Selection to Improve Performance of Cattle in Subtropical Regions Using Heat Tolerance EPD

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Introduction

Subtropical regions such as the South-Eastern United States as well as places like Brazil are characterized by average year round temperatures of 27˚C (80°F). In the summer months temperatures can rise to 43°C (110°F). These temperatures are usually associated with high humidity and low forage quality and it is imperative that beef cattle in these regions be able to withstand these warm, harsh environments without sacrificing their productivity. Beef cattle populations in these areas are largely made up of Brahman and various Brahman composite breeds due to their adaptation to such harsh, warm environments (Hammond et al., 1994). Brahman, a *Bos indicus* breed of cattle, perform better in subtropical regions than *Bos taurus* cattle however, they lack some of the positive production attributes *Bos taurus* cattle possess such as high grading carcasses and high milk production.

Brahman and zebu cattle have some disadvantages that come along with their thermotolerance and efficiency at digesting poor quality forages when compared to *Bos taurus*. Poor meat tenderness is associated with carcasses of *Bos indicus* cattle (Sherbeck et al., 1996; Ferrell and Jenkins, 1998; Crouse et al., 1989). *Bos indicus* have lower milk yields and decreased lactation persistency (McDowell et al., 1996). They have a longer prepubertal period (Rodrigues et al., 2002; McDowell et al., 1996), a shorter duration of estrus (Rae et al., 1999), and they have poor temperaments (Hammond et al., 1996; Voisinet et al., 1997). Due to these negative aspects cattle buyers often discount crossbred calves displaying the Brahman phenotype.

Bos taurus cattle, on the other hand, in general have higher marbling scores, higher milk yields, good temperaments, and a short prepubertal period. It would be economically beneficial for people in these tropical and subtropical regions to raise *Bos taurus* breeds of cattle because of their potential to increase revenues for the producer, whether they are in the feedlot or cow/calf business. Current research has begun to look at the existence of a gene(s) associated with heat tolerance in slick haired *Bos taurus* cattle. Trials were conducted in Brooksville, Florida to observe the ratio of slick haired to normal haired progeny from a Senepol (slick haired) x Hereford (normal haired) dam and an Angus (normal haired) sire. The objective of this study was to see if the resulting normal and slick haired cattle differed in rectal temperature and respiration rate, both of which are indicators of heat tolerance.

The presence of such a gene would allow the beef industry in subtropical climates to select for heat tolerant cattle that are easier to manage as well as favorable in their carcass characteristics. Genetic prediction of heat tolerance is necessary for maximizing profitability in areas with high ambient temperature. The following will detail the differences in performance between *Bos taurus* and *Bos indicus* cattle in subtropical regions, as well as suggest the use of heat tolerance predictions on sire selection for maximum profit in subtropical climates.

Review of Literature

Defining Heat Tolerance. The ability of an animal to tolerate heat is very important to their productive capabilities. An animal that is heat tolerant has the ability to maintain a normal body temperature under high ambient temperatures (Hammond et al., 1994). High ambient temperatures are often considered to be 24°C and higher (Fuquay, 1981) and an animal's ability to maintain normal body temperature is determined through measurement of rectal temperature (RT). Cattle that are not heat tolerant often suffer from heat stress in locations with temperatures exceeding 24°C.

Bos taurus breeds of beef cattle are extremely heat-susceptible compared to their *Bos indicus* counterparts. Zebu (a type of *Bos indicus*) cattle acquired genes that conferred thermotolerance at some point during their separate evolution from *Bos taurus* cattle making them more suitable for harsh, warm climates. Zebu cattle exhibit less severe reductions in their overall productivity when compared to European *Bos taurus* breeds (Hansen, 2004). A common response in heat stressed cattle is to decrease metabolic heat production by lowering feed intake (Mitlohner, 2001). Decreases in feed intake generally begin occurring once ambient temperatures exceed 25°C (Morrison, 1983) and can be the cause of negative effects on both reproductive and growth performance (Gaughan et al., 1999).

Heat Stress Effects on Reproduction in Bos Taurus Cattle. Heat stress affects many different aspects of reproduction including embryo development and survival, pregnancy rate, and sperm quality. Rocha et al. (1998) reported a marked decline in the number of oocytes collected as well as the quality of the oocytes from *Bos taurus* compared to *Bos indicus* cows during the hot season. A total of 89 oocytes were collected from Brahman cows while a total of only 28 were collected from *Bos taurus* cows. The percentage of these oocytes considered normal was 24.6% for *Bos taurus* cows and 77% for the Brahman cows. A different study found that Angus (*Bos taurus*) embryos exposed to 41°C developed slower than those of Brahman (Hernandez-Ceron et al., 2004). Another heat shock study determined that the total number of cells per embryo for Holstein and Angus cows was reduced compared to those for Brahman cows exposed to 38.5°C (Paula-Lopes et al., 2003). Brahman cows and their embryos tend to be affected less severely by heat stress than cattle of the *Bos taurus* influence.

