The importance of Water efficient and adaptable Beef Cattle

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Introduction

Over the past 7 years the United States has had 5 to 80% of its land mass affected by drought (NOAA, 2015). Moderate drought (D1) is when some damage has occurred to crops and pastures and where streams, reservoirs, or wells are low. Severe drought (D2) is when there is a high probability for crop and pasture losses and water shortages are common. Extreme drought (D3) is when there are major crop and pasture losses and widespread water shortages.

The drought observed in the United States throughout 2012 was one of the worst since the 1050's. In 2012, 80% of agricultural land was affected by the drought (USDA, 2012). In the 21st century, food and water security will be a priority for mankind (Nardone et al., 2010). The world is experiencing a change in global climate which will effect local climate as well as impact local and global agriculture (Nardone et al., 2010). Indirect effects of global warming that may impair animal production more than direct effects include soil infertility, water scarcity, grain yield and quality, and diffusion of pathogens (Nardone et al., 2010). Global warming is predicted to cause a 25% loss in animal production within developing countries and may be more severe in Africa and some zones in Asia (Nardone et al., 2010). High environmental temperatures may lead to a decrease in reproductive efficiency in both males and females which would have a negative impact on milk, meat and egg production (Nardone et al., 2010). It is estimated that the total economic loss in the United States due to farm animals suffering heat stress is between 1.69 and 2.36 billion dollars (St-Pierre et al., 2003). Of those losses 58% occurred in the dairy industry, 20% in the beef industry, 15% in the pork industry, and 7% in the poultry industry (St-Pierre et al., 2003).

Beef cattle are particularly susceptible to extreme climate conditions as well as extreme changes in the weather (Nardone et al. 2010). Fat cattle are especially susceptible because of their increased body condition. Two other factors that can decrease heat tolerance are extra fur cover and darker colored hair. Performance in cattle doesn't seem to be affected when temperatures range from 18-29°C, but when temperature reach above 30°C there is reported to be a daily drop in dry mater intake, average daily gain, carcass weight, lower fat thickness, and an increase in disease incidences (Nardone et al., 2010). Kadim et al. (2004) reported that during the hot season there is a decrease in carcass quality. Kadim et al. (2004) also reported higher pH level, lower Warner-Bratzler shear force measurements and darker colored meat than carcasses collected during the cool season.

With global warming, water will become the weak point in all livestock systems. Not only is water becoming more salinized, but water may also contain chemical contamination from either organic or inorganic material, as well as have high concentrations of heavy metal and biological contaminants (Nardone et al. 2010). Animals that are in hot environments are expected to drink 2-3 times more than animals in cooler climates (Nardone et al. 2010). These animals run a higher risk of exposure to contaminated water and diseases. All the effects of global warming on water availability could force the livestock sector to establish a new priority in production animal products that require less water (Nardone et al. 2010).

Water:

Growing concerns on the availability of clean drinking water have pushed to determine the amount of water that is used by livestock. Freshwater is approximately 2.5% of all water resource and off the freshwater almost 70% is unusable made up to glaciers and permeant ice (Thornton et al., 2009). Agriculture is the largest user of freshwater using almost 70% (Thornton et al., 2009). A problem with freshwater availability is that it is unevenly distributed globally. Water scarcity is a global issue causing problems with food production, human health, and economic development and effecting 1-2 billion people worldwide (MA, 2005). It is predicted that in 2025 64% of the world population will live in a water deprived basin compared to the 38% in 2009 (Rosegrant el al., 2002). Very little research has been conducted to quantify how much water individual cattle drink daily. What little work has been done has been based on pen averages or intakes recorded on individual housed individually in pens. Water intakes based on pen averages give a rough estimate on how much water each animal consumes, but doesn't account for variation among animals. It is crucial to be able to quantify the variability in individual intake to be able to make selection decision to improve water efficiency or to decrease the amount of water required for cattle to still perform.

Approximately 760 billion liters of water is consumed by beef cattle per year (Beckett and Oltjen, 1993). However, environmental and weather factors could have a drastic effect on this number. Heat stress has been shown to have a negative effect on performance in feedlots during the summer session (Arias and Mader, 2011). Cattle experiencing heat stress and are limited on water availability tend to have their normal heat exchange impeded (Arias and Mader, 2011). Daily water requirements in beef cattle are influenced by environmental factors, diet, breed, and body weight. How these factors interact together make it challenging to determine the daily water requirement for beef cattle. These factors combined with difference in genetic backgrounds causes there to be in daily water intake for beef cattle. Arias and Mader (2011) reported that cattle finished during the summer season drink 87.3% more water than cattle finished during the winter season. During the summer season cattle are trying to reduce heat load and this would account for the increase in daily water intake that is seen (Beede and Collier, 1986). Primary way cattle reduce heat load is through evaporative cooling (Morrison, 1983) but this puts higher demands for water consumption to maintain body homeostasis. Hicks et al. (1988) reported averaged daily water intakes during the summer months of 35.9 liters per day and 37.1 liters per day for cattle managed under 3 different salt diets and when housed in confinement, respectively. Parker et al. (2000) collected intakes on 50,000 head of feedlot steers located in the high plains of Texas and the daily water intake was reported to be 35.6 liter per day. Difference in daily water intake reported by these different studies indicates that temperature plays an important role in the daily water requirements for beef cattle. The previous studies only looked at the effect that temperature plays on daily water intake. Previous studies have shown that solar radiation and relative humidity along with temperature influence cattle performance and wellbeing (NRC, 198; Sakaguchi and GaugHan, 2004).

