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Environmental Temperatures In A Tunnel Ventilated Barn And In An Air Conditioned Barn In Florida

D. R. Bray[1], R. A. Bucklin[2], L. Carlos[3] and V. Cavalho[4]

ABSTRACT

In the first study, environmental conditions in an air-conditioned barn were compared to those in an adjacent feed barn with a sprinkler cooling system. THI in the air-conditioned barn was always below 72. THI in the fan and sprinkler barn was never below 75 during daylight hours.

In the second study, a free stall barn with large fans in the end wall of the barn, curtains on the side of the barn and an insulated roof was monitored. Sprinklers over the feed alley were used to wet the cows. Airflow from the large fans evaporated the water from the cows, just as in the usual fan and sprinkler system that uses many smaller fans spaced down the feed lane. This design was compared to an open free stall barn with sprinklers over the feed space but using large blade (7 m) ceiling fans. THI's below 75 were never observed in either the tunnel ventilated barns, or the barn with large ceiling fans.

KEYWORDS. Air condition, Tunnel ventilation, Heat stress

INTRODUCTION

Hot, humid weather causes heat stress in dairy cows that leads to declines in feed intake, milk production, and fertility. These declines can be reduced by using a heat stress relief program consisting of an appropriate combination of shades, feed and water offered under shade, ventilation, sprinkler and fan cooling, and the use of cooling ponds (Bucklin et al., 1991).

Results of air conditioning studies on dairy cattle housing conducted in the 1960's and 1970's (Wiersma and Stott, 1966; Johnson et al., 1966; Hahn et al., 1969; Thatcher et al., 1974) indicated that air-conditioning had the potential to effectively cool cows. However, it was judged that air-conditioning dairy housing was too expensive to run and maintain to be practical.

As refrigeration technology has improved, air conditioners have become more efficient and in addition, design and insulation of buildings have improved. The management practices on many large dairies have also changed. The care of the transition cow, the late dry period through the early fresh period, has been become more highly managed than in the past. In the southeastern United States, cows calving in the summer give less milk than cows calving in the cooler times of the year (2000 Florida DHIA Annual Report). Death loses are also higher in the summer.

Many managers wish to keep heavier cows on a pack of sand or sawdust to reduce feet and leg problems and improve overall cow comfort. The traditional fan and sprinkler systems cannot be used with a pack because they wet the pack and cause other problems. Air conditioning may be a good option to cool this type of housing.

Dairies in northern areas of the US have recently been installing tunnel ventilation systems in housing and have achieved satisfactory results in both summer and winter. Tunnel ventilated housing has seen only limited use by dairies located in hot, humid areas.

[1]Extension Agent IV, Animal Science Dept, University of Florida, Gainesville, FL.
[2]Professor, Agricultural and Biological Engineering Dept, University of Florida, Gainesville, FL
[3]Student, Rural Engineering Dept, University of São Paulo, Piracicaba,, SP, Brazil
[4].Graduate Assistant, Agricultural and Biological Engineering Dept, University of Florida, Gainesville, FL

STUDY #1, AIR-CONDITIONING COMPARED TO FAN AND SPRINKLER COOLING

Internal barn temperatures, and relative humidities of an air-conditioned barn were compared with values observed in a Florida feed barn equipped with a sprinkler cooling system and with external conditions. The Florida feed barn was an open sided barn 50 meters in length, 20 meters wide and 4.5 meters high at the eaves with a 2:12 roof slope with a ridge cap and a galvanized steel roof. The low pressure sprinkler system (138 kPa, 20 psi) was activated when the barn temperature reached 23.9° C (75°F. There were no fans in the barn. Figure 1 shows the sprinkler cooled feed barn.

