Feeding and Nutrition Management for Hot Weather

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Introduction
Heat stress can severely impact both production and reproduction in dairy cows. Although great advances have been made in cow cooling, reduced feed intake and milk yield still occur during hot weather. Estimated losses in milk yield and DMI, and reproductive losses due to heat stress were calculated for the entire United States. Losses in milk ranged from a low of 150 lb per cow per year for Wyoming to a high of 4568 lb per cow per year for Louisiana. Florida and Arizona were 3975 and 1607 lb, respectively (St-Pierre et al., 2003). Losses in dry matter intake (DMI), milk yield, and reproductive performance are quite significant for a number of states, emphasizing the potential gains by recovering some of those losses. There are nutritional modifications that can be made for hot weather feeding but many of those dietary changes are made to compensate for reduced feed intake or in the attempt to regain a normal physiologic status for the cow. Once economically realistic attempts have been made to cool the cow and sustain intake, dietary modifications become necessary.

The effects of heat stress on animal production are well documented. Pioneering research in Missouri established the relationship between high ambient temperature and increased rectal temperature of dairy cows (Kibler and Brody, 1949), and the impact of high temperature on feed and energy intake and on milk yield (Johnson et al., 1963). The effects of high environmental temperatures are magnified by high relative humidity (RH). High yielding cows are more affected by heat stress than low producers (Johnson, 1987) because high producers consume more nutrients and produce more metabolic heat. Environmental modifications to minimize heat stress coupled with an excellent nutritional program are necessary to maintain DMI and milk yield during the summer months.

Hot Weather Effects on the Cow
The normal body temperature of a dairy cow is 101.5°F. When ambient temperatures exceed about 77°F or when the temperature-humidity index exceeds 72, cows show signs of heat stress. Indicators that cows are suffering the effects of hot, humid weather include:

- Body temperature exceeding 102.6°F
- Panting greater than 80 breaths/minute
- Reduced activity
- Feed intake reductions greater than 10-15%
- Milk yield reduced by 10 to 20%, or more!!

Heat stress (HS) can be chronic over an entire summer as in the deep south and western states or can occur in intense bursts for shorter periods in mid-western regions. These intense bursts of hot weather can be devastating for lactating dairy cows not adapted to hot weather. The dairy cow has several mechanisms to help dissipate body heat and maintain body temperature. Conduction, convection, and radiation depend on a relatively large differential between body and environmental temperatures, and evaporation works best at low relative humidity. These mechanisms can be exploited to cool the cow, passively or mechanically.
However, when the environmental temperature nears the cow’s body temperature, especially in the presence of high relative humidity, all the cow’s cooling mechanisms are compromised. As a result the cow’s body temperature rises and the cow exhibits physiologic responses to hot weather.

During heat stress the dairy cow eats less feed, which is considered a protective mechanism to reduce metabolic heat production. However, there are several factors which influence the extent of heat stress for the cow, including:

- Severity of the environmental conditions
- Level of milk yield and quantity of feed consumed
- Stage of lactation
- Size of the cow
- Cooling management
- Exercise requirements
- Breed (?), and color

These factors influence metabolic heat production, heat dissipation, and ultimately the degree of stress to which the cow is subjected.

The NRC (1981) predicts that dry matter intake (DMI) for a 1322 lb cow producing about 60 lb of milk will decline from 40.1 lb at 68°F to 36.8 lb at 95°F, and maintenance costs for the cow will increase by 20% (Table 1). At 104°F maintenance increases by 32% and DMI falls to about 56% of that eaten by cows in thermoneutral conditions. The effect of high environmental temperature on cow performance is mediated through the body temperature of the cow. Each 1.0°F increase in body temperature above 101.5°F resulted in 4 and 3 lb. decreases in milk yield and TDN intake (Johnson et al., 1963).

