

MANAGING HEAT AND COLD STRESS OF FEEDLOT HOLSTEIN STEERS

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Introduction

Seasonal variations in climatic conditions continue to impact confined cattle feeding operations. Annually, it is estimated that heat stress results in economic losses to livestock industries across the United States between \$1.69 and \$2.36 billion. The dairy industry accounts for \$897 to \$1500 million, and the beef industry for \$370 million (St-Pierre et. al., 2003) of these losses.

It is not only the seasonal variations that cause considerable economic hardship. Periods of inclement and severe weather conditions are often unexpected, particularly severe and generally incur the greatest economic loss. Heat waves that occurred in the Midwest of 1995 and 1999 caused nearly 5,000 cattle deaths in each incident. In the 1990's early snowstorms in the southern plains resulted in feedlot losses in excess of 60,000 head (Mader, 2003).

In addition to mortalities associated with severe climatic conditions, reductions in performance generate sizeable economic losses. Research continues to assess the impact of climatic stressors on the physiological (Gaughan et al., 1998) and dynamic responses of animals. At the same time, feedlot managers and cattle feeders continue to search for management options to alleviate and reduce the effect of severe weather on feedlot performance.

This paper is intended to summarize some management considerations during both hot and cold climatic conditions. The majority of the information presented is derived from research conducted with fed beef cattle but can be extended to Holstein steers.

Management Considerations for Hot Weather

Mechanisms of heat balance. Mammals attempt to maintain a relatively constant core body temperature. Cattle do this by balancing the heat gained from metabolic processes (digestion of feed) with that gained from or lost to their surrounding environment. This heat balance is achieved through various mechanisms and is exerted through energy exchanges involving convection, conduction, radiation and evaporation (Figure 1).

In the standing animal, conductive heat transfer (transfer of heat from the skin to material in direct contact with the skin) plays a minor role in the total heat transfer with the environment. In the prostrate animal, conductive heat transfer will be greater. If the

temperature of the ground is lower than skin temperature, heat can be lost by conduction (Robershaw, 1985). This is most evident in the feedyard when the ground is wetted from sprinklers. Cattle can utilize this wetted, cooler ground to lose heat back to the environment. On the other hand, if the air or ground temperature is greater than the skin temperature of the animal, the gradient is reversed and heat is gained by the animal.

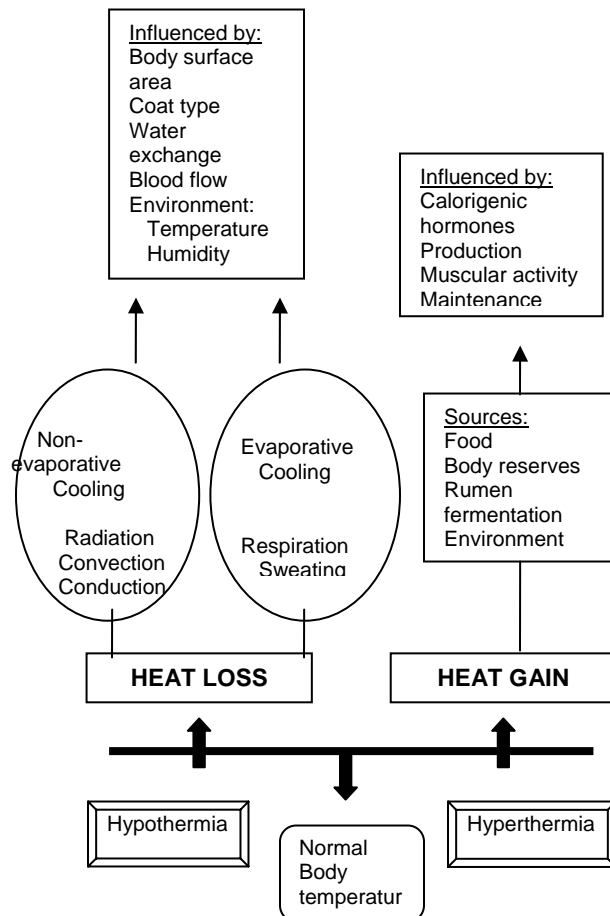


Figure 1. Body temperature as a balance of heat loss and heat gain. (adapted from Yousef, 1985).

This is often an additive effect of hot weather. To avoid this, cattle will consistently move away from situations where heat is gained.

