

BILL E. KUNKLE INTERDISCIPLINARY BEEF SYMPOSIUM: Animal welfare concerns for cattle exposed to adverse environmental conditions¹

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ABSTRACT: Increasing awareness of animal welfare has become a priority in food production systems involving animals. Under normal working environments, production practices are constantly evaluated to maintain optimum levels of animal well-being. However, during periods of adverse weather, optimum conditions for animal comfort, as well as animal performance, are often compromised. In the Midwest and Great Plains states, the heat waves of 1995, 1999, 2006, 2009, 2010, and 2013 were particularly difficult on animals reared in confinement, with documented cattle losses approaching 5,000 head each year. Additionally, during the summer of 2011, nearly 15,000 head of cattle across 5 states were lost as a result of heat stress. During prolonged periods of heat stress, lower conception rates are observed in livestock. In addition, animals reared in confinement buildings are often compromised because of limitations in ventilation systems. Under the opposite environmental spectrum, the winters of 1992 to 1993, 1996 to 1997, 1997 to 1998, 2006 to 2007, and 2008 to 2009 caused hardship for livestock producers, particularly for those rearing animals in an outdoor environment. During the winters of 1996 to 1997 and 2008 to 2009 up to 50% of

the newborn calves were lost in many areas, with over 75,000 head of cattle lost in the northern plains states. Late fall and early winter snowstorms in 1992, 1997, 2006, and 2013 resulted in the loss of over 25,000 head of cattle each year in the Great Plains region of the United States. Economic losses from reduced performance of cattle experiencing severe environmental stress likely exceed losses associated with livestock death by 5- to 10-fold. Use of alternative supplementation programs may need to be considered for livestock challenged by adverse environmental conditions. Use of additional water for consumption and cooling, shade, and/or alternative management strategies need to be considered to help livestock cope with heat stress. For animals reared outside during the winter, strategies that increase animal space and environmental buffers need to be employed to minimize effects of mud, wet conditions, and wind chill. The above-mentioned weather events suggest that there are ample opportunities for livestock producers to enhance animal welfare and minimize impact of environmental stress. Caretakers need a greater understanding of animal responses to weather challenges to help animals cope with adverse climatic conditions.

Key words: animal welfare, environmental stress, livestock management

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J. Anim. Sci. 2014.92:5319–5324
doi:10.2527/jas2014-7950

INTRODUCTION

Ruminants have the ability to generate a substantial amount of heat through fermentation of feedstuffs. In particular, high-producing animals fed high-energy diets generate large amounts of metabolic heat, which is usually transferred from the body to the environment

using normal physiological processes. Failure to transfer this heat in the summer results in an accumulation of heat within the body and predisposes the animal to heat stress (Gaughan et al., 2010b; Mader et al., 2010b). This can cause animal discomfort or even death in the summer, whereas preservation of body heat results in an opposite effect in the winter. Regardless of season, under extreme environmental conditions, management of livestock discomfort and potential for deaths must be a higher priority than performance losses. Animal discomfort and related heat flux management can be achieved through behavioral changes initiated by the animal, changes to facilities, and/or feed management

¹Based on a presentation at the Bill E. Kunkle Interdisciplinary Beef Symposium at the 2014 Meeting of the Southern Section of ASAS, February 1–4, 2014, Dallas, TX.

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Received April 16, 2014.

Accepted August 16, 2014.

changes initiated by the caretaker (Mader et al., 2006, 2007, 2008).

The primary objective of any environmental mitigation strategy is to aid the animal in the winter to keep body temperature elevated throughout the day and in the summer to reduce peak body temperature during the day and/or help the animal drive body temperature down at night (Fig. 1). Studies reported herein were conducted under harsh environmental conditions, either in laboratory or natural environments, in an effort to better understand animal responses to those conditions and develop mitigation strategies for those conditions.

COLD MITIGATION STRATEGIES

When winter conditions are severe enough, productivity is compromised as a result of increased maintenance energy requirements associated with exposure to cold, wet, and/or windy conditions. For most animals reared in the United States in outside environments, maintenance energy requirements are approximately 20% greater in the winter than in the summer (NRC, 2000). In addition, under winter conditions, if an animal's coat cover is wet and muddy, then energy requirements for maintenance can easily double, particularly if the animal is not protected from the wind.

