Shade Management in Subtropical Environment for Milk Yield and Composition in Holstein and Jersey Cows

R. J. Collier
University of Florida

R. M. Eley
University of Florida

A. K. Sharma
University of Florida

R. M. Pereira
University of Florida

D. E. Buffington
University of Florida

Shade Management in Subtropical Environment for Milk Yield and Composition in Holstein and Jersey Cows[1]

R. J. COLLIER, R. M. ELEY,[2] A. K. SHARMA,[3]
R. M. PEREIRA,[4] and D. E. BUFFINGTON
Dairy Science and Agricultural Engineering Departments
Institute of Food and Agricultural Sciences
University of Florida
Gainesville 32611

ABSTRACT

Forty-eight cows were assigned randomly to shade (15 Holsteins, 8 Jerseys) or no shade (16 Holsteins, 9 Jerseys) for 102 days beginning 12 June 1977 to examine effects of solar heat load on milk yield and composition. Rectal temperatures, respiration rates, and rumen contractions/min were monitored between 1200 and 1700 h on 20 randomly selected days. Morning and evening milk weights were recorded daily. Once weekly, morning and evening milk samples were collected from each cow and analyzed for fat, protein, acidity, freezing point depression, and somatic cell number. Black Globe temperature, rectal temperature, and respiration rate were elevated in no shade 38.8°C, 39.6°C, and 114.8/min from 30.1°C, 38.7°C, and 78.5/min. Afternoon Black Globe temperatures had little effect on morning or evening milk yield of the same day, whereas Black Globe temperatures 24 and 48 h prior were associated with depressed yield. Milk composition did not differ between shade and no shade cows. However, freezing point depression and fat were greater in evening milk in both shade and no shade cows, and treatment interacted with time so that evening milk contained less water per unit solids, and this was more pronounced in no shade cows. Benefit of shade is in reducing total heat load while preserving sensible avenues of heat loss. Time delay of temperature effects in milk yield indicates that reduced feed intake and possibly reduced rate of passage are major reasons for reduction in yield of milk.

INTRODUCTION

Climatic variables such as ambient air temperature, wind speed, and humidity affected milk yield and composition (6, 10, 13). Solar radiation combined with high temperature also had detrimental effects on milk yield (3, 4). Reduction of exposure of cattle to solar radiation by a shade management system in a subtropical environment increased both lactation performance and solids-not-fat composition of milk over those of unshaded controls (5, 11).

Thermal stress during summer months also was associated with increases in incidence of mastitis, somatic cell content of milk, and California mastitis test scores (7, 12, 15). Although Paape et al. (8, 9) reported that neither heat stress nor injection of ACTH increased the number of somatic cells in milk produced from healthy glands, their acute studies were in climatic chambers, and it is possible that healthy cows or cows with subclinical mastitis may respond differently when chronically heat stressed.

Heat stress, as measured by combined temperature (C) and radiation (Langleys), is greater during the day than the night. It is possible that response of the cow to diurnally changing temperatures would be reflected in yield and compositional differences between morning and evening milk. Objectives of this study were to ascertain such differences and

Received August 25, 1980.
[1] Florida Agricultural Experiment Station Journal Series No. 2540.
[2] University of Nairobi, Department Animal Physiology, Chiromo, P. O. Box 30197, Nairobi, Kenya.
[3] Departamento de Zootecnia, Universidade Federal de Santa Maria, 97100 Santa Maria, RS, Brazil.
[4] Universidade Federal De Cerea, Centro Die Ciencias Agrarias, Departmendo De Zootecnia, CAIXA Postal 354, Fort Alexa, Ceara, Brazil.

TABLE 1. Effect of shade on heat stress indices in Holstein and Jersey cattle.

