BURNETT CENTER INTERNET PROGRESS REPORT

No. 10 – February, 2001

Shade and water application to decrease heat stress of heifers in an experimental feedlot

F. M. Mitlöhner[a], M. L. Galyean[a], J. B. Patterson[a], G. A. Nunnery[a], G. B. Salyer[a], J. L. Morrow-Tesch[b], J. W. Dailey[b], and J. J. McGlone[a]

[a]Department of Animal Science and Food Technology
Texas Tech University, Lubbock 79409-2141, and
[b]USDA-ARS, Livestock Issues Research Unit, Lubbock, TX 79409

Introduction

Chronic heat stress can substantially affect beef cattle productivity (Hahn, 1999). During hot periods, cattle show signs of disrupted behavior, impaired physiological functions, and an increased incidence of morbidity (Hahn and Mader, 1997). A coping strategy of cattle during heat stress is to decrease metabolic heat production by lowering feed intake, which adversely affects productivity. Environmental modifications can help maintain feed intake and decrease the heat load. Ray (1991) summarized several environmental modifications (shading, sprinkling, misting, and fogging) to cool heat-stressed beef cattle in Arizona and California. In West Texas, these cooling modifications are generally not used in commercial feedlots because they are not thought to be cost effective; hence, the efficacy of cooling techniques has not been determined in West Texas. The FASS (1999) guide stated that direct wetting of cattle during heat can be a very effective practice to lower heat stress; however, we speculated that misting feedlot cattle with water might be a less effective means of decreasing heat stress than providing shade.

In the present experiments we investigated the effects of shade, water sprinkling, and(or) water misting on performance, carcass traits, behavior, and physiology of feedlot cattle during two summers.

Figure 1: Sprinkle, mist, and shade treatments (front to back) in Exp. 2.

Experimental Procedures

General. The experiments were conducted at the Texas Tech University Burnett Center experimental feedlot in New Deal, TX over two summers. Exp. 1 took place from 06/23/1999 until 10/13/1999 and Exp. 2 from 6/13/2000 until 10/20/2000. Animals were housed and used in accordance with the Guide for the Care and

Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999), and the Texas Tech University Animal Care and Use Committee approved the project.

Sixteen pens, each with a concrete, partially slatted floor and a pen area of 108 ft^2 were used in both experiments. Waste fell through the slatted floor and was collected in flush tanks at the end of the alleyway. Fences were built with metal pipe construction and secured to the concrete floor. A concrete feed bunk was located on one end of each pen, and one water trough, with a float-activated water supply, was shared by two pens.

Treatments in Exp. 1 were arranged factorially and included:

(1) no shading or misting (CONT);
(2) only misting (MIST);
(3) only shading (SHADE); and
(4) hading and misting (SHMI).

Ten pens (eight treatment and two buffer pens) were shaded with black, 80% light-occluding polypropylene shade cloth. A PVC-structure was built to cover two-thirds of the area of the pen, and the shade material was fixed at a height of approximately 9 ft (10% slope) from the slatted floors. Conventional water misters were used that were located between every other pen at a height of 5 ft. The misters delivered 1/8 gal of water mist/min, with a very fine droplet size. Misters were manually turned on when ambient temperatures exceeded 90° F and kept operating until temperatures dropped below this threshold.

In Exp. 2 four treatments also were used:
(1) no shading or misting (CONT);
(2) only water sprinkling (SPRINKLE);
(3) only water misting (MIST); and
(4) only shading (SHADE).

The MIST and SHADE treatments in Exp. 2 were very similar to those in Exp. 1. Pens between treatments were empty (buffer pens). In Exp. 2, SPRINKLE was a treatment that consisted of the application of 1.5 gal of water per min with a large droplet size. Water was sprayed into an area of 2/3 of the pen from an overhead sprinkler construction (8 ft height). The sprinkler system was activated by a thermostat that automatically opened the main water valve when temperatures exceeded 85° F. Furthermore, a timer controlled the intervals (every 30 min for a period of 5 min) at which the valve for the sprinkler system was turned on and off.