Environmental factors are not the only thing that effects daily water requirements. Daily water intake is also effected by dry matter intake and body weight. As animals grow and become large their daily water requirements increase. In general, larger animals need and drink more water than smaller animals. During the winter season cattle tend to have an increase in dry mater intake and a decrease in daily water intake (Arias and Mader, 2011). However, the opposite tends to happen during the summer season where cattle tend to have a decrease in dry matter intake consumption and an increase in daily water intake (Arias and Mader, 2011). Hicks et al. (1988) and NRC (1981) found a positive relationship between dry matter intake and daily water intake.

Heat stress:

Heat stress has become a major concern in the welfare of animals. Welfare of an animal is its state in regard to its ability to cope with the environment (Broom, 1986). Heat stress is a major problem that hinders livestock production in the tropical belt and arid areas (Silanikove, 2000). Heat stress effects growth, milk production and reproductive performance because of drastic changes in biological functions (Habeeb et al., 1992).

Mammals maintain a relatively constant body temperature level because of the balance between heat production and heat loss. Heat production can be created by exercising, shivering, imperceptible tensing of muscles, chemical increase in metabolic rate, heat increment and disease (such as fever; Silanikove, 2000). Factors decreasing heat loss are an internal shift in blood distribution, decrease in tissue conductance and counter-current heat exchange (Silanikove, 2000). Factors that increase heat loss from an animal are sweating, panting, a cooler environment, increase skin circulation (vasodilation), shorter hair, increased sensible water loss, increase radiating surface area? and increased air movement or convection. (Silanikove, 2000).

Animals can lose heat through conduction, convection, radiation, evaporation of water, and through expired air. As ambient temperature rises, non-evaporative measures of heat loss decline and the animal becomes more dependent upon peripheral vasodilation and water evaporation to increase heat loss and keep body temperature from rising (Berman et al., 1985). Water is an important medium in ridding body heat from animals through sweating and respiration as ambient temperature rises (Silanikove, 2000). Cattle can lose up to 15% of their heat load from their body core through respiration (Silanikove, 2000).

The texture and color of an object will affect the amount of heat that is absorbed by direct solar radiate heat. Dark colored surfaces absorbs more heat than light colors surfaces at the same temperature (Silanikove, 2000). Animals with black coat color have an absorbance of 1 direct radiation, white colored animals have an absorbance of 0.33 and red colored animals have an absorbance of 0.65 (Silanikove, 2000). Radiant heat can be transferred in both directions and always moves from warmer surfaces to cooler surfaces. It has been shown that providing shade for cattle and sheep is beneficial to improve thermoregulatory and productive responses (Legates el al., 1991).

Hot climate reduces the chance for non-evaporative heat loss and thus the animals have to rely on the evaporation of water to get rid of excess heat (Silanikove, 2000). However, when humidity rises, evaporative cooling effects decline because humidity reduces respiratory and surface evaporation, which results in rising rectal temperature and a reduction in feed intake and milk production (Silanikove, 2000). Animals can also be cooled by convection. Convection cooling occurs when cool air meets a warmer body. The layer of air that surrounds the body is warmed as it absorbs heat and rises away from the body. When cattle are in the optimal thermoneutral l conditions, the physiological efforts of thermoregulation are minimal, so the animal's health is optimum and growth rate and milk yield are maximized (Bianca, 1968).