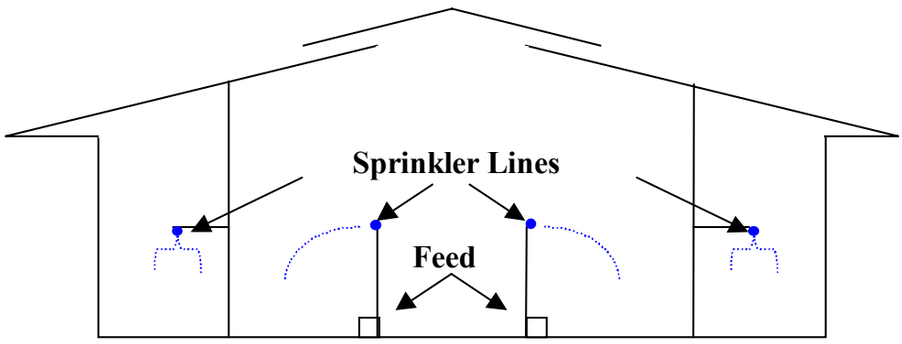

Figure 1. Feed barn with sprinkler evaporative cooling system

The air-conditioned barn is 70 meters in length and 25 meters wide with an eave height of 4.5 meters. The walls and ceiling are insulated with R16 insulation. The floor is bedded with sand, with an open floor plan. The barn is equipped with five 25 ton (87.9 kw) air-conditioning units. The units are controlled by thermostats and are activated at a temperature of 21ºC. Utility bills during the summer averaged $5,400 monthly for about 90,000 kwh. Figures 2 and 3 show the air-conditioned barn.

Figure 2. End of the barn with air conditioning equipment.

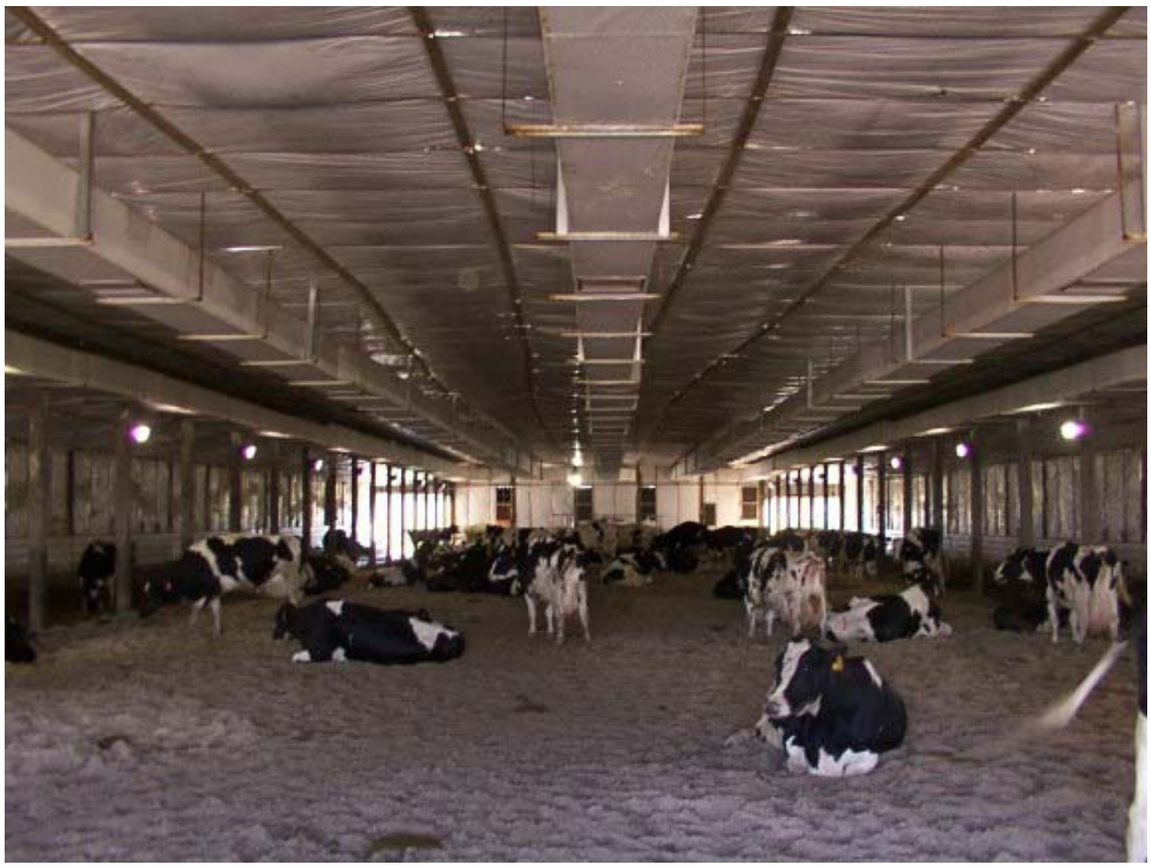

Figure 3. Interior of barn with air-conditioning system.

