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Effect of Different Systems for the Control of Environmental Temperature on the Performance of Sows and Their Litters*

Oscar Ernesto dos Santos Morales[1], Márcio Antônio Dornelles Gonçalves[1], Andressa Alves Storti[2], Mari Lourdes Bernardi[3], Ivo Wentz[1] & Fernando Pandolfo Bortolozzo[1]

ABSTRACT

***Background*:** In tropical and subtropical regions, temperature values above thermoneutrality for pigs are often experienced and lactating sows maintained outside the thermal comfort zone might have their performance compromised. The use of ventilation or evaporative cooling to maintain animal thermoregulation might be alternatives to minimise animal production losses. The objective of this study was to evaluate the influence of three different systems for the control of environmental temperature on the productivity of sows and their litters.

***Materials, Methods & Results*:** Three systems of environmental temperature control were evaluated: air-conditioned: AC (n = 79), with farrowing facility temperature controlled by a system of evaporative cooling pads combined with negative pressure ventilation; snout cooler: SC (n = 82), with a cold air outlet directed toward sows, combined with management of curtains; and management of curtains: MC (n = 83). Piglet weight was recorded at cross-fostering, and at 14 and 20 days of age. Temperature (TEMP) and relative humidity (RH) were measured daily at five time points (8:00, 10:00, 12:00, 14:00 and 16:00 h). The variables concerning the sows were analysed with the MIXED procedure of SAS, including the fixed effect of system and random effects of period and period × system interaction. The weight of piglets, TEMP and RH inside the farrowing facility were analysed as repeated measures using the MIXED procedure. Means were compared with the Tukey-Kramer test. The weight of sows at farrowing, the number of cross-fostered piglets and weight of piglets at cross-fostering were similar among the systems ($P > 0.10$), with overall means of 241.2 kg, 11.4 piglets and 1.4 kg, respectively. In the AC system, TEMP (23.1ºC) was on average lower ($P < 0.05$) than in the SC (26.8ºC) and MC (26.8ºC) systems. Overall, higher RH ($P < 0.05$) was observed in AC (88.3%) than in SC (74.5%) and MC (73.6%) systems. Sows of the MC system had a lower daily feed intake (DFI) than AC sows ($P < 0.05$) and tended (P = 0.082) to have lower DFI than SC sows (4.7 vs. 5.2 vs. 5.1 kg for MC, AC and SC sows, respectively). There were no differences ($P > 0.10$) among AC, SC and MC systems regarding sow weight loss during lactation (3.3% vs. 5.0% vs. 4.0%) and weaning-to-estrus interval (4.5 d vs. 5.0 d vs. 4.5 d). The number of weaned piglets was similar among the systems ($P > 0.10$) with an overall mean of 10.8 weaned piglets. The weight of piglets at weaning tended to be lower ($P = 0.083$) in the MC than the SC system (5,977 g vs. 6,209 g), whereas piglets of the AC system had an intermediate weight (6,152 g).

***Discussion*:** The temperature in SC and MC systems was above the upper critical temperature for sows, mainly between 12:00 and 16:00, which could explain the lower feed intake of sows in the MC system. The higher feed intake of SC sows compared to MC sows is probably related to the microenvironment created by the fresh air over the heads of SC sows improving their thermoregulation and comfort, and preventing a reduction in feed intake. The AC system was the most efficient in reducing the temperature in the farrowing facility. However, the higher feed intake of AC sows compared to that of MC sows did not result in differences in piglet weight. As the temperature in the AC system was close to the lower critical temperature for the piglets, heating provided to piglets was probably insufficient and they required an extra energetic demand for heat production to maintain their body temperature. The higher weight of SC piglets is probably explained by the higher feed intake of sows and by the fact that temperature in the farrowing facility did not decrease as in the AC system.

Keywords: cooling systems, feed intake, temperature, humidity, lactating sows.

