

Behavior of Dairy Cows Housed in Environmentally Controlled Freestall

M. Perissinotto¹, D.J. Moura², S.V. Matarazzo¹, A.S. Mendes², I.A. Naas²

¹ ESALQ/University of São Paulo, Department of Exact Sciences

² State University of Campinas. College of Agricultural Engineering, Po Box 6011, ZIP 13083970

daniella.moura@agr.unicamp.br.

ABSTRACT

Due to the importance of dairy production in Brazil and the losses that occur during hot weather conditions this study aimed to evaluate the thermal preference of dairy cows housed under two different evaporative cooling systems: sprinkler and fogging, associated with forced ventilation. The study was carried out in a commercial dairy farm located in São Pedro County, state of São Paulo, Brazil. The trial had two groups of 10 Holstein cows each in the same stage of milk production, and took place for six consecutive days starting on November 2003. Relative humidity and dry bulb and black globe temperatures were recorded in intervals of 15 min during all the experimental period. The behavioral pattern of the animals was used to evaluate their thermal preference. The area occupied by the cows (drinker, feeder, bedding close to cooling systems, bedding in the opposite side to cooling system, alley near the cooling system, and alley away from the cooling system) as well as their activities inside the building (eating, drinking, ruminating, idle, standing and lying) were monitored using video cameras between 9:00 A.M. to 5:00 P.M. The mean dry bulb temperature was 27.3°C while mean relative humidity was 60% during the trial. In both treatments Temperature and Humidity Index (THI) did not differ statistically and did not reach thermoneutral zone parameters. The cows generally spent more time where there was sprinkling systems, especially near the feeding area. From results it was not possible to select a specific type of cooling system because there are more variables influencing cow's behavior than the ones studied. Further studies need to be implemented in this field of knowledge under hot weather conditions.

Keywords: thermal comfort, behavior, dairy cows, heat stress, evaporative cooling, thermal preference, temperature and humidity index.

1. INTRODUCTION

Milk production presents significant reduction during summer months in Brazil due to the incidence of extreme environmental temperature associated to high relative humidity. Heat stress also leads to decline in dairy fertility as well as making the cows vulnerable to develop diseases such as mastitis that not only decreases milk yield but also the quality of the milk produced.

Most previous research has focused on the effects of heat stress or environmental conditions above the thermoneutral zone of 5 to 20° C (Curtis, 1983). McGuire et al. (1989) measured dry matter intake and milk yield of Holstein cows and suggested the thermal comfort zone from 19 to 25° C while the heat stress zone from 25 to 40° C. Nääs (1989) suggested a thermoneutral zone

for Holstein cows between 4 and 24° C, depending on the environmental relative humidity and the solar radiation, this zone may vary within values from 7 to 21° C. Huber (1990) considered this variation between 4 to 26° C. It is clear that summarizing the previous results the mentioned authors supposed the thermoneutral zone for dairy cows within the range of 4 to 26° C.

Environmental control for dairy cows housed inside freestall is generally provided by the use of cooling systems based on sprinklers or misting associated to fans. It is well documented in the literature the effect of heat stress on dairy cows (Curtis, 1983; Barnett & Hemsworth, 1990; Huber, 1990; Van Borell, 1995; and Pires et al., 1998a), as well as the benefit of using cooling systems for improving milk production during hot weather conditions (Bucklin & Bray, 1998). Comprehensive knowledge of the characteristics of behavioral activities of farm animals is important for the improvement of animal husbandry (Gordon, 1995). Behavioral pattern has been associated to heat stress and is based on occurrence of abnormal behavior (Van Borell, 1995) while according to Fraser et al. (1975) animals try to adapt drastically in order to compensate the effect of heat exposure by modifying their physiological responses and behavioral characteristics seeking thermal balance. Cows need to spend considerable time lying for maximum feed efficiency by decreasing maintenance of energy requirements and effective rumination, and for optimum health by, for instance, prevent lameness.

