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Spatial distribution of lactating sows in thermally controlled facilities and their productive performance during the pre-weaning phase

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Abstract – The objective of this work was to evaluate the effect of a farrowing unit with an adiabatic evaporative cooling system with negative pressure and longitudinal air flow on the catabolism and performance of lactating sows. Twenty eight multiparous sows were housed in a farrowing unit with cooling system. During the 24 days of lactation, the animals were submitted to two treatments: pad cooling, with sows close to the evaporative system, and exhaust, with sows close to the exhaust fans. The microclimatic variables temperature and humidity, as well as intake, body condition score, and litter weight, which indicate the productive performance of the sows, were assessed. The variables were subjected to mean analysis using the generalized linear model (GLM). An installation equipped with a negative pressure adiabatic evaporative system does not provide homogeneous microclimate throughout the facility, resulting in different thermal environments for the lactating sows. Placing sows near evaporative pads does not affect body condition scores and improves piglet weight and sow feed intake in the farrowing pen.

Index terms: *Sus scrofa domesticus*, animal welfare, bioclimatology, heat stress.

Distribuição espacial de porcas lactantes em instalações termicamente controladas e seu desempenho produtivo na fase pré-desmame

Resumo – O objetivo deste trabalho foi avaliar o efeito de uma unidade de maternidade com sistema de resfriamento evaporativo adiabático com pressão negativa e fluxo de ar longitudinal sobre o catabolismo e o desempenho de porcas lactantes. Vinte e oito fêmeas multíparas foram alojadas em uma unidade de parição com sistema de resfriamento. Durante os 24 dias de lactação, os animais foram submetidos a dois tratamentos: pad cooling, com porcas próximas ao sistema evaporativo, e exhaust, com porcas próximas aos exaustores. As variáveis microclimáticas temperatura e umidade, bem como o consumo, o escore de condição corporal e o peso da ninhada, que indicam o desempenho produtivo das porcas, foram avaliados. As variáveis foram submetidas à análise de médias usando o modelo linear generalizado (GLM). Uma instalação equipada com sistema evaporativo adiabático de pressão negativa não proporciona um microclima homogêneo em toda a instalação, resultando em diferentes ambientes térmicos para as porcas em lactação. Colocar as porcas perto dos respiradores evaporativos não afeta os índices de condição corporal e melhora o peso dos leitões e o consumo de ração das porcas na gaiola de maternidade.

Termos para indexação: *Sus scrofa domesticus*, bem-estar animal, bioclimatologia, estresse térmico.

Introduction

The control of the thermal environment in farrowing units aims to enhance the performance of lactating sows (*Sus scrofa domesticus*) and minimize the losses caused by heat stress, since pigs present difficulty in dissipating heat due to the absence of functional sweat glands, consequently the high metabolic rate of the lactating sow make them more sensitive to heat stress (Ribeiro et al., 2018; Seibert et al., 2018; Dourmad et al., 2022; Zhang et al., 2022). Temperatures above the thermoneutral zone, of 16 to 22ºC (Bragança et al., 1998; Ma et al., 2023), have negative effects on the reproductive aspects of sows (Bertoldo et al., 2012; Perin et al., 2016; Lucy & Safranski, 2017; Schwarz et al., 2021) and reduce their voluntary feed intake (Baxter et al., 2018; Ribeiro et al., 2018).

Although the swine production has been optimized, which led to larger facilities and higher accommodation capacity, there is less efficient air renewal, lower room temperature control, and worse thermal comfort for the lactating sows (Rigo et al., 2019). Therefore, researchers are searching for better strategies to create a favorable microclimate for the sows inside the barns, such as technologies based on wind force, water evaporation, and floor cooling, which are often combined (Godyń et al., 2020).

Ventilation over the body surface, to dissipate sensible heat, is an effective strategy for cooling the animals and controlling their homeothermy. However, ventilation over the animals hinders heat exchange, since it carries heat away, bringing the bodies to the saturation stage. The more animals dissipate heat and the longer the wind current travels, the less the thermal environment becomes homogeneous (Zhang et al., 2022).