Olson et al. (1991) found that heat stress also had an effect on pregnancy rate. Evaluating *Bos indicus* x *Bos taurus* and *Bos taurus* x *Bos taurus* cows for pregnancy rate they found the *Bos taurus* x *Bos taurus* to be 5.8% lower in Florida compared to the *Bos indicus* x *Bos taurus* cows. However, this difference decreased to 1.8% when the two crosses were evaluated in Nebraska. This evidence leads to the assumption that pregnancy rate in *Bos taurus* cattle is negatively affected by the heat stress associated with tropical environments.

Heat stress has also been reported to have negative affects on sperm quality (Meyerhoeffer et al., 1985). The percentage of motile sperm in Angus bulls subjected to 35°C was decreased compared to the controls. Ax et al. (1987) found similar results in dairy bulls exposed to 29.4°C and also noted a high frequency of abnormal sperm. Another study reported a 4.9% increased incidence of primary abnormalities in the sperm of *Bos taurus* bulls when compared to *Bos indicus* bulls following exposure to 40°C (Skinner and Louw, 1966). The work reviewed in this section shows that heat stress impacts both males and females and that both sexes are equally impacted.

Heat Stress Effects on Growth in Bos Taurus Cattle. Growth potential is a very important factor to the beef producer because the more quickly an animal grows, the less time it will spend in the feedlot. This saves the feedlot a great deal of time and money; however, a heat

stressed animal will cost additional time and money resulting in a reduction in profit. This is because heat stressed cattle consume less feed than those under normal conditions. Brahman cattle subjected to a temperature of 38°C have been found to gain 670 g/day while Friesian cattle gain only 590 g/day (Colditz, 1972). In addition, it was noted that the Brahman cattle were able to accomplish this higher gain on less feed than the Friesian cattle. This work implies that in addition to gaining more weight, the Brahman cattle were also more feed efficient under heat stress.

Anatomical Differences. It has been proposed that the appendages on Zebu cattle are an important reason for their superior thermoregulatory ability because they increase the surface area of these animals. These appendages, such as the hump or the ears, are some of the defining characteristics of Zebu cattle. McDowell (1958) demonstrated that surgical removal of the dewlap or hump of Red Sindhi bulls had no significant effect on thermoregulatory ability. Therefore, some other unknown physiological aspect in these animals is responsible for their ability to regulate deep body temperature.

Ledger (1959) suggested that differences in the method of fat deposition could be a physiological difference that accounts for the differences in heat tolerance between these two species of cattle. He reports that as *Bos taurus* cattle increase in fatness during the feeding period they are incapable of reducing the amount of subcutaneous fat deposited. This in turn causes heat stress, which also causes a reduction in feed intake. *Bos indicus* on the other hand, do not deposit a large amount of subcutaneous fat and therefore, do not suffer from heat stress as severely. Although some research has been focused on physiological causes, most of the research behind heat tolerance has mainly focused on coat types.

Coat Type Differences. The coat types of *Bos indicus* and *Bos taurus* cattle are very different from one another and have been studied to explain some of the properties of thermoregulation in *Bos indicus*. Zebu cattle have a light-colored hair coat that is sleek and shiny while European type cattle have a denser, wooly coat typically darker in color (Hansen, 1990). The sleek and shiny hair coats of the Zebu cattle reflect a greater proportion of incident solar radiation than those of *Bos taurus*. The coats of European type cattle reduce heat flow via conduction and convection and increase the effects of heat stress (Finch et al., 1984). Finch (1985) demonstrated that the wooly coats of Shorthorn cattle (a *Bos taurus breed)* prevent them from sweating under conditions of high humidity while those of Zebu cattle allow them to sweat efficiently. This was thought to be due to the trapping of humidified air in the wooly coats of the Shorthorn cattle.