The percentage of cows (under shading associated to cooling systems) resting or ruminating in the standing position has been observed to increase linearly as temperatures reach heat stress levels (Shultz, 1984; Igono et al., 1987). The authors found that by standing, cows maximize evaporation from body surfaces and also benefit from convection due to wind. Frazzi et al. (1998) also found similar behavior in cows housed under freestall. Frazzi et al. (2003) studied the behavior of dairy cows exposed to different cooling systems during summer season and observed that the cows showed preference in staying wet by the misting system rather than being wet by the showering due to sprinklers.

Behavior may also be affected by the building design. Gaworski et al. (2003), comparing two freestall designs in a cross-over experiment found that stall location and stall design can affect stall usage and cleanliness, suggesting that certain barn designs may be much more effective than others. The use of video techniques for recording animal behavior has been a useful tool. Overton et al. (2003) used a time-lapse video photography to examine effects of environmental temperature and management on dairy cattle lying behavior and develop a stall-use index.

The objective of this research was to evaluate the thermal preference of dairy cows housed in two different types of evaporative cooling systems: fogging and sprinkler associated with forced ventilation. Cow's behavioral pattern was used as parameter, and the trial was done under Brazilian summer conditions.

2. MATERIALS AND METHODS

The experiment was carried out with cows from a freestall commercial herd in the Southern region of Brazil. The trial was done from November 1st to 28th, 2003. Twenty Holstein lactating cows (20kg/cow/day) in the same stage of production (180 days) and mean weight of 650kg were selected. This selected herd was divided into two groups of ten cows each one staying in an area with cooling systems. The treatments were such as: treatment 1 (T1) used forced ventilation

associated to sprinkling system, and treatment 2 (T2) used forced ventilation associated to fogging system (Figure 1 a, b). During the first week the selected animals were preliminarily exposed to the treatments for adapting to the new environment. The control used environmental data from the outside area of the freestall. Freestall dimensions were 120 m long, 28.0 m wide and 9.0 m high in the center and 3.5 m at eave. The building was East – West solar oriented and the roof was made of ceramic tiles. Central alley was 2.9 m wide and could house 240 milking cows divided in four groups with approximately 60 cows each. The bedding material was made of chopped tire mixed with sawdust involved with impermeable high density cloth with dimensions of 1.10 x 2.12m. The total number of bed was 114/herd divided in two rows of 57 beds.

Forced ventilation in both T1 and T2 used 5 axial fans CASP® VA 92 plus, (0.37 kW) in each treatment placed at 2.0 m height in the rest area and 2.5 m above the feeders. The fans were 15 m apart from each other. This provided an average air stream of 2.5 m s⁻¹ within a radial distance of approximately 14 to 15m over the cows.



Figure 1. Overview of the sprinkler system (a) and fogging system (b) used in the experiment.

Both cooling systems were installed just below the axial fans over the feeder using PVC pipes with valves within 1m distance. Figure 2 shows a schematic view of the experiment set up. Both fans and cooling systems were controlled by a thermostat and timing equipment was used as shown in Table 1 as well the nozzles water flow on both cooling systems.

Table 1 Treatment specifications used in the trial

Treatment	Cooling Systems			
	Water Flow (L/h)	Nozzle Pressure (MPa)	Timing on (s)	Timing off (s)
T1	30	0.08	60	660
T2	2.5	1.00	20	40

The choice of the timing for both T1 and T2 were based on previous experiments (Perissinotto et al., 2003).

Dry bulb (DBT) and black globe temperatures (BGT) and relative humidity (RH) for all treatments were registered using a datalogger HOBO®, -20°C to +70°C temperature range and relative humidity range of 0 to 95%; model H08-00X-02 with accuracy of $\pm 0.7^\circ\text{C}$ at 21°C and $\pm 5\%$, equipped with external temperature probe for recording of the BGT. Three datalogger were used such as: one in each geometric center of the treatment at 3m height; and the other in the outside area under a shade at 1.5m height.

Recordings were made every 15 min during 24h continuously; however for calculating the Temperature and humidity index (THI) and Black globe and humidity index (WBGT) and enthalpy (H) data were selected within the range of 9:00 A.M. to 5:00 P.M. when the critical heat stress hours occurred and the cooling systems within the treatments were turned on.

