FEEDING STRATEGIES DURING HOT WEATHER

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Introduction

Heat stress severely limits production and reproduction of dairy cows. Few studies have investigated diet alterations which might allow high-producing cows to better cope with hot environmental temperatures. This paper will deal with feeding strategies to alleviate detrimental effects of heat stress in dairy cows.

Keep Feed Intake Up through Cooling of Cows

A main factor causing decreased milk production during "heat stress" is lowered intake of feed relative to cows' needs and not increased body temperatures (14), even though they usually occur concurrently (16). Table 1 (17) shows that maintenance requirements of lactating dairy cows increase about 30% if ambient temperatures are raised from about 77 to 104°F for 6 hr per day. Voluntary intake of DM decreases to about 55% of that eaten by cows in the thermal neutral zone (TNZ) which is from about 40 to 75°F. Depressed intake causes milk yields to drop to less than 50% of that produced in the TNZ. A general increase in water consumption is expected up to about 95°F, but further increases in ambient temperatures decrease water intake due to inactivity and lowered feed intake.

Ambient daily temperatures often have a variable effect on feed intake and consequent milk production, depending on humidity and relative time cows are exposed to stressful temperatures (17). At even moderately high temperatures, decreases in milk production might be magnified by high humidity and poor acclimatization of cows to heat stress. A change in eating patterns from day to night feeding has been associated with hot days and cool nights and is one way for cows to acclimatize to hot temperatures.

Cooling systems for modification of environment to alleviate heat stress exert their effect largely through increased intake. Corral and holding pen cooling systems markedly increase time which lactating cows spend at the manger. A typical observation has been that after cows are cooled in holding pens (before and after milking), they eat for a longer time when returned to corrals than cows which are not cooled. Moreover, cows which are pen-cooled during hot weather approach the feed manger more frequently than those not cooled. Misting of cows at the manger during hot, dry periods has increased feed intake and milk production.

Feed High Energy, Low Fiber Diets to Minimize Body Heat

Body heat production and rectal temperatures are higher on high forage compared to high concentrate diets. Greater heat increment has been associated with the higher acetate production in the rumen of cows eating high forage diets (24). Often cows voluntarily limit forage consumption during hot weather, even to the extent of drastically shifting acetate to propionate ratios, resulting in sub clinical acidosis, off feed conditions and a lowering butterfat in milk.

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Addition of buffers (about 1% $NaHCO_3$, K_2Co_3 or $KHCO_3$ and .6% MgO) alleviates the milk fat depression and cows maintain a healthier rumen fermentation during periods of heat stress when forage consumption is less than 1% of body weight (3). Lower heat production is elicited in fermentation of high quality compared to low quality forages (due to the difference in their fiber content), but a minimum fiber of about 20% ADF is recommended for maximizing intakes and for good rumen function.

Added Fat in Hot vs. Cool Cows

Supplementation of 10% fat in rations of thermally stressed cows by Moody et al. (18) in 1967 did not increase milk production, but feeding high molasses (30 vs. 10%) increased DM intakes of cattle in a hot environment (88°F) (26). However, such high levels of fat and molasses would likely depress fiber digestion if included in diets for high producing dairy cows.

A recent study at the University of Arizona (11) in heat-stressed cows showed increased milk yield (2.6 lb/day) by feeding 2.5% supplemental fat as prilled fatty acids. A second study in Arizona conducted during hot summer temperatures showed only small increases in milk yields (1.5 lb/d) in evaporatively cooled or non-cooled cows fed added fat, but evaporative cooling significantly improved production (3.5 lb/day) regardless of fat supplementation. These, compared to other Arizona studies (Table 2), suggest less response from added fat in heat-stressed than cool cows (4.9 lb/day). We had hypothesized that added fat would reduce heat of fermentation during heat stress, but both studies during high ambient temperatures showed that neither rectal temperatures nor respiration rates decreased in cows fed supplemental fat.

