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# PHYSIOLOGICAL RESPONSES OF DAIRY COWS AS A FUNCTION OF ENVIRONMENT IN HOLDING PEN

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**ABSTRACT**: This research aimed to assess the climatization configuration in a holding pen for dairy cattle considering physiological responses of animals and thermal comfort indexes. Experimental design consisted of 16 cows in a Latin square design containing four groups of four animals (G1, G2, G3 and G4) and four periods (P1, P2, P3 and P4), in which four environments were used as treatments: EXT – external environment (control); SHA – shading with polypropylene mesh, 80% light interception; S+S – shading and water sprinkling; and S+S+V – shading, sprinkling and ventilation. Dry and wet bulb temperature, black globe temperature, wind speed and humidity were recorded during the climatization process, between October 13 and December 7. Subsequently, temperature-humidity index (THI), black globe temperature and humidity index (BGTHI), radiant heat load (RHL) and heat load index (HLI) were calculated. After climatization, respiratory rate (RR), surface temperature (ST), and rectal temperature (RT) were recorded. Animals submitted to EXT presented physiological responses that indicated heat stress. The best physiological response was found in S+S+V, which reduced RR by 58.6% when compared to the other environments.

**KEYWORDS**: shading, adiabatic evaporative cooling system, thermal indexes.

## INTRODUCTION

In tropical regions, an almost constant occurrence of temperatures above the thermoneutral environment of dairy cattle is predominant, with values ranging from 0 to 16 °C (PEREIRA, 2005). As an adaptation strategy, animals trigger thermolysis mechanisms, such as changes in metabolic rate, body temperature and respiratory rate, resulting in decreased milk production. Thus, climatization strategies began to be used aiming at reducing the effect of heat stress, which may reflect directly on improving animal productive performance (RODRIGUES et al., 2010; NASCIMENTO et al., 2013).

In this context, holding pens or pre-milking parlors are critical points inside dairy properties because in these environments animals remain on average 15 to 75 min before entering the milking parlor. This process has as conditioning factors of stress crowding and exposure to an adverse environment (COLLIER et al., 2006).

Among the climatization techniques, shading has an important role in reducing the radiant heat load on animals (SOUZA et al., 2010). Water sprinkling is also an important technique that aims to speed up heat exchange by the evaporation process (SCHÜTZ et al., 2011; CERUTTI et al., 2013).

Adiabatic evaporative cooling system (AECS), which combines ventilation and air humidification using sprinklers, is a technique that has been used successfully in holding pen climatization, showing satisfactory results in reducing the internal temperature of facilities and improving comfort conditions (ALMEIDA et al., 2013).

To validate a climatization strategy in the dairy industry, AECS needs to bring benefits to the animal environment, which can be assessed by thermal comfort indexes. In this sense, temperature-humidity index (THI), black globe temperature and humidity index (BGTHI) and radiant heat load (RHL) are the most used thermal comfort indexes, presenting high correlations with physiological

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responses that indicate heat stress (AVILA et al., 2013).

Therefore, this research aimed to assess the climatization configuration in a holding pen for dairy cattle considering physiological responses and thermal comfort indexes.

## MATERIAL AND METHODS

The experiment was conducted in Trindade, GO, Brazil, located at geographical coordinates 16°38’58” S and 49°29’20” W and altitude of 756 m. Regional climate is classified as Aw (tropical humid) according to KÖPPEN, with a dry season in winter.

For the experiment, 16 lactating dairy cows ⅞ Holstein + ⅛ dairy Gyr homogeneous in relation to milk production (20 kg ± 5 kg), weight (550 ± 50 kg), lactation stage (120 ± 40 days) and a number of lactations (2 to 4) were selected.

Treatments consisted of four environment types for holding pen: EXT – external environment at full sun (control); SHA – shading with polypropylene mesh (80% shade); S+S – shading with polypropylene mesh (80% shade) and sprinkling; and S+S+V – shading with polypropylene mesh (80% shade), sprinkling and ventilation.

The experiment was conducted from October 13 to December 7, 2014 (during spring), totaling 56 days. Treatments were applied in four periods of 14 days each, with the first 7 days of each period destined to animal adaptation to different environments/treatments.

Experimental design was a 4 × 4 Latin square design containing four groups of four animals (G1, G2, G3 and G4) and four experimental periods (P1, P2, P3 and P4) in which the treatments were applied, totaling 16 repetitions.

The holding pen was built with dimensions of 12.0 × 4.9 m and 3.5 m in height. As covering material, two layers of polypropylene mesh with 80% solar radiation protection was used, being fixed with plastic cable ties (nylon type).

