PERFOMANCE OF AN EVAPORATIVE COOLING SYSTEM OF A FINISHING PHASE SWINE BARN

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ABSTRACT: The thermal environment inside of a finishing phase swine barn has great influence on the success of swine production. This environment can be characterized by the black globe temperature and humidity index (BGHI), that represents the air temperature, humidity, wind speed and radiation. Due to the small number of Brazilian reports on this specific subject, this experiment was performed to verify the effect of one kind of evaporative cooling system on the thermal comfort of the animal in a swine barn, during the 98/99 summer at Patos de Minas, MG, Brazil. Two constructions were used, divided in 36 barns, each one with 15 animals, 110 to 150 days old. Along a side of one barn, four cooling devices were installed, with a ventilation system connected to a sprayer, to form an evaporative cooling system (ECS). The other barn did not have any cooling system being a control unity (COS). The ECS provided an improvement of the environmental thermal conditions, reducing the index of black globe temperature and humidity inside the building, from 83.5 to 82.4, during the critical period of the day (2 p.m.). The ECS provided also an improvement of the food conversion, from 3.27 to 2.88, and a tendency of a substantial weight gain, from 0.97 to 1.02 kg per day.
Key words: ventilation, thermal environment, thermal comfort

DESEMPENHO DE UM SISTEMA DE RESFRIAMENTO EVAPORATIVO EM INSTALAÇÕES PARA SUÍNOS EM FASE DE TERMINAÇÃO

RESUMO: O ambiente térmico no interior das instalações para suínos em fase de terminação tem importância vital para o sucesso da atividade suinícula. Esse ambiente pode ser representado pelo índice de temperatura de globo e umidade (ITGU), que inclui a temperatura, a umidade relativa e a velocidade do ar, e a radiação. Baseado nisto foi desenvolvido um trabalho com o objetivo de avaliar o efeito de um sistema de resfriamento evaporativo no conforto térmico de instalações para suínos em fase de terminação. O experimento foi realizado no período de verão (98/99) no município de Patos de Minas, MG. Foram utilizadas duas instalações divididas em 36 baias. Em cada baia foram alojados 15 animais por um período de 40 dias, com idade média inicial de 110 dias. Na lateral de uma instalação foram instalados quatro equipamentos de resfriamento composto de sistema de ventilação e nebulização, tendo-se o tratamento com resfriamento evaporativo (TRE); na outra instalação não foram utilizados equipamentos de resfriamento, tendo-se o tratamento testemunha (TES). O TRE proporcionou melhoria das condições térmicas ambientais, reduzindo o índice de temperatura de globo e umidade, no período crítico do dia (14h00), de 83,5 para 82,4, no interior da instalação. O TRE também proporcionou melhoria na conversão alimentar dos animais, de 3,27 para 2,88, e uma tendência de maior ganho de peso dos mesmos, de 0,97 para 1,02 kg por dia.
Palavras-chave: ventilação, ambiente térmico, conforto térmico

INTRODUCTION

Modern intensive pig production is based on breeding, the pursued goal being meat quantity with the pest cost/benefit ratio. Genetically improved animals require adequate management, nutrition and facilities, which allow the production to be maximized.

In this case, the environment is defined as the collection of all factors that directly or indirectly affect animal development. With the exception of food and pathogenic agents, the factors having the greatest effect on the habitat and, consequently, on animal production are the temperature, relative humidity of the air, radiation and wind speed. They constitute the thermal environment of an animal, which can be quantified by the black globe humidity index (BGHI).

Under summer conditions, the intense solar radiation, high air temperature and relative humidity generate conditions of almost permanent thermal discomfort to the animals, inhibiting their production performance and becoming one of the main problems in swine production (Curtis, 1983). In this period the unfavorable conditions can be alleviated through a well-planned facility project, with the use of thermal modification techniques for the environment, and adequate animal feeding and management. Several alternatives for natural thermal conditioning have been suggested to attenuate the summer adverse thermic environmental conditions that occur inside facilities, such as: choosing an adequate place, longitudinal orientation of the facility in the east-west direction, reflective cover, plant cover around the facility, wide eaves, tall ceiling, a clerestory and wide openings to allow the air to move in and out (Baêta & Souza, 1997). For some regions, however, it is necessary to employ more effective resources to improve the environment conditions inside the facilities.

One alternative choice to improve the environment conditions for pig production, after all natural thermal conditioning possibilities have been exhausted has been the forced ventilation this system is, however, not always satisfactory because it does not reduce air temperature. Evaporative cooling of the air is another system that could be utilized, which consists in incorporating water vapor into the air, causing an increase in humidity and a reduction in temperature (Baêta & Souza, 1997).