Radiant heat transfer involves the exchange of short wave (solar) and long wave energy exchanges of the animal with its surroundings (Robershaw, 1985). The extent of the solar heat load placed on the animal is a function of the surface area exposed to the radiation along with the color and structure of the coat. Robertshaw and Finch, (1976) concluded that in a brown (*Bos indicus*) cow standing in the noon sun on the equator, approximately 60% of the radiant heat absorbed at the hide surface was re-radiated back to the environment and 10% was dissipated by convection, and the remainder was added to the metabolic heat load of the animal.

Evaporative heat loss can be achieved through the sweat glands (cutaneous heat loss – sweating) or by continuous movement of air over the upper respiratory surfaces (respiratory heat loss – panting). Sweating is considered to be far more effective than panting. Sweating accounts for approximately 84% of the total evaporative heat loss occurring when the air temperature is 104⁰F (McLean, 1963).

Convection is dependent on the surface temperature of the body, surface characteristics and size, and on the air temperature and air movement rate that impinges on the body. Free convection occurs when air temperature rises near the skin and air density decreases causing the air to move up and away from the animal. Forced convection involves external wind or movement of the animal which tends to break up the layer of air entrapped by the hair coat and increase convective heat transfer (Robertshaw, 1985).

Energy Requirements. Energy requirement during heat challenge is dependent on the severity and duration of the heat episode, along with prior acclimatization, diet, level of productivity, coat type, and health status. Maintenance requirements increase as a result of using energy to employ heat dissipation mechanisms. Depending on the severity of the heat episode, the type and intensity of panting by the animal can provide useful guidelines for adjustments in maintenance requirements (NRC, 1981). At the onset of a heat episode first-phase panting may be observed. First-phase panting is characterized by closed mouth, rapid shallow respirations. Early research (Kibler and Brody, 1951) indicates that maintenance requirements are increased 7% during this phase. As the intensity and duration of the heat episode worsens, cattle shift to a deeper second-phase panting. Second-phase panting is recognized as cattle tending to breathe deeper with mouths open. In some instances it almost appears as if animals are coping considerably better as the respirations are not quite as rapid. However, don't be fooled, the shift to the second-phase causes an additional increase of 11 to 25% in energy requirement.

Holsteins do maintain some advantages over beef breeds during heat episodes. Thinner hide, less subcutaneous fat, shorter hair coat length, and reduced hair coat density means Holsteins are able to more effectively dissipate heat through evaporative and conductive cooling mechanisms.

Water requirements. Water requirements during hot conditions more than double (Table 1). When air temperature is above 86⁰F, cattle tend to drink more often, at least every 2 hours (Yousef et al., 1968).

Table 1. Water requirements of beef cattle in different thermal environments (NRC, 1981).

Thermal environment	Water requirements (lb/lb DMI)
>95⁰F	17.6 to 33.1
77 to 95⁰F	8.8 to 22.0
25 to 59⁰F	4.4 to 8.8

Management strategies. Shade structures do not reduce air temperature or humidity but can reduce the radiant heat load by 30% or more by intercepting direct solar radiation. In Iowa during a heat wave (July, 1995), death loss among shaded cattle was only 0.2% (35 feedlots) compared to 4.8% (46 feedlots) for unshaded cattle (Busby and Loy, 1996). Most (79%) feedlots without shade experienced some cattle loss while only 14% of shaded feedlots experienced death loss. The effect of shade on animal performance may be offset by a lack of air movement under the shade structures. Overcrowding of cattle underneath shade structures or windbreaks in close proximity reduce air movement and benefits (Mader *et al.*, 1997).

Non-evaporative cooling requires a heat gradient. The effectiveness of evaporative cooling is reduced by environmental factors such as low wind speed, and high humidity. During hot summer days differences between the animal and air temperature are often too small to allow effective cooling for much of the day. Cattle become more efficient at dissipating heat back to the environment during the cooler night time hours without incurring radiant heat.

The use of sprinklers, either to wet cattle or ground, is an effective tool to alleviate heat load, and is more beneficial when used in the evening hours. During the day the effectiveness of non-evaporative mechanisms is progressively reduced to zero at the point when body temperature and air temperature are the same. Evaporative heat loss mechanisms become vital to temperature regulation at this point. Utilizing sprinklers in the evening is more advantageous, and there are distinct advantages.