For the ventilation system, two fans with 1.0 m diameter and air speed of 3 m $s^{-1}$ were installed at a height of 2.5 m (measured from the center of the equipment) on the south side of the holding pen.

Sprinkling system was composed of a PVC line of 25 mm and six rotating microsprinklers with a 1.2-mm nozzle, average flow rate of 66 L $h^{-1}$, and the distance between nozzles of 2.40 m.

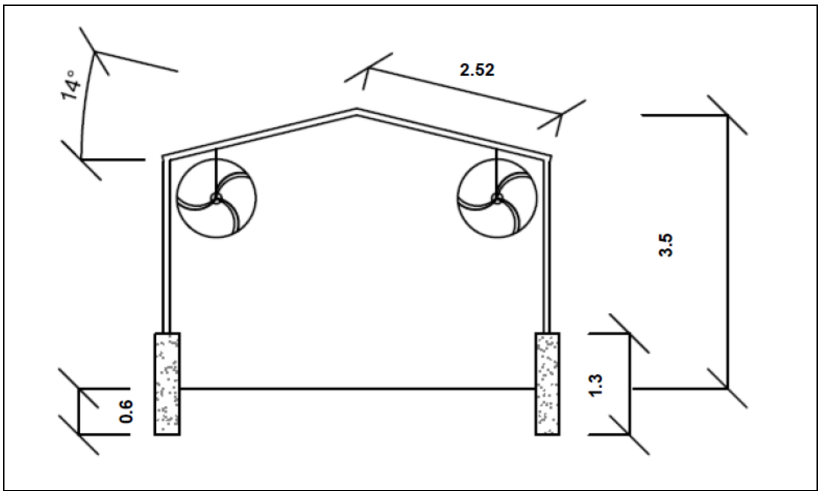


FIGURE 1. Cross section of the holding pen, with dimensions in meters.