One of the forms of air evaporative cooling is a fogging system associated to ventilation, ensuring fast water evaporation, a wide exposure area inside the facility and minimal precipitation. As water goes from the liquid to the gaseous state, it removes about 2,50 MJ (mega Joules) from the environment for each kg of evaporated water, lowering its temperature (Wylen & Sonntag, 1993).

Teixeira (1995) studied the effect of a forced ventilation system and of an evaporative cooling as means of improving the thermal comfort conditions for lactating sows, concluding that the evaporative cooling system gave smaller BGHI values, lower water consumption and higher feed consumption by the matrices, and greater weight gain by the shoats.

Sartor (1997) also studied the effect of forced ventilation and of evaporative cooling as means of improving the thermal comfort conditions for lactating sows, in summer conditions, for the Ponte Nova - MG region. The author concluded that the treatments with evaporative cooling presented the best results, since they provided a significant reduction in BGHI and in Radiant Thermal Load (RTL) inside the facilities; a decrease in matrice rectal temperature and respiratory frequency; an increase in food consumption; and greater weight gain by the shoats.

However, in relation to the finishing stage, little is known about the benefits of evaporative cooling as a relief for animal stress and which management procedures are required by this system.

The efficiency of evaporative cooling is influenced directly by the local microclimate conditions and by the physiological and behavioral responses of the animals (Curtis, 1983; Wylen & Sonntag, 1993).

The objective of this work was to evaluate the performance of an evaporative system on the thermal environment inside finishing stage swine facilities, based on thermal environment indices and physiological responses of the animals.

MATERIAL AND METHODS

Data collecting for the experiment took place during the 1998/1999 summer season, at Patos de Minas, MG, Brazil, at 42° 33' S, 18° 44' W, and altitude of 832 m. The climate in the region, according to the classification of KÖPPEN is Aw (hot, tropical with a dry winter season).

The evaporative cooling (TER) system was compared in relation to the control (TES), using two finishing swine facilities, measuring 59.0 m length, 10.3 m width, 3 m internal height, 1 m eaves, and a concrete floor with a lowered level for a shallow water depth, and covered with asbestos roofing. These facilities were divided into 36 feedlots (15 Large White race animals were sheltered from the age of 110 to 150 days) measuring 3.3 m x 4.5 m, displaced in two lateral rows with a central aisle, having internal partitions and borders closed on the sides with a masonry wall 0.7 m high (Figure 1).

The model of the evaporative cooling equipment was "Agri-Flash 2000", having the following features: an axial fan with a rotation frequency of 1400 rpm; air flowrate 150 $m^3 min^{-1}$; water flow rate in the fogging system of 40 L h^{-1}, provided by eight fogging nozzles; working pressure in the fogging pump was 5.515 kPa; and, nylon pressurized water hosing to withstand high pressure.

For the evaporative cooling treatment (TRE), four pieces of this equipment were installed at the side of one facility, in the direction of the predominant winds, distributed every 15 m and 1.50 m above ground, with a 10% downward slope, according to the recommendations of Hellickson et al. (1983).

During the day the ventilation system would start when the black globe temperature inside the facility exceeded 25°C, triggered by sensors inserted in the black globes, located 0.5 m above the floor and at the center of the feedlots. The air humidification system, also controlled by sensors, started whenever the ventilation system was in operation and the relative humidity inside the facility was below 80%.

The evaluation of the environmental conditions was made based on the air relative humidity (RH) and the black globe humidity index (BGHI). The RH was obtained from a psychrometric chart, after obtaining the dry and wet bulb temperatures. The BGHI was calculated by using the equation proposed by Buffington et al. (1981), which takes into account the effects of the dry bulb temperature, relative humidity, radiation and air velocity. This index is calculated by the following expression:

$$BGHI = Tgn + 0.36Tpo - 330.08 \qquad (01)$$

where: Tgn = black globe temperature, K; Tpo = dew point temperature, K.