1. Non-evaporative cooling mechanisms are less effective during the day as the temperature differences between an animal's body temperature and air temperature can be extremely small. Night cooling becomes more effective with the reduction and loss of solar radiation and a larger gradient between the animal's body temperature and air temperature.
2. During the daytime the water load on the feed yard is greatest. Cattle spend a larger amount of time around the water tanks and increase water usage during this time. Sprinklers and wetting systems used during the day may cause problems by increasing the water load in the feed yard.

3. Sprinkling and ground wetting at night increases the length of time the area being wetted remains cool (Figure 2).

In recent years, research at South Dakota State University (unpublished) has observed that during heat episodes cattle cooled in the evening hours performed better than those that were not cooled (Table 2). Body temperatures of cooled cattle were lower than non-cooled cattle (Figure 3).

Based on research conducted at South Dakota State University over several years, sprinkling recommendations are presented below.

Time of sprinkling	6pm – 7pm Midnight – 1am
Amount of water applied	5 – 6 gallons/head/day
Sprinkler placement	Mounds preferred Away from water tanks and bunks
Space of wetted ground	15 – 20 square feet/head

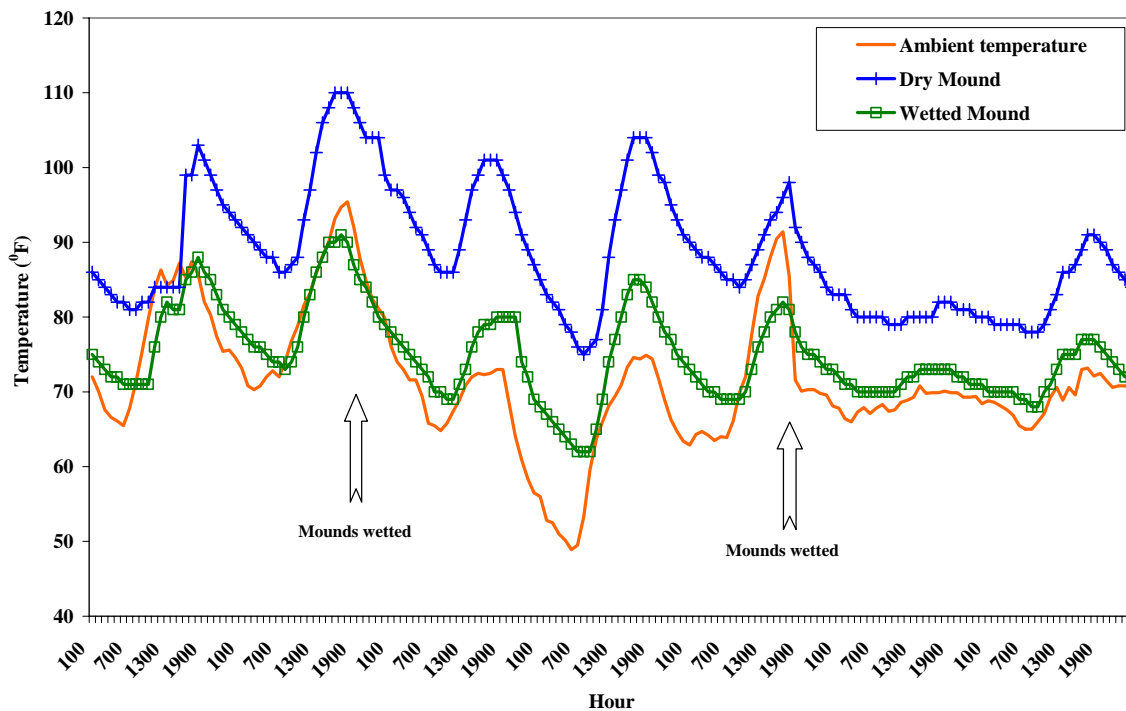


Figure 2. Temperatures of sprinkled versus non-sprinkled mounds during a hot weather.

Table 2. Performance of cattle during a heat episode^a

	Control	Night cooling	SE
Body weight, lbs	1201	1193	1.8
Dry matter intake, lbs	23.1	23.5	0.07
ADG, lbs	3.02	4.07	0.032
F/G	7.68	5.81	0.154

^aAngus crossbred steers, performance data from day 62 to 84 days on feed

The question that remains is how we decide when it is necessary to initiate our sprinkling or ground wetting program. The temperature-humidity index (THI) has been used as an indicator of heat load in cattle. More recently, the THI-Hour concept, which is an adaptation of the THI incorporating a time dimension, has been used to assess the accumulation of the heat load placed on cattle. It is not only the intensity of the heat episode but the duration that is important, along with the amount of time cattle have to recover at night.