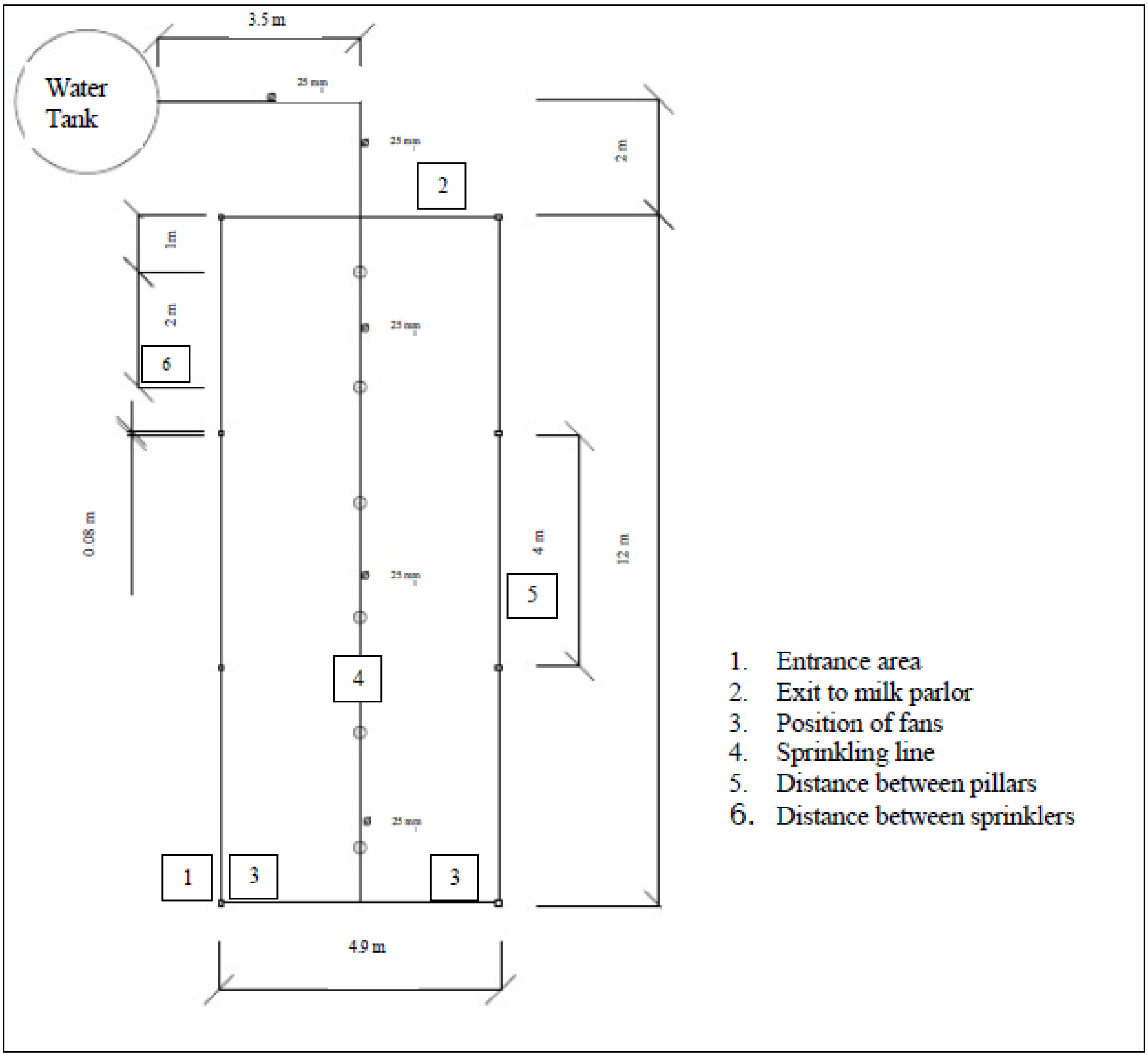


FIGURE 2. Floor plan of the holding pen where the experiment was conducted.

The climatization system was turned on only when the air or dry bulb temperature was higher than 26 °C, as recommended by Silva et al. (2011).

For meteorological data record, two data loggers micro-station were installed, one external to the environment and other inside the holding pen at its geometric center. Each device was equipped with four sensors (dry bulb temperature, humidity, black globe temperature and wind speed), which recorded the variables at each minute.

Data storage of micro-stations was performed by means of dedicated software, allowing calculating thermal comfort indexes using the eqs (1) to (7):

a) THI – Temperature-Humidity Index (THOM, 1959):

$$THI = Tdb + 0.36 \times Tdp + 41.5 \quad (1)$$

where,

Tdb is the dry bulb temperature (°C) and

Tdp is the dew point temperature (°C).

b) BGTHI – Black Globe Temperature and Humidity Index (BUFFINGTON et al., 1981):

$$BGTHI = Tbg + 0.36 \times Tdp + 41.5 \quad (2)$$

where,

Tbg is the black globe temperature (°C) and

Tdp is the dew point temperature (°C).

c) RHL – Radiant Heat Load (ESMAY, 1982):

$$RHL = \tau (MRT)^4 \text{ and} \tag{3}$$

$$MRT = 100\left\{\left[2.51(WS)^{0.5} \times (Tbg - Tdb) + \left(\frac{Tbg}{100}\right)^4\right]\right\} \tag{4}$$

where,

τ is the Stefan-Boltzmann constant ($\tau = 5.67 \times 10^{-8}$ W $m^{-2}$ $K^{-4}$);

MRT is the mean radiant temperature;

WS is the wind speed (m $s^{-1}$);

Tbg is the black globe temperature (K), and

Tdb is the dry bulb temperature (K).

d) HLI (2002) – Heat Load Index (GAUGHAN et al., 2002):

$$HLI = 33.2 + 0.2\,RH + 1.2\,Tbg - (0.82\,WS)^{0.1} - \log(0.4\,WS^2 + 0.0001) \tag{5}$$

where,

RH is the air relative humidity (%);

Tbg is the black globe temperature (°C), and

WS is the wind speed (m $s^{-1}$).

e) HLI (2008) – Heat Load Index (GAUGHAN et al., 2008):

$$\text{If } Tbg > 25\,°C,\ HLI = 8.62 + (0.38 \times RH) + (1.55 \times Tbg) - (0.5 \times WS) + [e^{2.4 - WS}] \tag{6}$$

$$\text{If } Tbg < 25\,°C,\ HLI = 10.66 + (0.28 \times RH) + (1.33 \times Tbg) - WS \tag{7}$$

where,

Tbg is the black globe temperature (°C);

RH is the relative humidity (%);

WS is the wind speed (m $s^{-1}$), and

e is the base of the natural logarithm (2.71828).

For the analysis of physiological responses of animals, rectal temperature (°C), hair coat temperature (°C) and respiratory rate (move $min^{-1}$) were measured during the afternoon milking for all animals after they pass through the climatization for 30 minutes in their respective environments.

Respiratory rate was measured through side movement count for 30 seconds, being subsequently multiplied by two in order to be expressed in move $min^{-1}$. Rectal temperature was measured by means of a clinical thermometer inserted directly into the rectum for two minutes.