RESULTS AND DISCUSSION

Data collected included Dry Bulb Temperature, Relative Humidity and Dew Point Temperature. Based on these data, Temperature Humidity Index (THI) values were calculated using the expression given by Thom et al. (1958):

$$THI = Ts + 0.36To + 41.5 \quad (1)$$

Where:

Ts = Dry bulb temperature, °C.

To = Dew point temperature, °C

Values of climatic variables were recorded at hourly intervals on a 24-hour basis, by three dataloggers installed in both barns and outside 20 meters from the AC barn, and 30 m from the feed barn.

Data from 64 days were grouped by time and then statistically evaluated using a randomized block experimental design. Averages were compared using SAS® (SAS Institute Inc) to conduct Tukey's Test at 5% significance level. As shown in Table 1, statistically significant differences were found between the treatments.

THI values were not significantly different between external conditions and inside the EVAP barn (Table 1). However, highly significant differences were observed between external conditions and conditions inside the AC barn. THI values above the 72 are stressful for high production cows (Valtorta and Gallardo, 1996). During the day, animals in the evaporatively cooled feed barn and the in external environment were subjected to heat stressing conditions as

shown in Figure 4. However, cows in the air conditioned barn were always exposed to THI values of 72 or below.

Average values of THI were 70 for the barn with air conditioning, 73 for the evaporatively cooled feed barn and 73 for the external environment. Based on the observed environmental conditions, the air conditioned barn provided the best conditions for cows.

Table 1. Average Environmental Conditions for 64 days

	TEMP °C			RH (%)			THI		
	EVAP	AC	EXT	EVAP	AC	EXT	EVAP	AC	EXT
12 M	22.3 a	21.8 b	21.6 b	91.8 b	86.3 c	94.5 a	71 a	70 b	71 a
6 am	20.7 a	21.1 a	20.3 a	95.0 b	86.9 c	97.1 a	69 a	69 a	69 a
8 am	20.8 a	19.7 a	20.3 a	95.8 b	88.6 c	97.5 a	69 a	69 a	69 a
10 am	23.8 b	21.1 c	23.9 a	87.9 b	88.3 a	87.1 c	73 a	69 b	73 a
11 am	25.5 a	21.9 b	25.7 a	80.2 b	86.5 a	78.8 c	75 a	70 b	75 a
12 N	26.9 a	22.5 b	27.1 a	73.9 b	85.0 a	72.8 b	76 a	71 b	76 a
1 pm	27.6 a	22.9 b	27.9 a	70.0 b	83.5 a	69.1 c	76 a	71 b	77 a
2 pm	28.2 a	23.0 b	28.5 a	67.2 b	82.8 a	65.9 b	77 a	71 b	77 a
3 pm	28.2 a	23.1 b	28.5 a	66.7 b	82.4 a	65.4 b	77 a	71 b	77 a
4 pm	28.0 a	23.2 b	28.3 a	67.1 b	82.5 a	66.0 b	77 a	72 b	77 a
6 pm	26.8 a	22.5 b	27.0 a	71.8 b	82.3 a	71.2 b	76 a	71 b	76 a
8 pm	24.7 a	21.5 c	24.4 b	82.0 b	86.9 a	87.4 a	74 a	70 b	73 a
10 pm	23.1 a	22.0 c	22.6 b	88.1 b	86.2 c	90.7 a	72 a	70 b	71 a

Averages followed with equal letters for the same parameter, do not differ among themselves for Tukey Test at 5% probability. EVAP, Feed Barn with Sprinkler System; AC, Air Conditioned Barn; EXT, External Conditions.