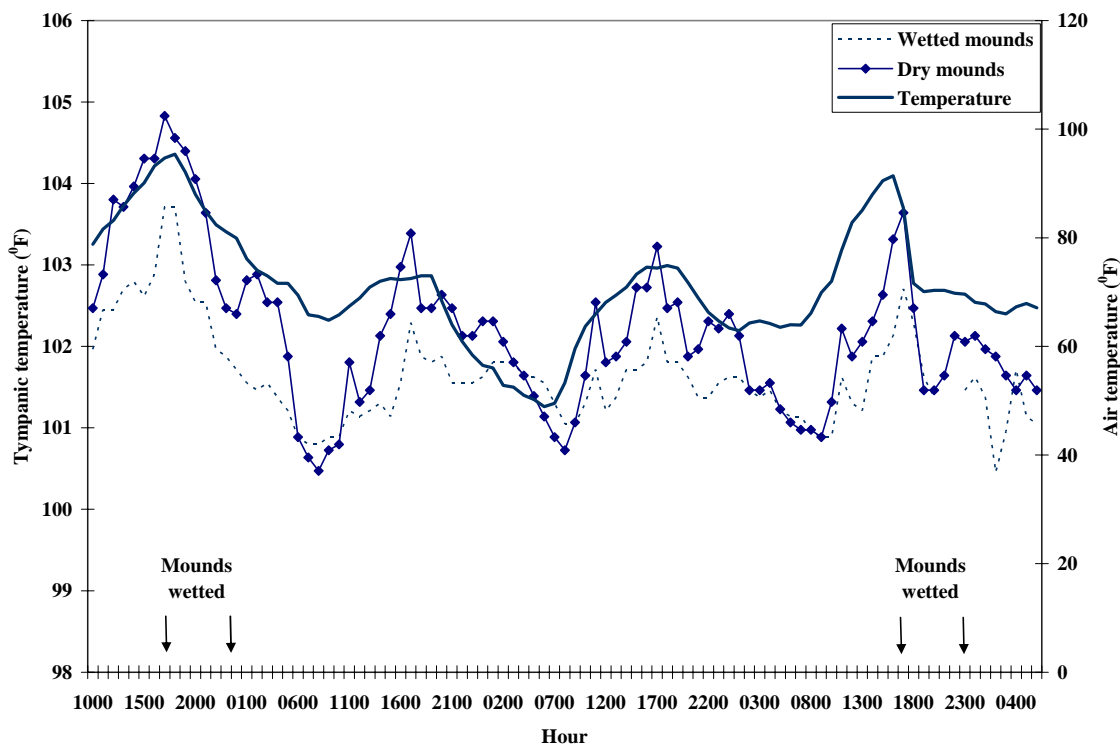


Figure 3. Body temperature (as measured by tympanic temperature) of steers during hot weather.

Incorporating a time dimension is achieved by assessing the amount of time (hours) the THI exceeds a threshold index, which is based on animal vulnerability. In general, three

threshold indices are used (73, 79 and 84). These values are the lower THI values for the alert, danger and emergency categories.

The THI hours is calculated by the following equation:

Daily THI in degree hours = ((current THI – base threshold THI) x hour)

The accumulated THI hours without relief from the heat episode indicate the severity of the heat strain on the animal.

Recovery time is also important, and so THI hours below a recovery threshold should also be calculated. Recovery generally begins when THI is 74 or below. Recovery time is calculated by the following equation:

Daily THI in degree hours = ((74 – current THI) x hour)

The accumulation of 10 THI hours by 5pm would warrant initiating a cooling strategy. Although this number appears to be low, the aim is to provide cattle with adequate recovery ability in the evening to reduce the amount of heat load before the next day arrives.

All too often we incorporate reactive procedures into our feedlot management protocols. In the case of heat stress management, typically we wait until cattle are observed to be suffering from hot conditions (excessive panting and reduced feed intake) before intervening.

In most instances, once physical signs appear (restlessness, excessive panting, etc.) it is already too late to prevent performance losses. Proactive strategies that can be implemented as part of a summer management plan will minimize performance and economic losses due to heat stress.

