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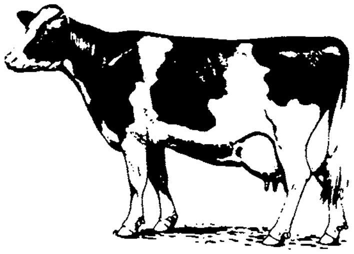

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NUTRITIONAL MANAGEMENT OF LACTATING DAIRY COWS DURING PERIODS OF HEAT STRESS

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INTRODUCTION

Heat or thermal stress results when it becomes increasingly difficult for dairy cows to maintain a normal core body temperature of 101.3 to 102.8° F (rectal). The thermoneutral or comfort zone (TNZ) for cows is at an environmental temperature of 41 to 77° F. Within the TNZ, heat production from normal metabolic functions is about equal to the heat loss from the body and maintaining a normal body temperature is relatively easy. In the upper midwest, temperatures are either in or below the TNZ most of the year. However, there is 2 to 3 months where the TNZ can be exceeded. During these heat stress periods, responses by cows to maintain normal body temperatures are observed in reduced feed intakes, 10 to 25% lower milk production, decreased milk fat percentage, decreased fertility, depressed immune system, higher maintenance requirements, and overall less efficient milk production (1, 13).

Two sources of heat impact the cow; the environmental temperature and the heat produced internally from basal nutrient metabolism. Heat produced from nutrient metabolism is a lesser factor than environmental heat sources. However, as milk production and feed intake increase, more heat from nutrient metabolism is produced aggravating any heat stress being incurred from environmental sources. Therefore, higher milk production cows will begin experiencing heat stress before lower producing or dry cows.

The primary sources of heat derived from the environment are solar radiation and elevated ambient air temperatures. These are influenced by high relative humidity and a lack of air movement. Providing shade is the best way to decrease the effects of solar radiation. During periods of high temperature and/or humidity, evaporative cooling with water in the form of sprinkling or fogging with natural or forced air movement is the best way to cool cows. Modifying the environment is the most effective way to reduce heat stress. In the upper midwest where heat stress days are considerably less than TNZ or cold stress days, the financial investment in facilities and environmental modification to reduce heat stress has to be evaluated

carefully. However, simple strategies like using soaker hoses and improving natural or forced air movement can be cost effective during periods of heat stress (1, 11).

PHYSIOLOGICAL RESPONSES TO HEAT STRESS

Heat stress induces a number of physiological responses by the cow in an attempt to keep body temperatures within normal limits. The following are some of the physiological changes occurring in the cow as heat stress conditions are incurred:

1. Respiration rates increase and may reach the stage of panting. In this attempt to increase evaporative cooling, increased amounts of CO_2 are exhaled resulting an a decrease in H_2CO_3 and an increase in blood pH. In response to the decrease in blood pH, the kidney increases resorption of H^+ and more HCO_3^- and cations, primarily sodium, are excreted in the urine.
2. Heat stressed cows lose two thirds of their evaporative water loss by sweating and one third by panting. The maximum sweat loss at 95° F is estimated to be $150 g/m^2$ of body surface per hour. Cows lose potassium rather than sodium through sweating.
3. Reticulo-rumen motility and overall rate of digesta passage is decreased during heat stress. There also is a change in rumen fermentation with less total volatile fatty acids produced and an increase in the molar percent of acetate.
4. Blood flow to the digestive tract and other internal tissues is decreased and flow to the skin surface is increased
5. Urine volume generally increases.

DRY MATTER INTAKE (DMI)

Voluntary DMI can decrease by 50% of that in the TNZ during heat stress (Table 1). Much of the decrease in milk production observed during heat stress can be attributed to the decreased DMI. Cows decrease DMI in an attempt to reduce heat production from the digestion and metabolism of nutrients. Maintaining a normal body temperature is critical as a 3 to 4 pound decrease in milk production and TDN intake occur with each 1° F increase in body temperature above 101.5° F (13).

At the same time DMI or nutrient intake is decreasing, nutrient requirements for active cooling processes like panting are increasing. Also, blood flow to internal organs like the mammary gland is reduced delivering fewer nutrients to these organs for metabolism. Thus, fewer nutrients are available and used for milk production during heat stress.