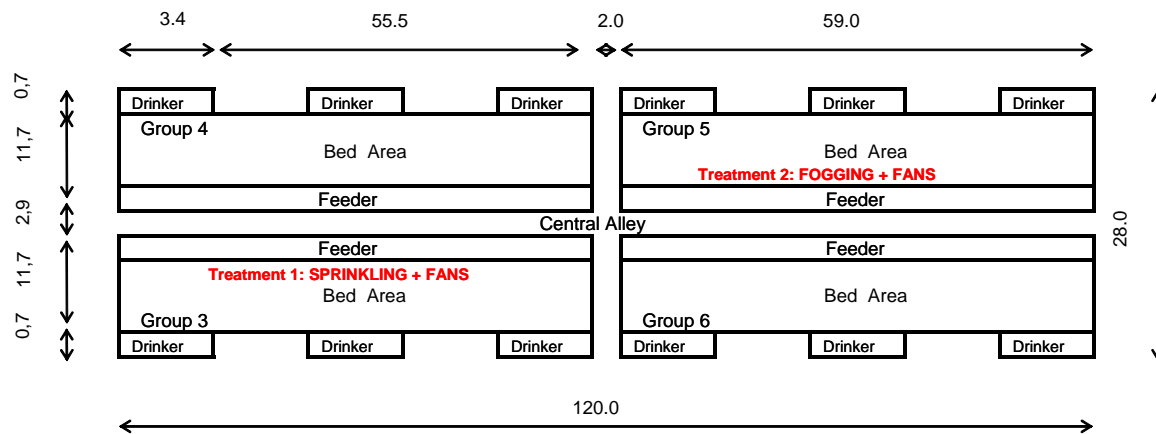


Figure 2. Schematic view of the treatment's distribution and set up inside the freestall.

According to Buffington et al. (1981) Temperature and relative humidity index (THI) (originally developed by Thom, 1958) is commonly used for evaluating cows heat stress, while the Wet bulb and black globe temperature index (WBGT) relates the wind effect as well as the solar radiation influence in the animal's thermal sensation, as can be seen in equations below:

$$\text{THI} = \text{DBT} + 0.36 \text{ DPT} + 41.7 \quad (1)$$

Where:

DBT= dry bulb temperature, ° C; DPT = dew point temperature, calculated from WBT (wet bulb temperature), ° C.

$$\text{WBGT} = \text{BGT} + 0.36 \text{ DPT} + 41.5 \quad (2)$$

Where WBGT = black globe temperature ° C.

For calculating enthalpy values (H) Equation 3 was used, described by Furlan (2001) as:

$$H = 6.7 + 0.243 * \text{DBT} + \{ \text{RH}/100 * 10^{\wedge} [(7.5 \text{ DBT}) / (237.3 + \text{DBT})] \} \quad (3)$$

Where:

H = enthalpy (kcal/kg dry air⁻¹); DBT = dry bulb temperature, ° C; RH = relative humidity, %.

Water and feed were given to the cows *Ad libitum* during the experiment, and the dairy cows were milked three times a day (3:00 A.M.; 10:00 A.M.; 5:00 P.M.). In each treatment five cows were selected randomly and their behavior was monitored. They were identified with colored collars in order to be recognized through the video image. Eight analogical color video cameras (NTSC system) with definition of 300 horizontal lines and sensibility of 1 lux using 2.45 mm lens were used in the trial. In each treatment four cameras were installed at the height of 2.75 m such as: one above the drinker, two above the feed line and one above the rest area. They were connected to a computer with image capture hardware and recorded continuously. Image analysis was performed using 10 min interval within the recorded data. The software TopWay® was used for both image recording and management.

The following cow's spatial presences were observed and considered: presence within the feeder area; presence within the drinker area; presence within the bedding area near the cooling system; presence within the bedding area opposite to the cooling system; presence in the alley near the cooling system; and presence in the alley in opposite to the cooling system. According to the cow's behavioral pattern the following behaviors were observed from 9:00 A.M. to 5:00 P.M: eating, drinking, ruminating, idle, standing and lying down.