Environmental conditions are directly related to the cow’s ability to maintain homeothermy. One way to characterize environmental conditions has been to calculate a temperature-humidity index (THI), which considers the combined effects of ambient temperature and relative humidity (NOAA, 1976). Intake for Holstein and Jersey cows was negatively correlated with minimum and maximum daily THI (-0.63 and -0.62, Holsteins; -0.62 and -0.55, Jerseys) [Holter et al., 1997; Holter et al., 1996]. In a study to determine which environmental factors had the greatest impact on milk yield and DMI, it was determined that the mean air temperature two days earlier had the greatest effect on DMI, while the mean THI two days earlier had the greatest effect on milk yield. The second most important environmental variable for milk and DMI was the mean THI three days earlier (West et al., 2003). From these data it appears that mean conditions (including night time) are more important that maximum heat, and that the true effects of heat stress are delayed; that is, it takes two to three days for the maximum effects of heat stress to be expressed in performance.

**Benefits of Cooling**

Shading is one of the most important and cheapest ways to improve the cow’s environment during hot weather. Florida research showed over 10% gain in milk yield simply by shading cows, and cows shaded during the dry period yielded almost 1800 lb (13.6%) more milk in a 305 day lactation and had calves that weighed more at birth (Collier et al., 1982). However, shade alone is rarely enough and additional cooling from fans and sprinklers or evaporative coolers is usually needed. Although it is not the intent of this paper to evaluate different cooling methods it is crucial that cooling be used to minimize losses in DMI. Nutritional methods to balance diets should be used in concert with cooling.
Cooling research in Florida, Kentucky, Missouri and Israel using fans and sprinklers improved DMI by 7 to 9%, milk yield by 8.6 to 15.8% (4.4 to 7.9 lb) per day, and reduced rectal temperature by 0.8 to 1.0°F and respiration rate by 17.6 to 40.6% (16 to 39 breaths/minute) [Bucklin et al., 1991]. Cows that were cooled using sprinklers and fans during the dry period maintained lower body temperatures and delivered calves that were 5.7 lb. heavier and cows averaged 7.7 lb more milk daily for the first 150 d of lactation than shade only controls, even though cows were managed similarly following calving (Wolfenson et al., 1988).

**Practical Feeding Considerations**

Energy intake is directly related to DMI and practical approaches to maintain DMI include more frequent feeding, use of high quality forage, ensuring that the diet is palatable, proper nutrient balance, and greater nutrient density. Because feed intake declines during hot weather, ration nutrient density must increase to deliver sufficient nutrients. In addition, changes in eating patterns from day to night feeding occur with hot days and cooler nights. The quality of feed delivered during hot weather is of great importance. Remember that each pound of dry matter intake can be worth 2 to 3 pounds of milk. Following are some low cost tips that can help cows eat more feed, and make the dairy producer more profits. Know what’s going on in the feed bunk!

- Feed should be present in the bunk at all times to ensure free access.
- Are feed bunks empty?
- Are cows in the holding pen too long, keeping them away from feed too long?
- Can cows reach the feed? Is feed pushed up often?
- Is feed/silage hot or spoiled? Is there a musty smell to feed?
- Are rations mixed consistently and uniformly?
- Is there room for all cows at the feed bunk?
- Adapting to changing intake patterns? (More feed consumed at night, less during the day)
- How does the total mixed ration (TMR) look?
  - Is the mix consistent?
  - Is the particle size adequate, or is it overmixed or pulverized?
  - Can cows sort feed ingredients due to large particle size?
  - What are cows sorting for or against?
  - Is the ration dry; will intake benefit from added water?