Bedding and Pen Space

A number of things can be done in the winter to enhance animal comfort. Bedding, such as crop residues or saw dust, can be used to help insulate cattle from the cold ground during severe cold outbreaks. One to two kilograms of bedding per head per day can make a big improvement in productivity. A summary of Colorado and South Dakota data found that gains and feed efficiencies can be improved nearly 7% through the use of bedding (Mader, 2003). Interestingly, more significant responses came during the later vs. early portion of the feeding period. This is likely due to problems heavier cattle often experience with wet, muddy conditions, which accompany late winter and early spring precipitation events. Lighter cattle, once they are on feed, are generally not impacted as much.

Under today's feed costs, the daily feed cost to maintain an animal that is partially wet, under winter conditions, is up to 3 times the cost of the bedding needed to keep the animal dry. Bedding is a relatively cheap alternative, especially if hay, corn, or other feed prices are relatively high when compared with bedding cost. Furthermore, once the animal is dry, bedding usage decreases, whereas if bedding is not utilized, the moisture laden facilities usually remain wet and the animal stays wet. However, the benefits of bedding are diminished

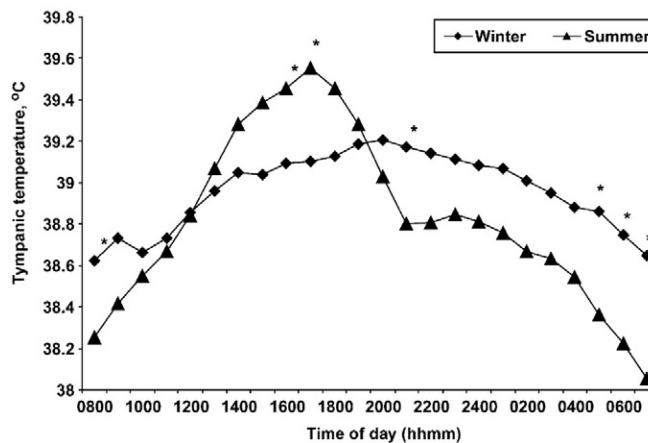


Figure 1. Effects of season on tympanic temperature over a 24-h period in feedlot heifers. Asterisks indicate that means within an hour differ by season ($P < 0.05$; $SE = 0.10$). Each point represents the mean of 12 pens of cattle. Results are from Mader and Kreikemeier (2006).

when ample space is provided for the cattle. In studies conducted in Nebraska, it was found that doubling normal pen space in the winter was as effective as using bedding (Mader and Colgan, 2007). Some cattle operations do not have the luxury of doubling space, nor is there a desire to bed cattle. Nevertheless, at the very least, young animals or animals that are susceptible to getting sick are candidates for bedding. If bedding is used, the bedded areas must be cleaned periodically. In addition, livestock should be provided with as much dry area as possible to allow them to spread out and lay down. The more concentrated the animals are under wet conditions, the less chance there will be for surfaces to dry, which will increase maintenance energy requirements. One of the greatest hindrances to cattle performing in nonsummer months is mud (Mader, 2011).

Windbreaks and Shelters

On average, cattle fed in the winter that have wind protection have slightly better performance than cattle without wind protection (Mader et al., 1997a). In general, cold stress will stimulate intake; however, with less daylight in the winter combined with the cold conditions, cattle may not aggressively go to feeding areas; thus, feed intake is not always increased. Under these conditions, windbreaks have been found to be useful, especially for heavyweight cattle. It is important to design windbreaks to keep snow out of the areas where cattle are held. Wind protection needs to be far enough away to prevent snow from dumping into the area holding the cattle.

New cattle coming into the feedlot and cattle 30 to 45 d from slaughter are most susceptible to cold stress (Mader, 2003). They need shelter and/or bedding to maintain health and stay on feed. It is satisfactory to

change to a higher-roughage diet when a snowstorm is imminent to minimize overeating or acidosis, but this change should not be made too aggressively. A more stable DMI can maintain a more stable rumen environment.