Mader et al. (2002) demonstrated that coat color also had a large impact on the heat tolerance of cattle. They noted that the dark-colored group of cattle had the greatest percentage of individuals showing moderate to excessive panting as well as bunching behavior under thermoneutral climatic conditions. Increased panting and bunching behavior have been shown to be associated with heat exposure in previous experiments (Lefcourt and Schmidtmann, 1989) and these findings demonstrate that darker coated animals are less tolerant to increases in temperature than lighter coated animals. In addition, Mader and colleagues noted that dark coated cattle had mean tympanic (ear) temperatures that were significantly higher than cattle with light hair coats when subjected to a temperature of 28.6°C.

Evidence of Coat Type Importance. Olson et al. (2003) compared Senepol/Hereford x Angus calves with purebred Senepol calves in their rectal temperature (RT) and respiration rates. This cross was used because previous studies had shown that Senepol (a tropically adapted *Bos taurus* breed) are equal in heat tolerance to Brahman cattle (Hammond et al., 1994). The

offspring produced from this cross were either slick haired or normal haired. Slick haired heifers showed a lower respiration rate than normal haired heifers, which shows evidence for the importance of coat type in thermoregulation (Olson et al, 2003). These same researchers also found that RT increased with higher quantities of hair. Animals with a hair score of 4 (normal haired) showed a significant increase in RT when compared to animals with a hair score of 1 (slick haired). In addition, it was discovered that the resulting calves of these crosses had a ratio of slick hair to normal hair not much different from the 1:1 ratio you would expect assuming that all of the dams were heterozygous for a slick hair gene. This was an important observation because it points to the possibility that there is a slick hair gene that is dominant in mode of inheritance.

Hammond et al. (1994) investigated rectal temperature as an index of heat tolerance in Senepol, Brahman, Angus, Hereford, and crossbred Senepol cattle under summer conditions in subtropical Florida. This study found that Angus females always had the highest RT and Senepol cows the lowest. Angus and Hereford heifers had the highest RT, Brahman intermediate, and Senepol the lowest. These findings imply that cattle with heavier, thicker coats (Angus and Hereford) exhibit higher RT levels than those with slicker coats (Senepol and Brahman). In addition, this same study compared grazing times of Senepol and Hereford cows and found that mean daily grazing time was longer for Senepol than Hereford. Senepol showed the tendency to graze more in the late morning while Herefords tended to graze more at night when the temperature was cooler. When RT level and grazing time were looked at, it was discovered that total grazing time was negatively correlated with rectal temperature across all cows throughout the trial. Animals with higher RT temperatures responded to heat stress less favorably than those with lower RT, which resulted in reduced feed consumption.

Dowling (1959) compared the RT of Shorthorns with medullated coats to Shorthorns with highly insulating hair coats, made often of long silky unmedullated hairs. A medullated hair coat is often shorter and stiffer than a nonmedullated coat and is thought to enhance air movement and heat dissipation. Significant differences in heat tolerance were observed between these two groups. Those animals with more medullation exhibited more heat tolerance than those with less medullation.

Some experiments have also been performed in which longhaired cattle were clipped to simulate a shorthaired animal in order to observe the effects on RT. Hammond et al. (1994) did this as part of their experiment and noted that the clipped Hereford calves had rectal temperatures intermediate between the unclipped Hereford calves and the Senepol calves. Vajrabukka et al. (1984) also observed that wooly-coated heifers had higher rectal temperatures than clipped heifers under climate chamber conditions. The results of these two studies indicate that heat tolerance is improved once the animal is clipped; however, the RT of these clipped individuals is still not the same as a slick haired individual. This leads to the idea that a short hair coat is partially responsible for an animal being thermotolerant, but that there must also be some other genetic effect involved.

Performance Differences. After reviewing the effects that slick hair has on the ability of an animal to tolerate heat the next logical step is to look at the performance in these animals compared to those with normal hair. Olson et al. (2003) documented that the mean marbling score for slick-haired calves corresponded to Low Choice while that of normal-haired steers of the same breed composition corresponded to High Select. These differences raise the question as to whether this is due to the slick hair condition or some other phenomenon. If in fact it is due to the slick hair condition this implies that the slick hair gene could be linked to marbling genes.

In order to look at the growth differences in heat tolerant cattle and temperate cattle, Frisch (1981) developed two closed lines of Hereford X Shorthorn crosses, one which was selected principally for growth rate under conditions of moderate to high environmental stress and the other which was an unselected control line. Frisch measured the growth rate of both groups when they were exposed to high ambient temperatures and observed that the selected line had consistently higher live weights from weaning onwards. In addition, he discovered that bulls in the selected line had a higher gain per day, a larger feed intake per day, a higher final live weight, as well as a lower rectal temperature than those in the control group. These results imply that it is possible to select for heat tolerant *Bos taurus* cattle that are presently considered temperate type cattle.

