MITIGATION OF HEAT STRESS IN BEEF CATTLE THROUGH SUPPLEMENTARY FEEDING STRATEGIES: A REVIEW

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INTRODUCTION

Tropical and subtropical climates have both direct and indirect effects on livestock. Furthermore, it is predicted that climate change will have a more extreme effect on the African continent than on any other continent (Scholtz, et al. 2010). Ambient temperature is the factor that has the largest direct effect on livestock production. Most livestock performs at their best at temperatures between 4 and 24°C (McDowall, 1972). In the tropics and subtropics temperatures frequently rise above this comfort zone and it is therefore important that livestock are adapted to these higher temperatures (Linington, 1990). Climate change will exuberate this situation. High temperatures and solar radiation decreases intake in order to reduce digestive heat production, and reduce grazing time (animals do not graze in hot midday hours), whereas sweating and water intake increases.

Nutrition stress has the largest indirect effect on the grazing animal in the tropics and subtropics. In these environments, natural pasture has both lower nutritional value and lower tiller density than in temperate regions (Linington, 1990). However, the fact that higher temperatures also causes a loss of certain mineral metabolites (losing of an-, cat-ions) in the animal is often ignored. This causes loss of appetite, lower feed intake during the day and reduced production (milk, muscle growth, wool). By changing of mineral content in supplement feeding to grazing livestock this can be mitigated and loss of production minimized. This can be done by changing the anion / cation balance of the supplement. 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 which in turn may assist the animal to cope with high temperatures.

DISCUSSION

Climate Change

Climate change is already affecting food security (food availability, food accessibility, food utilization and food systems stability) on a global level (FAO, 2009). People living in fragile ecosystems (i.e. semi-arid landscapes) are most at risk. Despite current efforts, changes in the climate will continue to occur (Environmental

Agency, 2009). Adaptation and mitigation strategies should be done on at local and specific levels (FAO, 2009). The uncertainties related to climate change impacts and vulnerabilities are considered as an impediment for action (FAO, 2009). The UK has in place a Climate Change Act (2008) that provides a legal framework for addressing climate risks and promoting adaptation (Environment Agency, 2009).

Increases in global temperatures over the last century were stated as 0.74º (FAO, 2009) and 0.8ºC (Environment Agency, 2009) with an expected rise of 3ºC in this century. The rise in average global temperature for this current century might be adjusted upwards (Environment Agency, 2009, FAO, 2009). It is predicted that in South Africa the interior will warm around 2 to 3 degrees Celsius by 2050 and thereafter to between 6 and 7 degrees Celsius (Department of Environmental Affairs, 2010). Many studies on societal adaptation to climate change (i.e. global warming, FAO 2009) have been reported. Those searching for coping strategies to endure global warming must preferably first investigate the possibilities to utilise existing strategies, rather than to developing yet to be identified unique and untested ones (FAO, 2009). The Department of Environmental Affairs (2010) stated in its green paper that there are indications that intensive livestock production systems are vulnerable to increasing demands and costs associated with thermal stress reduction, water use and pressure to contain greenhouse gas emissions. The green paper also stated that encroachment of scrubs into grassland will lead to disruption of existing productive activities such as cattle farming.

Heat stress

Livestock in tropical and sub-tropical areas are under heat stress during certain periods of the year (Salles et al., 2010). Animals that are under heat stress show a decrease in their productivity potential with devastating economic consequences to global animal agriculture (Bernabucci et al., 2010). With the accepted increase in global temperatures and higher increases in certain areas, as mentioned before, more areas will become arid with increasingly erratic weather conditions (Department of Environmental affairs, 2010). This will result in longer periods where livestock will experience heat stress.

Heat stress in livestock can be defined as a physiological condition in which the core body temperature is higher than its normal activity range. Core body temperature is the result of total heat load (internal heat production and environmental heat) minus the ability to dissipate heat from the body. If the heat load is above its heat dissipation capability, the animal will respond to it through behavioural and physiological changes (Bernabucci et al., 2010). Heat stress can occur when temperatures are above 25ºC for dairy cattle, when combined with high humidity, low air flow and direct sun light (Berman et al., 1985; Hahn, 1999). In beef cattle the threshold temperature above which dry matter intake is adversely affected, is 30ºC with a relative humidity of below 80%, if relative humidity is above 80% the threshold temperature drops to 27ºC (Hahn, 1999, Figure 1). In cattle complete adaptations to constant temperatures are not attained within 9 weeks of exposure, however it is not certain if the data from respiratory chambers are applicable to the outdoors (Berman et al., 1985).