Hair coat temperature was measured in five points (head, back, udder, cannon bone and croup) by means of an infrared thermometer positioned at 0.5m from the animal surface. Subsequently, the average temperature (arithmetic average of the five points collected) and surface temperature were calculated according to [eq. (8)] (PINHEIRO et al., 2005).

$$T_{hair\ coat} = 0.10 \times T_{head} + 0.70 \times T_{back} + 0.12 \times T_{cannon\ bone} + 0.08 \times T_{udder} \quad (8)$$

Data from environmental variables and thermal comfort indexes were submitted to analysis of variance by the F test, and when relevant, the means were compared by the Scott-Knott test at 1% significance level. For physiological variables, mean comparison was performed by the Tukey's test at 5% probability. The data were analyzed by using the software Sisvar 5.3 (FERREIRA, 2011).

## RESULTS AND DISCUSSION

During the morning milking, average air temperature was 21.08 °C, not being necessary to turn on the climatization system, since the temperatures were lower than 26 °C during this period.

Statistical differences were observed between treatments for the assessed thermal comfort indexes (P<0.001), as shown in Table 1.

TABLE 1. Average of temperature-humidity index (THI), black globe temperature and humidity index (BGTHI), radiant heat load (RHL) and heat load index (HLI) for all treatments and their respective coefficients of variation and statistical probabilities.

| Bioclimatic index | TREATMENT | | | | CV (%) | Prob. F |
|---|---|---|---|---|---|---|
| | EXT | SHA | S+S | S+S+V | | |
| **THI** | 76,30 a | 75,12 a | 71,74 b | 71,10 b | 4,48 | 0,0001 |
| **BGTHI** | 79,90 a | 77,25 b | 72,62 c | 71,32 c | 5,53 | 0,0001 |
| **RHL (w m$^{-2}$)** | 549,91 a | 509,02 b | 459,10 c | 440,93 c | 8,99 | 0,0001 |
| **HLI (2002)** | 83,52 a | 80,85 b | 78,56 c | 77,06 c | 3,73 | 0,0001 |
| **HLI (2008)** | 81,67 a | 76,47 b | 67,83 c | 63,98 c | 11,04 | 0,0001 |

EXT: external environment; SHA: shading; S+S: shading and sprinkling; S+S+V: shading, sprinkling and ventilation. Means followed by different letters in the rows differ from each other by the Scott-Knott test (P<0.01).

The values of THI for EXT and SHA did not differ from each other and remained above 72, the critical value established by GANTNER et al. (2011). On the contrary, S+S and S+S+V differed significantly from the other treatments and presented values below the critical limit established in the literature.

When assessing the climatization with nebulization and ventilation in a holding pen, ALMEIDA et al. (2010) reported a decrease in THI values from 77.8 to 73 after 30 minutes when compared with a holding pen with only shading. Similarly, SILVA et al. (2011) found a decrease from 78.6 to 74.4 under the same conditions.

For BGTHI, no significant difference was found for EXT and SHA (P<0.01), which presented values of 79.9 and 77.25, respectively. OLIVEIRA et al. (2013), also using polypropylene mesh (80% shade) for shading paddocks, observed a proportional decrease similar to that found in this study, with an average value of 85.39 in the external environment and 81.57 in the shaded environment.

Regarding the radiant heat load (RHL), only the treatment SHA provided a reduction in its values close to 8% when compared to EXT (P<0.01). For S+S and S+S+V, the reduction in RHL was even more significant, with reduction values of 19% and 24%, respectively. When compared to EXT. NAVARINI et al. (2009) also observed the shading reduced RHL by 12%, with values of 571 and 508 W m$^{-2}$ in full sun and in shade, respectively, in the period from 9:00 to 18:00 h.

Using the methodology described by GAUGHAN et al. (2008), the treatments S+S and S+S+V presented average values of heat load index (HLI) below 70, which is the value found by GAUGHAN et al. (2010) as a thermoneutral condition for cattle.

SOUZA et al. (2010) assessed the effect of natural shading using trees of different sizes using the methodology of GAUGHAN et al. (2002) and found a similar decrease at 14:00 h, with HLI values of 83 in the external environment and close to 78 in shading with trees.

Statistically significant differences were found for physiological variables between different environments (P<0.005), as shown in Table 2. Animals submitted to EXT presented the highest respiratory rate, followed by animals submitted to SHA; the lowest values were observed for S+S and S+S+V, which did not differ from each other.