The hypothesis of this work is that a 120-meter-long installation with a negative pressure adiabatic cooling system, an evaporative panel, and a set of exhaust fans arranged on opposite sides do not provide favorable microclimate conditions nor thermal comfort for lactating sows evenly throughout its length, resulting in a negative impact on the sow's consumption and productive performance.

The objective of this work was to evaluate the effect of a farrowing unit with an adiabatic evaporative cooling system with negative pressure and longitudinal air flow on the catabolism and performance of lactating sows.

Materials and Methods

The project was approved and followed the ethical standards established by the Ethics Committee on Animal Use of Universidade Federal de Mato Grosso do Sul (approval nº 1,057/2019).

The experiment was carried out in a commercial piglet production unit located in the municipality of São Gabriel do Oeste, in the state of Mato Grosso do Sul, Brazil (19º23'43"S, 54º33'59"W, 658 m of altitude). According to the Köppen-Geiger (Nóbrega, 2010), the climate of the region is in the transition between temperate and humid tropical, with dry winters and rainy summers. The experiment was conducted in September 2019, a period in which the average daily temperatures recorded in the region varied between 19 and 35°C (Accuweather, 2023).

Twenty-eight Camborough sows (Agroceres PIC, Rio Claro, SP, Brazil) with a high genetic potential and contemporary multiparous, with mean values of 4 of parity order and 292 kg of body weight, were housed in a farrowing unit for three days of prepartum and 25 days of lactation, divided equally into two groups. The animals had water and feed ad libitum, using nipple-type drinkers and individual feeders. The diet was based on corn and soybean meal and met the specific nutritional requirements of the Camborough genetic line. All the management, health, and biosecurity protocols were followed as described in the production standard operating procedure (SOP) and applied equally to the groups evaluated.

The facility, installed in 2013 by the producer, was oriented in an east-west magnetic direction, measuring 120 m long, with the capacity to house 240 sows and a recommended minimum space of 9 m^3 per lactating sow (Figure 1). The facility was divided into four sets of pens between aisles with no physical separation and equipped with a negative pressure adiabatic cooling system (Corti Avioeste, Cunha Porã, SC, Brazil), constant longitudinal ventilation and lateral insulation provided by curtains and screens. The pens were equipped with metal boxes fixed to a masonry base and closed wooden cages with suspended plastic floors heated to 28°C to provide greater thermal comfort for the suckling piglets.

The system consisted of three sets of cooling plates, with a circulating water curtain flow on the east side, and four exhaust fans on the west side of the installation. The mass of air sucked in comes into contact with the water curtain of the plates, cooling, humidifying, and flowing through the installation, and finally being sucked out of the installation by the exhaust fans.

The 28 sows were divided into two treatments in a randomized block design, with parity order being considered as a blocking factor. The sows were distributed in two opposite rooms in the facility: the pad cooling treatment, located in room 1, close to the evaporative plates; and the exhaust treatment, located in room 4, close to the exhaust fans. Each sow corresponded to an experimental unit, totaling 14 replicates per treatment: five sows with three reproductive cycles; four sows with four reproductive cycles; and five sows with five reproductive cycles. To select of sows for the experiment, the same expected farrowing date was considered.

The sows were transferred to the farrowing unit three days before their due date and were placed side by side in rooms 1 and 4, the pad cooling and exhaust treatments, respectively. All delivery events occurred at 115 days of pregnancy, on the due date, accompanied by a professional, not following any protocols to farrowing induction. On the farrowing day, the sows were fasted for six hours before farrowing and encouraged to drink water and eat afterwards.

The experimental period lasted 24 days, starting on the second day after farrowing, when the litters were homogenized. The management of cross fostering followed the protocol adopted by the farm, carried out separately in each treatment and block, with 13 piglets distributed equally per sow.