Little is known about the effects of heat stress on DMI of the dry and particularly close-up dry cow. However, it is apparent that any cause of off-feed or major decrease in DMI during the dry period can lead to more health problems at parturition and potentially reduce milk production during the subsequent lactation. As much attention should be given to alleviating heat stress in dry cows during the last trimester of gestation through environmental and dietary changes as is given to lactating cows.

Table 1. Changes in maintenance requirements, dry matter intake, milk production and water intake with increasing environmental temperatures[1].

Temperature ° F	Maintenance, % of required at 50° F	DMI for maint. + 60 lb milk		Water intake gallons/day
		Needed (lb/day)	Expected	
-4	151	47	45	14
32	110	41	41	17
68	100	40	40	18
86	111	42	37	21
95	120	43	37	32
104	132	45	23	28

[1] Adapted references 8, 13.

NUTRIENTS

Water. Water is the most important nutrient for lactating cows and especially heat stressed cows. As milk production and DMI increase, water intake increases. Dado and Allen (3) reported a correlation of .94 for water intake and milk production and a .96 for water intake and DMI. The amount of water intake per pound of milk production will vary depending on DM, salt and protein content of the diet; however, cows should generally consume between 2 to 4 pounds of water per pound of milk produced. Water intakes increase sharply as environmental temperatures increase (Table 1). At environmental temperatures above body temperature, however, water intake decreases because of reduced DMI and inactivity.

Cows should have an unlimited quantity of fresh clean water in an easily accessible area. Water tanks should be located close to the feeding area to encourage both DMI and frequent drinking. Fans and sprinklers or at least shade should be located over the feeding and watering area to encourage consumption. Given a choice, cows will choose a shaded or cooled resting area over eating and drinking from an uncooled, sunny area.

Both Texas (12, 15) and Florida (1) research indicates cooling of drinking water below well water temperature is unnecessary. Water cooled to below 59° F helped dissipate body heat during hot weather, but the small increase in milk production did not justify the cost of cooling the water. When given a choice, the cows preferred warm (70 to 80° F) over cooled water. Having easily accessible clean waterers with an ample source of clean fresh water should be the first and foremost consideration in water nutrition of dairy cattle.

Protein. Both the quantity and form of protein in the diet need to be considered when feeding heat stressed cows (6). Feeding crude protein (CP) in either excess or less than required amounts will increase body heat production. Deficiencies of CP reduce digestibility of the diet whereas feeding excess amounts of CP increase energy requirements for the synthesis and excretion of urea from the body. Huber et al. (5) reported on Missouri research where cows were fed diets containing either 20 or 40% soluble protein in either TNZ or heat stressed conditions. Cows fed the low soluble protein diet had higher milk yields and DMI during both climatic conditions than cows fed the high soluble protein diet. Arizona researchers (6) reported heat stressed cows fed a high CP (18.5%), high degradable protein diet (65% of CP) had 6 percent lower DMI and 11 percent lower milk yield than cows fed either the high CP with lower degradable protein (59%) or a lower CP (16%) diet with either a high or low degradable protein content. Based on this research, it is suggested that during heat stress rumen degradable protein should not exceed 61 percent of CP. A possible reason why high degradable protein diets are deleterious during heat stress is rumen motility and rate of passage decline allowing for a longer protein residence time in the rumen and more extensive degradation to ammonia. Any ammonia in excess of what is normally needed for metabolism in the body is an energy cost and increases heat production as it is metabolized to urea and excreted in the urine.

Fiber. As DMI decreases during heat stress, a concern about having adequate amounts of fiber (ADF, NDF and effective or forage NDF) in diets arises. However, fiber digestion results in a higher heat increment (sum of heat produced from rumen fermentation and nutrient metabolism) than digestion of fat or nonfiber carbohydrates (NFC). Acetate, the end product of fiber digestion, has a lower efficiency of utilization in the body than propionate or glucose from NFC digestion and both fiber and NFC endproducts are utilized less efficiently than fat (13). Thus, feeding high forage diets during summer months can add significantly to a cow's heat load. Feeding a minimum, but adequate amount of total and effective fiber should be the objective during summer months.