Recently, interest has been shown in solid-floor confinement feedlot units, in which bedding is applied year-round in the pens on a weekly basis (Pastoor et al., 2012). These units can cost 2 to 3 times more than traditional outside feedlot units and have shown promise for controlling the total amount of waste that has to be managed and for greater control of environmental factors. These units appear to have the greatest benefit in areas where surface drainage is poor, soil and winter drying conditions enhance mud buildup, and added waste water generated from normal precipitation constitutes a disposal problem. In today's cattle-feeding environment, it is becoming increasingly important that optimum cattle comfort be maintained not only for optimizing efficiency but also for enhancing consumer perceptions and acceptance. Keeping cattle dry, clean, and comfortable is critical for accomplishing this goal, whether in open lots or in more confined structures.

To enhance animal comfort in feedlot pens and other areas in the winter, the following guidelines can be utilized: 1) Facilities should be designed to properly drain water away from areas where animals normally accumulate. 2) Pushing snow out of pens (preferably after every storm) or at least to the low end of the facilities will minimize the effects of gradual melting and aid in drying out resting areas. 3) Rough (frozen) surfaces that may impede access of feed and water should be smoothed out or knocked down. 4) Space allocation per animal should be doubled (the added space minimizes mud accumulation and allows for greater access to dry areas for animals to lie down). 5) If animals are prone to getting wet, then use bedding and/or structures that provide wind protection while minimizing moisture effects.

SUMMER MITIGATION STRATEGIES

Improved cattle welfare during periods of hot weather depends, in part, on the timely assessment of animal status in regard to heat load. Panting score (PS) has been found to be an easy and effective method for assessing heat related animal discomfort (Mader et al., 2006). The PS system assesses the respiratory dynamics of cattle using a 4-point system (scores of 0, 1, 2, 3, and 4; Mader et al., 2006; Gaughan et al., 2008b). Studies have used PS to assess heat load in feedlot cattle and have shown a direct relationship between environmental thermal load and PS (Mader et al., 2006; Gaughan et al., 2010a). In addition, Brown-Brandl et al. (2006) and Gaughan et al. (2010b) reported that PS was a good visual method for determining differences in thermal tolerance between cattle breeds.

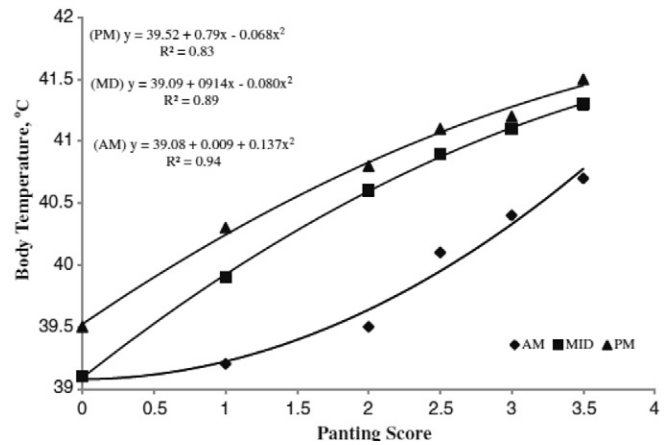


Figure 2. Relationship between body temperature and panting score in the morning (AM), midday (MD), and afternoon (PM). Entire study-unshaded cattle. Results are from Gaughan and Mader (2013).

In addition, Gaughan and Mader (2013) found a strong relationship between PS and body temperature (BT):

$$y = 39.01 + 0.38x \quad (R^2 = 0.68; P < 0.001), \quad [1]$$

where y = BT (in degrees Celsius) and x = PS

A quadratic relationship was found between BT and PS when the time of day was considered: morning (AM), midday (MD), and afternoon (PM). These relationships are presented in the following equations, and the relationship between BT and PS is shown graphically in Fig. 2.

$$\text{AM: } y = 39.08 + 0.009x + 0.137x^2 \quad (R^2 = 0.94; P < 0.001), \quad [2]$$

$$\text{MD: } y = 39.09 + 0.914x - 0.080x^2 \quad (R^2 = 0.89; P < 0.001), \quad [3]$$

$$\text{PM: } y = 39.52 + 0.790x - 0.068x^2 \quad (R^2 = 0.83; P < 0.001). \quad [4]$$

The strong correlation between BT and PS in the current study confirms that PS is a good management tool for the assessment of heat load in cattle. Furthermore, relationships among BT, PS, and respiration rate have been defined further to provide producers with additional information in assessing animal discomfort as a tool in heat stress mitigation management (Mader et al., 2010a; Gaughan and Mader, 2013). Substantial details on the improvement in and development of new environmental stress indices, which are related to various environmental conditions and/or PS, have been published by Eigenberg et al. (2005), Mader et al. (2006, 2010b), and Gaughan et al. (2008b),