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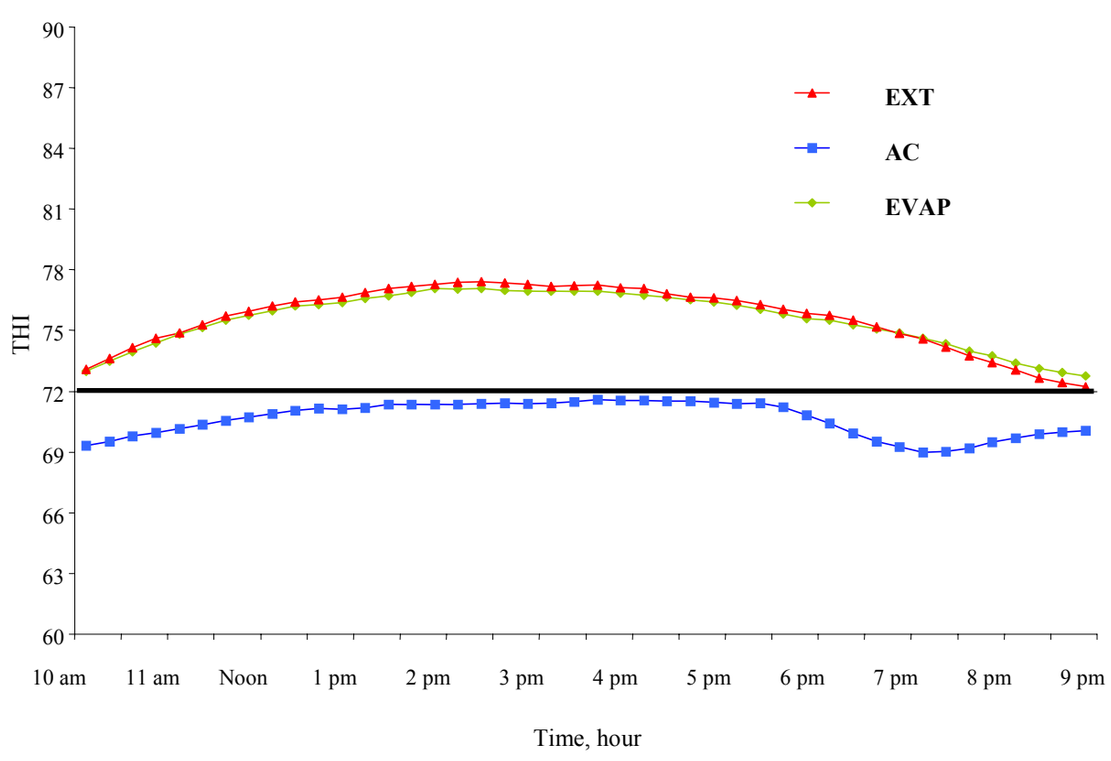

Figure 4. Average values of the Index of Temperature and Humidity (THI) for 64 days.

Study 2. Tunnel Barn vs. Open Barn

The use of tunnel-ventilated barns is common in the poultry industry in the southeastern United States, but has only been tested under experimental conditions in a hot, humid climate (Taylor et

al., 1986). The tunnel barn observed is 120 meters long by 30 meters wide, with an eave height of 4.5 meters. The underside of the metal roof is sprayed with insulating foam. The barn has canvas curtains on the sidewalls and has an open front. It is a 4 row tail to tail free stall barn with a drive through feed alley (Figures 5 and 6).