Maximum Production Resulted from Low Degradable, High Quality Protein

Louisiana workers (6) showed that dairy cows under heat stress consumed more feed and produced more milk when fed a diet of 20.8 compared to 14.5% crude protein. Higher respiratory rates and rectal temperatures were observed on low protein. Two protein solubilities were compared in cows subjected to heat stress or thermal neutral conditions in a study by Missouri workers (29). Higher milk yields and feed intakes were shown for the less soluble diet during both climatic situations. Milk and feed intakes were lowered in heat-stressed cows. Respiration rates and rectal temperatures increased during heat stress, but were not affected by protein solubility.

In support of the Missouri studies (29) and in contrast to the Louisiana results (6), our studies (9) showed that high protein diets (18-19%) of medium rumen degradability (65% rumen degradable protein, RDP) decreased milk production in heat-stressed cows (Table 3). Three trials involving 60 cows subjected to hot summer conditions (from May to September) in Tucson, Arizona showed that milk yields and feed intakes were reduced when cows were fed high protein of medium degradability. A high-protein diet lower in RDP (58%) and two 16% protein diets (65 and 60% RDP) resulted in higher miilk and FCM production in heat stressed cows. When the same diets were fed to dairy cows in Provo, Utah at moderate temperatures, high protein of medium degradability resulted in highest milk yields (8).

Taylor et al. (23) compared diets of medium and low protein degradabilities in evaporatively cooled or non-cooled cows during hot summer weather and showed that protein of low degradability improved milk yields in cooled and non-cooled cows, provided it was of high quality. Chen et al. (2) confirmed the importance of feeding high quality protein to cooled or non-cooled cows during hot weather (Table 4). Cows fed a combination protein supplement (HQ, comprised of soybean, blood and fish meals) produced 11% more milk than those fed corn gluten meal (LQ). Rumen degradable protein was low and similar for both diets (58% RDP), but lysine content was about 75% higher for the combination supplement and differences in other amino acids were minor. Even though uncooled cows responded to the HQ diet (5.3 lb/d), milk increases due to feeding HQ compared to LQ in cooled cows was considerably greater (8.4 lb/d).

In summary, for maintenance of maximum milk yield during heat stress periods, the data suggest that RDP should not exceed 61% of total dietary CP or that absolute RDP intake should not exceed the NRC (19) recommendations by more than 100 g N/day. Additionally, an important protein quality factor affecting milk yield during heat stress is Lys content of diets. Cows fed 1% Lys in DM or 241 g/d of dietary Lys produced about 6 lb/day more milk than those fed .6% Lys (137 g/d).

Pay Special Attention to K, Na and DCAB during Heat Stress

Higher levels of Na and K for lactating cows during hot weather than indicated by NRC recommendations (19) were suggested by Coppock and West (3), Beede (1) and Sanchez et al. (20a). Raising dietary Na from .18 to .55% of DM as $NaHCO_3$ or NaCl resulted in increased milk yields (Table 5). However, addition of $NaHCO_3$ increased milk fat more than NaCl. The need for more Na in heat-stressed cows was attributed to increased urinary secretion of Na (1). The increased dietary requirement of K in heat-stressed cows was attributed to greater excretion of K in sweat (20a). Also, less forage is eaten in hot weather, often decreasing K content of diets. Positive responses have been obtained in cows fed 1.5 to 1.8% K (1)), compared to NRC recommendations of .9 to 1.2% (19).

West et al. (28) demonstrated that heat-stressed lactating cows responded to increasing dietary cation-anion balance (DCAB, Na + K - Cl) from 120 to 460 meq/kg with higher dry matter intake; but response was independent of whether Na or K was used to increase DCAB. Large differences in DCAB were recommended for dry vs. lactating cows (27). Further, it was reported that diets high in cationic salts (as recommended for lactating cows in hot weather) cause higher incidence of milk fever when fed to dry cows compared to diets high in anionic salts (Cl and S). The desirable DCAB range for dry cows is -10 to -15 meq/kg and inclusion of S in a DCAB formula for dry cows is recommended [(Na + K) - (Cl + S)] (27). Milk yield and DMI responses differed in winter compared to summer for increased levels of several minerals (P, K, Cl, Ca and Mg) as did DCAB (20a) and high Cl was particularly detrimental in the summer.