For the microclimate evaluation, records of dry bulb temperature, in °C, wet bulb temperature, in °C, and relative humidity were obtained using an Eztemp-10 digital thermohygrometers (Minipa, São Paulo, SP, Brazil), with humidity ranging from 0.0 to 100.0%, 0.1% resolution, 3.0% accuracy, and a temperature scale of 0 to 40°C and 40 to 70°C with accuracy of 0.5 and 1.0 and resolution of 0.1°C, installed in an empty pen between stalls with the sows being assessed in each room, at a height corresponding to the sows' metabolic center. The records were collected four times a day: 7h30, 10h30, 13h30, and 16h00. The black globe humidity index (BGHI), proposed by Buffington et al. (1981), was used to describe the thermal environment: BGHI = Tbg + 0.36×Tdp + 41.5, where Tbg is the

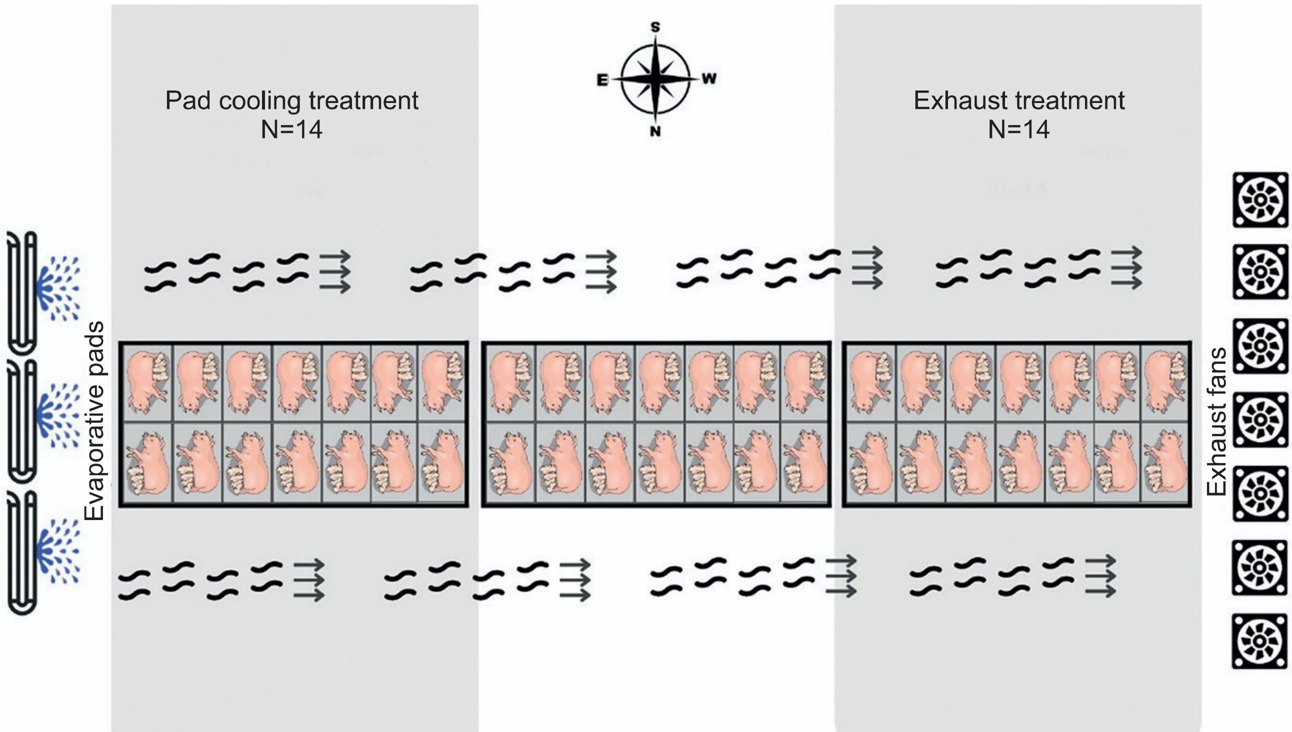

Figure 1. Representation of the installation used in the experiment, east-west oriented. The installation had evaporative plates to the east and exhaust plates to the west.

black globe temperature and Tdp is the dew point temperature. To analyze the productive performance of the sows during the lactation phase, the following variables were used: sow body condition score (BCS), individual daily food consumption of sows, weight of the sow's litter at weaning, number of weaned piglets per sow, and mortality of piglets in the litter per sow during the phase.