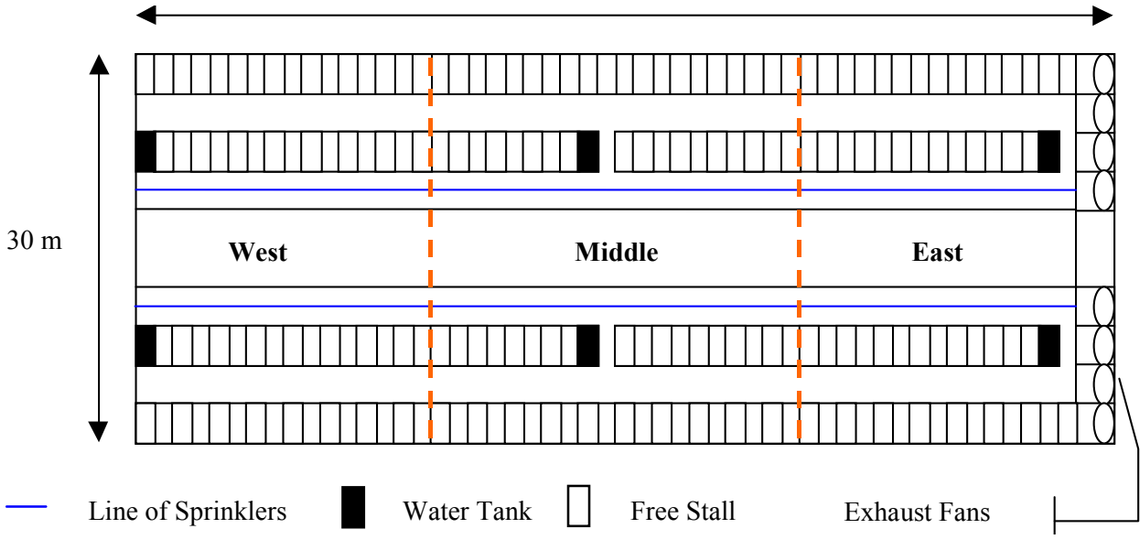

Figure 5. Tunnel ventilated barn with sprinkler evaporative cooling system.

Figure 6. Exhaust fans on tunnel ventilated barn with sprinkler evaporative cooling system.

Evaporative cooling was provided by sprinklers mounted above the feed face. Ventilation was provided by 30 belt driven exhaust fans 1.3 m (48 in) in diameter with 0.75 kw (1 hp) motors. The fans were activated when the temperature exceeded 22°C. At 24°C, all the fans were activated. The sprinklers were also activated at 22°C and ran for 1.5 minutes every 5 minutes.

Environmental conditions were read hourly by three dataloggers located next to the exhaust fans (east), in the center of freestalls and at the end opposite the exhaust fans (west) as shown in Figure 5. Ambient dry bulb temperature and relative humidity were recorded and Equation 1 was used to calculate THI as a comfort index.

Environmental conditions observed in the tunnel ventilated barn were compared to conditions in another freestall barn 150 meters away. Dimensions of both barns were the same. The second barn was open sided with a roof ridge vent 1 meter wide. Roof slope was 3:12 (33%), the same as the first barn, but the metal roof was not insulated. The second did not have exhaust fans. Instead, it was ventilated with three 7 m diameter ten-blade ceiling fans driven by 0.56 kw (0.75 hp) motors. The fans were mounted in the middle of the barn over the feed alley (Figures 7 and 8).

In addition to the ceiling fans, forty 1 meter diameter, 0.38 kw (0.5 hp) fans were located over the free stalls. These fans were located 5 meters apart, 3 meters above the floor as shown in Figures 32 and 34. The sprinklers were identical to those in the tunnel barn using the same timing and temperature set points.

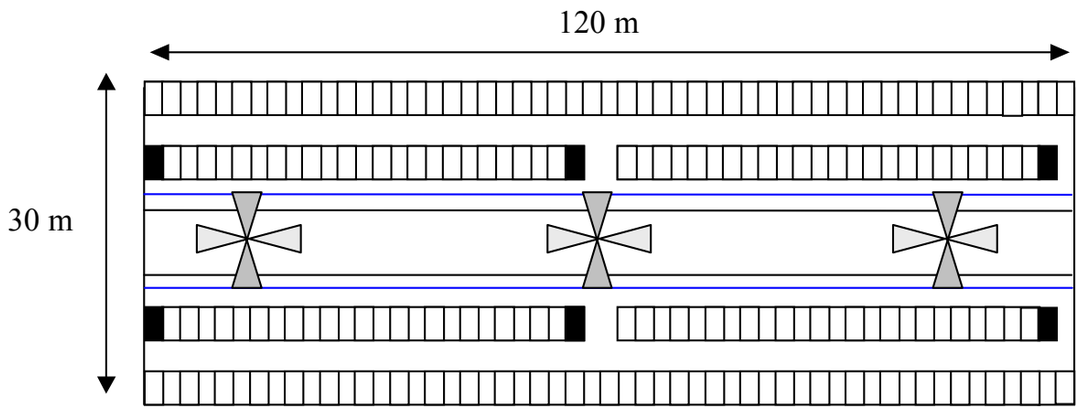

Figure 7. Barn equipped with ceiling fans.