	Shade			No shade			
Indice	Holstein	Jersey	$\bar{X}$	Holstein	Jersey	$\bar{X}$	SE
Black Globe temperature (C)[a]			30.1			38.8	.2
Rectal temperature (C)[a,b]	38.8	38.5	38.7	39.7	39.2	39.6	.1
Respiration rate/min[a]	77.5	78.6	78.5	114.2	115.1	114.8	1.3
Rumen contraction/min[a,b]	2.2	2.6	2.3	1.4	2.0	1.6	.1

[a]Shade different from no shade $P<.001$.

[b]Holstein different from Jersey $P<.01$.

further to examine shade management for reducing heat stress effects upon lactation in a subtropical environment.

MATERIALS AND METHODS

Forty-eight cows (31 Holsteins, H, and 17 Jerseys, J) were assigned randomly to shade (S: 15 H, 8 J) or no shade (NS: 16 H, 9 J) environments for 102 days beginning June 12, 1977. Details of S and NS areas were published in (11). Cows were given a 42-day adaptation to adjust to their environment. All cows were fed fresh cut pearl millet and approximately 9 kg of concentrate per cow on a group basis. On 20 days selected at random during the subsequent 56 days, rectal temperatures (RT), respiration rates (RR), and rumen contraction rates (RC) for all cows were monitored once between 1300 and 1600 h. Black Globe temperature (BGT) readings were recorded every 15 min from 1200 to 1700 h and averaged for that day. Milk weights were recorded at each milking. A morning (a.m.) and subsequent evening (p.m.) milk sample was collected each week for fat (Babcock), protein (formol titration), somatic cells (direct count), freezing point (cryoscope), and titratable acidity. Milk analyses were at the interstate milk testing station, White Springs, FL, by standard techniques (1). Data were analyzed by least squares analyses of variance.

RESULTS AND DISCUSSION

Table 1 depicts responses of temperatures and animals to treatments with greater thermal stress in NS than S. Average afternoon Black Globe temperature in S was approximately 8°C less than in NS. In addition, in the NS environment, since BGT were equal or greater than normal body temperature, sensible avenues of heat loss requiring a thermal gradient were compromised. Thus, cows in NS would have been unable to lose heat by conduction, convection, and radiation during afternoon hours. Evaporative heat loss via increased respiration rate and sweating would have been the major avenue of heat loss available to NS cows. This resulted in higher RT and RR in NS cows (Table 1). The relationship between average afternoon BGT and RT is in Figure 1. When average afternoon BGT was below 35°C, both breeds were able to maintain normal RT. However, as BGT increased above 35°C and approximated body temperature, there were sharp increases in RT in both breeds. Although RT response to BGT was similar for both breeds, RT in Jersey cows was always lower than that of Holsteins. Thus, breeds differed in RT response to BGT ($P<.01$). However, in both

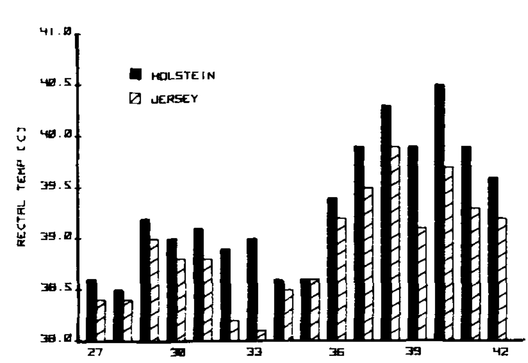

Figure 1. Relationship between average afternoon Black Globe temperature and rectal temperature in Holstein and Jersey cows in no shade.

breeds when BGT approximated body temperature, heat gain exceeded heat loss, and body temperature rose.

The relationship between RR and average afternoon BGT is in Figure 2. The trend in RR response to average afternoon BGT in both breeds is similar to the relationship between average afternoon BGT and RT. Again, when average afternoon BGT exceeded 35°C, increases in RR were sharp. However, breed differences in RT response to BGT were not evident in RR response to BGT (Figure 2, Table 1). Although respiratory volume was not measured, RR response to BGT was similar for breeds and appeared to plateau at average afternoon BGT of 38°C. Since RR did not differ between breeds, this avenue of heat loss was probably not responsible for breed differences in RT (Table 1, Figure 1). In addition to being a relatively inefficient method of heat loss (13), high RR contributes to reduced feed intake and rumination.