The BCS was measured at four intervals: on the 1st, 7th, 13th, 19th, and 24th days of the experiment, using a caliper (Knauer & Baitinger, 2015), which is a prototype to measure the dorsal angle at point P2, 6.5 cm from the dorsal midline posterior to the last pair of ribs. The instrument has three positions that describe the score: fat, ranging from 16 to 25; ideal, ranging from 13 to 15; and thin ranging from 5 to 12.

The sows were fed ad libitum four times a day: 7h, 10h, 13h, and 15h30. The diet was weighed daily using a BM-A08 portable digital hanging scale with a capacity of 50 kg, and the feed was adjusted to each sow individual consumption. The amount of feed provided at the last hour of the daily schedule was sufficient to supply the sows' consumption during the night, without restrictions. Daily feed consumption was calculated as the difference between the amount of feed provided the previous day and the feed left over at the end of the 24-hour period, corresponding to the interval between 7h on the previous day and 7h on the current day.

The piglets were weighed on days 2 and 25 postpartum, which correspond to days 1 and 24 of the experiment, respectively, using a BM-A08 portable digital scale with a capacity of 50 kg and a cloth strap wrapped around the piglet's abdomen to keep the animal suspended in a calm manner to not cause stress to the animal. Mortality during the phase was determined through daily records and was calculated by the difference in the number of piglets after uniformization and the final count of each litter at weaning.

All data was tested for normality using the Shapiro-Wilk's test. Variables that did not follow the normal distribution were transformed using the RANK procedure in SAS (SAS Inst. Inc., Cary, NC). The PROC RANK instruction with the normal option was used to produce a normalized transformed variable.

The microclimate and production-performance variables were analyzed using the generalized linear model (GLM) and compared at a 5% significance level. Parity order and initial piglet weight were used as random effects. The mathematical model used was: $Y_{ij} = \mu + T_i + B_j + e_{ij}$, where Y_{ij} is an observation in unit j in treatment i, μ is the overall mean, T_i is the spatial distribution effect, B_j is the block effect, and e_{ij} is the error associated with the observation in block j in treatment i.

To analyze daily feed consumption, the repeated measures model was applied, adopting the phase as the time interval for evaluation: 1st to 6th, 7th to 12th, 13th to 18th, and 19th to 24th days corresponding to phases 1, 2, 3, and 4, respectively.

Results and Discussion

The pad cooling and exhaust environments differed in their microclimate characteristics (Table 1). The pad cooling room, located next to the evaporative cooling system, had an average room temperature 3.2°C lower and relative humidity 16.33% higher than the exhaust room, next to the fans. The BGHI was lower for the pad cooling treatment, being in the range between 65 and 70, while the index for the exhaust treatment remained in the range between 70 and 75.

Given the results, the adiabatic evaporative cooling system with negative pressure and ventilation flowing longitudinally over a 120-meter route, promoted an inefficient homogeneous thermal environment for the lactating sows throughout its length. In industrial pig farming, homeothermic control with forced ventilation is the most common thermal mechanism, in which the convective efficiency of heat dissipation is due to the necessary temperature gradient between the air mass

Table 1. Means and standard deviation of air temperature, relative humidity, and black globe humidity index (BGHI) of sows housed in rooms with a pad cooling system and rooms with exhaust fans in a farrowing unit equipped with an evaporative adiabatic cooling system, in the municipality of São Gabriel do Oeste, Mato Grosso do Sul state, Brazil.