The heifers in both experiments were weighed individually and identified with ear tags after their arrival at the experimental feedlot. Animals were then placed in large, dirt-floored pens where they were adapted to the high-concentrate diet.

In both Exp. 1 and Exp. 2, 80 heifers were used, of which 48 were Angus-crossbred and 32 were Charolais-crossbred heifers. Heifers were assigned randomly to 16 pens with two Charolais-crossbred and three Angus-crossbred heifers per pen. The diet was a 90% concentrate (Table 1), fed once daily (at approximately 1000) in quantities sufficient to ensure ad libitum consumption, and water was available at all times.

Before transport to the Burnett Center, cattle in Exp. 1 were implanted with Ralgro (Schering-Plough Animal Health, Union, NJ), and received injections of vitamins A and D (Bayer Animal Health, Kansas City, MO), Vision 7 (Bayer Animal Health,), IBR/BVD (Pfizer Animal Health, Exton, PA), and Dectomax 1% (Pfizer Animal Health). Cattle in Exp. 2 received implants of Synovex H (Fort Dodge, Websa, FL), and injections of Vision 7 (Bayer Animal Health), IBR Lepto (Pfizer Animal Health), and Ivomec Plus (Merial, Iselin, NJ).

On d 0 of Exp. 1, the heifers were weighed, selected randomly, and divided into their pen groups (five heifers per pen) following stratification by breed and BW. On d 0 of Exp. 2, heifers were weighed and assigned randomly to one of four weight blocks. On d 56, heifers in both experiments were reimplanted with Revalor H (Intervet, Millsboro, DE).

Performance. All BW measurements were obtained using a single animal scale (C&S Single Animal Squeeze Chute set on four load cells) that was calibrated with 1,000 lb (Texas Dept of Agric.) before every weigh day. In both experiments, cattle were weighed on the receiving day, d 0, 28, 56, 84, 112, and either 131 (Exp. 1) or 122 (Exp. 2) of the study. The dry matter intake (DMI) per pen (experimental unit) was measured daily, and DM content was determined weekly to calculate DMI. The average daily gain (ADG) and DMI were used to calculate feed:gain (F:G). The ADG, DMI, and F:G were calculated for each 28-d period and for the entire study period.

On d 131 (Exp. 1) or 122 (Exp. 2), respectively, heifers were weighed and then transported to slaughter at the Excel Corp. packing plant in Plainview, TX.

Carcass Traits. In Exp. 1, 77 of the initial 80 heifers were used for carcass measures collected at d 131. Carcass measurements were obtained by personnel from Texas Tech University in Exp. 1 and by personnel from the West Texas A&M University Beef Carcass Research Center in Exp. 2. In Exp. 2, 74 of the initial 80 heifers were slaughtered, and the carcass measures were obtained. The missing animals in both experiments died or were removed from the studies for reasons unrelated to the treatments.

In both studies, carcasses were chilled for approximately 36 h after slaughter, at which time carcass characteristics and USDA quality and yield grades were obtained. The carcass measurements were yield grade, kidney, pelvic, and heart fat (KPH), longissimus muscle area (LMA), and hot carcass weight (HCW). These measurements were used to calculate the final yield grade. Furthermore, liver abscess rate and incidence of dark cutters were determined.

Behavior. Before the main behavioral observations started in Exp. 1, a pilot study was conducted to determine the necessity of behavioral observations at night. Because heifers primarily showed lying behavior during the night, only daylight observations were conducted. Therefore, the following behaviors: standing, head in the feed bunk, lying, drinking, and walking were measured during all the daylight hours of Exp. 1. Standing was considered to be an inactive upright posture (no locomotion). It was impossible to distinguish between feeding and merely standing at the bunk. As a result, this behavior, which involved both feeding and shade seeking (for CONT) was defined as “head in the bunk.” Lying was defined as body contact with the ground, and drinking, with the same challenge as feeding, was defined as the head over or in the water trough. Walking was defined as any change of body location within the pen. Two trained persons measured behaviors by live observations each month throughout the experiment. During the daylight hours (0800 to 2000), the five behaviors of the 80 heifers in Exp. 1 were directly entered into a computer spreadsheet at 10-min scan intervals. Data were expressed as a percentage of total observations. In Exp. 2, behavioral measures were not taken.