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*Article based on a Dissertation submitted by the senior author in partial fulfillment of requirements for the Doctor's Degree, Graduate Program in Veterinary Sciences (PPG-CV), Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil. [1]Setor de Suínos, Faculdade de Veterinária (FaVet)-UFRGS, Porto Alegre. [2]Faculdade de Veterinária, Universidade Federal de Uberlândia (UFU), Uberlândia, MG, Brazil. [3]Departamento de Zootecnia, Faculdade de Agronomia-UFRGS, Porto Alegre. CORRESPONDENCE: F.P. Bortolozzo [fpbortol@ufrgs.br - Tel.: +55 (51) 3308-6132]. Av. Bento Gonçalves n. 9090, Bairro Agronomia. 91540-000 Porto Alegre, RS, Brazil.

INTRODUCTION

Temperatures above the thermal comfort zone (TCZ) are often experienced during pig production in tropical and subtropical regions. The greatest challenge regarding the maintenance of the environmental comfort of pigs occurs in the farrowing facility because it has two categories of animals, i.e., sows and piglets, with very different TCZs [14]. The thermoneutrality for lactating sows is characterised by temperatures ranging between 12 and 22ºC [4], and the upper critical temperature (UCT) is above 22-25°C [4,8,17].

The negative effect of high temperature during hot seasons on the reproductive performance of sows has been reported in several studies [7,13,24]. Sows exposed to temperatures above 25°C might have a reduced feed intake, milk yield and poor performance of their piglets [15-17]. Due to a lower feed intake, sows increase the mobilisation of body reserves, which might also compromise their subsequent reproductive performance [20].

The use of ventilation or evaporative cooling in the farrowing facility to improve thermoregulation of sows might be one alternative to reduce production losses. The objective of this study was to evaluate feed intake and weight loss of sows during lactation as well as the litter performance under three different systems used to control the environmental temperature.

MATERIALS AND METHODS

The study was conducted in a commercial sow farm in southeastern Brazil, in the state of Minas Gerais, Alto Paranaíba region, during the summer period (between December and March). A total of 244 sows (Landrace x Large White, Agroceres PIC®) were allotted to a randomised complete block design with three systems of environmental temperature control: air-conditioned - AC (n = 79), with farrowing facility temperature controlled by a system of evaporative cooling pads combined with negative pressure ventilation; snout cooler - SC (n = 82), with a cold air outlet directed towards the sows, combined with management of curtains, and management of curtains - MC (n = 83), where the environmental conditions were controlled only by the management of curtains. Sows were randomly distributed among the systems according to the parity order, which averaged 3.6 ± 0.37 farrowings.

The farrowing facilities had a roof made of clay tiles. In the MC and SC rooms, the short wall side, made of masonry, was 1.5 m in height with curtains on both sides of the room. In the AC room, the wall side was entirely made of masonry. Farrowing rooms had the following dimensions: 12.0 m width, 14.0 m length and ceiling height was 3.0 m. Farrowing crates were distributed in four rows of seven crates each. Farrowing crates had a fully slatted metal floor, with a central part in the crate for the sow with an area of 1.32 m^2 (0.6 × 2.2 m) and on the sides, 0.66 m^2 (0.3 × 2.2 m) as an exclusive area for the piglets. Inside the crates there were nipples to provide water in an *ad libitum* access, and feeders for sows. The heating for the piglets was provided by one heat lamp (60 watts) without the use of a creep area.

The room with an AC system had a curtain-like plastic ceiling 2.70 m from the floor and the temperature was controlled by an adiabatic evaporative cooling system provided by a set of evaporative cooling pads installed on the south side of the room, with dimensions of 7 m in length, 1.5 m in height and 0.25 m in thickness. Combined with the evaporative cooling pads, there was a system of negative pressure ventilation composed of three fans[1] of 1.27 m each located on the north side. The system of evaporative cooling pads and the negative pressure ventilation was turned on when the temperature registered on the thermostat located in the center of the room was above 24°C.