The black globe, dry, and wet bulb temperatures were recorded in the interior of each facility, inside four

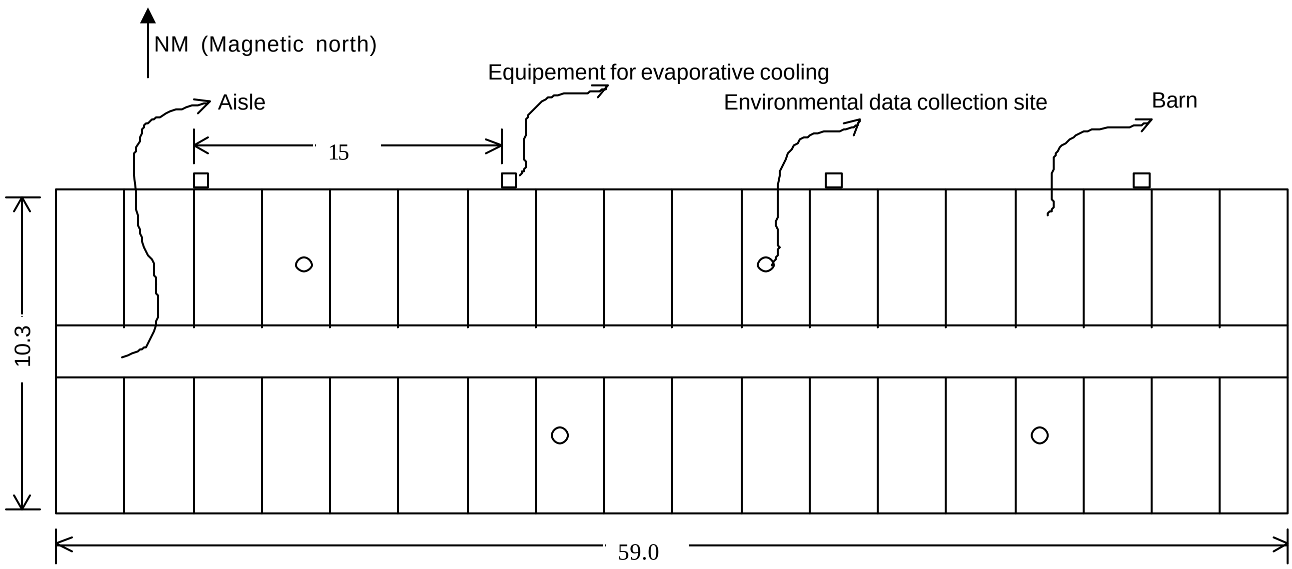

Figure 1 - Facility utilized for evaporative cooling, demonstrating feedlot layout, location of cooling equipment and place where data were collected in the internal environment (out of scale).

feedlots at a height of 0.5 m. On the outside, the dry bulb and wet bulb temperatures (inside a weather house), and the black globe temperature at a 1.5 m height in relation to the ground, were also recorded. Readings were made every 2 hours, from 8am to 6pm and every 3rd day, during the whole experimental period. The experiment had a duration of 40 days (while the animals remained in the finishing stage); corresponding to 14 reading days and the calculation of thermal environment indices (BGHI and RH) was performed based on the daily means of the readings.

The evaluated physiological responses of the animals were weight gain (WG) and food conversion efficiency (FCE).

In order to evaluate these variables we utilized the animals lodged in the four feedlots having the equipment measuring climatic conditions. WG was calculated based on animal weights at the start and end of the experiment, while FCE was obtained from the ratio of the weight gain and the food consumption by the animals during the same period.

The statistical analysis of BGHI and RH, was performed considering a completely randomized design, laid out as split-plots, where plots consisted of the two treatments, and subplots were represented by the six observations hours (8am, 10am, 12pm, 2pm, 4pm and 6pm), with four replicates (readings taken inside four feedlots, according to Figure 1). For FCE and WG the setup was regarded as a completely randomized design, with two treatments and four replicates (animals of the four feedlots under evaluation).

Results were interpreted through analysis of variance and regression analysis. The means of qualitative factors were compared by the F or Tukey tests, and the levels of 1 and 5% were adopted.

RESULTS AND DISCUSSION

Black globe humidity index (BGHI)

There was a difference between treatments (T) and time of day (H), at 1%, and the interaction T x H, at 5%, in relation to BGHI. The interaction T x H was then studied, by partitioning its factors. There were differences between treatments in the diurnal period, from 8am to 6pm, and the evaporative cooling system influence in reducing BGHI values was evidenced (Table 1).

During the entire observation period there was a better performance of the evaporative cooling system, providing a reduction of BGHI values relative to the control (Table 1). The smallest BGHI values probably occurred because of a more adequate air renewal and a greater efficiency of this system in evaporatively cooling the air blown inside the facility.

The BGHI value that provides thermal comfort to finishing stage swine cannot be found in the literature; however, from the ideal black globe temperature and relative humidity it can be estimated that the ideal BGHI is around 75. Therefore, TRE would provide a greater reduction of BGHI values, especially at 2pm (critical period of greatest heat stress on the animals), to approximate the internal conditions of that facility to the comfort condition for the animals. This value of 75 is only an estimate, since it can be altered as a function of animal breed and their adaptation to the thermal environment, among other things.