Physiology. In both experiments, respiratory rates were measured in two heifers per pen once weekly (at approximately 1300) by counting the animal's flank movements per minute. Also in both experiments, one Angus-crossbred and one Charolais-crossbred heifer per pen were chosen randomly, and their respiration rate was measured once per week.

Weather. Weather data, including precipitation, wind speed and direction, relative humidity, solar radiation, and temperature were recorded at the site by a weather monitoring station (Campbell Scientific 21X Micro Logger, Dallas, TX).

Experimental Design and Statistical Analyses. In Exp. 1, a completely random design was used with a 2 x 2 factorial arrangement of the four treatments: (1) no shading or misting, (2) only misting, (3) only shading, and (4) shading and misting. Exp. 2 was arranged as a randomized complete block design, blocked by weight. In both experiments, the pen was the experimental unit, with five heifers per pen. Four replications (pens) were used per treatment in both experiments. The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used for the analyses.

Respiration rate was analyzed as a split-plot in both experiments to determine the day effect. In Exp. 1, breed type and breed type x treatment interactions were included in the analysis, again with the pen as the experimental unit. The error term was pen within shade x mist x breed type.

For behavioral data in Exp. 1, the model included shade, misting, shade x misting, day, and time of day. Duration (per hour) of each behavior was converted to a percentage of the total time per hour, and these percentages were then square root-arcsine transformed to achieve a normalized distribution. Transformed behavior data were analyzed as a completely random design, with a 2 x 2 factorial arrangement of treatments, in a split-split plot. The first split represented the monthly observations, and the second split represented the time of day. For all measures, the predicted difference test in the GLM procedure in SAS was used to separate means when the overall F-value was significant ($P < 0.05$).

Results

Performance. The overall performance results of Exp. 1 are presented in Table 3. After stratification and random assignment of the heifers at d 0, their initial BW averaged 741 lb. The final BW on d 131 was 59 lb/heifer greater (1,147 vs 1,206, respectively; $P < 0.01$) for the shaded vs unshaded heifers. Daily DMI was 7% greater (19.4 vs 20.9 lb/d, $P < 0.01$) in shaded vs unshaded heifers. As would be expected from differences in BW, ADG was 11.8% higher ($P < 0.01$) in shaded vs unshaded cattle (3.53 vs 3.11 lb/d), and F:G was 6.3 vs 5.9 (unshaded vs shaded heifers, $P = 0.086$). Calculated NEm and NEg values for the diets were similar between shaded and unshaded treatments. Water misting had no effect on performance (P > 0.10), and no interactions (P > 0.10) between misting and shading were found for performance measurements (data not shown).

Performance results of Exp. 2 are presented in Table 4. The average initial BW of the heifers was 752 lb. After 122 d, the final BW for SHADE, MIST, SPRINKLE, and CONT, respectively, were 1,194, 1,152, 1,166, and 1,149 lb. Even though heifers in SHADE were 46 lb heavier than the ones in CONT, the difference was not significant (P > 0.05). The DMI for SHADE, MIST, SPRINKLE, and CONT, respectively, was 20.01, 18.60, 19.25, and 18.52 lb/d (P > 0.05). The ADG for SHADE, MIST, SPRINKLE, and CONT, respectively, was 3.58, 3.29, 3.40, and 3.26 lb/d. The difference in ADG between SHADE and CONT was 10 %; however, because of high variation in the data, these differences were not significant (P > 0.05). The F:G for the treatments was 5.59, 5.66, 5.70, and 5.68 (P > 0.05), for SHADE, MIST, SPRINKLE, and CONT, respectively.

Carcass Traits. In Exp. 1, the HCW of shaded heifers was 35 lb greater than that of unshaded heifers (745 vs 710 lb; P < 0.05; Table 5). Fat thickness was higher (P < 0.05) for shaded vs unshaded heifer carcasses. The KPH, LEA, USDA quality grade, and USDA yield grade did not differ (P > 0.10) among treatments. Carcasses graded on average low Choice (small marbling). When analyzed with HCW as a covariate, carcass traits were not affected by treatment. No dark cutters were observed among the heifer carcasses in Exp 1.