In the SC room, the air was conditioned by a system formed by evaporative cooling pads located externally, at the west end of the room, connected to a curtain-like plastic duct[2] 1.0 m in diameter. The cooled air coming from the evaporation cooling pad was pushed into the duct by means of an axial fan, and was thus conducted to the interior of the rooms. Inside the SC room, this duct was split into two independent ducts of the same diameter, located 3.0 m above the floor, one for each two rows of crates. From the two ducts, terminal ducts 12 cm in diameter ended at each cage, through which the air reached the anterior third of the cage. The SC system was turned on manually via a control panel inside the room, and was shut down in the period between 01:00 and 07:00. The management of curtains was also used together with this system.

In the MC room, the criteria for raising or lowering the curtains depended on the standard operating procedure of the farm, which takes into account the perception of the employee in relation to aspects such as light, thermal sensation, wind speed, age of the piglets, air quality and amount of gases.

When the sows reached approximately 110 d of gestation, they were moved from the gestation facilities to farrowing crates, where they were fed a corn-soybean lactation diet (18.5% crude protein and 3,600 kcal ME/kg). From their entry into the farrowing facility until farrowing, sows were fed twice a day. They received 3.0 kg/d of feed from 110 to 113 d of gestation and 2.0 kg/d until the day before the expected farrowing date. After farrowing, feed was provided with a gradual increase (0.5 kg/d) until the fourth day post-farrowing. From this time until weaning, sows were fed *ad libitum*. The daily feed intake (DFI) was determined by the difference between feed delivery and refusals collected daily before the first feeding in the morning.

Weight and backfat thickness (BT) at farrowing were measured within a period of 24 h post-farrowing. The sows were also weighed at weaning. BT was measured by A-mode ultrasound[3] at the last rib (P2 standard position), about 6 cm from the midline, on both sides.

Piglets were tattooed and individually weighed. Litters were cross-fostered up to 24 h after birth. Pigs were again weighed when 14 and 20 d old. From the sixth day of age until weaning, piglets were creep fed with a diet containing 22% crude protein and 4,060 kcal/kg (0.250 kg of feed per litter/d).

Room temperature and relative humidity (RH) were measured daily with a digital dry bulb thermometer[4]. Measurements of current temperature and RH were performed five times daily (at 08:00, 10:00, 12:00, 14:00 and 16:00). Maximum and minimum values for the temperature and RH were recorded daily at 09:00.

The comparison of the three systems was performed at three different time points, designated as periods for purposes of statistical analysis. The interval between the first and second period was 27 d and was 32 d between the second and third one. Three farrowing rooms were used simultaneously in each period, each one being subjected to one of the three systems of temperature control. In each period, 25 to 28 sows were evaluated for each system.

All statistical analyses were performed using SAS software [21]. Sow weight and BT, the number of piglets per litter after cross-fostering, weight of the piglets at cross-fostering, the DFI of sows during lactation, weight loss of sows during lactation, weaning-to-estrus interval (WEI), minimum and maximum temperature and minimum and maximum RH were analysed using the MIXED procedure of SAS. The system was considered a fixed effect, whereas period and period × system interaction were included as random effects.

The piglets were weaned between 19 and 21 d of age, the weight being adjusted to that at 20 d of age. Piglet weight was analysed as a repeated measure by the MIXED procedure, considering the litter as the experimental unit. The model included the fixed effects of the systems, day of weighing and interaction between these factors. The effect of period as well as of period × system interaction were included as random effects, and the weight of litter at cross-fostering was included as a covariate. For the temperature and RH data, which were measured five times a day, the analysis was performed using the MIXED procedure for repeated measures. Included in the model were fixed effects of system, time of day, system × time of day interaction, random effects of period and period × system interaction. Maximum and minimum temperature and RH were analysed with the MIXED procedure including the fixed effect of system and random effects of period and period × system interaction. Means were compared by the Tukey-Kramer test, considering the level of 5% as significant and between 5 and 10% as a trend. Data are presented as means ± standard error of the mean.