Reduced gut motility and RC during thermal stress have been reported (2, 14). Rumen contractions were related inversely to BGT and RT in our study (Table 1, $P<.001$), and breeds differed in both S and NS, which appears to be related to differences in RT (Table 1 and Figure 1). These results agree with those of Attebery and Johnson that environmental temperature appears to depress rumen activity directly.

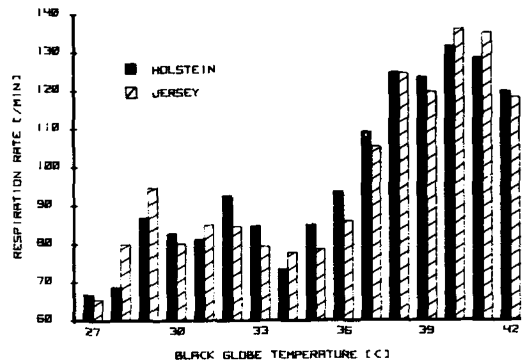

Figure 2. Relationship between average afternoon Black Globe temperature and respiration rate in Holstein and Jersey cows in no shade.

Arithmetic means of RT and RR (Figures 1 and 2) indicate major increases in both indicators of heat stress around 38°C or body temperature. Primary benefits of shade appear to be that it reduces total heat load and preserves sensible methods of heat loss.

We failed to detect effect of S or NS en-

TABLE 2. Least squares analysis of variance for milk composition.

Source	df	Error term	Freezing point	% Acidity	Total protein	Fat %	Somatic cells
			Significance				
Treatment (T)	1	CBT	....	....	....	....	....
Breed (B)	1	CBT	*	*	***	***	....
B × T	1	CBT	....	....	....	....	....
Cow (BT)	39	Residual	***	***	***	***	***
Week (W)	8	Residual	***	***	***	***	....
T × W	8	Residual	....	....	....	***	*
B × W	8	Residual	....	....	....	....	....
T × B × W	8	Residual	*	....	....	....	....
Time (Ti)	1	Residual	***	***	....	**	....
T × Ti	1	Residual	*	....	....	***	....
B × Ti	1	Residual	....	....	....	....	....
Ti × W	7	Residual	***	***	....	***	....
Residual MS	443		153.2	697.5	12.8	6767.8	50996.7

*$P<.05$.

**$P<.01$.

***$P<.001$.

TABLE 3. Milk composition and incidence of mastitis.

	Shade	No shade
Freezing point depression	−.5497	−.5485
% Acidity	.1650	.1725
Total protein	3.34	3.31
Fat %	3.62	3.61
Somatic cells/ml milk	382765	337419
Mastitis cases	11	6
Mastitis incidence (no/total cows)	23.1	22.2

vironment on mean freezing point depression, percent acidity, total protein, fat percent, or somatic cell content of milk (Table 2, 3). However, breeds differed in all of these variables except somatic cell content. Mastitis incidence in NS was numerically greater (11 cases versus 6 in S, Table 3). However, these means were not different (Table 3).

Although mastitis incidence tended to be higher in NS, somatic cell concentrations in milk of NS and S cows were not different (Tables 2, 3). Interaction of treatment by week in somatic cell content of milk was detected (Table 3). This was from a slightly higher somatic cell count in milk of NS cows at the beginning of the experiment and a slightly higher count in S cows towards the finish of the experiment. Thus, we failed to detect a temperature effect on somatic cell numbers. These results agree with those of Paape et al. (8, 9), who were unable to detect effect of acute heat stress on somatic cell content of milk.