Management Considerations for Cold Conditions

Energy requirements. Maintenance requirements increase during periods when temperatures fall below the animals Lower critical temperature (LCT). Although, Holsteins have some advantages during hot conditions due to their thinner skin, less subcutaneous fat, and reduced hair coat density, this becomes a distinct disadvantage during periods of severe cold conditions.

Early research conducted suggested the LCT for dairy cattle to be estimated at 7⁰F (NRC, 1981), and that this LCT is dependent on specific housing, pen conditions, age, nutrition, time after feeding, thermal acclimation, and hair coat etc. This estimate assumes that the animal is standing outside with no effects of wind, snow, or mud. In comparison, the LCT for beef breeds is estimated at -32⁰F and is lower than for dairy breeds due to greater internal and external insulation (NRC, 1981).

More recent estimates using the NRC (1996) prediction equations indicate maintenance requirement adjustments occur at higher temperatures. Using a 1000lb, 10 month old

Holstein steer fed outside with no wind, feed intake increases 0.4lb as air temperature drops from 40 to 20⁰F. A further increase in feed intake of 1.7lb occurs when air temperature continues to fall to 0⁰F (Table 3).

If we take the same animal and the coat is wet from rain or wet snow, feed intake at 20⁰F is 3.1lb lower than for a dry animal. In addition, as air temperature falls to 0⁰F, feed intake is increased 1.5lbs but is still 3.3 lbs lower than the dry animal.

Energy available for gain can be adjusted for air temperature, wind and coat condition. Using the same animal as in the above example, maintenance requirements increase and gain is decreased as the animal is exposed to lower air temperatures, greater wind speeds and wetter coats (Figures 4 and 5). At 40⁰F an animal with a wet coat with no impact of wind gains 1.14lb less than the same animal with a dry coat.

Inserting the effect of wind into the equation also reduces gain and increases maintenance requirements. Increasing the wind speed to 10 mph at 30⁰F for a dry, partially muddy and wet coat reduces gain by 0.58, 0.82 and 0.85lb, respectively. The reductions in gain become more severe as the air temperature decreases.

Table 3. The effects of coat condition and wind speed on DMI of Holstein steers^a

Air temperature	Clean and dry coat		Some mud on lower body		Covered with wet snow or mud	
	0 wind	10 wind	0 wind	10 wind	0 wind	10 wind
40	19.9	19.9	19.9	19.9	16.9	16.9
30	19.9	19.9	19.9	19.9	16.9	16.9
20	20.3	20.3	20.3	20.3	17.2	17.2
10	20.3	20.3	20.3	20.3	17.2	17.2
0	22	22	22	22	18.7	18.7
-10	22	22	22	22	18.7	18.7
-20	22	22	22	22	18.7	18.7