Depressions in milk yield during average daytime temperatures of 96° F were found to be less when ADF content of the diet was 14 compared to 17 or 21 percent (2). Also, decreases in DMI were found to be more closely associated with the daily high minimum temperature than with the maximum temperature. At any given minimum temperature, DMI was highest in cows fed the lowest ADF diets. However, as the daily minimum temperature increased, the decline in DMI was greatest in the 14 percent ADF diet. Thus, heat loads in cows are associated as much with total energy or DMI as with fiber content of the diet. This result also was found in research from Georgia where diets containing different NDF contents were fed during both cool and hot weather (13). As NDF content of the diets increased, DMI decreased during both cool and hot weather (Table 2). Amount of fiber consumed was not as different between diets as the percentage of NDF in the diets would suggest.

Table 2. Effect of increasing the percentage NDF in the diet on DMI and milk production under a cool and hot, humid environmental conditions[1].

		Bermuda hay added to diets, %			
		0	7.6	15.2	22.8
		Dietary NDF, %			
Item	Environment	30.2	33.8	37.7	42.0
DMI, lb/day	Cool	51.4	48.1	45.4	41.9
	Hot	40.3	39.2	38.4	36.1
Milk, lb/day	Cool	71.2	71.9	69.2	63.7
	Hot	54.2	56.9	58.2	50.0

[1] Reference 13.

Feeding low fiber diets during the hot summer months will improve DMI, milk production and help reduce heat stress. However, a minimum amount of effective, high quality fiber will need to be fed to maintain normal rumen function. High quality forages are the best source of digestible fiber that is effective and produces minimum heat when fermented in the rumen. Feeding forages in a TMR is recommended during heat stress as cows will reduce forage intake relative to grain and concentrates when given a choice.

Fat. The advantage to including fat in the diet during hot weather is improved efficiency of energy use and greater energy intake as fats are 2.25 times greater in energy than carbohydrates. Because fat is more efficiently utilized as a source of energy than other feeds, it produces less heat during digestion and utilization. However, research on feeding fat during heat stress periods has not consistently shown the improved milk yields expected from feeding an energy dense cool feed (6, 13). Arizona researchers reported adding 2.8 percent fat to the diet only resulted in a small increase in milk production (average of 1.4 pounds per day) compared to evaporative cooling which increased milk production 3.5 pounds per day (5). This data suggests modification of the diet to minimize heat stress is secondary to the potential benefits of providing cows with a cool comfortable environment.

Minerals and vitamins. The electrolyte minerals, sodium (Na) and potassium (K), are important in the maintenance of water balance, ion balance and acid-base status of the heat stressed cow. Sweating by heat stressed cows results in a considerable loss of K. Florida research (1) has shown cows in mid day during heat stress conditions without shade lost five times more K per day than cows under shade. Current Dairy NRC (9) recommendations of 1 percent K in the dietary DM appear to be to low during periods of heat stress. Milk production increases of 3 to 9 percent and increased DMI intakes have been found when K level in the dietary DM has been 1.2 percent or higher (10). Increasing Na in diets to .45 percent or greater has improved milk production (7 to 18%) more than increasing K during heat stress periods (10).

The ratio or balance of cations (Na and K) and anions (Cl and S) may be as important during heat stress periods as altering the concentrations of individual minerals in the diet. Georgia research demonstrated heat stressed cows responded to increasing the dietary cation anion balance (DCAB, Na + K - Cl) from 120 to 464 milliequivalents per kilogram regardless of whether Na or K was used to increase the DCAB (14). Florida data indicates increasing Cl concentration in the diet decreased DMI and milk production resulting in a maximum recommendation of .35 percent of the DM (1, 10).

Little is known about vitamin nutrition of heat stressed cows. One recent experiment evaluated injection of vitamin E (3000 IU) or placebo at the time of AI during summer breeding (4). Vitamin E had no effect on pregnancy rate during heat stress (pregnancy rate: 22.3% - vitamin E; 21.7% - placebo).

FEED ADDITIVES

Buffers. Feeding buffers can be beneficial during heat stress periods for two reasons. First, if fiber content of the diet is minimized and/or cows are selecting against eating forages, buffers can help prevent a low rumen pH and rumen acidosis problems. Secondly, the most common macromineral in a buffer is usually Na, exception of K in $KHCO_3$, which when increased in diets fed during heat stress has increased DMI and milk production.