Fungal Cultures Have Alleviated Heat Stress in Some Studies

Studies at the University of Arizona (10) and in California (7) have shown reduced rectal temperatures in cows fed a culture of *A. oryzae*. Milk yields were generally increased, but not in all studies. One of the studies was conducted at a large commercial dairy in which there was also observed a 12% increase in conception rates of fungal-fed cows compared to controls. Confirmation of improved reproduction and its relationship to heat-stress alleviation due to feeding the fungal cultures await further investigation. In a Utah study (25) conducted under moderate climatic conditions, a fungal culture increased milk yields in early lactation cows (6 lb/d), but also increased rectal temperatures. A summary of performance data from many studies of cows fed the fungal culture shows a trend towards increased milk yields and decreased rectal temperatures with no change in milk composition (Table 6). Variations between studies suggest that the culture is not effective in all situations.

The higher milk yields in cows fed fungal cultures have been associated with better rumen utilization of fiber, increased numbers of cellulolytic organisms and more rapid ruminal turnover of lactic acid (10); but the reason for rectal temperature and respiration rate reductions during heat stress periods needs further clarification.

Equal Response to BST in Hot and Cool Climates

Complete lactation experiments using daily injections conducted in Mississippi (12) and Florida (4) showed production responses to BST similar to those reported in states with moderate temperatures (25 to 39% increase over controls). West (27a) summarized 6 studies with maximum ambient temperatures ranging from 83 to 103°F and relative humidities from 55 to 100%. Increased milk yield due to BST averaged 19% with a range from 3 to 49%. It was suggested that the large range in response may be attributable to specific conditions in the different experiments. Even though the higher milk production stimulated by BST resulted in greater heat production, it was offset by increased heat loss through skin and vaporization (20a).

The Arizona study (22) which employed sustained release injections of BST (500 mg/14 d) showed just as great a response in milk yield during hot summer months (June, July, August) as during March, April and May when ambient temperatures were considerably lower (Table 7). Even though cows in Arizona were evaporatively cooled to reduce heat effects, BST-treated cows tended to show higher rectal temperatures than controls. Responses to BST observed in Arizona with sustained release injections were similar to those of companion studies (5) conducted in New York, Utah and Missouri where heat effects were considerably less.

Missouri workers (13) reported that daily injections of BST under hot environmental conditions (Table 8) increased milk yields (20-25%) just as much as they did under thermal neutral (TN) conditions. Feed intakes were increased by BST, but less in hot than TN conditions. It was shown that BST increased both heat production and heat loss, with no net change in heat balance or rectal temperatures (15). Calorigenic hormones (T_3 and cortisol) were reduced by injection of BST to heat-stressed cows. West (20a) concludes and this author agrees that the studies reported to date have not subjected cows to severe heat stress, in that cows were allowed cooling periods for some relief. In severe, continual heat stress, I would recommend against the use of BST.

Summary

Milk production decreases during heat stress are primarily because of reduced feed intakes and not increased body temperatures, but the two factors are intimately related. Energy deprivation is magnified during heat stress because of increases in maintenance requirements and the lack of desire to eat. Several cooling systems now available for relieving heat stress result in increased feed consumption, milk production and reproductive efficiency.

Diets high in grain and low in forage reduce heat stress for lactating cows because of lower heat of digestion. However, digestive disorders increase during hot summer conditions when forage intake is severely limited, either voluntarily or through restriction. Feeding of buffers and/or supplemental fat allow for feeding diets higher in energy without the undesirable side effects. Several byproduct feeds (almond hulls, citrus pulp, etc.) might also aid in keeping milk yield and feed intakes at acceptable levels during heat stress.

More studies are needed to investigate dietary alterations for diminishing heat stress. Work at the University of Arizona shows that milk yields and feed intakes are decreased in heat-stressed cows fed diets high in protein of medium degradability; whereas, cows in moderate temperatures reacted differently to similar diets. High quality protein (of low degradability) resulted in large increases in milk yields in cows subjected to hot environmental temperatures, but responses to protein quality were greater in cooled than non-cooled cows. Milk yields are higher in heat-stressed cows when Na and K in diets increased the DCAB (Na + K - Cl) to over 400 meq/kg, which is considerably above NRC recommendations. Dry cows should be fed diets of negative DCAB, regardless of ambient temperature. Feeding a fungal culture alleviated heat stress while increasing milk yields and feed intakes, but results have been inconsistent. Milk yield increases in response to BST were as high in cows subjected to hot environmental temperatures as they were for cows in thermal neutral conditions, but the hormone is not recommended in conditions of severe, continual heat stress.