^a Estimates based on 1000lb Holstein steer, 10 months of age

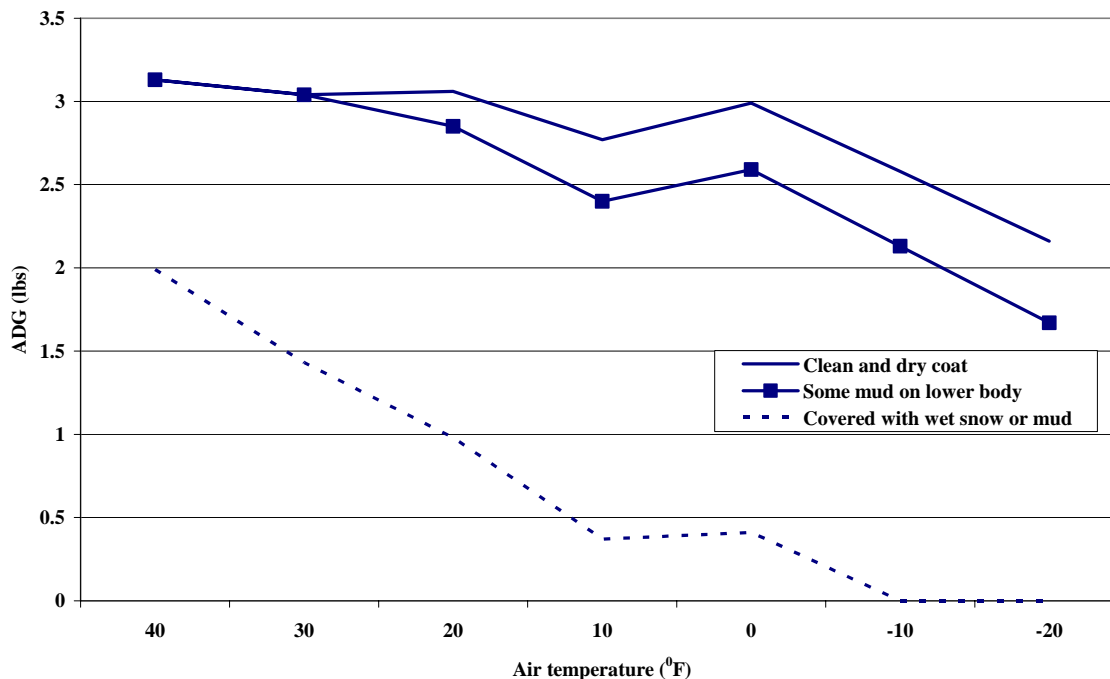


Figure 4. The effect of coat condition on ADG of Holstein steers under various temperatures

Water requirements. Water should not be limited during cold conditions. Cattle still require access to clean, fresh water at all times, and attention should be given to water tanks to ensure that they remain open and do not freeze. Cattle can learn to eat snow to meet water requirements, but this requires generation of heat. Energy for maintenance, in this instance, would increase if snow is the only form of water available. Water intake is reduced nearly 4-fold when the form of water available changes to snow or ice.

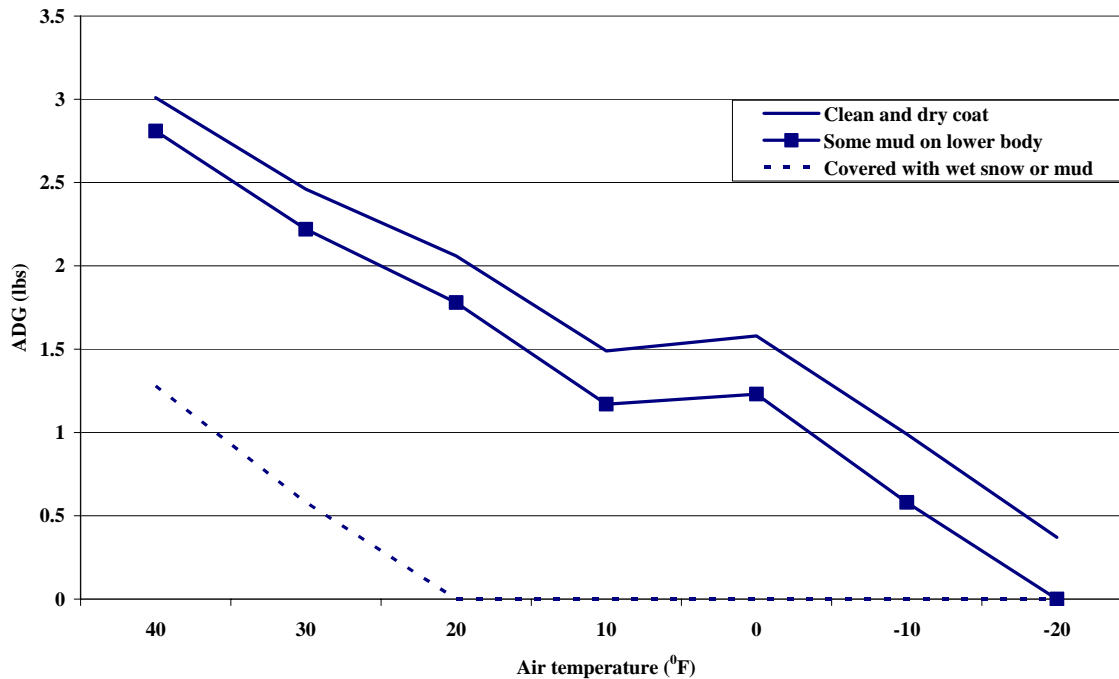


Figure 5. The effect of coat condition on ADG of Holstein steers under various temperatures subjected to a 10 mph wind.