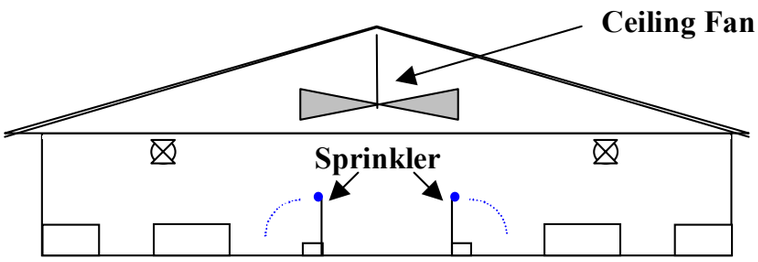

Figure 8. Sprinkler lines, vertical fans and ceiling fan.

Temperature and relative humidity were measured manually each hour from 11 am to 4 pm. Data were collected at three locations inside the barns and the average of the three values was used with Equation 1 to calculate THI values. SAS (SAS Institute Inc) was used to analyze results using a randomized block design and Tukey's Test at 5% probability.

As shown in Table 2 and Figure 9, environmental conditions in both the barn equipped with the sprinkler evaporative cooling system and in the barn equipped with ceiling fans were more comfortable for cows than conditions observed outside.

Table 2. Comparison of hourly averages of dry bulb temperature, relative humidity and THI for sprinkler evaporative cooling (TUN) combined with tunnel ventilation, ceiling fans (CF), and the external environment (EXT).

	Temp °C			RH (%)			THI		
	EXT	TUN	CF	EXT	EVAP	CF	EXT	TUN	CF
11 am	31.3 a	26.9 b	27.8 ab	61.4 a	66.6 a	65.1 a	82 a	76 b	77 ab
Noon	33.7 a	28.3 b	28.6 b	53.2 a	60.1 a	60.7 a	83 a	77 b	78 b
1 pm	34.8 a	29.6 b	29.5 b	49.7 b	53.8 ab	56.8 a	84 a	78 b	79 b
2 pm	35.5 a	29.7 b	31.0 b	43.3 b	51.3 a	50.2 ab	84 a	78 b	79 b
3 pm	34.7 a	30.0 b	31.4 b	47.2 a	52.8 a	52.5 a	83 a	78 b	79 b
4 pm	33.1 a	29.4 b	30.0 b	45.5 a	51.4 a	47.0 a	81 a	78 b	78 b

Averages followed with equal letters for the same parameter, do not differ among themselves for Tukey Test at 5% probability.

Environmental conditions inside the two barns were not statistically different. THI values above 72 are considered to produce heat stress for producing cows (Valtorta and Gallardo, 1996). The average THI value was 83 for the external environment, and 78 for the two barns. It was concluded that the choice between the two cooling systems should be based on initial costs and on water and energy consumption.

