b]	79.9	32.0	0.01*
% time spent	3.5	3.5	1.5	-	-	-

*Kruskal-Wallis test; ns = not significant.
[1] Residual standard deviation.
[2] From an analysis of variance whereas, within a line, means with different superscripts are significantly affected by treatment ($P<0.05$).

evaporative critical temperature of the sow (i.e., 22 °C, Quiniou and Noblet, 1999). Under our tropical humid conditions, the average minimum and maximum temperatures observed in the conventional farrowing rooms (21.0 ± 1.5 and 25.7 ± 2.5 °C) and the average minimum and maximum temperatures observed in the semi-outdoor farrowing rooms (20.7 ± 0.9 and 26.5 ± 3.4 °C) frequently exceeded 22 °C. Therefore, lactating sows suffered from heat stress most of the time in our experimental conditions. The RH was high during the experimental period (76% and 78% on average, respectively for the conventional and semi-outdoor pens). This high humidity is due to the rainy season, which occurs during the summer period in this region of the country. This may have contributed to affect the behaviour and performance of the sows in the different types of farrowing rooms during our study, especially by fostering the feed intake of sows offered the control treatment.

The sows from the semi-outdoor farrowing pens were exposed to higher ambient temperature variations than the sows exposed to the conventional farrowing rooms (5.8 vs. 4.7 °C, respectively). This difference can be attributed to the fact that the building of the semi-outdoor farrowing room was not provided with adequate insulation against sun radiation, which allowed the higher temperature variation observed. According to Hötzel et al. (2004), the lack of insulation walls leads to the overnight falling temperatures and does not protect against the daytime radiation. Under our tropical conditions, an average BGHI of 74 was observed during the study for all treatments. According to Turco et al. (1998), the discomfort zone for lactating sows is characterised by a BGHI value of 72, whereas below this value the sows can be considered under thermal comfort. This observation is consistent with the increase of rectal temperature (i.e., +0.4 °C on average for T1 and T3 sows) and increase of the respiratory rate (i.e., +18; +5.7; +14.9 breaths min^{-1}, respectively for T1, T2 and T3 sows) observed between the morning and the afternoon. As an increase in the respiratory rate is one of the physiological mechanisms used by pigs to increase heat loss to the environment (Renaudeau et al., 2005), the response observed for the sows from T1 and T3 groups would indicate a greater thermal discomfort to which these animals were exposed. Differently from the sows of T1 and T3 groups, the sows of the T2 group did not require use of their physiological mechanisms, as that the floor was efficiently cooled to keep them in thermal comfort. The floor-cooling treatment improved the efficiency of the sensible heat loss between the animal and the floor as a result of an increase in the temperature gradient between the sow's body and cooled floor, thus favouring homoeothermic balance.

The higher surface temperatures observed for T1 and T3 sows are attributed to an increase in peripheral blood circulation as a way to dissipate body heat. Confirming a possible relationship between surface temperature and body-heat loss, Collin et al. (2002), Quiniou and Noblet (1999) and Renaudeau et al. (2003) reported rises in the surface temperatures of lactating sows when the environmental temperature increased from 20 to 28 °C. The floor cooling under the T2 sows affected the temperatures of neck and chest. These results are similar to those obtained by Silva et al. (2006, 2009c)). The response observed for the sows of the cooled floor can indicate that these animals were more efficient in losing heat by non-evaporative mechanisms (by the cooled floor) than by respiration.

The increase in feeding time observed for the T3 sows (i.e., 6.5% vs. 6.5% vs. 7.5%, respectively for the T1, T2 and T3 sows) in this study also explains the higher feed intake of these animals. The highest feed intake of sows in numerical values of this treatment also led to higher intakes of lysine and digestible energy. However, all treatments had intake of lysine and energy needed to keep MP similar. According to Dourmad et al. (1998), digestible lysine intake above 46 g day^{-1} by the sow maintains the MP within the normal range for the species.

Nevertheless, the sows from the T1 group showed a shorter meal time but a higher frequency of visits to the feeder. These results can be explained by the diurnal feeding behaviour of the sows. At constant daily temperatures in temperature-controlled rooms (Quiniou et al., 2000b; Renaudeau et al., 2002), or with experimentally generated nycthemeral fluctuations of daily temperature (Quiniou et al., 2000a) or under naturally fluctuating temperatures (Gourdine et al., 2006; Renaudeau et al., 2003; Silva et al., 2009b,c), two peaks of feeding activity occur during the day. One peak is observed in the morning, and the other is observed before the beginning of the night. Our results, under naturally fluctuating temperatures, agree with these observations. In a same way, Martins et al. (2008), studying lactation behaviour of sows, also verified that the animals showed two peaks of consumption, one early in the morning and the other late in the afternoon. The lower feed intake observed in our study for the floor-cooling sows differs from those findings of Silva et al. (2006, 2009c). The later authors observed a higher voluntary feed intake for the cooled-floor sows and attributed it to the fact that the cooling of the floor improved the efficiency of the sensible heat loss between the animals and the floor as a result of an increase in the temperature gradient, thus strengthening the notion that the sows did not need to reduce their voluntary feed intake to maintain homoeothermic balance. The explanation for the differences between our findings and the later authors could be related to the lower maximum temperatures observed in our farrowing rooms (i.e., 26.1 vs. 29.5 °C), characterising a less effective heat stress.