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Table 1. Relative changes in maintenance and dry matter (DM) requirements for 1,323 lb. cows producing 59.5 lb. milk of 3.7% fat at various ambient temperatures along with estimates of actual intakes of DM and water (adapted from Ref. 17).

Temperature[a] (°F)	Maintenance requirements (% of req. at 50°F)	Dry matter Needed[b] (lb/d)	Dry matter intake[c] (lb/d)	Milk yield (lb/d)	Water intake (gal/d)
- 4	151	46.9	44.9	44.1	12.7
14	126	43.6	43.6	55.1	14.5
32	110	41.4	41.4	59.5	16.0
50	100	40.1	40.1	50.5	16.7
68	100	40.1	40.1	59.5	16.9
77	104	40.5	39.0	55.1	18.4
86	111	41.6	37.2	50.7	19.7
95	120	42.7	36.7	37.9	30.0
104	132	44.5	23.1	26.4	26.5

[a] Values for 71°F and higher temperatures are for days with at least 6 h exceeding the temperature class but not more than 12 h.
[b] Estimated requirements of DM intake for maintenance and milk.
[c] Estimates of intakes of DM and water and milk yield on water-free choice and *ad libitum* feeding of a ration of 60 percent hay and corn silage with 40 percent concentrates.

Table 2. Response to added fat in hot or moderate temperatures (11).

Ambient temperature	DMI		NE_L intake[2]		Milk ~~protein~~ Yield		RT (°F)[3]		RR/min[4]	
	Con.	EB[1]	Con.	EB[1]	Con.	EB[1]	Con.	EB[1]	Con.	EB[1]
	---- (lb/d) ----		---- (Mcal/d) ----		---- (lb/d) ----					
Hot	50.5	52.9	37.3	41.0	72.5	75.2[a]	103.3	103.3	86.7	84.2
Hot	56.9	54.5	42.3	42.7	66.8	68.1	102.7	102.9	81.2	85.2
Moderate	53.4	55.8	40.6	45.3	69.7	75.4[b]	...	...	...	...
Moderate	60.0	59.1	44.6	46.4	71.9	75.6[b]	...	...	...	...

[1]EB = Energy Booster 100 (Milk Specialties Co., Dundee, IL).
[2]Estimated from NRC (19).
[3]RT = Rectal temperature (°F).
[4]RR = Respiration rate (breaths/min.).
[a]Significantly higher than control ($P < .10$).
[b]Significantly higher than control ($P < .05$).
[c]Significantly lower than control ($P < .05$).

Less Response to Fat During Heat Stress

Table 3. Influence of protein level and degradability on performance of lactating cows at hot and moderate temperatures (from Ref. 9).

Protein level, % of DM	18.4	18.5	16.1	16.1
Rumen degradability, % of CP	65.3	58.3	65.0	60.0
Hot environment (60 cows)				
Milk, lb/d	59.2	63.7	62.7	62.5
3.5% FCM, lb/d	52.0^{a}	58.6^{b}	57.7^{b}	59.5^{b}
DM intake, lb/d	47.4^{c}	48.2^{c}	51.3^{d}	50.9^{d}
Milk fat, %	2.72	3.04	3.01	2.95
Milk protein, %	3.04	3.04	3.13	3.11
Moderate environment (60 cows)				
Milk, lb/d	80.6^{a}	77.1^{ab}	75.1^{b}	79.3^{ab}
3.5% FCM, lb/d	76.4^{a}	70.0^{b}	71.1^{ab}	71.4^{ab}
Milk fat, %	3.11^{a}	2.89^{b}	3.04^{a}	2.78^{b}
Milk protein, %	2.89	2.94	2.92	2.96

^{a,b}Means not showing a common superscript are different ($P < .05$)
^{c,d}($P < .10$).