A great deal of research has been performed on cattle in the dairy industry due to the substantial economic losses associated with heat stress in these animals. Bohmanova et al. (2006) evaluated the female progeny of a set of sires in order to determine those sires transmitting the most heat tolerance. They concluded those bulls transmitting the highest tolerance to heat stress produced daughters with lower milk yields, longer productive lives, and worse dairy form when compared to daughters of less heat tolerant bulls. Although daughters of high heat tolerant bulls have lower milk yields, these cows will be more consistent in their milk yields throughout an entire year while the milk yield of daughters of less heat tolerant bulls will fluctuate with temperature. The current trend centers around selection of the highest milk producing individuals, which at the same time may be compounding problems associated with heat stress. Selection in favor of heat tolerance will result in a lower culling rate and an increase in profit because of the lack of need to replace older individuals in their peak lactation. This evidence in favor of selection for heat tolerance in temperate dairy cattle implies the possibility for selection of heat tolerance in *Bos taurus* beef breeds.

Conclusions and Implications to Genetic Improvement of Beef Cattle

Currently subtropical regions are at a disadvantage when it comes to beef production. Producers in these regions predominately raise heat tolerant breeds such as Brahman or other breeds of Zebu cattle because they are efficient digesters of poor quality forage and able to withstand hot, humid climates without compromising their production. Although they are hearty, they are also known for their inferior meat tenderness and poor temperament. In addition, these breeds are difficult to manage due to their long prepubertal period and short duration of estrus. Temperate breeds, however, are known for their superior meat tenderness and palatability, shorter prepubertal period, and longer duration of estrus. Incorporating temperate breeds of cattle into their production systems would allow producers in subtropical regions to produce a more profitable carcass while enabling them to manage their cattle more easily. Although these temperate breeds will require some supplemental feed due to the poor quality forage in these areas, the returns will compensate for any losses associated with the additional feed.

The review of literature in this paper has provided evidence in favor of the idea that the slick hair coat type plays an important role in the heat tolerance of cattle. Although there are probably other factors at work in determining heat tolerance, a shorter hair coat does have an effect on thermotolerance. Evidence has been provided that implies the existence of a single, major gene that is dominant in mode of inheritance. If there were a way of genetically predicting thermotolerance in temperate *Bos taurus* cattle, the beef industry in subtropical climates would benefit by being better able to compete in the United States beef market. In addition, these cattle producers would have the heat resistance required by the hot environment along with the superior carcass characteristics and favorable temperaments that temperate breeds bring to the industry.

There has not been an effort described thus far for genetically predicting thermotolerance, nevertheless, a great deal of evidence has been presented in favor of the need for a prediction. Hot, humid climates have been shown to induce heat stress in temperate cattle, which has negative effects on their reproductive and growth performances. Extreme care must be taken to develop an expected progeny difference (EPD) for heat tolerance that is clearly separate from predictions for carcass traits and milk yield since deficiencies in these traits are often characteristic of heat tolerant cattle. This will ensure the production of high producing, high grading animals in tropical regions.

Developing an EPD for heat tolerance for each *Bos taurus* breed will enable producers in subtropical climates to raise purebred *Bos taurus* cattle successfully without compromising their performance. The incorporation of genetic prediction for heat tolerance in *Bos taurus* breeds would allow them to be raised in areas with very high ambient temperatures where they could not be optimally raised before. *Bos taurus* breeds in subtropical regions would be able to produce up to their full potential as well as yield a more profitable, desirable carcass that would allow beef producers in these regions to be more competitive in the world beef market.

References

Ax, R.L., G.R. Gilbert, and G.E. Shook. 1987. Sperm in poor quality semen from bulls during heat stress have a lower affinity for binding hydrogen-3 heparin. J. Dairy Sci. 70(1):195-200.

Bohmanova, J., I. Misztal, S. Tsuruta, H.D. Norman, and T.J. Lawlor. 2006. National genetic evaluation of milk yield for heat tolerance of United States Holsteins. Available at: http://www-interbull.slu.se/bulletins/bulletin33/Bohmanova.pdf. Accessed February 20, 2006.

Colditz, P.J. and R.C. Kellaway. 1972. The effect of diet and heat stress on feed intake, growth, and nitrogen metabolism in Friesian, F1 Brahman x Friesian, and Brahman heifers. Aust. J. Agric. Res. 23:717-725.