**Water is Critical**

Cows need an abundance of clean, cool water. Water is closely linked to performance, and cows consume 2 to 4 pounds of water for each pound of feed intake and an additional 3 to 5 pounds of water for each pound of milk produced. As the environmental temperature increased from 40 to 80°F the water consumption of dry cows increased from 6.1 to 8.2 gal/day, for 40 lb producers from 15.8 to 26.4 gal/day, and for 80 lb producers from 25.9 to 44.9 gal/day. Water intake increases sharply as the temperature increases (Table 1) because of water loss from sweating and with more rapid respiratory rates (panting), both efforts aimed at increasing evaporative cooling for the cow. Practical considerations are to supply unlimited quantities of clean water under shade within easy walking distance. Water usage patterns studied in a four row free stall barn were revealing. Cattle given access to a water trough at the milking parlor exit consumed 10% of their daily water needs there, and 35 to 45% of their consumption was from a trough at the center crossover for each pen. Cattle drank the least amount of water from the trough located in the crossover farthest from the pen entrance (Brouk et al., 2001). Make sure water is readily accessible to cows and consider:
Do cows have to compete for space at the trough?
Is the water supply adequate for summer demands?
Is water clean and cool? Are troughs cleaned regularly?
Is water close to feed and housing?
Is water shaded or do cows have to go into the sun to drink?

Meals Create Heat
The heat production of metabolic functions accounts for about 31% of the intake energy by a 1322 lb cow producing 80 lb of 4% fat-corrected milk (Coppock, 1985), and energy expenditures for maintenance increase by 20% when the temperature is 95°F compared with a thermoneutral temperature (Table 1). Thus heat production is a high proportion of consumed energy and increases as production rises, but increasing amounts of energy are diverted to maintenance during hot weather. Following a meal metabolic heat production increases. Different feedstuffs have varying heat increments and in moderate to high producing dairy cows the heat increment of feeds can be about two-thirds of total heat production (Chandler, 1994). Dietary fat has a low heat increment and because of a high efficiency of utilization, heat production is lower. Fiber has a high heat increment when compared with concentrates (Baldwin et al., 1980).

Perhaps heat increment can be exploited for hot weather feeding. An obvious advantage of reduced heat production by the cow is that less heat must be dissipated. Lower heat increment also means improved efficiency of energy utilization because energy is used for productive purposes and is not lost to heat production. Diets formulated with added fat, high quality fiber at proper, but not abnormally low, levels and using high quality commodities should be beneficial during hot weather.

Milk yield as a function of nonstructural carbohydrates in the diet


Concentrates and Forage
A common approach to improve dietary energy density during hot weather is to reduce forage in the ration and increase concentrates. The logic is that less fiber (less bulk) will encourage intake, while more concentrates increase the energy density of the diet. Unfortunately this logic sometimes fails. The figure shows the milk response curve to dietary non-structural carbohydrate (NSC) content. On the
leading edge of the curve milk yield is low because of lower energy content (less readily fermentable NSC in the diet). However, with high dietary NSC the milk yield actually declines despite high energy density. The reason is that excessive grain in the diet causes acidosis, leading to low milk fat percentage, off-feed conditions, digestive upsets, laminitis and sore feet. The optimum NSC concentration appears to be in the range of 33 to 38%, although 40% NSC is acceptable with good fiber content and fiber particle length. Recommendations for feeding grain and fiber include:

- Do not exceed 55-60% concentrate in rations
- Nonstructural carbohydrates (NSC) should be 35 to 40% of diet DM
- NDF should be 27-33%
- Maintain adequate particle size!

Fiber digestion may add significantly to the cow's heat load. Cows given a choice between hay and concentrate consumed less hay when subjected to heat stress (Johnson et al., 1963). Beef heifers fed pelleted diets containing 75% concentrate (low fiber) had lower heat production compared with those fed pellets containing 75% alfalfa (high fiber) [Reynolds et al., 1991], suggesting that high fiber diets do have a greater heat increment than diets low in fiber.

Diets with no hay, or low, medium, and high levels of Tifton 85 bermudagrass (NDF content for TMRs was 27.3, 29.7, 32.2, and 34.6%, respectively) resulted in lower DMI as dietary NDF levels increased (West et al., 1995). The DMI decline occurred with increasing NDF during both cool and hot weather, but when hot weather DMI was adjusted for cool weather treatment effects, differences in DMI between diets disappeared, suggesting that intake differences among treatments were due primarily to the dietary fiber content. Lack of an interaction between hot weather intake and treatments suggests that heat increment associated with fiber level in the diet was not a factor during heat stress. However, intake was lower on high fiber diets and total fiber intake did not differ as much as fiber percentages suggest. Results in this study, like those of Cummins (1992), suggest that total DMI is a greater factor affecting heat stress response than fiber content of the diet.