Management considerations. One of the most effective methods of alleviating cold stress on feedlot animals is to provide insulation in the form of bedding. This should be considered particularly in late-winter and early-spring when the air temperature is still fairly cold and wet weather is more prevalent. Cold, wet conditions predispose cattle to cold stress. In a pooled analysis (Mader, 2003) of two separate studies (South Dakota and Colorado) providing a little over ½ lb of straw/animal during the feeding period improved gains approximately 7% and efficiency of gains more than 6%. Furthermore, the economic benefits averaged \$11/head after accounting for the cost of bedding.

Protection from the effects of wind during cold conditions is of importance. In outside pens, when possible, wind protection is best placed outside of the pen to reduce the build up of snow within the pen. Windbreaks will provide protection downwind to a distance of 5 to 10 times their height (Mader, 2003). Mader, (2003) offers some considerations when using shelters or windbreaks.

- Windbreaks should be a minimum of 82 feet from fence lines, however temporary forms of shelter can be set closer.
- Windbreaks in close proximity to pens should allow 10 to 20% open space allowing for some air movement to prevent build up of snow in front of the shelter.

Equally important when considering shelter for cattle in the winter, is whatever is an advantage in the winter is often a disadvantage in the summer. Shelters and windbreaks will reduce air flow in the summer impeding cattle performance.

Pen design and layout should also be considered during cold conditions. Poor pen design can cause pens to remain wet and muddy, causing increased maintenance requirements and poor performance. The provision of mounds will enable dry areas for cattle and can direct watershed away from water tanks and bunks.

Aprons and bunks should be clear of snow and ice build-up. Cattle eat several meals a day, and if they have trouble reaching the bunk due to slippery or wet and muddy conditions then they are less inclined to return to the bunk for a second or third meal. Snow that is trapped in bunks can cause feed to freeze down, reducing intake.

Feeding management and delivery schedules are another strategy used to reduce the impact of cold conditions on feedlot cattle. Restricting feed intake of high energy diets has been researched, and has mostly focused on restricting intake of high energy diets as an alternative management practice to full feeding high roughage diets during the growing phase (Loerch, 1990; Sip and Pritchard, 1991). These studies reported improved feed efficiency and reduced cost of gain for limit-fed cattle compared to those fed ad libitum. Research conducted at South Dakota State University suggests that altering the feeding time for limit-fed cattle in the winter can help to maintain body temperature (Holt and Pritchard, 2005). Steers were limit-fed a high moisture ear corn diet (0.58 Mcal/lb NEg) at 0900h (AM), 1500h (PM) or 50% at 0900h and 50% at 1500h (SPLIT) to allow for 2.5lb ADG. Maintenance energy requirements were 5.6% and 7.6% higher for AM and SPLIT groups compared to the PM group. Tympanic temperature data suggests that the AM treatment group was unable to maintain TT during the coldest period of the day (evening hours 2130 to 0730h). In contrast PM treatment group were able to maintain TT during the evening hours possibly taking advantage of heat of fermentation (Figure 6). Previous research conducted at South Dakota State University, under cold conditions, indicated that if basal metabolic rate has to be increased to maintain body temperature, animals may overestimate energy requirement and increase body temperature above normal levels (Figure 7). The abnormally high TT of the SPLIT treatment group may be an indication of this overestimation.

Summary

Managing cattle during periods of inclement weather remains a challenge. Management strategies are aimed at alleviating rather than eliminating climatic challenges on feedlot animals. The structural design of many feedlots means that cattle are unable to utilize their normal behavioral activities to maintain heat balance. With confined animals there are opportunities for altering the environment by using shade structures, shelters, windbreaks, and sprinklers, or via management such as changing feeding times to improve conditions. Continuing research in animal responses to varying weather conditions is providing a better understanding of the way in which animals cope with these adverse climates.