The statistical design adopted was randomized considering as a block the days and the treatments. Tukey's test was used for comparing the means using the software SAS (1992).

3. RESULTS AND DISCUSSION

Figures 3 and 4 shows the hourly average values of dry bulb temperature (°C) and relative humidity (%) in each treatment and outside (external environment) for the studied period. Mean environmental variables resulting from the statistical analysis are presented in Table 2 (It would be interesting to present the hourly variations for a typical day).

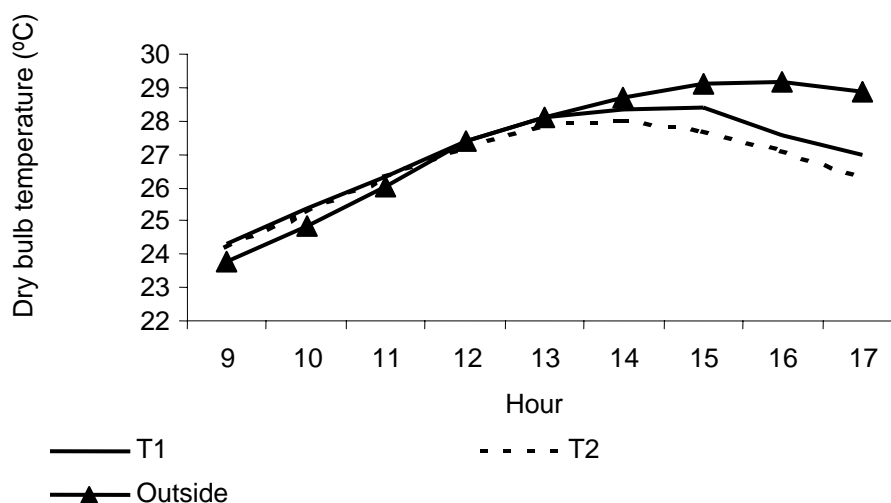


Figure 3. Average values of dry bulb temperature in each treatment and outside the freestall.

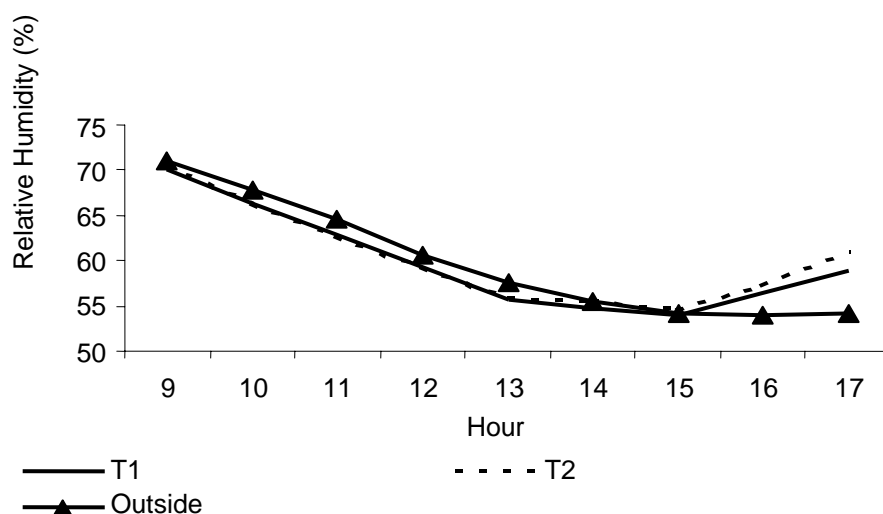


Figure 4. Average values of relative humidity in each treatment and outside the freestall during the trial.

Dry bulb temperature, black globe temperature, wet bulb and black globe temperature index and enthalpy decreased significantly in T2 when comparing to T1. Same results were found by Bucklin & Bray (1998). When comparing to control it was evident that the use of cooling system made an important impact in reducing the maximum dry bulb temperature to nearly 1°C, and in T2 this decrease reached 1.6 °C. The found best result still is above the suggested thermoneutral zone by McGuire et al. (1989) and Huber (1990).