RESULTS

The weight and BT of sows at farrowing, and the number and weight of piglets after cross-fostering per sow were similar between systems ($P > 0.10$), with overall means of 241.2 ± 3.0 kg, 13.0 ± 0.24 mm, 11.4 ± 0.08 piglets and 1.4 ± 0.02 kg, respectively.

Room temperature increased significantly from 8:00 to 14:00 in all systems, but was lower in the AC system than in SC and MC systems ($P < 0.05$; Table 1). The minimum and maximum temperatures were higher in SC and MC systems than in the AC system ($P < 0.05$; Table 1). There was an effect of the interaction system × time of the day on humidity. In the AC system, the humidity at noon was similar to that observed at 8:00 and 10:00 am, whereas it had significantly decreased at 10:00 in MC and at noon in the SC system ($P < 0.05$). Higher humidity was observed at 8:00 and 10:00 than at 14:00 and 16:00 in all systems ($P < 0.05$). The AC system showed a higher average, minimum and maximum RH compared to SC and MC systems ($P < 0.05$, Table 1).

Table 1. Temperature and relative humidity (RH) inside the farrowing facility according to the systems used for the control of environmental temperature (means ± SEM).

Variable	AC	SC	MC	Overall mean
Temperature - minimum, ºC	19.7 ± 0.25a	23.3 ± 0.26b	22.7 ± 0.26b	---
Temperature - maximum, ºC	25.3 ± 0.27a	29.2 ± 0.29b	29.5 ± 0.28b	---
Temperature - 8 h, ºC	20.7 ± 0.12	25.0 ± 0.12	24.7 ± 0.12	23.5 ± 0.07A
Temperature - 10 h, ºC	22.5 ± 0.17	25.9 ± 0.17	26.0 ± 0.17	24.8 ± 0.10B
Temperature - 12 h, ºC	23.5 ± 0.17	26.8 ± 0.17	27.0 ± 0.17	25.8 ± 0.10C
Temperature - 14 h, ºC	24.4 ± 0.21	28.0 ± 0.21	28.3 ± 0.21	26.9 ± 0.12D
Temperature - 16 h, ºC	24.4 ± 0.23	28.1 ± 0.23	28.1 ± 0.23	26.9 ± 0.13D
Overall mean, ºC	23.1 ± 0.13a	26.8 ± 0.13b	26.8 ± 0.13b	---
RH - minimum, %	81.0 ± 1.74a	63.1 ± 1.78b	60.5 ± 1.76b	---
RH - maximum, %	93.1 ± 0.92a	83.2 ± 0.93b	82.4 ± 0.92b	---
RH - 8 h, %	90.5 ± 0.80A	80.0 ± 0.80A	79.4 ± 0.80A	83.3 ± 0.67
RH - 10 h, %	90.5 ± 0.87A	78.9 ± 0.87A	77.9 ± 0.87B	82.4 ± 0.70
RH - 12 h, %	89.3 ± 1.09A	75.4 ± 1.09B	74.3 ± 1.09C	79.6 ± 0.80
RH - 14 h, %	85.9 ± 1.36B	69.9± 1.36C	68.6 ± 1.36D	74.8 ± 0.92
RH - 16 h, %	85.2 ± 1.38B	68.5 ± 1.38C	67.9 ± 1.38D	73.8 ± 0.93
Overall mean, %	88.3 ± 1.04a	74.5 ± 1.04b	73.6 ± 1.04b	---

AC: Air-conditioned; SC: Snout Cooler; MC: Management of Curtains; SEM = standard error of the mean. a,b in the same row, indicate significant differences ($P < 0.05$). A,B,C, D in the same column indicate significant differences ($P < 0.05$).

Sows in the MC system had a lower DFI ($P < 0.05$) than sows in the AC system and tended ($P = 0.082$) to have a lower DFI than sows in the SC system (Table 2). Weight loss during l actation and WEI were not different ($P > 0.10$) among systems (Table 2).