The higher time spent at the drinker by the T3 sows can be related to the higher temperatures observed in the semi-outdoor farrowing rooms; this increase in water consumption could have been to compensate the thermal discomfort experienced by these animals. Similar results were obtained with the use of drinking chilled water on the performance of lactating sows under heat stress. Jeon et al. (2006) found an increase of 40% in voluntary feed intake when sows had access to chilled water; the authors attributed this increase in the feed intake to the fact that chilled water absorbs more heat than non-chilled water, thus improving the thermoregulation process of the sows. In addition, the drinker model may also have contributed to the behavioural differences. In the semi-outdoor farrowing rooms, the drinker was of the nipple kind, while in the conventional farrowing pen the drinker was of the bowl kind.

The animals submitted to treatment with access to the outdoors may have benefitted from the installation type because these farrowing pens were provided with ceramic roofs and cement floors; and this may have affected the skin-surface temperatures, as the sows of the T1 had higher skin-surface temperatures than the sows of the T3, and this can be associated with a better animal welfare and consequently with their more efficient thermoregulation.

By studying the behaviour and welfare of lactating sows, Levrino and Robinson (2003) observed that lactating sows in outdoor systems had better welfare conditions when compared with sows kept in farrowing pens with cages. As observed as regards physiological parameters (temperature of the neck and leg in contact with the floor in the morning and temperatures of the floor in the morning and afternoon) and behaviours (higher frequency of nursing, less time standing and in other postures), the sows kept in the semi-outdoor farrowing pens had better welfare conditions when compared with sows kept in conventional farrowing pens without floor cooling (T1). According to Broom (1991), when the animals are in a position of discomfort they tend to have stereotyped behaviours. Martins et al. (2008) observed that sows under heat stress remained a greater time in lateral recumbency and/or lying on the udder, which according to these authors can be related to thermal discomfort. Hötzel et al. (2004) also observed higher frequencies of abnormal behaviours and more time spent on lateral recumbency and/or lying on the udder in lactating sows in conventional farrowing crates when compared with sows in outdoor systems.

Although the sows in conventional farrowing crates with cooled floor spent more time in other postures, similar to sows of T1, the effects of floor cooling on the sows can be observed, as these animals showed a lower incidence of abnormal behaviours, such frequency to go in the water drinker without needing to drink water (i.e., 34 vs. 27, respectively for T1 and T2) and the frequency of stay standing (i.e., 4.9 vs. 3.8 for T1 and T2). Silva et al. (2006, 2009c) observed that sows kept on conventional floors spent more time doing other activities during a day than sows kept on cooled floors.

The treatments do not affect significantly the performance parameters, with exception of weight loss of sows in weaning. At the beginning of the experiment, the lack of a difference in BW and BFT of postpartum sows between treatments indicates that the three groups of animals started the experiment with similar body conditions. This fact is relevant, as the body condition of sows after farrowing is one of the factors that might influence their performance during the lactation period (McNamara and Pettigrew, 2002). The T1 sows lost 8.2 kg more BW than the T2 sows and 16.6 kg more than the T3. It can be hypothesised that the T1 sows mobilised more body reserves to maintain their production potential and to adapt to the thermal environment. The BW loss of T2 sows indicated that floor cooling of improved the environmental conditions of the sows and moved away the piglets due to the lower floor temperatures, reducing deaths by crushing, especially in the first days after birth. Moreover, these sows lost less weight, consumed less food and kept the production of piglets.

The higher piglet mortality observed for the T3 sows can be related to the absence of the protective cage bars for piglets, as the highest cause of death was by crushing. Moreover, according to Manteca and Gasa (2005), the fenced fields are a challenging environment for the piglets, due to the fact that they are more exposed to severe weather variations and highest immunological challenges.

Although the T3 sows had higher nursing frequency than sows of T1 and T2 groups, still this was not sufficient to influence milk yield. Therefore, it is possible to infer that the welfare conditions of sows in semi-outdoor farrowing pens were not sufficient to permit increase in the MP capacity, as the maintenance energy may have increased due to higher displacement of the sows in the semi-outdoors systems and they had more heat loss to the environment (especially at night, where normally, there is a decrease of the ambient temperature).

The higher frequency of nursing was not enough to change the intake, although these sows have stayed more time at the feeder (6.5% vs. 7.5% for T1 and T3). The more energy spent by the T3 sows during the 2 h spent on the field did not affect the milk yield or the energy efficiency for production, because although they were more exposed to ambient-temperature variations they showed better behaviours and physiological parameters than T1 sows.

The thermal discomfort, to which the T1 sows were submitted, was not sufficient to reduce feed intake, but it may have been responsible for the deviation of the energy from milk synthesis to heat dissipation to maintain body homeothermy. Conversely, the welfare conditions of the T3 sows may have favoured the feed intake to ensure satisfactory MP with excess of energy to ensure BW gain. The results obtained from the semi-outdoor farrowing pens (T3) was not equal to or greater than the results of conventional farrowing pens, mainly due to the higher mortality rates observed in this treatment.

5. Conclusions

Cooling the floor under the sow in the conventional farrowing room or the use of semi-outdoor farrowing rooms improves the thermal environment and the lactation efficiency of the sows housed in hot ambient temperatures at 28-day lactation in the summer period, indicating an improved welfare.

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