The BGHI values obtained for the internal and external environments presented a similar behavior; however, for the external environment the thermal amplitude was wider (Figure 2). This occurred especially because a cover was present, which substantially diminished the radiant heat exchange. The BGHI values substantially increase, reaching their maximum between 12pm and 2pm, decreasing from this time on, which was also verified by Turco (1993) in Viçosa, MG, by Teixeira (1995) in Patos de Minas, MG, and by Sartor (1997) in Ponte Nova, MG, Brazil.

This daily behavior of BGHI values mainly occurs because of the daily behavior of the dry bulb temperature, direct solar radiation, both diffuse and reflective, and long wave radiation, since during the day the relative humidity decreases in relation to the night period. Thus, in the 10am to 4pm period, a greater temperature increase occurs in the neighborhood of the black globe, represented, according to Bond et al. (1954), by the soil, sky, cover, animal and horizon.

Relative humidity (RH)

There was a difference of RH between treatments (T) and time of the day (H), at 1%, and the interaction T x H, at 5%. The interaction T x H was then studied, by partitioning its factors.

In general, the TRE had a tendency to show higher RH values (Table 2). The greater humidity values found for TRE are associated to the application of water into the air, in order to decrease its temperature by water evaporation. However this increase was only significant for the 8am reading. A possible explanation for this fact could be the occurrence of some problem with the humidity sensor, which maintained the fogging system running even when the relative humidity inside that facility was above 80%. If the system would be working properly, there should have been a similar RH behavior for all observed times.

There was little difference in relative humidity between treatments, except for the reading taken at 8am, although the relative humidity was always higher during the entire day for TRE (Figure 3).

When the behavior between RH values inside the facilities and in the external environment is compared, no great differences occurred between these environments; this occurred especially because there were dominant openings on the sides of the facility, which contributed to approximate the internal and external conditions, and because of the small amount of water applied under high pressure by the evaporative cooling equipment, facilitating water evaporation, thus avoiding excessive surface wetting inside the facility.

Estimate of BGHI reduction by the evaporative cooling system

The evaporative cooling system did not reach its maximum potentiality (RH = 80%) during the 10am to

Table 1 - Mean values of black globe and humidity index as a function of the time of day for the treatments.

Hours of the day	Evaporative cooling	Control
8h00	73.33 b	73.92 a
10h00	76.96 b	77.50 a
12h00	80.58 b	81.25 a
14h00	82.38 b	83.56 a
16h00	81.71 b	83.10 a
18h00	80.39 b	81.81 a

Means followed by a common letter, on each row, do not differ by the Tukey test at 5%.

Table 2 - Mean values of percentage relative humidity of the air (RH), as a function of the time of day for the treatments.

Hours of the day	Evaporative cooling	Control
8h00	89.85 a	85.23 b
10h00	78.47 a	77.51 a
12h00	67.15 a	65.81 a
14h00	61.62 a	60.71 a
16h00	64.00 a	61.36 a
18h00	65.75 a	64.83 a

Means followed by a common letter, on each row, do not differ by the Tukey test at 5%.

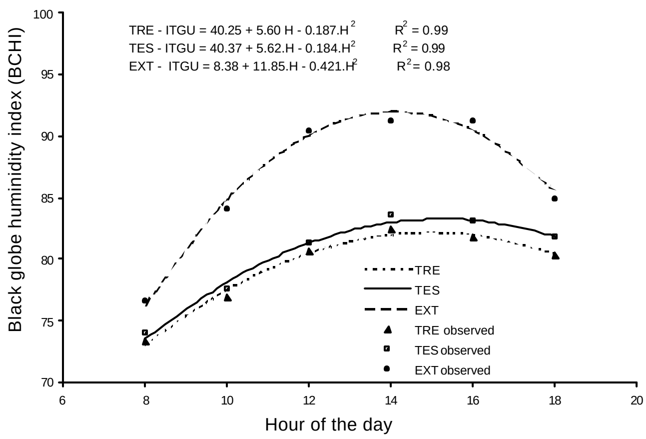

Figure 2 - Estimated values of the black globe humidity index (BGHI) for treatments with evaporative cooling (TRE), control (TES), and external environment (EXT).

