SDSU Extension

BEEF

Chapter 8

Cold Stress Impacts on Cattle

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Introduction

One of the features of the climatic conditions of the Northern Plains and Midwest is extended periods of cold weather. These environmental conditions mean that the cattle raised in those areas are susceptible to cold stress for significant portions of the year. Understanding the effects of cold weather on the well-being and performance of cattle is important in order to efficiently and profitably produce beef under these environmental conditions.

Estimating Effective Air Temperature and Lower Critical Temperature

The effective air temperature that an animal experiences is a function of both the actual air temperature and wind. That relationship, commonly referred to as wind chill is shown in Table 1. As wind speed increases, a greater amount of heat from the animal is lost to

Table 1: Wind chill temperatures based on air temperature and wind speed. *Adapted from National Weather Service.*

Estimated Wind Speed (MPH)	Actual Thermometer Reading (°F)									
	40	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-45**
	Equivalent Temperature (°F)									
Calm	40	30	20	10	0	-10	-20	-30	-40	-45
5	36	25	13	1	-11	-22	-34	-46	-57	-63
10	34	21	9	-4	-16	-28	-41	-53	-66	-72
15	32	19	6	-7	-19	-32	-45	-58	-71	-77
20	30	17	4	-9	-22	-35	-48	-61	-74	-81
25	29	16	3	-11	-24	-37	-51	-64	-78	-84
30	28	15	1	-12	-26	-39	-53	-67	-80	-87
35	28	14	0	-14	-27	-41	-55	-69	-82	-89
40	27	13	-1	-15	-29	-43	-57	-71	-84	-91
50	26	12	-3	-17	-31	-45	-60	-74	-88	-95
60	25	10	-4	-19	-33	-48	-62	-76	-91	-98

Frostbite Times		
30 minutes	10 minutes	5 minutes

Key Points

- The Effective Air Temperature that an animal experiences is a function of both the actual air temperature and wind.
- Wet conditions from rain or melting snow can dramatically increase the Lower Critical Temperature regardless of hair cover because of reduced thermal insulation and from the heat lost from the body as the water evaporates.
- As a rule-of-thumb, for every 1°F that the effective ambient temperature is below the Lower Critical Temperature, the energy requirements increase by one percent.
- Cattle have the ability to acclimate to changing environmental conditions.
- Hypothermia occurs when an animal's body temperature drops below normal.
- There are two approaches that can be taken to mitigate the effects of cold stress on the performance and well-being of cattle; 1) practices that reduce the amount of heat lost to the environment and 2) those that increase the amount of heat produced by the animal.

the environment. Because wind exerts such a large influence on an animal's thermal environment, management adaptations and animal behavior responses tend to address the effects of wind as a way to mitigate the impact of cold stress.

Cattle perform at their optimum level when conditions are in the thermal-neutral zone (TNZ) where animals do not have to expend additional energy to maintain their body temperature (Tarr, 2007). This concept is illustrated in Figure 1. When the Effective Air Temperature is below the Lower Critical Temperature (LCT), the animal experiences cold stress and an increase in the amount of energy required for maintenance. The energy required to drive the increased metabolism must come from either feed intake or body reserves (NRC, 1981; Young, 1983). As ambient temperatures decrease further, a point of maximum heat production (summit metabolism) is reached. At that point continued cold exposure will lead to hypothermia and death of the animal (Young et al., 1989).

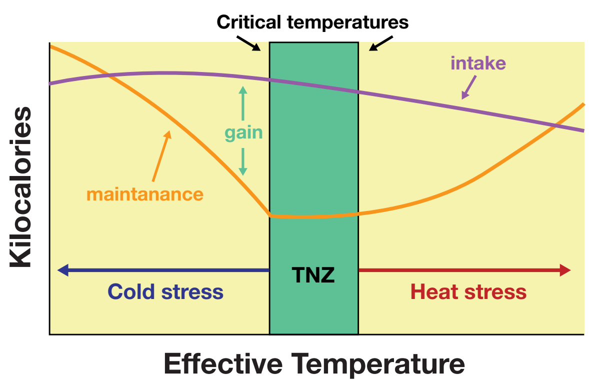

Figure 1: Effect of temperature on beef cattle maintenance, gain, and intake. *Adapted from Taylor, 1984.*

Estimated Lower Critical Temperatures for beef cattle are shown in Table 2 (Ames, 1978). As would be expected, the impact of ambient temperature on an animal is influenced by the amount of insulation provided by hair. Wet conditions from rain or melting snow can dramatically increase the LCT regardless of hair coat because of reduced thermal insulation and from the heat lost from the body as the water evaporates (Ames, 1978; Young et al., 1989). Snow that remains dry and powdery doesn't reduce the insulative value of hair as much as wet snow or rain (NRC, 1981). As a practical matter it is difficult to precisely identify the LCT of cattle because of the interactions from a number of variables and because of physiological and behavioral responses of the animal due to cold conditions (Young et al., 1989).