Attention to fiber quality in hot weather diets is critical and feeding high quality fiber is preferred over minimal fiber diets. Rations should contain a minimum 19% ADF, 27 to 33% NDF, and 75% of NDF should come from forages. In addition, Penn State particle size recommendations for total mixed rations are 6 to 10% or more of particles > 1.90 cm, 30 to 50% in the 0.79 to 1.90 cm range, and 40 to 60% <0.79 cm long. The greater overall particle length, the less total forage required in the diet as long as the cow consumes it and does not sort it from the ration.

**Feeding Dietary Fat During Hot Weather**

Fat contains 2.25 times as much energy as the same quantity of carbohydrate, and is particularly valuable as an energy supplement when DMI is limited, as it is during hot weather. Adding fat to the diet during hot weather does not consistently alter DMI but can improve milk yield. Diets with supplemental fat during hot weather improved fat-corrected milk yield (Knapp and Grummer, 1991; Skaar et al., 1989). In both studies fat was also fed during cool weather. In one study, no environment by diet interaction occurred (Knapp and Grummer,1991), suggesting no additional benefits from added fat during hot weather over those seen in cool temperatures; however, Skaar et al. (1989) found that dietary fat was beneficial only to cows that calved during the warm season. During hot weather in Arizona a prilled fat increased milk yield by 2.6 lb/day, and in another study increased milk yield by only 1.5 lb/day in cooled or non-cooled cows (Huber et al., 1994). The Arizona results suggested less response from added fat in heat-stressed than in cool cows, even though they expected that added fat would reduce heat production and lower heat stress. The data further suggest that cooling the cow is necessary to achieve full benefits of dietary adjustments such as added fat.
Diets containing 15% whole cottonseed (WCS) or 15% WCS + 1.2 lb of calcium salts of fatty acids reduced heat production in excess of maintenance by 6.7 and 9.7%, evidence that added fat does indeed reduce metabolic heat production, of great value during hot weather (Holter et al., 1992). Although cows may not show signs of reduced heat stress in response to added dietary fat, cows benefit from greater energy density during periods of depressed intake. Fats are used efficiently by the cow, and improved efficiency could reduce heat production, making fats particularly valuable during hot weather. However, just like other feeds, too much fat is not a good thing. Excessive fat causes digestive upsets and reduced fiber digestion. Practical applications are to add fat, not exceeding 5 to 7% total fat in the diet. Fat levels beyond these should be supplied using a rumen inert fat. As a general guideline, no more than 30 to 40% of total dietary fat should come from whole oilseeds (a source of unsaturated oils), 40 to 45% from other basal ingredients, and 15 to 30% ruminally inert fats.

**Crude Protein During Hot Weather**

It is obvious that insufficient dietary protein can reduce milk yield, and older Louisiana heat stress work showed that protein at 14.3% (adequate) or 20.8% (high) improved milk yield by 6% at the higher protein level. Inadequate quantities of dietary protein have an immediate negative impact on milk yield, but excess intake protein requires energy to process and excrete. In one study where 19 and 23% crude protein diets were fed, milk yield was reduced by over 3.1 lb simply by feeding the high protein diet (Danfaer, 1980). Calculations revealed that the energy cost of synthesizing urea and the energy cost to excrete that urea accounted for the reduced milk output (Oldham, 1984). Thus formulations with either inadequate or excess CP can reduce performance by lactating cows.