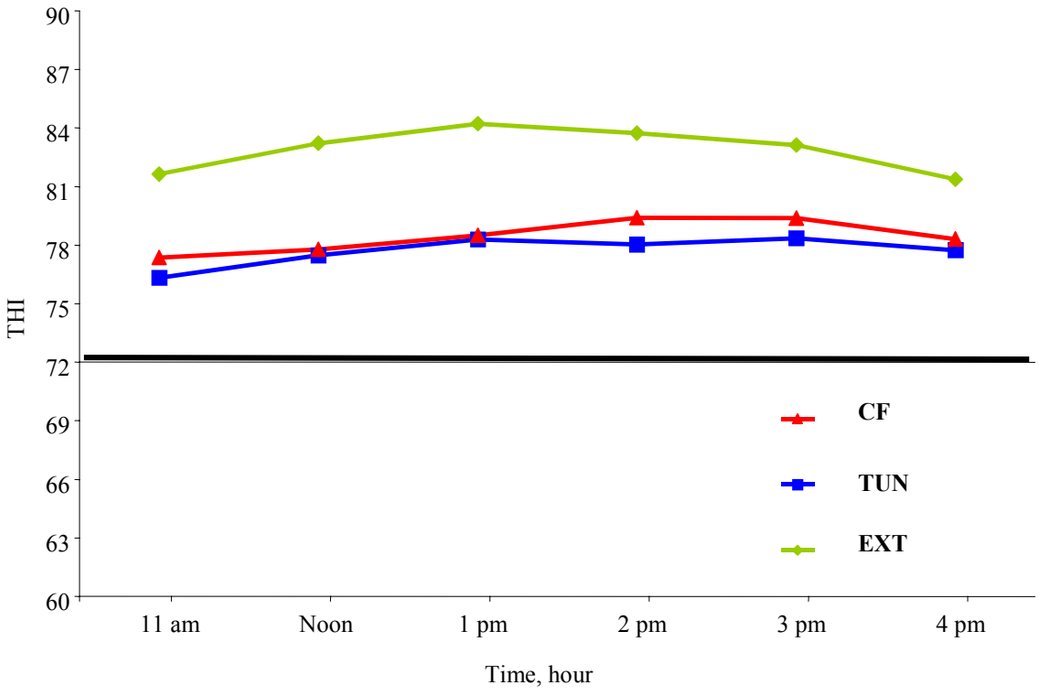

Figure 9. Average values of THI for each treatment. TUN – sprinkler cooling with tunnel ventilation; CF – sprinkler cooling with ceiling fans; EXT – External.

CONCLUSION

In hot humid climates, barns cannot be free of heat stress (THI below 72), without air conditioning. Cows in an air conditioned barn should never suffer any of the effects of heat stress. This is especially important for the "Transition Cow", who must go through the most stressful period in her life, giving birth. Thus this type of barn may be affordable to build and maintain because of all the health problems dairy cows suffer in the summer in these hot and humid conditions. All the other barns tested rely on evaporative cooling methods to reduce heat stress. These barns cannot provide constant cooling. Cows must lie down in an area away from the water and at night the water must be turned off because of high humidity. More research is planned to determine cows' body temperatures under all the structures observed in this study,

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REFERENCES

1. Bucklin, R. A., L. W. Turner, D. K. Beede, D. R. Bray and R. W. Hemken. 1991. Methods to Relieve Heat Stress for Dairy Cows in Hot, Humid Climates. Applied Engineering in Agriculture 7(2):241-247.
2. Hahn, G.L. and D.D. Osburn. 1969. Feasibility of summer environmental control for dairy cattle based on expected production losses. Transactions of the ASAE 12(4):448-451.
3. Johnson, J.E., E.J. Stone and J.B. Frye, Jr. 1966. Effect of hot weather in the productive function of dairy cows. Louisiana State University Agricultural Experiment Station Bulletin No. 608.
4. Shahr, S.L. 1992. Methods and systems for cow identification. In: Large Dairy Herd Management, Edited by: H. H. Van Horn and C. J. Wilcox. American Dairy Science Association, Champaign, IL. pp 672-681.
5. Taylor, S.E., D.E. Buffington, R.J. Collier and M.A. DeLorenzo. 1986. Evaporative cooling for dairy cattle in Florida. ASAE Paper No 86-4022. St. Joseph, MI:ASAE.
6. Thatcher, W.W. 1974. Effects of season, climate and temperature on reproduction and lactation. J. Dairy Sci, Vol. 57, No. 3.
7. Thatcher, W.W., F.C. Gwazdauskas, C.J. Wilcox, J. Toms, H.H. Head, D.E. Buffington and W.B. Fredrickson. 1974. Milking performance and reproductive efficiency of dairy cows in an environmentally controlled structure. Journal of Dairy Science 57:304-307.
8. Thom, E. C. 1977. Cooling degrees: day air conditioning, heating, and ventilating. Transactions of the ASME, 55(7): 65-72.
9. Titto, E. A. L., A. M. F. Pereira, R. Passini, Balliero G. Neto, A..C. A. Fagundes and C. G. Lima. 1989. Estudo da tolerância ao calor em tourinhos das raças Marchigiana, Nelore e Simental. In: Congresso Brasileiro De Biometeorologia, 2., Goiânia, 1998. Anais. Goiânia:SBBiomet, pp.2-37.
10. Titto, E.A.L. 1998. Clima: Influência na Produção de Leite. In: Simpósio Brasileiro De Ambiência Na Produção De Leite. 1., Piracicaba, 1998**.** Anais. Piracicaba: FEALQ, pp. 10-23
11. Valtorta, S. and M. Gallardo. 1996. El estres por calor en produccion lechera. Temas de Produccion Lechera, n.81, outubro. pp.85-112
12. Wiersma, F. and G.H. Stott. 1966. Microclimate modification for hot weather stress relief of dairy cattle. Transactions of the ASAE 9(3):309-313.