Carcass data for Exp. 2 are presented in Table 6. The HCW for heifers in the four treatments SHADE, MIST, SPRINKLE, and CONT, respectively were 739, 725, 721, and 719 lb, but even the 20 lb difference between SHADE and CONT was not significant. No differences (P > 0.05) were found for dressing percent, fat thickness, KPH, LEA, quality grade, and USDA yield grade.

Dark cutters for the treatments SHADE, MIST, SPRINKLE, and CONT were 0%, 10% 5.6%, and 21.1%, but because of the relatively small numbers of dark cutters, the statistical significance could not be estimated. Differences in liver abscess scores also could not be assessed because of the small rate of occurrence.

Behavior. In Exp. 1 (Table 7), standing behavior was affected by shade (P < 0.01) and head over/or in the waterer behavior was affected by mist (P < 0.05). Other behaviors did not differ among the four treatments.

Physiology. In Exp. 1, main-plot analysis showed that MIST heifers had the highest and SHMI heifers the lowest average respiration rate (RR). The RR of the four treatments were 74, 80, 106, and 88 for SHMI, SHADE, MIST, and CONT, respectively (P < 0.05). Over the period of 12 wk, respiration rates showed fluctuations (Figure 1) and were less for the first 9 wk for shaded vs unshaded heifers (P < 0.05). At the end of the study in October, 1999 (wk 10 to 12), respiration rates were the same for shaded and unshaded cattle. In Exp. 2, MIST and CONT had the highest (P < 0.05) and SHADE the lowest RR. The RR of the four treatments were 67, 94, 89, and 97 for SHADE, MIST, SPRINKLE, and CONT, respectively (P < 0.05). Over the period of 12 wk, shade was always lower ($P < 0.05$) compared with the other treatments (Figure 2).

Discussion

The Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999) states that beef cattle in research facilities should have opportunities for behavioral thermoregulation (e.g., access to windbreak and shade). It also recommends the following methods for decreasing heat-stress:

- direct sprinkling of water on cattle with 2.6 to 5.3 gal/h (in 5- or 10-min intervals/30 min);
- no use of foggers;
- shade for cattle that are unconditioned to heat, as well as sick animals; and
- proper airflow and ventilation.

Our findings from Exp. 2 indicate that direct sprinkling of water in intervals was largely ineffective under our conditions. Our studies confirmed that the use of misters (equivalent to foggers with a fine droplet size) was counter productive. Misting with water increased respiration rate and negatively affected performance compared with shade. It is very likely that fine water droplets increased local, micro-environment humidity, which decreased the animal's heat dissipation (transpiration) because of a decrease in the vapor pressure gradient between the animal and environment.

Shade was the most effective environmental modification. Not only did it positively affect performance and physiology of the cattle, but it also increased profitability. A potential disadvantage of shade in experimental facilities can be its effect on airflow. When the facility is equipped with high bunks or other "wall-like" structures, the addition of shade can totally diminish airflow and thereby decrease convective cooling of the animals.

In the past, heat stress research with beef cattle has been predominantly studied under controlled (climate chamber conditions), with the focus on its effect on production. Morrison and Lofgreen (1979) investigated beef cattle responses to heat in climate chambers by using three different climatic regimens (69, 75, and 85º F). The difference between the higher and lower treatment groups (69 and 85º F) showed that heat stress induced decreases in DMI of 11%, ADG of 15%, and F:G of 7%. Shaded vs unshaded heifers in our Exp. 1 showed a decrease in DMI of 7%, ADG of 11.8%, and F:G of 6%. The biggest difference between the controlled-condition study of Morrison and Lofgreen (1979) and Exp. 1 was found in DMI, whereas differences between stressed and unstressed cattle in ADG and F:G were similar between the two studies. In Exp. 2, we found that shade caused differences of similar magnitude to those in Exp. 1; however, these results were not significant because of high variation in the data set.