Week of sampling also was significant in all variables except somatic cells. This reflects well-known stage of lactation effects on milk composition. Effects of time of milking were detected for freezing point, acidity, and fat with the evening milk having lower freezing point and higher acidity and fat. These effects of time of day could reflect milking interval (1300 h, 2100 h), yield (a.m. > p.m.), or temperature differences. The latter is indicated by the significant interaction of treatment by time for freezing point and fat. These results suggest that environmental temperature may influence water or solids content of milk slightly because p.m. milk contained less water per unit solids, and this was more pronounced in NS animals.

Average daily milk yields for S and NS cows at the beginning of this experiment were 16.63 and 16.45 kg. Average milk yields over the experiment for the same groups corrected for stage of lactation were 15.12 and 12.67 kg. Thus, shade management system had a beneficial effect on milk yield as reported by others (5, 11). Effects of BGT 2 days prior, 1 day prior, and day of milking on a.m. and p.m. milk yield were examined to determine time relationship between heat stress and reduction in milk yield. Results are in Figures 3 and 4. As expected, a.m. milk yield was unaffected by BGT that afternoon (Figure 3). However, BGT 36 h prior to milking had negative effect on yield. That p.m. milk yield was not affected greatly by the same day's temperature (Figure 4) indicates that the majority of negative effects of heat stress on milk yield are delayed. From combined information from Figure 3 and 4 it appears that maximum response of milk yield to thermal stress occurs between 24 and

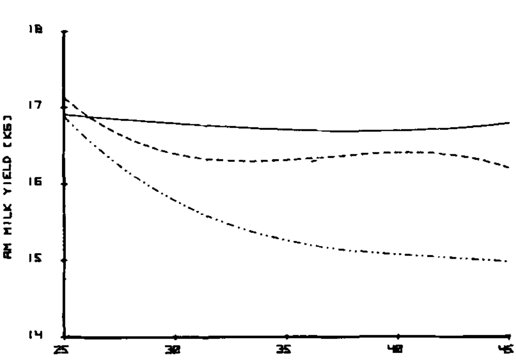

Figure 3. Least squares regressions of average afternoon Black Globe temperature 2 days prior to (–··–), 1 day prior to (––), or day of (–) a.m. milking on milk yield.

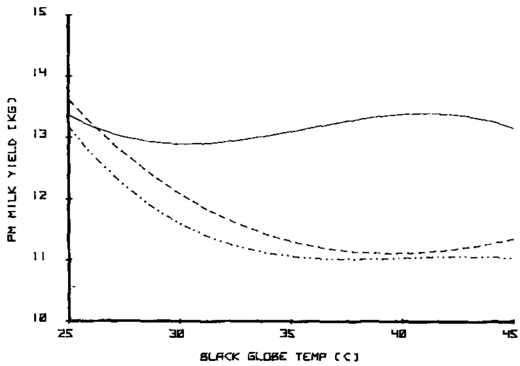

Figure 4. Least squares regressions of average afternoon Black Globe temperature 2 days prior to (-···-), 1 day prior to (--), or day of (-) p.m. milking on milk yield.

48 h following exposure. The delayed response of milk yield to BGT may be related to altered feed intake or delayed response in change of metabolic or endocrine state of the animal. These results agree with those of Harris et al. (4), who reported delayed effects of solar radiation on milk yield in Holstein and Jersey cattle. In this study heat stress had only small direct effects on that day's milk yield as related to composition (Table 2, Figure 3, 4).

Major benefits of shade management on milk yield appear to be related to indirect effects such as feed intake and digestive tract performance rather than direct effects on ability of the mammary gland to synthesize milk. When BGT approaches body temperature, increased RR, reduced feed intake and RC, and possibly altered metabolic rate of animals are associated with declines in milk yield 24 and 48 h later. However, large differences in heat load on cows prior to a.m. or p.m. milking appear to have only slight effects on milk composition, which may be related to water or solids content of milk.