Adaptability:

Water scarcity:

Adaptability to water scarcity has been seen by ruminants that live in arid lands. These ruminants can graze far away from water sites and withstand prolonged periods of water deprivation (Mirkena et al., 2010). When livestock require small amounts of water and don't have to get a drink every day, can graze far away from watering sites accessing more pasture during times of drought. Camels are one examples of a ruminant that can go long periods of time without taking a drink of water. Schmidt-Nielsen (1955) reported that camels can go 17 days without drinking when consuming dry feed during the summer or 30 to 60 days when grazing green vegetation. Camels are not the only ruminants that can go long periods of time without drinking. Other ruminants are donkey, goat, sheep, and some breed of cattle can go several days before they have to get a drink of water (Bayer and Feldmann, 2003). Ruminants that can go several days without water, drink large amounts of water quickly and still end up drinking less total water than animals that consume water daily (Mirkena et al., 2010). Livestock that reduce water intake tend to also reduce feed intake and have a slower metabolic rate allowing livestock to survive longer during a drought needing less feed and water resources (Mirkena et al., 2010). Desert goats, like black Bedouin and Barmer goats, can often go up to 4 days between drinking events (Khan et al, 1979). Small black Moroccan goats that are well adapt to water scarcity have developed that ability to have a low water turnover to maximize use of available water (Hossaini-Hilali et al., 1993). Desert goats have been able to adapt to water scarcity by developing mechanisms to withstand dehydration and minimize loss of water through urine and feces (Mirkena et al., 2010).

Genomic selection:

Adoption of genomic selection in beef cattle has had a slower uptake then in other livestock species. Genomic selection has the potential to substantially improve the genetic gain in beef cattle because reproduction, carcass traits, carcass quality, feed efficiency, and adaptability are traits that contribute to profitability (Hayes et al., 2013). The issue is that accuracies reported for these traits so far have been low to moderate at best (Pimental and Konig, 2012). The lower accuracies are due to smaller reference populations compared to the dairy industry and several different beef breeds are of importance including two different subspecies (*Bos taurus* and *Bos indicus)* (Hayes et al., 2013). With beef cattle having several different breeds of importance it makes it difficult to assemble large enough reference populations to reach desired accuracy levels. One way around this could be to pool different breeds together to make larger reference populations. The problem with pooling different breeds together is genetic prediction across breeds has been very unsuccessful up to this point (Hayes et al., 2013). Difference between linkage disequilibrium phases between single nucleotide polymorphisms (SNPs) and the causative markers across breeds could be causing the challenge of across breed genomic predictions. Not only do the above issue poses issues developing genomic selection for adaptability but also adaptability is challenging to define and measure. Adaptability data is also time consuming and costly to measure which makes it hard to develop large training populations.

Conclusion:

Water is an essential and an economically important nutrient. It is not only an important nutrient for life, but it also is an important limiting resource in the environment. Changes in the environment such as do to global warming and the amount of high-quality drinkable water that is available to be utilize will affect animal production. When ruminants encounter water restriction, it decreases their dry matter intake which in turn decreases their productivity. As more and more of the global population starts living in freshwater deprived areas, it is important that they have cattle that can survive in these areas. Most of these water scarce areas are located in developing countries that rely primarily on livestock to make a living. The ability of these producers to be successful relies on the ability for livestock to adapt to the harsher environment and become more water efficient. To start making beef cattle more water efficient, there first needs to be an understanding of how much water our current beef populations are consuming and how much individual variation there is in our populations. From there, individuals can be selected that require less water while still maintain high productivity. As the use of genomics continues to improve they can play an important role in improving water efficiency of beef populations. With an expected increase in global population, there is going to be an increase demand for meat production. Increase in production is going increase water usage on human consumption side and in meat production.

Water scarcity can further be enhanced when areas encounter drought conditions. Drought conditions that occur during the summer season are associated with high temperatures. Beef cattle will not only have to deal with less feed and water availability but they also must deal with added heat load. Heat stress is a major contributor to loss of production in livestock systems and is further enhanced during water and feed scarcity. There are many ways that beef cattle can compensate for heat stress and water plays an important role in a few of the mechanisms that are used for cooling.

Adaptability is an economically relevant trait that until recently has not been at the forefront of selection decisions by producers. As climate continues to change it is vital to the success of producers and the livelihood of the population that producers select cattle that will be able to adapt to the changes. Not only will they need to adapt to survive, but they also need to maintain high productivity. Selection for improving adaptability is a slow and difficult process. Adaptability is a challenging trait to not only define but also measure. There is currently not a measure of adaptability in the beef industry. Measures of adaptability depend on what type of adaptability that the producer is looking to improve (i.e. heat stress, insect tolerance, water scarcity). Different adaptability traits make it challenging to define one measure for adaptability. Genomic prediction can be very helpful on improving adaptability in the beef industry, but that to happen, the beef industry needs better across breed prediction equations and have the ability to generate large training populations. Adaptability must become a key selection trait for the beef industry. Without priority put on adaptability and more specifically water efficiency, there runs the risk of losing productivity in the future. Fresh water supplies should no longer be viewed as endless. With their potentially being a limited supply of freshwater available for consumption, there needs to be an understanding of how much water is need for beef production. Selecting for water efficient cattle is going to be just as important as selecting for feed efficient animals. Water scarcity will be becoming more of a problem, especially when drought occurs. It’s important that the beef cattle industry starts making strides to improve water efficiency in beef cattle.

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