Fungal cultures. In a series of experiments, Arizona researchers have shown feeding *Aspergillus oryzae* reduced heat stress in cows through lowering rectal temperatures (average .86° F). Milk production increased in some studies and was attributed to improved fiber digestion in the rumen (6).

Niacin. In a five-herd study, feeding niacin during the summer increased milk production across all cows by an average of about 2 pounds per day, but cows producing over 75 pounds per day increased over 5 pounds per day (7). No change in milk components occurred.

FEEDING MANAGEMENT AND STRATEGIES

Some alterations in the feeding program can help entice cows to eat during heat stress periods. Increasing the number of feedings offered per day has two advantages. First, the feed will be fresher encouraging more consumption; secondly, cows are curious and if the feeding area is comfortable, cows will be stimulated to come to the feed manger more frequently with increased feedings. The number of feedings to obtain benefits is not known, but practically it is probably a minimum of three per day.

Time of feeding also is important. During hot weather, cows will eat mostly during the nighttime and after milkings. Having fresh feed in the mangers after milking, especially when cows have been cooled in holding areas, is a good way to encourage DMI. The majority of fresh feed should be fed at night when heat stress loads. Feeding at sunset and then again about an hour before sunrise are good times.

Feeding a TMR is preferable to component or separate ingredient feeding during heat stress periods. A TMR with forages mixed in will help reduce the cow's tendency to selectively consume concentrates rather than forages. A well balanced TMR will allow diets to be formulated at minimum fiber levels encouraging DMI and minimizing rumen fermentation fluctuations and pH declines.

Adding water to diets may help DMI during summer months. Water will soften fiber feeds, and reduce dustiness and dryness of the diet increasing palatability and DMI. A three to five percent addition of water is recommended.

Also, be sure managers or bunks are kept clean. Remove refused feed every day. Check and clean any moldy and/or heating feed from the corners and edges of feeding areas at least three times a week or oftener if animal protein and fats are fed. Feeding areas with a decaying feed smell reduce DMI even when fresh feed is offered.

SUMMARY

A reduction in DMI is the primary reason milk production declines during heat stress periods. At the same time DMI decreases, maintenance cost of the cow increases in an attempt to maintain body temperature and thus, the overall availability of nutrients and energy for milk production is decreased. The most effective feeding management strategy to minimize production losses during heat stress periods is to provide a cool, comfortable environment by shading, sprinkling and/or forced air flow. Modifying the environment will result in bigger gains, or fewer losses, during heat stress periods than any dietary manipulations. Diet changes will have only a small effect on productivity and should be considered supportive and an enhancement to environmental cooling.

The concentration of all nutrients will need to be increased in diets as DMI decreases during heat stress. Guidelines for nutrients that have been specifically shown to have an influence on DMI and milk production during heat stress are:

Nutrient	Change and dietary concentration (DM basis)
1. Energy	Increase to compensate for reduced DMI. A .80 Mcal NE_L per pound is probably the maximum that can be obtained with adequate fiber levels.
2. Fiber	ADF minimum - 18%. NDF minimum - 25%. NDF from forage or effective fiber - 21%.
3. Fat	Added amount should not exceed 4%. Strategy suggested is add 1 lb from animal, 1 lb from vegetable and a final 1 lb from a rumen inert source.
4. Protein	Meet overall CP requirement by adjusting concentration as needed. Use a combination of rumen degradable and undegradable sources achieving a rumen undegradable level of 36 to 40% of CP.
5. Sodium	Increase using buffers to .45 to .55%
6. Potassium	Increase to 1.2% or more. High quality alfalfa is a good source.
7. Salt	Feed 3 to 4 ounces per cow per day.
8. Chlorine	Minimum - .25%, maximum - .35%.
9. DCAB	Na + K - Cl ~ 35 to 45 meq/100g DM (Na + K) - (Cl + S) ~ 25 to 35 meq/100g DM
10. Magnesium	Increase to between .3 and .35%.
11. Niacin	6 g per cow per day
12. *Aspergillus oryzae*	3 g per cow per day

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