Sows weaned on average 10.8 ± 0.07 piglets without any difference among systems ($P > 0.10$). The weight of the piglets tended to be lower ($P = 0.083$) in the MC than in the SC system, whereas piglets in the AC system had an intermediate weight (Table 3).

Table 2. Average daily feed intake, weight loss during lactation and weaning-to-estrus interval (WEI) of sows according to the systems used for the control of environmental temperature in the farrowing facility (means ± SEM).

Variable	AC	SC	MC
Number of sows	79	82	83
Feed intake/sow/d, kg	5.2 ± 0.16AB	5.1 ± 0.16B	4.7 ± 0.16C
Weight loss*, kg	8.4 ± 1.55	12.7 ± 1.50	9.6 ± 1.52
Weight loss*, %	3.3 ± 0.63	5.0 ± 0.61	4.0 ± 0.62
WEI, days	4.5 ± 0.23	5.0 ± 0.21	4.5 ± 0.22

AC: Air-conditioned; SC: Snout Cooler; MC: Management of curtains; SEM = Standard error of the mean. Different letters in the same row indicate significant differences (AB x C; $P = 0.039$) or trends (B x C; $P = 0.082$). *The weight loss at 20 d of lactation was measured in 158 sows (51, 54 and 53 from AC, SC and MC systems, respectively).

Table 3. Weight of piglets at 14 and 20 d according to the systems used for the control of environmental temperature in the farrowing facility (means ± SEM).

Variable	AC	SC	MC	Overall mean
Number of litters	79	82	83	
Weight at 14 days, g	4552.5 ± 103.0	4700.6 ± 102.0	4437.7 ± 101.9	4563.6 ± 92.8A
Weight at 20 days, g	6152.1 ± 112.1	6209.2 ± 110.4	5977.0 ± 110.2	6112.8 ± 96.0B
Overall mean	5352.3 ± 106.6ab	5454.9 ± 105.3b	5207.4 ± 105.2a	

AC: Air-conditioned; SC: Snout Cooler; MC: Management of curtains; SEM = Standard error of the mean. A,B in the same column indicate significant difference ($P < 0.05$). a,b in the same row indicate a trend to be significant ($P = 0.083$).

DISCUSSION

The lower ambient temperature observed in the AC system proved its effectiveness in decreasing room temperature by air humidification [1]. The similarity in temperature between SC and MC systems indicates that directing cool air over the heads of the females with the SC system did not alter the room temperature. The mean room temperature recorded at different times of day in SC and MC rooms was near, or above 25°C, indicating that sows in these systems were under thermal stress most of the time. The UCT for sows is between 22 and 25°C [4,8,17] and sows housed at a room temperature of 28ºC are considered to be in thermal stress [19]. It is recommended that the farrowing room temperature should be below 27ºC and never above 29ºC [5]. The mean maximum temperature recorded in the SC and MC systems was above 29ºC, showing that at some points during the day, critical values above UCT were reached. These high temperatures can lead to decreased performance of sows and their litters by decreasing feed intake and increasing the mobilisation of body reserves [20].

The higher feed intake of sows in the AC system might be due to the lower temperature observed with this system, which was close to the TCZ of lactating sows. In several studies, a negative association was found between temperature and voluntary feed intake in the farrowing facility [11,15-17,22]. A decrease of 25% (5.5 to 4.1 kg) and 12% (5.2 to 4.6 kg) in daily feed intake has been reported when the temperature ranged from 16ºC to 27ºC and 21ºC to 27ºC, respectively [9]. Although it has been reported that the reduction in feed intake of sows of approximately 200 kg, is 0.17 kg/d for each 1°C increase in temperature between 16 and 32°C [4], the relationship between voluntary feed intake of lactating sows and the temperature is quadratic, with a marked reduction when the temperature exceeds 25ºC [17]. As the SC system did not have a reduced room temperature, the increase in feed intake of SC sows compared to that of MC sows might be attributable to a possible favorable microenvironment generated by cold air over the sow, helping the sow to be within the TCZ. A beneficial effect on feed intake was also observed [10] for sows exposed to an environmental temperature of 30°C in rooms with a system similar to the SC one.

