Cation-anion balance in supplementary feed to mitigate heat stress in grazing beef cattle

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Abstract

Beef cattle are expected to experience severe heat stress as a result of the changing weather patterns on both a global and regional scale. This may negatively affect the food production from cattle. Negative effects of increased ambient temperatures and thus heat stress include lower reproductive rates and lower weaning weights. The effects of heat stress at a metabolic level may include the loss of ions and changes in hormonal excretions. The loss of ions can possibly be addressed through supplementary nutritional strategies. There is, however, a need to research the effect of adding ions into the diets of veld-reared beef cattle and its potential to mitigate the effects of heat stress.

Keywords: Ambient temperature, climate change, ion loss, nutritional strategies
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Introduction

Tropical and subtropical climates have both direct and indirect effects on livestock. It is predicted that climate change will have a more extreme effect on the African continent than other continents (Scholtz *et al*., 2010). Ambient temperature has the most severe effect on livestock production, since most livestock perform at their best at temperatures between 4 and 24 ºC (McDowell, 1972; Hahn, 1999).

Climate change is already affecting food security on a global level. People living in fragile ecosystems (i.e. semi-arid landscapes) are therefore more at risk. Despite current efforts, changes in the climate will continue to occur. Adaptation and mitigation strategies should therefore be developed at local levels (FAO, 2009). Many studies on societal adaptation to climate change (i.e. global warming) have been reported. In searching for strategies to cope with global warming, one must preferably first investigate the possibilities to utilise existing strategies, rather than developing yet to be identified unique and untested strategies (FAO, 2009).

Nutrition stress has the largest indirect effect on the grazing animal in the tropic and subtropical environments (Linington, 1990). However, the fact that higher temperatures also cause loss of certain mineral metabolites (anions and cations) in the animal is often ignored. This causes loss of appetite, lower feed intake and reduced production (milk, muscle growth, wool). By changing the mineral content in supplementary feeding for grazing livestock, this can be mitigated and loss of production minimized. This can be done by changing the anion-cation balance in the supplement in accordance with the expected temperature. If the intake of mineral metabolites can be manipulated to balance the losses caused by heat stress, it can lead to a balanced level of anions and cations; this in turn may assist the animal to cope with high temperatures.

Balancing the electrolyte levels (cation and anion) in the animal through supplementary feeding to mitigate heat stress in grazing beef cattle has the potential to make a meaningful contribution to maintain or improve current production levels. It is trusted that this overview will create a better understanding of how nutritional strategies can be used to mitigate heat stress and pave the way for further research on the concept of using electrolytes to mitigate heat stress in grazing beef cattle.

Discussion

Animals under heat stress show a decrease in their production potential with negative economic consequences (Bernabucci *et al*., 2010). With the expected increase in global temperatures, more areas will become arid and weather conditions will become increasingly erratic. The predicted increases in aridity and erratic weather will therefore result in longer periods during which livestock can experience heat stress.

Heat stress in livestock can be defined as a physiological condition in which the core body temperature is higher than the normal activity range. Core body temperature is the result of total heat load (internal heat production and environmental heat) minus the ability of the animal to dissipate heat from the body. If the heat load is above the animal's heat dissipation capability, the animal will respond to it through behavioural and physiological changes (Bernabucci *et al*., 2010). Heat stress can occur in dairy cattle when temperatures are above 25 ºC when combined with high humidity, low air flow and direct sun light (Hahn, 1999). In beef cattle the threshold temperature above which dry matter intake is adversely affected, is 30 ºC with a relative humidity of below 80%. If the relative humidity is above 80% the threshold temperature for beef cattle drops to 27 ºC (Hahn, 1999) (Figure 1).

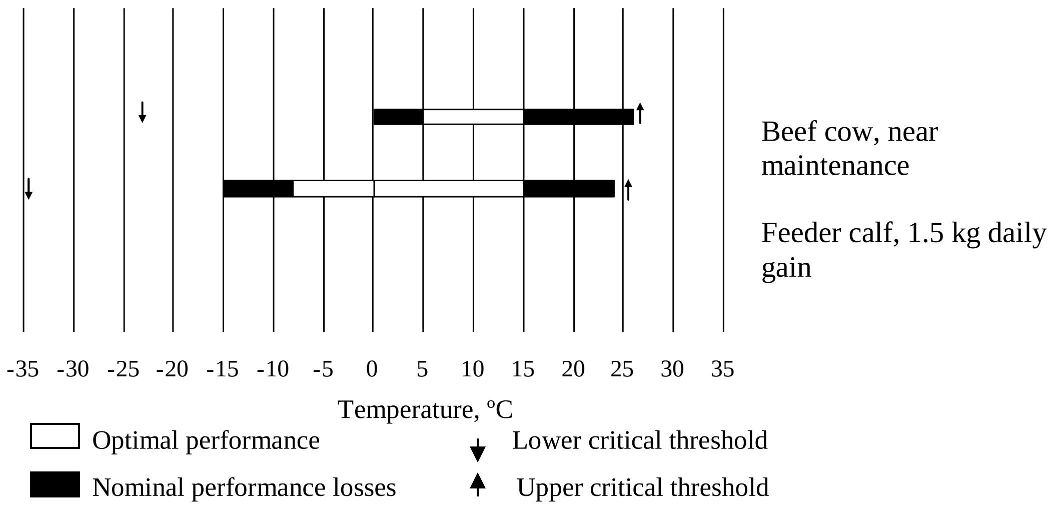

Figure 1 Critical ambient temperatures and zones for optimal performance and nominal performance losses in beef cows and feeder calves (adapted from Hahn, 1999).