Restricted or Managed Feeding Programs

Benefits of using restricted feeding programs under hot conditions have been reported by Mader et al. (2002) and Davis et al. (2003). In addition, Reinhardt and Brandt (1994) found the use of restricted feeding programs to be particularly effective when cattle were fed in the late afternoon or evening vs. morning. Implementing a bunk management regimen, in which bunks are kept empty 4 to 6 h during the daytime hours, is another management strategy that could be used to minimize peak metabolic heat load occurring simultaneously with peak climatic heat load (Mader and Davis, 2004). Even though this forces the cattle to eat in the evening, it does not appear to increase nighttime BT. In restricted feeding studies in which BT was measured, Mader et al. (1999b) housed feedlot steers under thermoneutral or hot environmental conditions. Steers were offered a 6% roughage finishing diet ad libitum (**HE**), were offered the same diet restricted at 85% to 90% of ad libitum DMI levels (**RE**), or were offered a 28% roughage diet ad libitum (**HR**). Steers fed the HR diet (39.7°C) had significantly lower BT under hot conditions than steers fed the HE (40.6°C) and RE (40.3°C) diets, whereas RE-fed steers had significantly lower BT than HE-fed steers. The lower BT of the HR- and RE-fed steers would indicate that ME intake before exposure to excessive heat load influences the ability of cattle to cope with the challenge of hot environments and that lowering ME intake can lower BT (Davis et al., 2003). Arias et al. (2011) reported similar results in that high-concentrate feedlot diets (3.04 Mcal ME/kg) promoted greater BT in the summer, whereas the lower-energy, higher-roughage diets (2.63 Mcal ME/kg) tended to produce lower BT in the winter.

Water Temperature Concerns

Under mob and cell grazing situations, aboveground water lines and small, dark-colored water-holding vessels can significantly increase water temperature and water requirements. An experiment performed at the University of New England (Armidale, NSW, Australia) with Merino wethers found that drinking water temperature can affect water intake (Savage et al., 2008). Analyses of water preference data revealed that in hot conditions, sheep drank considerably more ($P < 0.05$) 30°C water (6,708 g/d) than 20°C water (1,185 g/d). In the cool conditions, water intake was numerically greater ($P < 0.095$) from the 20°C water (4,024 g/d) than from the 30°C water (2,646 g/d). This study indicates that under hot conditions a greater quantity of water is required to cool animals as water temperature increases. Producers need to be sensitive to the effects of water temperature in storage devices and need to ensure that adequate waterer capacity and space are available for animals. Smaller water containers tend to limit water access and availability.

Waterer Space Requirements

Evaporation of moisture from the skin surface (sweating) or respiratory tract (panting) is the primary mechanism used by the animal to lose excess body heat in a hot environment (Gaughan and Mader, 2013). Under these conditions, waterer space availability and water intake per head become very important. During heat episodes, Mader et al. (1997b) found that as much as 3 times the normal waterer space (7.5 vs. 2.5 cm of linear space per animal) may be needed to allow for sufficient room for all animals to access and benefit from available water. In general, water consumption per unit of DMI in the summer is 2 times greater than in the winter.

Sprinkling Systems

In addition to pen design and altering feeding regimen, sprinkling can also be effective in minimizing heat stress. Benefits of sprinkling tend to be enhanced if sprinkling is started in the morning, before cattle getting hot (Davis et al., 2003). These data also show significant benefits to sprinkling or wetting pen surfaces. Sprinkling of pen surfaces may be more beneficial than sprinkling the cattle. Kelly et al. (1950) reported feedlot ground surface temperatures in excess of 65°C by 1400 h in the afternoon in Southern California. Similar surface temperatures can be found in most High Plains feedlots under dry conditions with high solar radiation levels. Cooling the surface would appear to provide a heat sink for cattle to dissipate body heat, thus allowing cattle to better adapt to environmental conditions vs. adapting to being wetted. Wetting or sprinkling can have adverse effects, particularly when the cattle get acclimated to being wet and failed or incomplete sprinkling occurs during subsequent hot days. Elevated relative humidity may also be problematic if large areas of the feedlot are sprinkled vs. isolated areas in pens.