Table 2. Mean environmental variables from 9:00 A.M. to 5:00 P.M. during the experimental period

Environmental variables	Treatments		
	T1	T2	Outside
Dry bulb temperature (DBT, ° C)	27.0 ^b	26.6 ^a	27.3 ^b
Relative humidity (UR, %)	59.8 ^a	60.3 ^b	60.0 ^{ab}
Black Globe temperature (BGT, ° C)	27.5 ^b	27.1 ^a	-
Temperature and humidity index (THI)	75.1 ^{ab}	74.7 ^{ba}	75.6 ^b
Black globe and humidity index (WBGT)	75.5 ^b	75.0 ^a	-
Enthalpy (H, kJ/kg of dry air)	77.7 ^b	77.0 ^a	78.0 ^b
Maximal temperature (Tmax, ° C)	29.4 ^a	29.0 ^a	30.6 ^b

a,b: means followed by different letter in the same line differ ($p < 0.05$)

As there was shadow in both treatments the building orientation influenced equally the effect of the cooling systems; however this effect was more evident in T2 (WBGT=75.0) where the fogging system presented significant reduction in the WBGT (Eq. 2 includes the effect of solar radiation).

The calculated thermal comfort index THI which does not include the solar radiation effect, did not present statistical difference between treatments. Enthalpy also was reduced at T2. Relative humidity increased more in T2 (60.3%) than in T1 (59.8%); however both values did not differ from control. This was expected as the building was open sided. Fogging cooling system produce more water vapor that leads to the increase in the relative humidity inside the housing while the use of sprinklers has little influence in the final environmental relative humidity. In the other hand the use of sprinklers wetting the cow's fur may increase milk yield, as demonstrated by Bucklin & Bray (1998).

There was a significant difference in the spatial presence regarding the treatments, as seen in Table 3. Those differences were: within the feeder area; within the bedding area opposite to the cooling system, and in the alley in opposite to the cooling system.

Time spent in the feeder area in T1 was 42.7% higher than the same at T2. Similar results were found by Frazzi et al. (1998) and Lin et al. (1998) when observing efficiency of sprinklers over the feeder area in order to maintain the animals near the feeder. Regarding the time spent on the drinker area no statistical difference was found in both treatments. A reason for that may be the fact that the drinker in both treatments was in the opposite side of the cooled areas and the cows when thirsty would drink the water and come back to the fresher area.

Table 3. Average time spent by the cows in each spatial area in percentage during the experiment

Treatment	Spatial presence (%)					
	within the feeder area	within the drinker area	within the bedding area near the cooling system	within the bedding area opposite to the cooling system	in the alley near the cooling system	in the alley in opposite to the cooling system
T1	28.7 ^a	6.0 ^a	41.0 ^a	7.3 ^b	13.0 ^a	4.0 ^b
T2	16.5 ^b	4.0 ^a	39.0 ^a	16.5 ^a	16.7 ^a	7.3 ^a

a,b: means followed by different letter in the same line differ (p<0.05)

In both treatments the cows preferred to stay within the bedding area near the cooling system. Apparently the animals distributed themselves regularly with regard to the presence within the bedding area opposite to the cooling system and within the feeder area in T2. As the feeder area did not attract the cows when using fogging system (when compared to the use of sprinklers), probably this affected directly the presence in the alley in opposite to the cooling system. This supposition may also apply to the results with their presence within the bedding area opposite to the cooling system.

It was also found a statistical difference in some of the cow's behavioral pattern with regard to the treatments, as seen in Table 4. In the resulting environmental conditions from T1 the animals showed preference to stay standing in the feeding area (both eating and/or just standing) when compared to T2. According to Pires et al. (1998b) the mean time spending eating for freestall housed cows is around 21% of the day during Southeastern Brazilian winter time (mean dry bulb temperature \cong 25 °C) while the corresponding time during Brazilian summer (mean dry bulb temperature \cong 30 °C) is of 18%. Considering that the cows in both treatments were exposed to quite similar ambient temperatures the results enhanced the effectiveness of the sprinkling over the cows, maintaining them eating and standing within the feeding area in T1.