Table 4. Effect of supplemental protein quality and evaporative cooling on feed intake, milk yield and composition and efficiency of feed utilization (from Ref. 2).

	Treatment				
Item	HQ-EC	LQ-EC	HQ-S	LQ-S	SEM
DM intake, lb/d^{d}	56.2	53.5	52.6	50.0	1.9
Milk, lb/d^{ac}	70.2	61.9	63.2	57.9	2.0
3.5% FCM, lb/d^{ac}	66.5	58.6	59.9	53.7	2.6
SCM, lb/d^{bc}	63.7	56.0	55.1	52.9	2.5
Fat, %	3.20	3.28	3.22	3.18	.11
Protein, %	3.09	3.07	3.13	3.22	.06
FCM/DMI	1.23	1.11	1.13	1.08	.07

[1] HQ, high quality protein; LQ, low quality protein; EC, evaporative cooling; S, shade. Treatment means adjusted for pretreatment by covariance. No interactions between protein quality and cooling were observed.
[2] No interaction effects were significant ($P < .10$).
^{a} Protein quality effect significant ($P \leq .01$), ^{b} ($P < .06$).
^{c} Cooling effect significant ($P < .03$), ^{d} ($P < .10$).

Table 5. Summary of increases in actual daily milk yield with increasing dietary potassium or sodium in complete diets (adapted from Ref. 1).

POTASSIUM Exp	Dietary level (%) Lower to higher	Milk yield % increases
1	.66 to 1.08	+4.6
	.66 to 1.64	+2.6
	1.08 to 1.64	no change
2	1.00 to 1.50	+2.8
3	1.30 to 1.80	+4.2
4	1.07 to 1.51	+3.4
5	1.07 to 1.58	no change
6	1.14 to 1.58	no change
SODIUM Exp		
7	.20 to .43	+3.6
8	.18 to .55	+ 9.6
	.18 to .88	+10.8
	.55 to .88	no change
9	.28 to .47	+3.4
10	.16 to .42	+9.2
11	.24 to .62	no change

[1]Exps 1, 2, 3, 4, 7, 8 and 9 (warm weather); 5, 6, 10 and 11 (cool weather).

Table 6. Summary of studies on effects of cultures of *A. oryzae* on milk yields and composition, and rectal temperatures in lactating cows.[1]

Item	No. Trials	No. Cows	Con.	*A. oryzae*	Remarks
Milk yield, lb/d	14	823	60.9	63.1	*AO* higher (*P* < .05) in 6 trials
Milk fat, %	8	561	3.49	3.49	...
Milk protein, %	8	561	3.13	3.12	...
Milk lactose, %	8	561	4.85	4.90	...
Rectal temp., °F	12	561	102.5	102.2	*AO* lower *P* < .05) in 5 trials

[1]Data summarized from Huber et al. (11).

Table 7. Effect of BST on 3.5% FCM during moderate and hot temperatures.[1]

	March	April	May	June	July	August
	lb/d					
BST	83.0	78.9	79.5	74.2	70.7	61.6
Control	73.8	69.6	67.8	63.0	57.3	51.7
Diff., lb	9.3	9.3	11.7	11.2	11.5	9.9
%	11.1	11.7	14.7	15.1	16.7	16.0
Ave. max. temp., °F	72.3	83.1	90.5	99.0	95.9	96.6

[1]40 cows/treatment (from Ref. 22).

Table 8. Influence of heat and cold stress on response to BST.[1]

	Milk prod. lb/d		Milk composition: Fat %		Milk composition: Protein %		Rectal temp. °C		Feed intake lb/d	
	C	BST	C	BST	C	BST	C	BST	C	BST
Farm (hot)	71.9	77.3**	--	--	--	--	102.9	103.3	--	--
TN[2]	55.1	72.2**	2.6	3.0**	2.9	3.0 **	101.3	100.9	67.8	80.7**
Heat[2]	46.9	62.1**	2.7	3.1**	2.7	2.95**	103.6	103.8	53.1	56.2*

*$P < .05$; **$P < .01$.
[1]6 cows/trt were injected daily with 25 mg of BST (from Ref. 13).
[2]Conducted in climatology laboratory. TN = thermal neutral.