That cows in S environment were able to maintain a lower RT than NS cows appears to be related not only to differences in solar heat load but also to ability of these animals to utilize sensible avenues of heat loss to a greater degree. Thus, cows in S environment are able to dissipate heat by radiation, conduction, and convection in addition to evaporation, while animals in NS environment are forced to store heat until cooler night hours. Apparently, evaporative heat loss most noticeable as an increase in RR is not effective enough to dissipate total heat load when BGT approximates core temperature.

ACKNOWLEDGMENTS

The authors wish to thank Angelita Mariano and Fred Lopez for technical assistance on milk sample analysis.

REFERENCES

1 Atherton, H. V., and J. A. Newlander. 1977. Chemistry and testing of dairy products. 4th ed. Avi Publ. Co., Westport, CT.

2 Attebery, J. T., and H. D. Johnson. 1969. Effects of environmental temperature, controlled feeding and fasting on rumen motility. J. Anim. Sci. 29:734.

3 Guthrie, L. D., J. E. Johnston, J. Rainey, and J. A. Lee. 1967. Effects of solar radiation and levels of fiber on production and composition of Holstein cows milk. J. Dairy Sci. 50:608.

4 Harris, L. D., R. R. Shrode, I. W. Rupel, and R. E. Leighton. 1960. A study of solar radiation as related to physiological and production responses of lactating Holstein and Jersey cows. J. Dairy Sci. 43:1255.

5 Ingraham, R. H., R. W. Stanley, and W. C. Wagner. 1979. Seasonal effects of tropical climate on shaded and nonshaded cows as measured by rectal temperature, adrenal cortex hormones, thyroid hormone and milk production. Am. J. Vet. Res. 40:1792.

6 Johnson, J. C., B. L. Southwell, R. L. Givens, and R. E. McDowell. 1962. Interrelationships of certain climatic conditions and productive responses of lactating dairy cows. J. Dairy Sci. 45:695.

7 Macleod, P., E. O. Anderson, and W. N. Plasteridge. 1954. Cell counts of platform samples of herd milk. J. Dairy Sci. 37:919.

8 Paape, M. J., W. D. Schultz, R. H. Miller, and J. W. Smith. 1973. Thermal stress and circulating erythrocytes, leucocytes and milk somatic cells. J. Dairy Sci. 56:84.

9 Paape, M. J., W. D. Schultz, R. H. Miller, and J. W. Smith. 1973. Failure of either corticosteroids or ACTH to increase the leukocyte concentration in milk. J. Vet. Res. 34:353.

10 Ragsdale, A. C., H. J. Thompson, D. M. Worstell, and S. Brody. 1953. Environmental physiology and shelter engineering, XXI. The effect of humidity on milk production and composition, feed and water consumption, and body weight in cattle. Missouri Agric. Exp. Stn. Res. Bull. 521, 1.

11 Roman-Ponce, H., W. W. Thatcher, D. E. Buffington, C. J. Wilcox, and H. H. Van Horn. 1977. Physiological and production responses of dairy cattle to a shade structure in a subtropical environment. J. Dairy Sci. 60:424.

12 Roussel, J. D., J. D. Ortego, J. H. Gholson, and J. B. Frye. 1969. Effect of thermal stress on the

incidence of abnormal milk. J. Dairy Sci. 52:912. (Abstr.)

13 Thatcher, W. W. 1974. Effects of season, climate, and temperature on reproduction and lactation. J. Dairy Sci. 57:360.

14 Thatcher, W. W., and R. J. Collier. 1980. Effect of heat on animal productivity. CRC Handbook on food and human nutrition. (In press).

15 Wegner, T. N., J. D. Schuh, F. E. Nelson, and G. H. Stott. 1976. Effect of stress on blood leucocyte and milk somatic cell counts in dairy cows. J. Dairy Sci. 59:949.