TABLE 2. Average of physiological variables in the afternoon milking: respiratory rate (RR, move $min^{-1}$), rectal temperature (RT, °C), surface temperature (ST, °C), average temperature (°C) and head, back, cannon bone, udder and croup temperatures (°C) for all treatments and their coefficients of variation and probability.

| Physiological variable | Treatment | | | | CV (%) | Prob. F |
|---|---|---|---|---|---|---|
| | EXT | SHA | S+S | S+S+V | | |
| **RR** | 81,37 a | 63, 56 b | 36,12 c | 33,68 c | 23,26 | 0,0001 |
| **RT** | 39,42 a | 39,11 a | 38,52 b | 38,50 b | 1,49 | 0,0001 |
| **Head temperature** | 34,95 a | 33,58 b | 30,60 c | 30,11 c | 4,23 | 0,0001 |
| **Back temperature** | 35, 72 a | 34,51 b | 31,36 c | 31,79 c | 3,47 | 0,0001 |
| **Cannon bone temperature** | 32,94 a | 31,84 b | 30,43 c | 30,13 c | 4,70 | 0,0001 |
| **Udder temperature** | 35,57 a | 34,66 b | 34,72 b | 34,36 b | 2,70 | 0,0001 |
| **Croup temperature** | 34,45 a | 33,86 a | 31,71 b | 30,24 c | 3,99 | 0,0001 |
| **Average temperature** | 34,73 a | 33,69 b | 31,77 c | 31,24 c | 2,87 | 0,0001 |
| **ST** | 35,29 a | 34,11 b | 31,63 c | 31,44 c | 3,18 | 0,0001 |

EXT: external environment; SHA: shading; S+S: shading and sprinkling; S+S+V: shading, sprinkling and ventilation. Means followed by different letters in the rows differ from each other by the Tukey's test (P<0.01).

Similar results were found by SCHUTZ et al. (2011), who observed the respiration rate of animals that had access to showers and found a decrease in its values of 66%. ALMEIDA et al. (2010) also reported a reduction from 61.5 to 35.3 move $min^{-1}$ using a climatization system with nebulization in a holding pen.

In the treatments that used water for climatization, rectal temperature was within the values considered as absence of heat stress (38.0 to 39.3 °C) according to DU PREEZ (2000). S+S and S+S+V had average values of rectal temperature of 38.52 and 38.50 °C, respectively, representing an average reduction of 0.9 °C in rectal temperature when compared to EXT. Similar results were obtained by CERUTTI et al. (2013), who reported a reduction of 0.6 °C in rectal temperature of cows submitted to climatization in pre-milking (shading and sprinkling) when compared to treatment without acclimatization.

This reduction in rectal temperature proves the effectiveness of these environments as a mitigating measure of heat stress, since this physiological variable is the main heat dissipation indicator produced by the animal metabolism. The heat is dissipated through conduction processes that take place between tissues and the blood that irrigates the surface, which at high surface temperatures are not efficient, leading to negative consequences for the metabolism and animal production (SOUZA & BATISTA, 2012).

Temperature data from the five points listed in the animal surface showed similar behavior, differing for EXT and SHA, except for croup temperature. The treatments S+S and S+S+V presented significant difference when compared to the others, not differing from each other. This behavior was not observed only for udder and croup temperatures.

Udder temperature did not present similar behavior of surface temperature or of the other points, which was also observed by OLIVEIRA et al. (2014), who correlated this increase in udder temperature with their formation process, i.e., the older the animal is, the lower its udder surface temperature.

The increase in surface temperature means a gradient loss between skin temperature and environment, hindering convective exchanges. According to COLLIER et al. (2006), if the hair coat temperature is higher than 35 °C, temperature gradient between the organism and hair coat is not large enough to occur the heat exchange processes.

In addition, the process of water sprinkling on the animal immediately cooled its body surface. In environments in which this type of climatization was used, the reduction in surface temperature was of 3.66 °C for animals submitted to sprinkling and of 3.85 °C for animals submitted to sprinkling and ventilation when compared to EXT.

This reduction in temperature may be attributed to hair coat and skin wetting during animal sprinkling, leading to losses of sensible heat by evaporation. SIMÕES (2014) found a similar result in which occurred a reduction in animal surface temperature by 4.74 °C when sprinkling was associated with ventilation.

Such reduction is significant even comparing SHA and S+S+V, which presented a difference of surface temperature of 2.67 °C between them. PINHEIRO et al. (2005) found a temperature difference of 0.95 °C in animals under the same environments, but in milder conditions than those observed in this study.

## CONCLUSIONS

Exposing animals to an environment without any acclimatization inside a holding pen reflects in negative responses on physiological variables, leading to a situation of heat stress.

The average value of rectal temperature of animals submitted only to shading demonstrates this environment is not enough to put the animal in a homeostasis situation.

Cooling systems that use water for acclimatization (S+S and S+S+V) present superior results for acclimatization in holding pen since environmental indexes and physiological variables were within the comfort standards recommended by the literature.

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