Table 2: Estimated lower critical temperatures for beef cattle. *Adapted from Ames, 1978.*

Coat Description	Critical Temperature
Summer Coat or Wet	60°F.
Dry Fall Coat	45°F.
Dry Winter Coat	32°F.
Dry Heavy Winter Coat	19°F.

Impact of Cold Stress on Maintenance Requirements

The increase in maintenance energy requirements can be estimated using the difference between the Effective Air Temperature and from the estimated LCT. The values in Table 3 represent the percentage increase in maintenance energy required for each degree that the effective temperature is below the LCT (Ames, 1978; Simms, 2009). The impact of a temperature change is dependent upon the insulation value of the hair cost and the size of the cow. Larger cattle and those with greater insulation from a hair coat are less sensitive to degree of cold stress. The amount of heat that is lost by the animal is proportionate to its surface area. The relationship between surface area and animal mass is not linear; i.e. a 1500 pound cow will not have a surface area that is 50% larger than that of a 1000 pound animal (NRC, 1996).

Table 3: Percentage increase in maintenance energy requirements for cattle per degree below Lower Critical Temperature (LCT). *Simms, 2009*

Coat Description	Cow Weight, lbs.			
	1000	1100	1200	1300
	Percentage Increase per Degree of Coldness			
Summer Coat or Wet	2.0	2.0	1.9	1.9
Fall Coat	1.4	1.3	1.3	1.3
Winter Coat	1.1	1.0	1.0	1.0
Heavy Winter Coat	0.7	0.7	0.7	0.7

As a rule-of-thumb, for every 1°F that the effective ambient temperature is below the LCT, the energy requirements increase by one percent, provided that the cattle have a winter coat. However, this impact is much higher if the period of cold stress occurs before the cattle have had time to adapt, or if accompanied by wet conditions. This can explain why late spring or early fall storms, such as was seen in early October 2013 in Western SD, can have such a devastating effect on animal well-being and survivability (Daly et al., 2013).

For example: 1300 pound cow with a heavy winter coat. Air temperature is 10°F with a wind speed of five miles per hour.

1. From Table 1, the effective air temperature is 1°F.
2. Table 2 would indicate that the LCT is 32°F.
3. The LCT minus the effective air temperature produces a difference of 31 degrees (32 – 1).
4. Using the factors from Table 3, the energy required for maintenance would increase by 21.7% (31 × 0.7 = 21.7).

In this example, the additional energy required would need to come from feed, from energy reserves (body fat) or a combination of the two. The use of body fat to meet metabolic needs would not cause serious concern for a short-term period of cold stress. However, if the energy deficit became a long-term condition, significant negative production impacts could be seen. In particular, spring-calving cows in this situation could enter a downward spiral. As more weight is lost, the insulation value due to body fat is diminished further exacerbating the effect of cold stress. The net result can be cows that calve in an unacceptably low body condition, resulting in negative impacts on calf health, survivability, and poorer reproductive success in the cows (Tarr, 2007).

Metabolic and Behavioral Adaptations to Cold Stress by Cattle

Cattle do have the ability to acclimate to changing environmental conditions and are relatively less sensitive to cold conditions compared to other domestic animals. This cold hardiness is due to their large size, their usually effective thermal insulation, and the amount of heat produced through normal digestion and metabolism. Cattle that are acclimated to the cold not only have a higher metabolic rate, but also a greater capacity to increase their rate of metabolism to prevent hypothermia during periods of severe cold stress. Because of these processes, cattle that are acclimated may survive cold conditions that would cause death in cattle that had not yet become accustomed to a cold environment (NRC, 1981).

As shown in Tables 2 and 3, the amount of hair or insulation that an animal has can affect the impact of cold conditions on the energy required. Research conducted in Canada has shown that increased hair growth is triggered by shorter periods of daylight. Exposure to cold temperatures causes a reduction in the amount of hair that is shed (Webster et al., 1970). Consequently, the animal would have the benefit of greater insulation during periods of extended cold conditions.

Another response to colder conditions is increased feed intake. Intake responses to different temperature ranges are shown in Table 4 (NRC, 1981). Provided that sufficient quantities of feed are available, increased appetite can serve as an effective method for animals to increase the amount of energy supplied by the diet, even if digestibility and passage rate of feedstuffs is reduced (Young, 1983). Cattle fed in unprotected yards showed a greater response in feed intake to colder wind-chill values, compared to cattle had the benefit of shelterbelt protection (Mader et al., 2001).