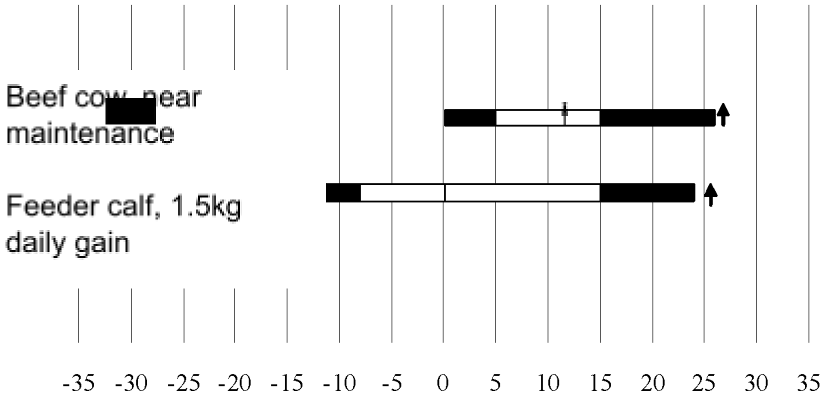

Figure 1 Critical ambient temperatures and zones for optimal performance and nominal performance losses in beef cows and feeder calves (adapted from Hahn, 1999).

Models and indices have been created to assess environmental stress in animals and have been found useful for characterizing the effect of environmental conditions on livestock productivity (Mader et al., 2010). Mader et al. (2010) developed an index which in their view can be used as a guideline in managing livestock. Heat tolerant breeds are in short supply and there is thus a need to identify such breeds, as well as heat tolerant cattle within breeds (Gaughan et al., 2010). The heat load index and panting score can help in assessing cattle under field conditions (Gaughan et al., 2010).

The immediate reaction to increased heat load is increased respiration rates, decreased feed intake and increased water intake (Bonsma, 1983; Silva, 2000). Further consequences are increased blood flow to the skin surface, reduced metabolic rate and altered water metabolism (West, 1990). The increase in heat stress also reduces reproductive abilities in both genders (Gwazdauskas, F.C., 1985; Bernabucci et al., 2010). The effect of heat stress on summer fertility may result in a 20 to 27% drop in conception rates (Lucy, 2002 and Chebel et al., 2004, as quoted by Bernabucci et al., 2010). Furthermore, heat stress may lead to impaired embryo developments and even embryo deaths. Sperm quality was also negatively affected by elevated ambient temperatures, i.e. reduced motility %, reduced sperm output and increased % of abnormal sperm and aged sperm (Meyerhoeffer et al., 1985).

The effect of heat stress on production can be severe and is generally thought to be a response to the reduced feed intake by the effected cattle. This seems not to be the case according to Bernabucci et al. (2010) who reported that reduction in feed intake only accounted for 35% of the reduction in milk production in mid-lactation cows. Hormonal changes that occur in response to heat stress can play an integral role in the decline in productivity (West, 1999). Beef cattle can particularly be vulnerable to extreme environmental conditions and to rapid changes therein (Bernabucci et al., 2010). Fat cattle with a lot of hair and dark coat are very sensitive to heat (Gaughan et al., 2009). Cattle can, within limits, adapt to environmental challenges to minimize adverse consequences (Hahn, 1999). However, at temperatures above 25ºC feed intake drops (Hahn, 1999).

In the USA beef cattle numbers decreased while quantity of beef produced increased since late 1970's (Hughes, 2001) suggesting increase in cow size and carcass weights (Luna-Nevarez et al., 2010). This is however detrimental to cow productivity (Arange & Van Vleck 2002; Calegare et al., 2009; Luna-Nevarez et al., 2010) of cows in arid rangeland production systems. Cows which were producing more milk for their calves also have higher feed requirements (Calegare et al., 2009) but if the available feed and intake is restricted in certain environments (arid areas and heat stress) cattle with a lower body weight and heat tolerant breeds seem to be more productive than pure *Bos taurus* breeds (Kattnig et al., 1993; Calegare et al., 2009; Luna-Nevarez et al., 2010). Beef cattle raised for slaughter during the hot season (average temperature of 34.3ºC) produced lower quality meat than cattle raised during the cool season (Kadim et al., 2004).