Microclimatic variable	Treatment		p-value
	Pad cooling	Exhaust	
Ambient temperature (°C)	21.40±1.04	24.60±1.52	<0.001(1)
Relative humidity (%)	68.51±2.30	52.18±7.10	<0.001(1)
BGHI	69.62±0.89	74.98±1.72	0.012(2)

(1)Means in the row differ by F test at 1% probability. (2)Means in the row differ by F test at 5% probability.

and the body surface. The lower the temperature of the air mass is, the greater the intensity of body heat is dissipated, resulting in a satisfactory heat-sensitive mechanism to promote better thermal comfort without producing endogenous heat (Rigo et al., 2019).

The pad cooling treatment provided better thermal comfort for the sows because of the processes of cooling and humidifying the air translocated from the plates to the inside of the facility, which was efficient in reducing the air temperature and raising the relative humidity of the air in the place closest to the air entering through the plates. On the other hand, under the exhaust fans, the cold air mass transported the surface heat of the sows along the entire length of the installation, which heated up and lost its convective capacity along the way. As a result, the sows near the air outlet of the installation were affected by the hot air mass, limiting body heat dissipation, characterizing a heat stress zone due to the raise of the ambient temperature of 22°C in approximately 3°C, the relative humidity below 55%, and the temperature index value above 74 (Williams et al., 2013; Luz et al., 2016; Wegner et al., 2016; Santos et al., 2024).

These findings contribute to the results presented by Rigo et al. (2019), who found that negative pressure cooling systems located at the opposite ends of an installation are insufficient to promote a homogeneous common microclimate that provides thermal comfort to sows in lactation phase. The increase in population of modern facilities and the high metabolic rate of contemporary sows compromise the lactation performance in the system, since there is greater production and dissipation of endogenous heat, saturating the air along the way and stopping heat exchange with the surface of the animals allocated closer to the exhaust fans.

The average weight of the litters at weaning, in kg, and the average voluntary consumption of the sows between the 19th and 24th days of lactation had different values in the two treatments, and piglet mortality reduced 2.39% in the lactation phase in pad cooling treatment (Table 2), approximately three more piglets for every 100 piglets weaned compared to the exhaust treatment. However, the voluntary consumption of the sows did not differ significantly between treatments in phases 1, 2, and 3 (Table 2).

Allocating the sows near the exhaust fans visually reflected in the greater mobilization of their body reserves: -1.000 for exhaust and -0.125 for pad cooling treatments (Figure 2). However, these values showed no statistically significant difference. In addition, body condition score remained ideal for both groups throughout the experimental period.

Although lactation is marked by the birth of the piglets, the lactation cycle involves earlier processes, from the development of the mammary gland, still in embryogenesis, to its regression after weaning the piglets (Hurley, 2019). The satisfactory development of the mammary gland enables sufficient milk production due to the endocrine response mechanisms combined with the stimulation of the piglets. Therefore, the conditions pregnant sows are subjected determine their ability to meet the needs of their litter. In the present experiment, all sows studied were housed in a common environment during pregnancy and subjected to the same health, nutritional, and environmental management, consequently, all the results found were directly associated with the spatial arrangement in which each group of sows was allocated.

Since milk is mainly composed of water, fat, protein, and lactose (Knight et al., 1994; Hui et al., 2024), efficient production depends on the mobilization of nutrients to the mammary gland. For lactogenesis,

Table 2. Mean production performance and feed intake values of lactating sows (*Sus scrofa domesticus*) subjected to a pad cooling system environment and exhaust fan environment in a farrowing unit equipped with an evaporative adiabatic cooling system, in the municipality of São Gabriel do Oeste, Mato Grosso do Sul state, Brazil(1).

Performance variable	Treatment		p-value
	Pad cooling	Exhaust	
Number of sows	14	14	
Number of piglets per sow	13	13	
Sow production performance			
Initial piglet weight (kg)	1.548±0.61	1.628±0.66	0.3204
Final piglet weight (kg)	7.211±0.69	6.414±0.78	0.0062
Piglet mortality (%)	7.735±1.44	10.130±2.13	0.0816
Sow feed intake(2)			
Phase 1	5.167±0.52	5.029±0.46	0.5696
Phase 2	6.437±0.64	6.605±0.53	0.5429
Phase 3	6.951±0.82	6.758±0.88	0.4718
Phase 4	7.676±0.65	6.659±0.62	< 0.001

