PERFORMANCE OF LACTATING DAIRY CATTLE IN THREE DIFFERENT COOLING SYSTEMS

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Summary

Ninety-six Holstein multiple-lactation cows averaging 115 days in milk (DIM) and 60 Holstein first-lactation cows averaging 97 DIM at the initiation of a 10-wk study between June 10 and August 22, 1998 were used to evaluate the effectiveness of three different cooling systems. Thirty-two multiparous cows and 20 first-lactation cows were assigned to each of three pens that contained different cooling systems. The three cooling systems consisted of : 1) a single row of 36-inch fans, spaced at 24-ft intervals over the freestalls and over the feed row, 2) 56-inch ceiling fans spaced at 12-ft intervals over the freestalls, and 3) polytube longitudinal cooling over the freestalls. Each of the three cooling systems utilized similar sprinkler systems located over the feed line. Dry matter intake, respiration rates, milk production, and body condition scores were measured. Cows cooled with overhead 36-inch fans produced more milk and had lower respiration rates than those cooled with other methods. The cows cooled with ceiling fans tended to produce more milk than those cooled via the polytube. Dry matter intake also tended to be greater for cows cooled by overhead 36-inch fans.

(Key Words: Heat Stress, Dairy, Milk Production, Cooling.)

Introduction

Elevated temperature and humidity during the summer months have dramatic effects on milk production of dairy cows. Heat stress occurs when the cow's heat gain is greater than her capacity to lose heat. Her heat load increases as the summer temperatures and relative humidity increase, whereas her ability to dissipate heat decreases. Cows regulate body temperature by increasing respiration rate, water consumption, and sweating and by decreasing feed intake. These combined events depress milk production and limit reproductive performance because of the shift in energy from those functions to body temperature regulation. The primary way dairy cows dissipate heat during heat stress is by evaporative cooling. Cooling occurs when sweat or other moisture is evaporated from the skin or respiratory tract. This explains why dairy cattle sweat and have higher respiration rates during heat stress. High humidity limits the ability of the cow to take advantage of evaporative cooling. By providing fans with sprinkler systems, the amount of evaporative cooling and the rate at which the cow dissipates heat are increased.

The objective of this study was to evaluate the effectiveness of three different cooling systems to reduce heat stress in lactating dairy cows. Cost of operation, initial investment cost, and milk production were used to evaluate the economics of the systems.

Procedures

Ninety-six older and 60 first-lactation cows were paired by DIM, milk production, and lactation number. Four pens with 100 Holstein cows per pen were housed within a 4-row freestall barn at a commercial dairy near Palmer, KS. The dimensions of the open-sided, east-west aligned barn were: length 420 feet, width 100 feet, eave height 13 feet, roof pitch 4:12, and ridge row width 30 inches. Each of the

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three pens contained 20 first-lactation and 32 multiparous cows monitored for this study plus other nonexperimental cows. Pens that housed cows in this study were located in the southwest, northeast, and northwest sections of the barn. Fans in all three systems were activated automatically at 72EF.

The first cooling system (FF) in the southwest section of the barn consisted of 14, 36-inch diameter circulation fans with 0.5 horsepower motors. A single row of fans was mounted every 24 ft over the freestalls and feed line and angled down at a 30E angle. Airflow delivery rates per fan ranged from 10,000 to 11,500 cfm.

The second cooling system (CF) in the northeast section of the barn used 14, 56-inch ceiling fans with 0.1-hp motors and a rating of 21,000 cfm. Fans were mounted 12 ft on center with a downward air movement.

The third cooling system (PT) located in the northwest section of the barn used four, 36-inch fans with 0.5 hp motors. Large polytubes were attached to the fans, and when turned on, the fans inflated the tubes. The fans and tubes were mounted 8 ft above the freestalls. The polytubes had 3-inch holes at the five and seven o'clock positions at 2-ft intervals.

All of the pens had identical sprinkler systems. The nozzles were rated to deliver 2.5 gal/hr and were spaced 78 inches on center. The sprinklers were set for a 15-min cycle with 3 min on and 12 min off and were activated when the temperature was above 80EF. The designed application rate was 0.02 inches/ft^2 of surface area, which consisted of 12 ft^2/headlock or 24-inch feeding space. The overall application rate was 50 gal/cycle (0.5 gal/24 inches of feed line space) or 16 gpm/pen when a sprinkler system was on.

All eligible cows received rbST at 14-day intervals. Daily milk production data were collected on days –15, 1, 30, 32, 38, 62, 72, and 74 of the study. Body condition of all cows and heifers was evaluated at the beginning and end of the study. Respiration rates were collected weekly on 10 older and 10 first-lactation cows in each treatment. Cows were group fed, and each group received the same total mixed ration. The amounts of feed fed and refused were weighed and recorded daily. Daily dry matter intake values represented the summer averages of all cows per pen and not specifically the 52 experimental cows per pen that were monitored during our study.

Results and Discussion

At the initiation of the study, no difference in the level of production, stage of lactation, or body condition score existed among the three treatments (Table 1). Average milk production of all cows is shown in Table 1. Cows in the FF pen produced an average of 5.5 lb more ($P<0.05$) milk than CF cows and 6.7 lb more milk than PT cows. Milk yield of multiparous cows appeared to be affected more dramatically by the different cooling systems than that of first-lactation cows. Cows housed in FF produced an average of 93.3 lb of milk, whereas CF and PT cows produced 87.3 and 82.3 lb, respectively. First-lactation cows in the FF pen produced 5.1 and 2.4 lb of milk more than CF and PT cows, respectively. Older cows housed in FF produced 6 and 11 lb of milk more than CF and PT, respectively.