Excessive dietary crude protein may impair reproductive performance. Cows were fed ryegrass pasture and supplemented with corn silage and a rumen undegradable protein (RUP) source so that diets contained 1) moderate (about 17.5%), 2) high (23.1%) crude protein (CP), or 3) moderate CP plus high rumen undegradable protein (RUP) [McCormick et al., 1999]. Cows fed excess CP had lower first breeding pregnancy rates (24.1 vs. 41.0%) and lower overall pregnancy rates (53.5 vs. 75.4%) than cows on the moderate CP diet. Reproductive performance was similar between the moderate CP diet and the high RUP diet. Excessive CP resulted in high blood urea N and ammonia contents, reducing conception rate. In another field study, cows were defined as having high or moderate milk urea N 30 days prepartum. The odds that a cow would be non-pregnant following breeding were unaffected by MUN during cool weather. However, cows calving in warm weather were 6 times more likely to be non-pregnant compared with cool weather calving cows when designated moderate MUN, but were almost 18 times more likely to be non-pregnant with high MUN (Melendez et al., 2000). The practice of feeding high CP diets during hot weather to compensate for lower intake should be pursued with caution.

When cows were either evaporatively cooled or shaded and offered diets containing high quality or low quality protein, protein quality did not affect DMI, milk yield was greatest for high quality protein diets, and the response to protein quality was greater for cows that were evaporatively cooled vs. shaded (Chen et al., 1993). Cows were most responsive to protein quality when they were evaporatively cooled, allowing maximal intake and milk yield and benefiting from the high quality protein. It is apparent that top production cows must be cooled and the diets must be modified to compensate for the effects of heat stress.

**Mineral Supplementation**

Mineral needs for cattle change during hot weather. Cows sweat just like other mammals but their sweat contains a large amount of potassium (K) unlike humans, whose sweat contains more sodium.
(Na). Consequently, K requirements increase during summer. In addition, cows need more Na during summer and magnesium needs to be boosted when high dietary K is fed. Dry matter intake was improved when dietary K was greater than NRC recommendations during hot weather (Schneider et al., 1986; West et al., 1987). Feed intake was improved when diets contained 0.55 vs. 0.18% Na during hot weather Schneider et al. (1986). Current ranges for mineral supplementation during heat stress are:

- Potassium: 1.4 to 1.6% of DM
- Sodium: .35 to .45% of DM
- Magnesium: .35% of DM

A ratio or balance of ions may affect performance by influencing buffering systems in the body. Escobosa et al. (1984) were the first to evaluate diets fed to lactating cows during heat stress using the electrolyte or cation balance equation, later termed as dietary cation-anion difference (DCAD). They reported greater DMI for diets containing 320 meq Na + K - Cl/kg of feed DM vs. diets containing 195 and -144 meq, suggesting that an alkaline diet based on DCAD may be beneficial to heat stressed dairy cows.
Increasing DCAD in the diet improved DMI and change of the equation using any of the three elements (Na, K, Cl) was equally effective in improving performance (Tucker et al., 1988). Increasing DCAD raised blood pH, serum cation-anion difference and blood bicarbonate, all indicators of improved blood buffering. There was improved DMI and milk yield with increasing DCAD in both cool and hot environments, indicating a response regardless of environment (West et al., 1991). During heat stress conditions DMI was improved as DCAD was increased from 120 to 464 meq Na + K - Cl/kg feed DM, regardless of whether Na or K was used to increase DCAD (West et al., 1992). This suggests that the DCAD equation is more significant than the individual element concentrations (barring deficiencies), and may cloud the issue of K content necessary in diets fed during hot weather. However, additional research is needed to more closely define the desired DCAD for lactating dairy cows and to resolve the issue of K versus Na supplementation. Note that the DCAD for lactating cows is highly positive, or alkaline, as opposed to the negative, or acidic, diets used for dry cow diets. The need for alkaline diets is consistent with addition of buffers to the diet, since the ideal means to increase DCAD for lactating cows is with Na or K in association with a metabolizable ion such as bicarbonate. The diet cannot be made more alkaline by the use of salt (NaCl) or potassium chloride (KCl). Use of dietary buffers is a common practice, especially during hot weather, and DCAD may provide further justification for the use of buffers during hot weather. Work with potassium carbonate as a source of supplemental K and dietary buffering showed positive results during heat stress (West et al., 1987). Rations should be formulated for hot weather mineral levels before the onset of summer, so that the mineral content is there when the cow needs it.