Lofgreen et al. (1973) studied the effects of sprinkling (not misting) on heat-stressed beef cattle and found increases in DMI and ADG by sprinkled vs unsprinkled control animals. In contrast, water misting in Exp. 1 and sprinkling in Exp. 2 did not affect performance of heat-stressed cattle. The FASS guide (FASS, 1999) suggested that sprinkling might be more effective than misting at ameliorating the effects of heat stress. However, this did not hold true;

under our conditions, sprinkling was not more effective than misting for either maintaining high production levels or for lowering the physiological strain.

Hahn et al. (1974) studied compensatory growth under thermoneutral (68º F), high (88º F), and very-high temperature conditions (100º F) in climate chambers. They reported that heifers stressed at 88º F showed compensatory gains 2 wk after the heat stress was relieved. Heifers under severe heat stress conditions of 100º F did not gain at all during the heat, and after the strain was over, they showed parallel growth compared with the unstressed control animals (no compensatory gain). In our experiments, SHADE heifers showed consistently higher BW than CONT cattle, which confirms the findings of Hahn et al. (1974) that compensatory gain and full recovery does not occur after long-lasting, severe heat stress conditions. Hahn et al. (1974) also found a difference in final BW of 44 lb between stressed and unstressed animals after a heat stress period of 42 d followed by a 14-d recovery period. In our Exp. 1, the difference in BW between SHADE and CONT heifers was 59.5 lb. In Exp. 2, the difference in BW was 46 lb. Thus, the controlled chamber work of Hahn et al. (1974) was confirmed and extended in our work in a feedlot environment during hot weather.

Heavier carcass weights were expected with shade in our experiments. However, these differences did not lead to differences in the USDA yield grades. In our study, carcass traits were largely unaffected by heat stress when adjusted to a common hot carcass weight.

Under the conditions of an experimental feedlot with limited space allowance per heifer and no environmental enrichments, behaviors are mainly limited to feeding, drinking, walking, standing, and lying. No behavior studies of cattle under comparable experimental feedlot conditions have been reported in the literature. It proved difficult to measure feeding behavior, because the unshaded cattle sought shade by placing their head in the feed bunk. Therefore, head-in/over-bunk behavior was not only feeding, but also shade-seeking behavior. Similarly, head in/over the water trough behavior not only described drinking but also body splashing with water. Heat-stressed cattle in feedlots are known to increase drinking and body splashing, but again, such results were not found in the present study. Altogether, the behavioral measures in our study were not suited to detect differences in response to heat stress across treatments; one main reason might be the small pens, which limited behavioral adjustments.

Implications

Heat stress negatively impacted production by finishing beef heifers in a West Texas experimental feedlot. Shade had no major effects on carcass quality. Neither misting nor sprinkling provided measurable relief from summer heat stress. Measurement of respiratory rates provided a non-invasive and practical assessment of heat stress in feedlot cattle under field conditions. Under our conditions in an experimental feedlot, shade seemed to be beneficial for improvement of well being of the animal and increasing cattle performance.

Literature Cited

FASS. 1999. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 1st rev. ed. Federation of Animal Sciences Societies, Savoy, IL.

Hahn, G. L. 1999. Dynamic responses of cattle to thermal heat loads. J. Anim. Sci. 77:10-20.

Hahn, G. L., N. F. Meador, G. B. Thompson, and M. D. Shanklin. 1974. Compensatory growth of beef cattle in hot weather and its role in management decisions. pp 288-295. Trans. Am. Soc. Agric. Eng.

Hahn, G. L., and T. L. Mader. 1997. Heat waves in relation to thermoregulation, feeding behavior and mortality of feedlot cattle. Trans. Am. Soc. Agric. Eng. Proc. of the 5th International Symposium, Bloomington, MN.

Lofgreen, G. P., S. R. Morrison, and R. L. Givens. 1973. Effects of sprinkling and space allotment on cattle fed on slotted floors during periods of heat stress. California Feeders' Day. pp 15-21. Univ. of California, Davis.

Morrison, S .R., and G. P. Lofgreen. 1979. Beef cattle response to air temperature. Trans. Am. Soc. Agric. Eng. 22: 861-862.

Ray, D. E. 1991. Heat stress in feedlot cattle. Proc. of Southwest Nutr. and Mgmt. Conf. pp. 69-81. Univ. of Arizona, Tucson.