Sprinkling may increase feedlot water usage 2- to 3-fold (Gaughan et al., 2008a). In addition, mud buildup is associated with sprinkling systems. Intermittent sprinkling is recommended and constitutes a 2- to 5-min application every 30 to 45 min or up to 20 min of application every 1 to 1.5 h. Whether cattle that need to be sprinkled (cooled) always go to or get under the sprinklers is unknown.

Use of Shade

Shade has also been found to be beneficial for feedlot cattle exposed to hot climatic conditions (Mader et al., 1999a). In general, the response to shade is greatest at the onset of heat stress even though shade use increases with time cattle are on feed. This indicates that cattle must adapt to shade or social order around and under shade before optimum shade use occurs. Although no

heat-related cattle deaths occurred in this study, these results indicate that shade improves performance in the summer, particularly when cattle are fed in facilities that restrict airflow and for cattle that have not become or have not had the opportunity to become acclimated to hot conditions. Sullivan et al. (2011) found that access to shade improved the welfare and performance of the cattle. However, the provision of a shade area greater than 2.0 m²/animal did not appear to provide any additional production benefits for short-fed cattle. Nevertheless, the PS and behavioral data, especially during heat waves, indicate that the 2.0 m²/animal treatment did not produce the same welfare improvements as the 3.3 and 4.7 m²/animal treatments.

Greater benefits of using shade are found in areas with greater temperature and/or solar radiation (Hahn et al., 2001). Mitlöhner et al. (2001) found excellent results when providing shade for cattle fed near Lubbock, TX. The overall economic benefit of using shade depends not only on location but also on cost of structures and maintenance.

Mitigation Strategy Economic Analysis

The economic effects of imposing various environmental stress mitigation strategies have been determined by Mader (2010a,b, 2012) on the basis of the comprehensive climate index (Mader et al., 2010b) and how the respective mitigation strategy changes apparent, or “feels-like,” temperature. In the summer analysis, moderate sprinkling was utilized vs. heavy sprinkling in an effort to minimize the quantity of excess runoff water. The pen area that was sprinkled was kept to around 2.3 m²/head. In addition to shade and sprinklers, the use of fans (with water injection under shade) was evaluated to determine the benefits of added evaporative cooling potential through the enhanced airflow under shade. From this analysis, the performance effects of sprinkling and shade on apparent temperatures were similar even though different physiological cooling properties are involved in the 2 strategies. Greater amounts of water tend to have a greater benefit than shade, whereas lesser amounts (i.e., misting) tend to have less benefit than shade.

Because of the limited heat tolerance of British crossbred cattle, they tended to have greater cost of gain (COG) than Holsteins under heat stress; an opposite scenario occurs under cold stress, with Holsteins having greater COG (Mader, 2010b). An analysis of Brahman cross cattle displayed a lower benefit and 1-time setup costs (break-even construction cost) compared with comparable costs for other breed types (Mader, 2010b).

In theory, sprinkling should always produce greater heat stress relief than shade or misting because of the high heat loss associated with the evaporation process. However, limited research data in feedlot cattle indicate

that shade provides a greater and more consistent performance response than sprinkling. When cattle are in very close confinement and the probability is great that water will be applied to the animal, then a more positive response to sprinkling or direct water application is found (e.g., dairy units). Well-designed and well-constructed shade and shelters tend to produce greater long-term benefits than sprinklers and/or less stable shade structures.

Heat stress is dependent not only on temperature and solar radiation but also on humidity and wind speed (Livestock Conservation Institute, 1970; National Oceanic and Atmospheric Administration, 1976; Hubbard et al., 1999). Adjustments for solar radiation and wind speed have also been developed and need to be considered when predicting heat stress (Mader et al., 2006; Chichester and Mader, 2012). The effects of environmental stress are dependent on not only the magnitude and duration but also the rate at which environmental conditions change.

SUMMARY AND CONCLUSIONS

Domestic livestock that are traditionally managed outdoors are particularly vulnerable to not only extreme environmental conditions but also rapid changes in these conditions. Management and facility alternatives need to be considered to help these animals cope with adverse conditions. Manipulation of dietary ingredients, energy density, and energy intake may also be beneficial for livestock challenged by environmental conditions. In addition, under hot conditions, high-volume water-holding devices and water availability are of utmost importance. Under cold conditions, maintaining facilities that prevent animals from getting wet is of utmost importance.

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