Feed Additives

In addition to formulating diets for adequate nutrient intake by the cow, a number of "non-nutritive" additives are available which have potential to improve performance during hot weather. However, an additive is only practical if it works in your herd and in your situation. Additives purchased to solve problems due to poor ration formulation are purchased for the wrong reasons. Buffers such as sodium bicarbonate are especially useful in low fiber diets, diets based on corn silage, when cows can select against forage consumption, and particularly during hot weather. Fed at about 0.75% to 1.0% of diet DM, or 5 to 8 ounces per cow per day, bicarb can help keep cows on feed and maintain milk fat percentage.

One should consider which cows will benefit from a product before using it. An example is a field trial conducted in the summer in Pennsylvania evaluating the B vitamin niacin (Muller et al., 1986). Six grams of niacin were fed to lactating cows, and when compared with the controls there was only a 2 lb increase in milk with niacin. However, when cows producing >75 lb of milk were evaluated, the higher producers responded with 5.3 lb more milk. The moral of the story is that an additive can be targeted at a specific group of cows which are most likely to be responsive, and not on a group that may not respond sufficiently to economically justify its use. An additive is only good if you need it!

Yeast cultures and fungal products help to maintain a stable rumen environment. Some have shown additional benefits during hot weather. Better protein use, stable rumen pH, and better fiber digestion are potential benefits of these products. One should rely on documented results and not testimonials when considering these products.

Huber et al. (1994) reviewed the use of fungal cultures added to diets during heat stress conditions. The species for which the heat stress data were available were of strains of *Aspergillus oryzae* (AO). In several of the studies summarized, rectal temperatures were lower in AO supplemented cows although there was no change in some studies. A number of studies also showed increased milk yield with AO.
use during heat stress. Ruminal effects associated with AO use include increased fiber digestion, greater numbers of celluolytic bacteria, increased turnover rate of lactic acid, and less variation in rumen pH, ammonia, and volative fatty acid production. Improved ruminal efficiency and reduced heat production could contribute to greater performance and reduced heat production. Any product which improves ruminal efficiency and stabilizes the rumen environment should contribute to improved performance during hot weather.

Summary
Reduced milk yield with heat stress occurs primarily because of declining feed intake. Greater maintenance costs during hot weather magnify the energy deficit of the heat-stressed cow. Protection from the heat using shade and cooling is the first step toward maintaining intake and milk yield during hot weather. Other steps to enhance performance include:

- During hot weather some form of cooling is necessary to minimize the reduction in intake and to achieve the desired response to dietary modifications.
- Abundant drinking water is needed due to greater consumption during hot weather.
- Ration formulation can be used to minimize heat production potential of the diet through the use of grains, fats, and high quality forage.
- Adequate high quality fiber must be used to maintain rumen function and cow health.
- Ration energy can be increased using grains and other highly fermentable carbohydrates, and using fats; acidosis is a potential problem to be avoided.
- Ration protein content and quality must be altered with heat stress. Excess degradable protein can have negative effects on intake and efficiency.
- Mineral content (especially potassium, sodium, magnesium) should be increased. Other elements and vitamins should be adjusted to offset reduced feed intake.
- Use additives that have a proven reason and benefit for your herd situation.

References

Table 1. Changes in maintenance requirements and DMI for 1323 cows producing 59.5 lb of 3.7% fat milk at various temperatures

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Maintenance (% of requirement at 50°F)</th>
<th>DMI needed (lb/d)</th>
<th>Expected DMI (lb/d)</th>
<th>Milk (lb/d)</th>
<th>Water intake (gal/d)</th>
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Adapted from NRC (1981).