Both temperature and RH affect thermoregulation and animal comfort. The optimal RH for pigs is between 60 and 80%; the increase of RH from 45 to 90%, at a temperature of 21°C, is responsible for reducing heat losses up to 8% [12]. Lactating sows under tropical climate conditions have a reduced feed intake compared to sows maintained in an environment with a RH close to the ideal, showing that high RH increases the negative effects of high temperatures [18]. In the present study, the RH recorded in the AC system was above the considered ideal for lactating sows, suggesting that sows kept in this system might have had a higher feed intake if the RH was not so high.

Although feed intake of sows in the AC system was higher than that for MC sows, the weight of their piglets was similar, which is probably explained by the fact that the temperature in AC rooms was below the lower critical temperature (LCT) for piglets. The LCT for piglets ranges from 34ºC to 33ºC and to 30ºC, at birth, on the first day of life and for the second to the fifth days of life, respectively [3]. When the room temperature is below the TCZ for piglets, usually there is a creep area to offer a warm environment for the piglets [14]. In the present study, heating was supplied to piglets by a heat lamp in all the systems, without an enclosure area specifically adapted for the piglets. Possibly, the lack of an enclosed and warm area was more damaging for the piglets in the AC system, in which the temperature was lower and the RH higher. Piglets are born with low body reserves and low thermal insulation capacity [6]. If the temperature is below the LCT for piglets, even if there is a heat source, their growth rate is compromised compared to piglets reared within their TCZ [4]. The fact that the temperature in the AC system was below the LCT for piglets [8] probably contributed to a greater energy loss to maintain their body temperature, impairing their development up to weaning. Room temperature was similar between SC and MC systems, but thermal comfort provided to SC sows contributed to an increase in their feed intake, therefore resulting in a higher weight of their piglets. Moreover, the higher temperature in SC rooms probably also helped to avoid the energy expenditure of piglets to maintain their body temperature as postulated for AC piglets.

Changes in the environment leading to changes in suckling behavior can affect the comfort and consequently the performance of piglets [8]. It can be speculated that the impaired performance of piglets in the AC system might be associated with the increased noise level caused by continued operation of the fans. The noise level in the AC rooms, with fans running at maximum power, was between 60 and 75 decibels compared with values between 55 and 60 decibels measured in the other two systems. A noise level of 85 decibels is considered to be critical in preventing piglets from adequately hearing the vocalisation of the sow to stimulate suckling [2]. However, even at the noisiest time of the day, the noise level in the AC system did not reach 85 decibels, thereby weakening the hypothesis that this factor was responsible for the impaired performance of piglets in this system.

The effect of systems for the control of environmental temperature in the farrowing facility on WEI has been controversial since an increase in WEI was observed in some studies [16,23] but not in others where room temperature differed from the TCZ for sows [10,18,20,22), suggesting that high temperature has less influence on WEI than feed restriction [11]. It is possible that WEI was not affected because weight loss was similar among sows of the three systems. In addition, longer WEI has been observed when weight loss during lactation is greater than 5% for primiparous and 10% for pluriparous sows [25]. The fact that weight loss of sows in this study was overall below 5%, probably also contributed to there being no impairment of their WEI.

CONCLUSIONS

The air-conditioned system is more efficient than snout-cooler and management of curtains systems to reduce the room temperature, resulting in increased feed intake by the sows. However, as the entire room is cooled in the air-conditioned system, piglet development is impaired in this system. As cold air provides greater comfort to the sow without cooling the piglets in the snout-cooler system, the increased feed intake of sows leads to improved performance of suckling piglets.

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[2]DuctoFan, Cumberland®, Marau, RS, Brazil.

[3]Renco lean meter ®, Renco Corporation, Minneapolis, MN, USA.

[4]HT-210, Instrutherm ®, São Paulo, SP, Brazil.

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