Table 4. Timing spent by the cows in each behavioral pattern in percentage (specify the corresponding total 100%)

Treatment	Behavioral pattern					
	Eating	Drinking	Rumination	Idle	Standing	Lying down
T1	30.0 ^a	5.0 ^a	30.0 ^a	35.0 ^b	57.5 ^a	42.5 ^b
T2	16.5 ^b	4.2 ^a	26.8 ^a	52.4 ^a	47.1 ^b	52.9 ^a

a,b: means followed by different letter in the same line differ (p<0.05)

Time spent in idle condition was higher in T2. When checking the results it can be seen that the cows had less time eating, drinking, ruminating and standing when exposed to treatment T2. The time standing found in this experiment disagrees with the results found by Shultz, (1984), and Igono et al. (1987), where the hypothesis for the cows to be standing was to increase evaporation from body surface, as the authors found that by standing, cows maximize evaporation from body

surfaces benefiting from convection due to continuous wind flow. In this trial this benefit was not evident as the fogging system did not wet the cow's skin.

Analyzing the thermal comfort indexes it is clear that both treatments T1 and T2 were not able to reach thermoneutral zone. Humidity and temperature index (THI) were statistically the same in both treatments, and above the recommended (72, Hahn, 1982). These results disagrees with Frazzi et al. (2001) whose authors used a fogging treatment that wetted the cow's skin, while in this experiment the fogging system were dimensioned to just provide evaporative cooling within the environment, not wetting the animals.

New studies need to be implemented for better understanding the use of cooling equipment in dairy cows housed under hot weather conditions, especially in the dimension in the water drop, or in the height of the nozzles for promoting the actual wetness of the cows as this is the condition that achieved better results.

4. CONCLUSION

Behavior of dairy cows housed in freestall under Brazilian hot weather conditions was influenced by the type of cooling system used for modifying the housing environment. Based on the results it was not possible to select or advice the use of a specific cooling system as cows showed the same preference for both eating and resting in each studied environment. Further research need to be pursued in order to better understand cow's behavior under cooling systems in hot weather conditions.

5. .ACKNOWLEDGEMENTS

The authors wish to express their gratitude for the financial support from FAPESP (Foundation for Research Funding of São Paulo State) and CNPQ (National Council for Scientific and Technological Development).

6. REFERENCES

- Barnett, J.L. and P.H. Hemsworth, 1990. The validity of physiological and behavioural measures of animal welfare. *Applied Animal Behaviour Science* 1: 177-187.
- Buffington, D.E., A. Collazo-Arocho and G. H. Canton. 1981. Black globe-humidity comfort index (BGHI) as comfort equation for dairy cows. *Transactions of the ASAE* 24(4): 711-714.
- Fraser, D., J.S.D. Ritchie and A.F. Fraser. 1975. The term "stress" in a veterinary context. *British Veterinary Journal* 13(1):653-662.
- Frazzi, E., L.Calamari, F. Calegari and L. Stefanini. 1998. Behavior of dairy cows in response to different barn cooling systems. *In Proc. International Dairy Housing Conference*, 4, 387-394. St. Louis, Missouri. St. Louis: ASAE.
- Frazzi, E., L.Calamari and F. Calegari. 2001. Animal Welfare Indicator and Behaviour of Dairy Cows Exposed to Different Climatization Systems During Summer Season. *In Proc. of the 6th International Symposium in Livestock Environment VI*, May 2001, 22-28. Louisville, Kentucky. American Society of Agricultural Engineers.