Acknowledgements

This study was supported by a specific cooperative agreement 58-3602-6-101 between Texas Tech University and USDA-ARS and by an Advanced Technology Program (ATP) grant. Caprock Industries, Amarillo, TX supported this experiment by supplying the cattle and feed.

The authors thank Kirk Robinson (Burnett Center Manager), Ricardo Rocha (Burnett Center Assistant Manager), Chris Ward and Hart Derrington (Burnett Center Technicians), Dr. Mark Miller, and Dr. Steven Wilson for their assistance with the experiment.

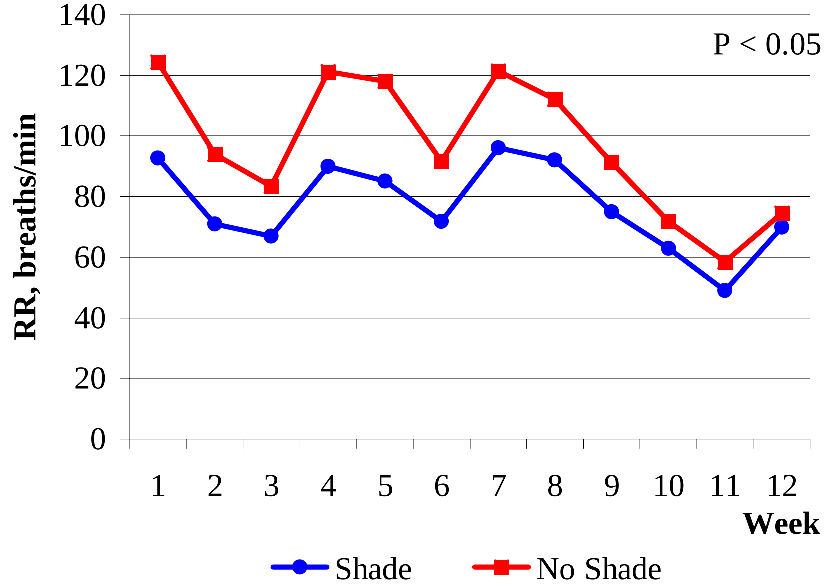

Figure 1. Respiration rate (breaths/min) of heifers over the course of 12 wk in Exp. 1.

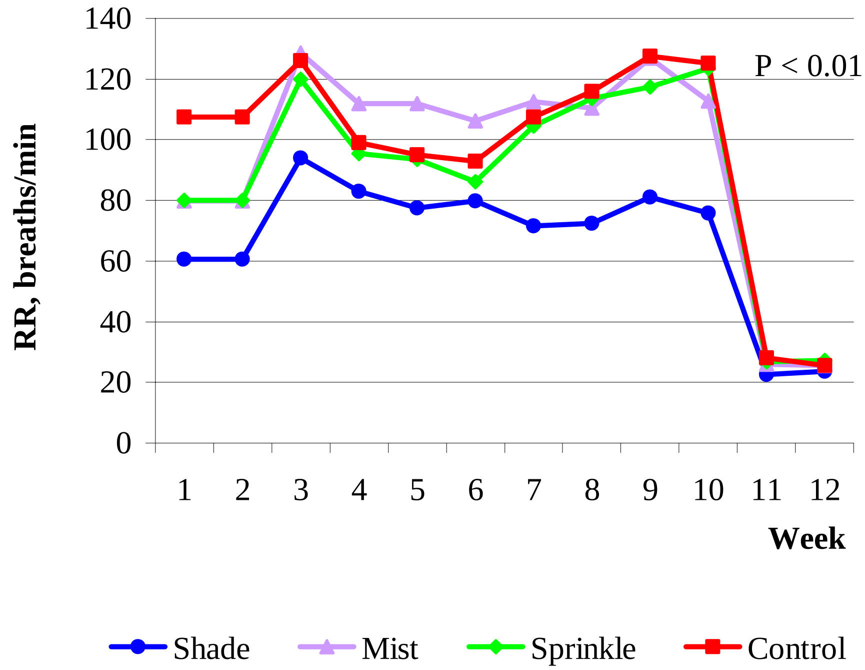

Figure 2. Respiration rate (breaths/min) of heifers over the course of 12 wk in Exp. 2.