Throughout the summer, cows in FF had an average respiration rate of 8.3 breaths/min less ($P<0.05$) than CF and 7.1 breaths/min less ($P<0.05$) than PT cows. The respiration rates of cows in CF and PT tended to be similar, with a difference of only 1.3 breaths/min.

Total amount of feed fed and refused and number of cows per pen were recorded daily. This information was used to calculate dry matter intake per cow per day. Because this information represented averages of all experimental and nonexperimental cows in the pens, statistical analysis could not be completed. Higher dry matter intakes were consistent with increased milk production and reduced respiration rates (Tables 1 and 2).

Body condition was evaluated at the beginning and end of the study (Table 1). Cows in FF, CF, and PT gained averages of 0.32, 0.22, and 0.18 BCS points, respectively. Changes in body condition for mature and first-lactation cows are shown in Table 2. Mature cows exposed to FF gained more (P<0.01) condition than those in PT.

Table 3 provides an economic analysis of the different cooling systems. This analysis was performed assuming a 20% reduction in milk production if cooling was not provided. The returns on investment for FF, CF, and PT were $84, $50, and $34 per stall, respectively. Sensitivity analysis showed increased milk production to be the biggest single factor affecting economic return.

Conclusion

All of the cooling systems studied had a positive net return on investment, but FF provided the highest return. Cows in FF produced more milk on a daily basis, maintained lower average respiration rates, and tended to have higher daily dry matter intakes.

Table 1. Milk Yield, Respiration Rates, Body Condition, and Feed Intake of Dairy Cows in Three Cooling Systems

	Cooling System[1]			
Item	FF	CF	PT	SEM
Initial milk, lb	94.9	94.3	95.4	1.1
Initial days in milk	105.7	105.8	105.7	1.0
Average milk, lb	88.4[a]	82.9[b]	81.7[b]	1.8
Respiration rate, breaths/min	75.3	83.5	82.3	1.9
Dry matter intake, lb	44.7	42.1	42.1	-
Change in body condition	+0.32	+0.22	+0.18	0.036

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.

[a,b]Means with uncommon superscript letters differ (P<0.05).

Table 2. Effect of Lactation Number on Cow Performance in Three Cooling Systems

	Cooling System[1]							
	Mature cows				First-lactation cows			
Item	FF	CF	PT	SEM	FF	CF	PT	SEM
Initial milk, lb	109.1	108.0	109.4	1.4	80.6	80.6	81.4	1.8
Initial days in milk	114.0	115.2	115.6	1.3	97.4	96.4	95.8	1.6
Average milk, lb	93.3	87.3	82.3	2.28	83.5	78.4	81.1	2.73
Respiration rate, breaths/min	74.6	83.6	82.4	2.71	76.0	83.6	82.2	2.69
Change in body condition	+0.31	+0.21	+0.13	0.048	+0.32	+0.23	+0.23	0.055

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.

Table 3. Economic Analysis of Three Different Cooling Systems

Item	Cooling System[1] FF	CF	PT
Number of fans per pen	14	14	4
Fan size (hp per fan)	0.5	0.1	0.5
Number of days cooling system used	100	100	100
Hours of operation during summer	1200	1200	1200
Electrical demand charge ($/kW)	10.65	10.65	10.65
Electrical energy charge ($/kWh)	0.0585	0.0585	0.0585
Milk price ($/cwt)	12	12	12
Number of stalls per pen	84	84	84
Annual demand charge for fans ($)	519	104	148
Annual energy charge for fans ($)	368	74	105
Total cost of electricity for fans ($)	886	177	253
Lb of milk needed to pay electricity cost (lb/stall/yr)	87.91	17.58	25.12
Total sprinkler water usage (gal)	66000	66000	66000
Rural water cost per 1000 gallons ($)	1.6	1.6	1.6
Cost of water for sprinklers ($/pen/yr)	106	106	106
Lb of milk needed to pay water cost per year (lb/stall/yr)	10.48	10.48	10.48
Daily milk production (lb/cow/day)	95	95	95
Production loss due to heat stress w/o cooling (%)	20	20	20
Production loss due to heat stress w/ cooling (%)	6.9	12.7	14
Milk production w/o cooling (lb/cow/day)	76	76	76
Milk production w/ cooling (lb/cow/day)	88.4	82.9	81.7
Cooling response (lb/cow/dy)	12.4	6.9	5.7
Feed cost ($/ton)	120	120	120
Extra production due to cooling (cwt/stall/yr)	12.4	6.9	5.7
Total extra income due to cooling ($/pen)	12544.56	6990.48	5745.6
Cost per fan ($/fan)	260	89	450
Expected fan life (yrs)	7	5	4
Total fan cost per pen ($/pen)	3640	1246	1800
Installation of fans in a pen ($/pen)	2838	1462	1462
Fixed and installation costs of sprinkler ($/pen)	500	500	500
Expected sprinkler life (yrs)	5	5	5
Total fixed cost of cooling systems ($/pen)	6978	3208	3762
Fixed fan cost ($/pen/yr)	925.43	541.60	815.50
Fixed sprinkler cost ($/pen/yr)	100.00	100.00	100.00
Variable cooling cost ($/pen/yr)	992	283	359
Feed cost ($/pen/yr)	2903.83	1618.17	1330.00
Interest rate if money was invested (%)	8.00	8.00	8.00
Interest ($/yr)	558.24	256.64	300.96
Gross income due to cooling system ($/pen/yr)	$12,545	$6,990	$5,746
Operating cost due to cooling system ($/pen/yr)	$5,479	$2,799	$2,905
Net income due to cooling system ($/yr/pen)	$7,065	$4,191	$2,840
Return on investment ($/stall/yr)	$84	$50	$34

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.