Table 4: Temperature effects on dry matter intake in cattle. *Adapted from Ames, 1978.*

Temperature, °F	Percentage Increase in Feed Intake
59 to 77°F	No impact due to temperature
41 to 59°F	2 to 5%
23 to 41°F	3 to 8%
5 to 23°F	5 to 10%
< 5°F	8 to 25%

One of the difficulties in managing grazing cattle in cold environments is the interaction between behavior and environment. While an animal's physiological response to cold stress is to increase feed intake, severe cold stress has been shown to reduce the amount of time that cattle spend grazing (Adams et al., 1986). The reduction in activity could be a method to conserve energy as one of the modifications to behavior observed in cattle and other animals is increased huddling or bunching as a way to reduce the exposed surface area and the amount of heat loss (Young et al., 1989). Other research has shown that as cattle become acclimated to cold conditions, they are less sensitive to short-term fluctuations in temperature than they were during the transition from fall to winter (Prescott et al., 1994).

Cattle can make other behavior modifications that mitigate the effects of cold stress. Thermal radiation from sunlight can increase the effective ambient temperature experienced by the animal as much as 5 to 9°F (NRC, 1996). Researchers in Montana observed that cattle would orient themselves to take advantage of sunlight on clear, yet cold days (Keren and Olson, 2006). They also noted that cattle modified their behavior in response to wind; they faced away from strong winds to minimize heat loss, but when wind speeds were low they tended to be oriented perpendicular to the wind direction so that the half of their body on the leeward side was protected. These researchers also noticed that the windbreaks available in this pasture were used by the cattle only twice during the course of the study during daylight, but the wind protection was utilized by the cows nearly every night. By adjusting behavior patterns, these cows used a combination of solar radiation during the day and wind protection and herd behavior at night to increase the effective ambient temperature in their environment.

Acute Cold Stress and Hypothermia

All of the adaptive processes described above are generally sufficient to protect the life of a grown beef animal. However, if the cold stress is severe enough or the animal does not have the ability to increase their metabolic rate quickly enough, death loss can and does occur due to hypothermia.

Even healthy cattle can succumb to hypothermia if conditions are severe enough. The death losses in western South Dakota and surrounding states from the blizzard in October 2013 are a prime example. A combination of freezing rain, snow, and wind chill values of 20°F or less led to the loss of tens of thousands of cattle. On post-mortem evaluation it was not uncommon to observe copious amounts of fluid running from the nose and mouth of dead animals. These observations caused some speculation that these cattle drowned because of breathing in high amounts of water. In reality the failure of the left-side of the heart to overcome increased blood pressure caused by acute cold stress caused blood and fluid to build up in the lungs (Daly et al., 2013). Although that event was a dramatic example of the possibility of death loss caused by hypothermia in adult cattle, in reality newborn calves are far and away the most likely class of the cattle population where death loss from hypothermia will occur (Bellows, 1997).

Hypothermia occurs when an animal's body temperature drops below normal (approximately 100°F for newborn beef calves). There are two classifications of hypothermia: exposure (gradual onset) or immersion (acute). Exposure hypothermia is brought about by steady loss of body heat in a cold environment, where immersion more typically occurs with newborn calves that are saturated with uterine fluid or that were exposed to wet conditions such as deep snow, wet mud, heavy rains, falling into streams, etc. (Torell et al., 1998).

The absolute air temperature, precipitation and other factors such as the level of calving difficulty and age of dam all interact to influence the degree of death loss experienced during calving. Azzam et al., (1993) examined the calving records from over 80,000 births and the climate conditions for each day of the calving season for a twenty year period at the Meat Animal Research Center in Clay Center, NE. They found that precipitation and cold temperatures had a much larger impact on observed death loss in calves born to two-year old cows compared to mature cows. Also, as would be expected precipitation had a much greater impact on calf mortality when conditions were colder compared to more moderate temperatures.

The nutritional status of the cow and the conditions surrounding the birth plays a role in the ability of the newborn calf to with deal with cold stress. Deficiencies of both energy and protein have been shown to interfere with the calf's ability to generate heat, thus increasing its susceptibility to hypothermia (Bellows, 1997). Calves that undergo a difficult birth also have reductions in their ability to generate heat (Vermorel et al., 1989). These reductions in the ability of the calf to regulate its temperature explain at least in part some of the reasons for increased mortality and sickness when the nutritional status of cows is poor or when increased levels of calving difficulty are observed.

Management Practices to Lessen the Impact of Cold Stress

There are two approaches that can be taken to mitigate the effects of cold stress on the performance and well-being of cattle; 1) practices that reduce the amount of heat lost to the environment and 2) those that increase the amount of heat produced by the animal. Reducing the amount of heat losses requires some investment or modifications to the environment of the animal with the benefit of lowering the animal's maintenance energy requirements. Increasing the heat production by the animal often but not always requires additional inputs in the form of feed.