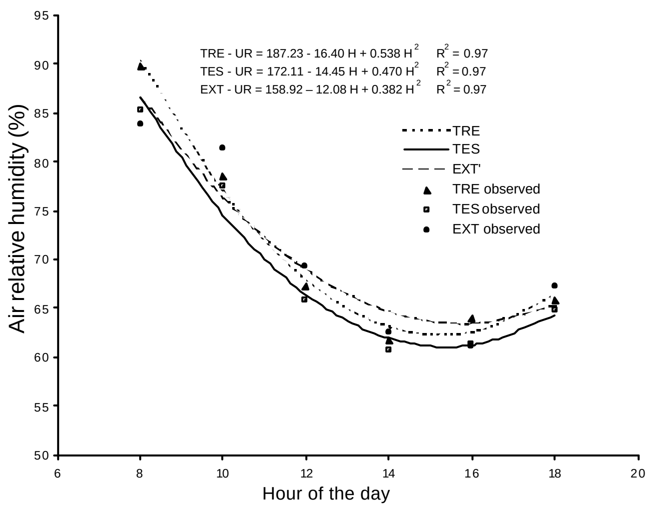

Figure 3 - Estimated values of relative humidity of the air (RH) for treatments with evaporative cooling (TRE), control (TES), and external environment (EXT).

6pm period, i.e., it could have provided a greater reduction in BGHI during this period (Figure 2). This would have been possible by an application of a greater water amount by the system during the period, increasing the relative humidity and reducing temperature, and consequently the BGHI values, which would be highly recommended since the relative humidity in that period was much below 80%, considered the upper threshold for finishing stage swine facilities (Benedi, 1986).

Figure 4 presents an estimate of BGHI values for a relative humidity at the level of 80% inside the facility and kept constant in the period from 10am to 6pm. RH values for the control and allows a comparison of the possible reduction in BGHI values by the evaporative cooling system (Figure 4). The reduction in BGHI by the TRE could have been much greater, in case its efficiency would be improved. For example, at 2pm BGHI was reduced from 83.6 (TES) to 82.4 (TRE), according to Table 1. However, by improving the efficiency of the system through an increase in relative humidity inside the facility to 80%, the BGHI value would be 79.7, indicating that the reduction in BGHI was approximately one unit during the period of greatest heat stress, when it could have been of four units. A more efficient system to humidify the air would provide more comfortable conditions for the animals.

The evaporative cooling system efficiency was low, especially because of the small amount of water applied inside the facility by the four pieces of equipment utilized with TRE. One way of improving the efficiency would be to increase the number of fogging devices in the facility. This option, however, would increase the implantation cost. It must be pointed out that the manufacturer specifications were followed in order to establish the number of foggers utilized.

Evaluation of physiological responses by the animals

There was no difference in relation to the weight gained by the animals. However, a difference at 5% was detected relative to the food conversion efficiency.

Animals housed in the facility with TRE had a better performance, based on WG and FCE, even though only FCE presented differences (Table 3). This probably occurred because of a better feed utilization by the metabolic system of the animals in view of better thermal conditions of the environment inside that facility

Table 3 - Mean values of weight gain for finishing stage swine (WG) and of food conversion efficiency (FCE), for the treatments.

Variable	Evaporative cooling	Control
	------ kg dia^{-1} ------	
FCE	2.88 b	3.27 a
WG	1.02 a	0.97 a

Means followed by a common letter, on each row, do not differ by the Tukey test at 5%.

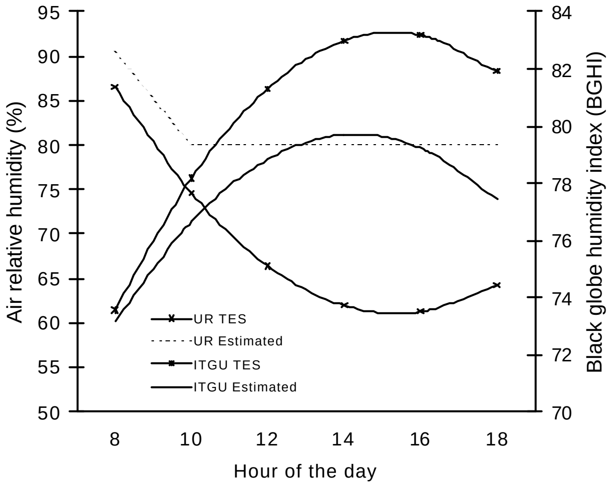

Figure 4 - Values of black globe humidity index (BGHI), and relative humidity (RH) for the control treatment (TES) according to equations shown in Figures 2 and 3, respectively; and estimated values of BGHI for a RH of 80% inside the facility.

(smaller BGHI values). In the case the equipment would provide a greater reduction in BGHI values, it is expected that the animals would further improve their performance.

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