The effects of heat stress are higher in cattle than in other ruminants due to their higher metabolic rate, and poorly developed water retention in the kidney and gut (Bernabucci et al, 2010). As water intake increases, as a coping mechanism to heat stress, and more water is expelled through sweating and panting, the body's water content and mineral concentrations can be disturbed (Bernabucci et al., 2010). The reduced feed intake further compounds 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 and reduced intake of minerals. The uptake of nutrients in heat stressed animals is diminished by reduced ability of the rumen to pick up nutrients as blood flows more to the skin for cooling purposes (West, 1999; Bernabucci et al., 2010). This can affect rumen health as less feed is consumed, less saliva enters the rumen, volatile fatty acids (VFA) build up due to low uptake (decrease in ruminal pH), combined with low levels of HCO_3^- in saliva, making cattle more susceptible to rumen acidosis (Kadzere et al., 2002). However Salles et al. (2010) found no difference in VFA concentrations between temperature treatments. In other work reported by Salles et al. (2010) there was even a reduction in VFA's in cattle subjected to heat stress.

In periods of heat stress when feed intake declines and demands of lactation increases, 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 Calsium (Ca) Phosphate (P) and K, declines (Kume at al., 1989). Dietary cation-anion difference can alter dry matter intake of beefs cows on rangelands (Hersom et al., 2010). Ross et al. (1994) reported that finishing steers maximized their gain and intake when fed diets that had a positive dietary electrolyte balance (15 mEq.100 g of DM). In the work of Ross at al. (1994) no consideration to temperature was taken into account and may explain why no differences on day 84 in plasma parameters were found. Positive results on production in cattle (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 (Escobosa et al., 1984; Schneider et al., 1986; Bernabucci et al., 2010).

Mitigation strategies

Management approaches may reduce the effects of hot climate, and may include mechanical cooling such as forced ventilation (Berman et al., 1985) water sprayers and shading. However these are difficult to apply to free grazing cattle and offer limited relief on a short term basis. With increasing cost of energy, these methods might become un-economical. Where temperatures rise above the upper critical threshold (Figure 1) may occur more frequently, which will probably happen as a result of climate change, the need for long term viable alternatives like breeding and changing the nutritional approaches may become more pressing.

This review will only focus on nutrition strategies, and the role of breeding will not be discussed.

Nutrition has an important role to play in the mitigation of heat stress effects. Cattle that experience heat stress will reduce intake in order to lower metabolic heat load. As a result of 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, but more in the blood and mobilized in kidneys to counteract CO_2 losses, cattle will require more concentrated feed, especially minerals such as potassium and sodium. However, energy provision, as a result of lower intakes, with sources such as maize may exacerbate the problem due to increased heat load by digestion of the energy source. The replacement of rapid fermentable carbohydrates with saturated fatty acid reduced rectal temperatures and increased milk yield for mid lactation dairy cows (Wang et al., 2010). The higher ammonia levels in the rumen due to reduced carbohydrate levels during periods of heat stress makes it important that levels of rumen degradable protein and soluble nitrogen sources are limited in cattle feeding. Feeding more by-pass protein during hot climatic conditions can result in higher production (West, 1999).

Dietary electrolyte balance has the capacity to alter 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 (Kattnig et al., 1993). There is some discussion on electrolyte balance (Ross et al., 1994; Hersom et al., 2010) in beef cow's/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 long periods of measurements were taken, 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 change feed management of cattle in temperatures above thermal comfort limits so that performance losses are reduced (Salles et al., 2010).

CONCLUSION

With the climatic changes and more erratic temperatures and expected increase of inland temperatures in the period up to the year 2050 in South Africa, it will become necessary that through management, breeding and nutrition, the beef industry is prepared for the challenges poses by climate change,. South Africa has indigenous breeds that are to some extent tolerant to our environmental conditions and have an edge over *Bos taurus* types and through selection can become more competitive in a changing climate. However this takes time, and immediate solution can be through adaptive nutrition, whereby beef cattle are fed according an expected weekly weather prognosis during summer periods. As most beef is kept on rangelands, the feeding will have to be through licks or supplements that may vary in energy (carbohydrates *vs.* fats) source, protein (rumen degradable *vs.* by-pass protein) source and minerals (cation-anion levels). Research on these aspects will assist in ensuring that the beef industry continues to produce at current levels into the future and become more efficient and do its part for national food security.

It is concluded 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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