- Frazzi, E., L. Calamari, and F. Calegari. 2003. Assessment of a thermal comfort index to estimate reduction of milk production caused by heat stress in dairy cow herds. *In Proc. of the Fifth International Dairy Housing*, January 2003, 269 - 276. Fort Worth, Texas. American Society of Agricultural Engineers.
- Furlan, R.A. 2001. Avaliação da nebulização e abertura de cortinas na redução da temperatura do ar em ambiente protegido. Ph.D. diss., Agronomic Eng., Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba.
- Gaworski, M. A., C. B. Tucker, D.M. Weary and M. L. Swift. 2003. Effects of stall design on dairy cattle behaviour. *In Proc. Fifth International Dairy Housing*, January 2003, 29-31. ASAE Publication Number 701P0203.
- Gordon, I.J., 1995. Animal-based techniques for grazing ecology research. *Small Ruminant Res.* 16, 203–214.
- Hahn, G. L. 1982. Compensatory performance in livestock: influence on environmental criteria. *In Proc. of the Second International Livestock Environment Symposium*, 2, 285-294. Iowa State University, St. Joseph, Michigan: American Society of Agricultural Engineers.
- Huber, J. T. 1990. Alimentação de vacas de alta produção sob condições de estresse térmico. In: *Bovinocultura leiteira*. Piracicaba: FEALQ. 1990. 33-48.
- Igono, M.O., H.D. Johnson, B.J. Steevens, G.F. Krause and M.D. Shanklin. 1987. Physiological, productive, and economic benefits of shade, spray, and fan system versus shade for holstein cows during summer heat. *Journal of Dairy Science*. 70(5):1069-1079.
- Lin, J.C., B.R. Moss, J.L. Koon, C.A. Flood, R.C. Smith Iii, K.A. Cummins and D.A. Coleman. 1998. Comparison of various fan, sprinkler, and mister systems in reducing heat stress in dairy cows. *Applied Engineering in Agriculture*. American Society of Agricultural Engineers 14(2):177-182.
- McGuire, M.A., D.K. Beede, M.A. DeLorenzo, C.J. Wilcox, G.B. Huntington, C.K. Reynolds and R.J. Collier. 1989. Effects of thermal stress and level of feed intake on portal plasma flows and net fluxes of metabolites in lactating Holstein cows. *Journal of Animal Science*, 67:1050-1060.
- Nääs, I.A. *Princípios de conforto térmico na produção animal*. São Paulo: Ícone Ed. 1989. 183p.
- Overton, M. W., D.A. Moore and W. M. Sischo. 2003. Comparison of commonly used indices to evaluate dairy cattle lying behavior. *In Proceedings of Fifth International Dairy Housing Conference*, 29-31 January 2003, Fort Worth, Texas. 25-130. ASAE Publication Number 701P0203.
- Perissinotto M., S.V. Matarazzo, I.J.O. Silva and Moura D. J. 2003. Variação da intermitência de acionamento do sistema de resfriamento adiabático evaporativo em freestall e seus reflexos nas trocas de calor sensíveis e latente. *In Proc. Congresso Brasileiro de Engenharia Agrícola*. Julho 2003. p. 52. Goiânia. Sociedade Brasileira de Engenharia Agrícola.
- Pires, M.F.A., H.M. Saturnino, A.M. Verneque and A.M. Ferreira. 1998 a. Efeito da estação do ano sobre a temperatura retal e frequência respiratória das vacas da raça holandesa confinadas em freestall. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 50(6):747-752.
- Pires, M.F.A., D. Vilela, R.S. Verneque, and R.L. Teodoro. 1998 b. Reflexos do estresse térmico no comportamento das vacas em lactação. In *Proc. Simpósio Brasileiro de Ambiência na Produção de Leite*. 68 – 102. Piracicaba: FEALQ.
- SAS User's Guide: Statistics* Ver. 6.08, pp. 620. Cary, N.C.: SAS Institute, Inc. SAS Institute.

- Shultz, T. A. 1984. Weather and shade effects on cow corral activities. *Journal of Dairy Science*. 67(4):868-873.
- Thom, E. C. 1959. The discomfort index. *Weatherwise* 12:57-59.
- Van Borell, E. 1995. Neuroendocrine integration of stress and significance of stress for the performance of farm animals. *Applied Animal Behaviour Science* 44:219-227.