Practices to Reduce Maintenance Requirements

Wind Protection

Providing protection from the wind is one of the most effective methods to reduce the impact of cold stress on cattle. As shown in earlier examples, reducing wind speed from 20 mph to 5 mph or less could reduce maintenance energy requirements by 10 to as much as 30 percent. Research studies in Nebraska with feedlot cattle have shown significant improvements in performance and feed efficiency when wind protection was provided (Mader, 2003). Windbreaks built as a solid barrier in a V-shaped design have been shown to be very effective in blocking wind and also in diverting snow around the sheltered area (Jairell and Schmidt, 1999). Factors that should be considered when planning for windbreaks include:

- Downwind protection ranges from 5 to 10 times the height of the windbreak.
- Windbreaks can range from temporary (portable structures, rows of large bales) to permanent (windbreak fences, shelterbelts).
- Permanent features that provide valuable protection in the winter may cause dead air areas in summer, leading to excessive heat stress in confined livestock. Consider the location of shelterbelts very carefully.
- In areas where there is significant snowfall, make sure that allowances are made for snow deposition. Placing windbreaks too close to buildings, livestock, feed supplies, etc., can result in snow drifting into those areas making access much more difficult.

Additional information on the planning and construction of windbreak structures for livestock can be found in Beef Housing and Equipment Handbook (MWPS, 1987).

Bedding

Providing bedding materials also will reduce the amount of heat lost to the environment and reduce the maintenance energy requirement. Research conducted at South Dakota State University (Birkelo and Lounsbery, 1992) as well as in North Dakota (Anderson et al., 2004) showed that performance and feed efficiency of feedlot cattle were improved by adding bedding. In the North Dakota study, researchers noted that the cattle that were bedded had less mud and manure clinging to the hair and hide. Hair that is dirty and matted down has an insulation value similar to hair that is wet. Bedding can be particularly useful during calving to alleviate cold stress on newborn calves. In that situation care should be taken to make sure that calving pens are kept well bedded and that bio-security practices are followed so that pathogens do not accumulate in the bedding pack and manure.

Increasing the Amount of Heat Produced by the Animal

Feed Intake and Feed Management

As discussed earlier, one of the primary responses of an animal is to increase their feed intake. Increased consumption of feedstuffs would provide additional energy to support the higher maintenance requirement. However, any factors that limit dry matter intake hinder the ability of the animal to meet its energy needs. Feeding protein deficient diets that rely on low-quality roughages, limited access to water, and insufficient bunk space are all conditions that can limit the amount of feed cattle will consume, and therefore their ability to mitigate the effects of cold conditions. During periods of long-term cold stress managers need to be prepared to eliminate as much as possible factors that hinder feed intake and to offer additional feeds as needed.

Conventional wisdom has held that high-roughage diets are better suited for cold conditions because of the amount of heat produced by fermentation (NRC, 1981). However, in feedlot conditions, switching to higher roughage diets under cold stress conditions was ineffective in improving daily gains and in fact, reducing the forage portion of the diet to increase the amount of dietary energy being fed was more effective (Mader et al., 2001). Changing diets in response to weather conditions may do more harm than good because of the increased potential for digestive upsets.

Altering the time of day that feed is offered is another management strategy that has been proposed as a way to deal with cold stress. If the time of feeding was in the late afternoon, peak heat production from fermentation should occur more closely to the time when daily temperatures were at their lowest. In a trial conducted at South Dakota State University, yearling cattle being fed a high concentrate diet gained faster during January when fed in the afternoon compared to the morning (Knutsen et al., 1994). By the end of the feeding period, however, there were no differences in ADG or feed efficiency between AM versus PM feeding. When individual temperatures were recorded by tympanic (ear) recorders, growing steers fed in the afternoon showed higher temperatures over the course of a day than those fed in the morning, but this response did not translate into consistent, significant differences in performance (Holt and Pritchard, 2005). While PM feeding doesn't appear to result in significant performance advantages, there do not appear to be any detrimental effects either and may be worth considering provided that there isn't additional expense incurred or that changing feeding schedules doesn't present logistical challenges.

Body Condition

The amount of body condition carried by an animal deserves additional consideration in a cold stress discussion, particularly for the beef cowherd. The relationship between body condition score and reproduction has been studied extensively. Increased amounts of body tissue, and specifically fat, can serve as an effective form of insulation, limiting the amount of heat that is lost by the animal. Body fat also serves as an important energy reserve to support metabolism and provides a measure of "insurance" in the event that cattle are under cold stress for an extended period of time. This is especially important under conditions where cattle may be unable or unwilling to increase feed intake, such as during severe storms. Part of the management plan for dealing with cold stress should include considerations for making sure that cows are in adequate body condition (Body Condition Score 5 or greater; Scale 1 to 9) before the worst winter weather conditions are expected to occur.

Photo by Warren Rusche

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