(1)Means in the row differ by F test at 1% and 5% probability. (2)Phase 1, days 2 to 7 postpartum; phase 2, days 8 to 13 postpartum; phase 3, days 14 to 19 postpartum; and phase 4, days 20 to 25 postpartum.

this mobilization is regulated by homeorhesis, which coordinates the distribution of nutrients in the body, both via portal vein and by mobilization of body reserves, a characteristic shared by female mammals of various species due to the high energy demanded to produce milk (Hartmann et al., 1997; Daniel et al., 2018). Therefore, lactating sows under heat stress may show a deficit in milk synthesis due to greater mobilization of resources to regulate body temperature, compromising the production and composition of milk, as well as the piglets' feeding frequency (Barros et al., 2008; Baxter et al., 2018, Ma et al., 2023).

The milk production of each sow and the daily milk intake of the piglets were not calculated; however, sows under the heat stress environment weaned piglets 800 g lighter, which increased the time for them to reach slaughter weight. Therefore, the lower weaning weight makes it possible to state that the piglets from heat-stressed sows had lower milk intake. These results corroborate Williams et al. (2013), who observed decreases of up to 500 g in the weight of piglets compared to piglets from sows housed in a thermally comfortable environment. In another experiment, researchers observed a reduction in litter weight at ten days of age and at weaning (18% and 17% lower, respectively) in sows subjected to temperatures between 28 and 30°C (He et al., 2019).

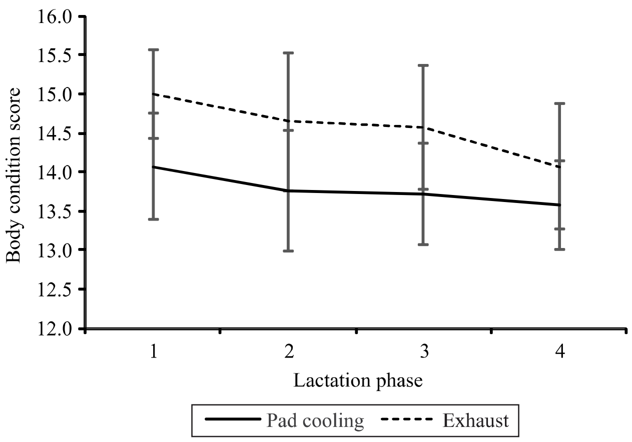

Figure 2. Body condition score of lactating sows (*Sus scrofa domesticus*) housed in a pad cooling system environment and exhaust fan environment in a farrowing unit equipped with an adiabatic evaporative cooling system, in the municipality of São Gabriel do Oeste, Mato Grosso do Sul state, Brazil.

Increasing the temperature to values below or above the thermal comfort range required by sows causes stress and disorientation, which can alter the consumption and feed intake capacity of the animals. The results of the present study showed that the housing location was the factor that limited daily feed intake, since the group submitted to the exhaust treatment maintained a lower consumption plateau in the last phase compared to the group subjected to the pad cooling treatment, which daily consumed approximately 1 kg more feed in the last six days of lactation, providing more nutrients to the mammary gland and, visibly, less mobilization of body reserves.

In this scenario, besides changes in feed intake, sow-piglet interaction was also affected. Although the results for piglet mortality in the pre-weaning phase showed no difference, three more piglets out of every 100 weaned could result in greater economic profitability for the system. The tendency towards higher mortality indicates that a thermal environment that does not meet ideal comfort can influence not only the productive performance, but can also modulate the social behavior of sows with their litters, affecting the sows' mood and reactivity, showing that the topic is relevant for future researches. Additionally, more studies on the sow-piglet relationship should be carried out.

Conclusions

1. An installation equipped with a negative pressure adiabatic evaporative system does not provide homogeneous microclimate throughout the facility, resulting in different thermal environments for the lactating sows.
2. Placing sows near evaporative pads does not affect body condition scores and improves piglet weight and sow feed intake in the farrowing pen.

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