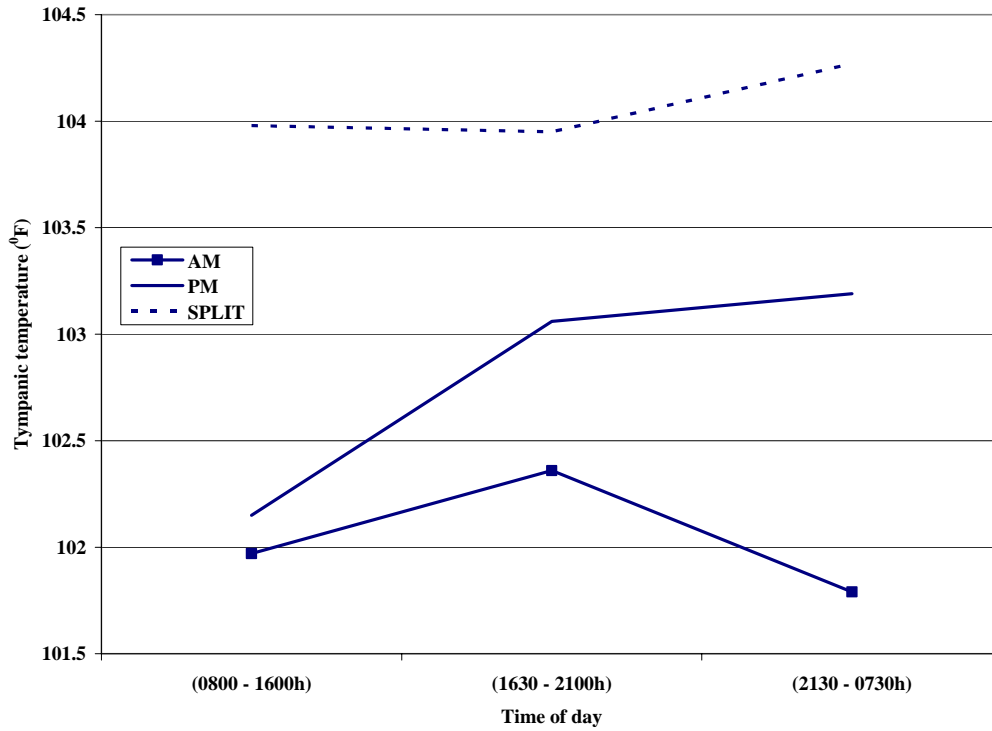


Figure 6. Maximum tympanic temperature of growing beef feedlot steers during cold conditions fed at varying times of the day

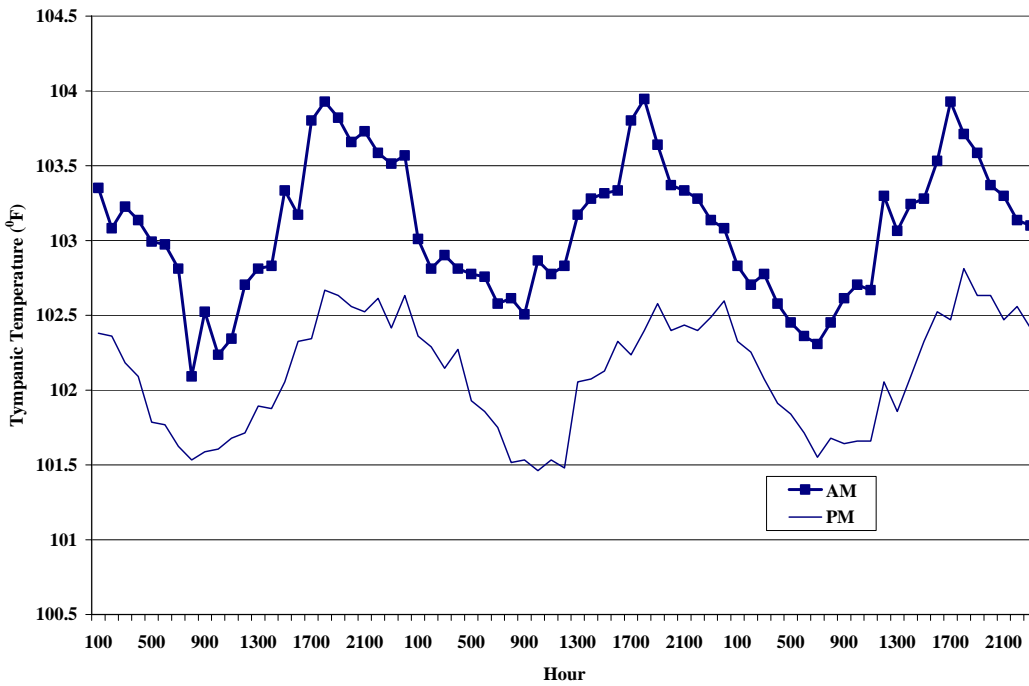


Figure 7. Mean hourly tympanic temperature of feedlot steers during cold conditions fed either in the morning (AM) or afternoon (PM).

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