The immediate reaction to increased heat load is increased respiration rates, decreased feed intake and increased water intake (Bonsma, 1983). Further consequences of this scenario include increased blood flow to the skin surface, reduced metabolic rate and altered water metabolism (West, 1990). Heat stress also reduces reproductive abilities in both sexes and the effect on summer fertility may result in a 20% to 27% drop in the conception rates.

The effect of heat stress on production can be severe as a result of reduced feed intake in cattle (Bernabucci *et al*., 2010), and hormonal changes that occur in response to heat stress can play an integral role in reducing productivity (West, 1999). Although cattle can adapt to environmental challenges to minimize adverse effects, feed intake drops at temperatures above 25 ºC (Hahn, 1999). Beef cattle are vulnerable to extreme environmental conditions and to rapid changes thereon (Bernabucci *et al*., 2010) and fat cattle with a lot of hair and dark coat are very sensitive to heat (Gaughan *et al*., 2009).

The effects of heat stress are greater in cattle than in other ruminants due to their higher metabolic rate, and poorly developed water retention in the kidney and gut. As water intake increases to cope with heat stress, more water is expelled through sweating and panting, which can disturb the body's water content and mineral concentrations (Bernabucci *et al*., 2010). Reduced feed intake further ads to the problem, as energy intake drops and energy expenditure increases to achieve euthermia. This will cause the animal to go into a negative energy balance state and will reduce the intake of minerals. The uptake of nutrients in heat-stressed animals is further diminished by the reduced ability of the rumen to absorb nutrients as more blood flows to the skin for cooling purposes (West, 1999; Bernabucci *et al*., 2010). This can affect rumen health as less feed is consumed, and, as a result, less saliva enters the rumen. This, combined with low levels of HCO_3 (carbonate) in the saliva, can make cattle more susceptible to rumen acidosis (Kadzere *et al*., 2002).

Management approaches may reduce the effects of increased temperature on livestock, and includes mechanical cooling such as forced ventilation, water sprayers and shading (Berman *et al*., 1985). However, these are difficult to apply to free grazing cattle and offer limited relief on a short term basis.

Furthermore, nutrition also has an important role to play in the mitigation of heat stress. The feed intake of cattle that experience heat stress will drop in order to lower metabolic heat load. Cattle will therefore require alternative supplements, especially minerals such as potassium and sodium, to counteract losses in cation (K^+ through sweating), anion (Cl^- through respiration). and gasses (CO_2 through lungs), and reduced buffering in the rumen (less saliva into rumen) caused by less bicarbonate in the rumen. Energy provision with sources such as maize to counteract the lower intake may exacerbate the problem due to increased heat load by the digestion of the energy source. Furthermore, levels of ammonia in the rumen will be higher due to reduced carbonate levels during periods of heat stress. This makes it important that levels of rumen-degradable protein and soluble nitrogen sources are limited in cattle feeds during heat stress periods. Feeding more by-pass protein during hot climatic conditions can result in higher production (West, 1999).

During periods of heat stress, feed intake declines and with the demand of milk production on lactating cows, an increased dietary mineral concentration is required (West, 1999). Potassium (K) is the primary cation occurring in bovine sweat and its concentration in sweat increases during hot climatic conditions (Jenkinson & Mabon, 1973). During hot temperatures the absorption of macro minerals, including Calcium (Ca) Phosphate (P) and Potassium (K), declines (Kume *et al*., 1989). Dietary cation-anion differences can alter dry matter intake of beefs cows on rangelands (Hersom *et al*., 2010). Ross *et al*. (1994) reported that finishing steers maximized gain and intake when fed diets that had a positive dietary electrolyte balance (15 mEq.100 g of DM). Positive results on the production of dairy cows in hot weather have been reported where potassium or sodium bicarbonate have been used as additives to increase the cation levels in rations (Bernabucci *et al*., 2010).

Dietary electrolyte balance has the capacity to alter the intake of beef cows and can improve feedlot performance. Although this principle is well established in the dairy industry, data on beef cattle production systems are limited (Luna-Nevarez *et al*., 2010) with no nutritional strategies to mitigate heat stress conditions. There are some studies on electrolyte balance (Ross *et al*., 1994; Hersom *et al*., 2010) in beef cows/feedlot cattle, but without the effect of climatic conditions. Most work on cation-anion levels were done in metabolic chambers (Salles *et al*., 2010) and/or for short periods of time with short adaptation periods. Where measurements were taken over longer periods, constant levels of cation-anion were provided (Ross *et al*., 1994; Hersom *et al*., 2010) without consideration of climatic conditions. There is a need to adapt the supplementary feeding management of beef cattle in temperatures above thermal comfort limits so that performance losses are reduced (Salles *et al*., 2010).

Conclusion

Global warming is expected to increase the inland temperatures of southern Africa and many other developing countries in the southern hemisphere. It is therefore essential that management, breeding and feeding strategies are adapted or developed, to position the beef industry for the challenges posed by climate change. There are indigenous and tropical adapted cattle genotypes available that are more adapted to higher temperatures, and it is also possible to breed cattle to be heat tolerant. Although breeding has a permanent and cumulative effect on beef producing cattle, it is a long term process. Adaptive supplementation, whereby beef cattle are fed according the expected weekly weather prognosis during summer periods, can be an immediate and complementary solution. As most beef cattle are kept on rangelands, the feeding will have to be through licks or supplements that may vary in energy source (carbohydrates vs. fats), protein source (rumen degradable vs. rumen undegradable protein) and minerals (cation-anion levels). Research on these aspects will assist in ensuring that the beef cattle industry continues to produce at current levels in spite of global warming. It is postulated that nutritional strategies (adaptive cation-anion balance) for maintaining production in ruminants affected by increased environmental temperatures (heat stress) due to climate change, can play a significant role to mitigate the effect of higher temperatures.

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