Table 1. Feed ingredients and nutrients of the diets in Exp. 1 and Exp. 2

Feed ingredients	Diet in Exp. 1, DMB, %[a]	Diet in Exp. 2, DMB, %
Steam flaked corn	74.72	64.3
Sorghum silage	10.09	-
Cottonseed Hulls	-	5.07
Ground alfalfa hay	-	5.08
Dry rolled corn	-	10.03
Supplement premix[b]	2.50	2.48
Cottonseed meal	4.44	4.71
MGA premix[c]	0.25	0.24
Urea	0.89	0.93
Fat	2.92	2.92
Molasses	4.19	4.24
Chemical composition, DMB, %		
DM	63.69	85.48
CP	13.18	13.70
Ash	4.62	4.01
Ca	0.44	0.57
P	0.30	0.31
ADF	8.98	8.76

[a]DMB=Dry matter basis.

[b]Contained Rumensin (33 mg/kg), Tylan (8.8 mg/kg), vitamin A, vitamin E, and minerals.

[c]Provided 0.044 mg/kg of MGA.

Table 2. Climatic measures during the two experiments in 1999 and 2000[a]

		1999				2000				
Item		Jul	Aug	Sep	Oct	Jun	Jul	Aug	Sept	Oct
	Min	68.2	66.4	58.1	45.3	64.4	66.0	64.9	56.3	52.0
Air temperature, ºF	Max	90.9	91.9	80.4	70.9	83.7	92.1	92.5	89.4	72.0
	Avg	80.1	80.6	69.4	58.1	73.2	79.3	79.7	73.8	61.5
	Min	32.2	29.9	41.4	37	49.0	31.1	24.8	19.2	46.0
Relative humidity, %	Max	79.9	79.3	87.4	86.1	94.4	85.5	74.7	65.6	86.9
	Avg	53.4	50.3	63.5	60.7	73.2	56.9	45.7	38.4	69.0
Precipitation, in	Total	0.5	0.3	1.2	0.7	6.4	2.9	0.0	0.0	3.1
Wind velocity, ft/s	Avg	8.9	6.6	7.9	6.9	10.5	7.2	6.6	8.2	9.5

Minimum (Min) and maximum (Max) values represent the average values for each month.

Table 3. Least squares means, pooled standard errors (SE) and probability-values of the performance of heifers in Exp.1

	Shade		SE	P-value		
Trait	No	Yes		Shade	Mist	Shade x Mist
Number of heifers	38	39	-	-	-	-
Number of pens	8	8	-	-	-	-
Initial BW, lb	739	743	7.3	0.67	0.36	0.35
BW at d 131, lb	1,147	1,206	13.2	0.007	0.61	0.49
ADG, lb/d[a]	3.11	3.53	0.11	0.004	0.99	0.17
DMI, lb/d	19.40	20.86	0.31	0.006	0.84	0.76
Feed:gain	6.27	5.91	0.14	0.086	0.70	0.13
NEm[b]	0.88	0.90	-	-	-	-
NEg[c]	0.59	0.60	-	-	-	-

[a]ADG = average daily gain.

[b]NEm = net energy for maintenance, calculated from performance data according to NRC (1996).

[c]NEg = net energy for gain, calculated from performance data according to NRC (1996).

Table 4. Least squares means, pooled standard errors (SE) and probability-values of the performance of heifers in Exp.2

Trait	Treatment				SE	Contrast[a]		
	Shade (SH)	Mist (MI)	Sprinkle (SP)	Control (CO)		SH vs others	CO vs MI & SP	MI vs SP
Number of heifers	17	20	18	19	-	-	-	-
Number of pens	4	4	4	4	-	-	-	-
Initial BW, lb	757	749	751	751	4.59	NS	NS	NS
BW at d 122, lb	1,194	1,152	1,166	1,149	24.98	NS	NS	NS
ADG, lb/d[b]	3.58	3.29	3.40	3.26	0.20	NS	NS	NS
DMI, lb/d	20.01	18.60	19.25	18.52	0.69	NS	NS	NS
Feed:gain	5.59	5.66	5.70	5.68	0.16	NS	NS	NS
NEm[c]	0.98	0.98	0.98	0.99	-	-	-	-
NEg[d]	0.68	0.68	0.68	0.68	-	-	-	-

[a]Observed significance level for orthogonal contrasts. NS = not significant, $P < .05$.

[b]ADG = average daily gain.

[c]NEm = net energy for maintenance, calculated from performance data according to NRC (1996).

[d]NEg = net energy for gain, calculated from performance data according to NRC (1996).

Table 5. Least squares means, pooled standard errors (SEM), and probability-values of different carcass traits for shaded vs unshaded heifers during the summer heat in Exp. 1

	Shade		SEM	P-value		
Trait	No	Yes		Shade	Mist	Shade x Mist
Number of heifers	39	39				
Number of pens	8	8				
Hot carcass wt, lb	710	745	9.92	0.028	0.65	0.38
Fat thickness	3.20	3.49	0.03	0.019	0.62	0.48
Marbling score[a]	429	446	11.5	0.33	0.92	0.21
LMA, in[2b]	12.80	13.20	0.17	0.14	0.37	0.20
KPH, %[c]	2.06	2.13	0.11	0.65	1.0	0.31
USDA yield grade	3.04	3.32	0.10	0.08	0.56	0.43
Quality grade[d]	456	489	16	0.19	0.47	0.31

[a]Slight = 300; Smalll = 400.

[b]Longissimus muscle area.

[c]Kidney, pelvic, and heart fat.

[d]Quality grade: 200 = low Select, 300 = Select, 400 = high Select, 500 = low Choice, 600 = Choice.

Table 6. Least squares means, pooled standard errors (SEM), and probability-values of different carcass traits for shaded vs unshaded heifers during the summer heat in Exp. 2

	Treatment					
Trait	Shade	Mist	Sprinkle	Control	SE	P-value[a]
Number of heifers	17	20	18	19	-	-
Number of pens	4	4	4	4	-	-
Hot carcass wt, lb	739.1	725.6	721.3	718.5	16.79	0.82
Dressing percent	61.86	63.03	61.84	62.54	0.63	0.46
Fat thickness, in	0.60	0.47	0.52	0.47	0.08	0.51
Marbling score[b]	366.67	373.13	407.83	377.33	22.27	0.45
LMA, in^2[c]	14.60	14.94	13.90	13.94	0.44	0.20
KPH, %[d]	2.10	2.09	1.84	1.91	0.15	0.40
USDA yield grade	2.53	2.25	2.29	2.15	0.20	0.54
Dark cutters, %	0.00	10.00	5.56	21.05	-	ND
Quality Grade						
Select, %	52.94	57.89	50.00	53.33	-	0.96
Choice, %	47.06	42.11	50.00	46.67	-	0.96

[a]ND = not determined.

[b]Slight = 300; Small = 400.

[c]Longissimus muscle area.

[d]Kidney, pelvic, and heart fat.

Table 7. Least squares means (% of observations), standard errors and probability values of behaviors for heifers exposed to hot weather (Exp. 1)

	No Shade		Shade			P-value		
Measure	Control	Mist	Control	Mist	SEM	Shade	Mist	Shade x Mist
Number of replicates (pens)	4	4	4	4	-	-	-	-
Number of animals	20	20	20	20	-	-	-	-
Standing	46.32[b]	44.11[b]	49.17[b]	54.12[a]	5.76	0.010	0.48	0.98
Lying	36.22	37.73	34.32	33.73	6.13	0.23	0.77	0.80
Head-in-bunk	14.53	15.78	13.77	10.71	4.24	0.12	0.49	0.24
Head-in/over-waterer	1.21[a]	1.20[a]	1.41[a]	0.51[b]	0.72	0.38	0.027	0.08
Walking	1.00	0.71	0.82	0.62	0.60	0.72	0.33	0.75
Social	0.74	0.50	0.60	0.31	0.53	0.54	0.22	0.82

[a,b]Least squares means with different superscripts differ, $P < 0.05$.