Crouse, J.D., L.V. Cundiff, R.M. Koch, M. Koohmaraie, and S.C. Seideman. 1989. Comparisons of *Bos indicus* and *Bos taurus* inheritance for carcass beef characteristics and meat palatability. J. Anim. Sci. 67:2661-2668.

Dowling, D.F. 1959. The significance of the coat in heat tolerance of cattle. Aust. J. Agric. Res. 744-748.

Ferrell, C.L. and T.G. Jenkins. 1998. Body composition and energy utilization by steers of diverse genotypes fed a high-concentrate diet during the finishing period: II. Angus, Boran, Brahman, Hereford, and Tuli steers. J. Anim. Sci. 76:647-657.

Finch, V.A., I.L. Bennett, and C.R. Holmes. 1984. Coat colour in cattle: effect on thermal balance, behavior and growth, and relationship with coat type. J. Agric. Sci. (Camb.). 102:141-147.

Finch, V.A. 1985. Comparison of non-evaporative heat transfer in different cattle breeds. Aust. J. Agric. Res. 36:497-508.

Frisch, J.E. 1981. Changes occurring in cattle as a consequence of selection for growth rate in a stressful environment. J. Agric. Sci., (Camb.). 96:23-38.

Fuquay, J.W. 1981. Heat stress as it affects animal production. J. Anim. Sci. 52:164-174.

Gaughan, J.B., T.L. Mader, S.M. Holt, M.J. Josey, and K.J. Rowan. 1999. Heat tolerance of Boran and Tuli crossbred steers. J. Anim. Sci. 77:2398-2405.

Hammond, A.C. and T.A. Olson. 1994. Rectal temperature and grazing time in selected beef cattle breeds under tropical summer conditions in subtropical

Florida. Top. Agric. (Trinidad). 71: 128-134.

Hammond, A.C., T.A. Olson, C.C. Chase Jr., E.J. Bowers, R.D. Randel, C.N. Murphy, D.W. Vogt, and A. Tewolde. 1996. Heat tolerance in two tropically adapted *Bos taurus* breeds, Senepol and Romosinuano, compared with Brahman, Angus, and Hereford cattle in Florida. J. Anim. Sci. 74:295-303.

Hansen, P.J. 1990. Effects of coat colour on physiological and milk production responses to solar radiation in Holsteins. Vet Rec. 127:333-334.

Hansen, P.J. 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Anim. Repro. Sci. 82-83:349-360.

Hernandez-Ceron, J., C.C. Chase Jr., and P.J. Hansen. 2004. Differences in heat tolerance between preimplantation embryos from Brahman, Romosinuano, and Angus breeds. J. Dairy Sci. 87:53-58.

Ledger, H.P. 1959. A possible explanation for part of the difference in heat tolerance exhibited by *Bos taurus* and *Bos indicus* beef cattle. Nature (Lond.). 1405-1406.

Lefcourt, A.M. and E.T. Schmidtmann. 1989. Body temperature of dry cows on pasture: environmental and behavioral effects. J. Dairy Sci. 72:3040-3049.

Mader, T.L., S.M. Holt, G.L. Hahn, M.S. Davis, and D.E. Spiers. 2002. Feeding strategies for managing heat load in feedlot cattle. J. Anim. Sci. 80: 2373-2382.

McDowell, R.E., B.T. McDaniel, and N.W. Hooven. 1958. Relation of the rhomboideus (hump) muscle in zebu and European type cattle. J. Anim. Sci. 17:1229 (abstract).

McDowell, RE, J.C. Wilk, and C.W. Talbott. 1996. Economic viability of crosses of *Bos taurus* and *Bos indicus* for dairying in warm climates. J. Dairy Sci. 79:1292-1303.

Meyerhoeffer, D.C., R.P. Wettemann, S.W. Coleman, and M.E. Wells. 1985. Reproductive criteria of beef bulls during and after exposure to increased ambient temperature. J. Anim. Sci. 60(2):352-357.

Mitlohner, F.M., J.L. Morrow, J.W. Dailey, S.C. Wilson, M.L. Galyean, M.F. Miller, and J.J. McGlone. 2001. Shade and water misting effects on behavior, physiology, performance, and carcass traits of heat-stressed feedlot cattle. J. Anim. Sci. 79:2327-2335.

Morrison, S.R. 1983. Ruminant heat stress: Effect on production and means of alleviation. J. Anim. Sci. 57:1594-1600.

Olson, T.A., K. Euclides Filho, L.V. Cundiff, M. Koger, W.T. Butts Jr., and K.E. Gregory. 1991. Effects of breed group by location interaction on crossbred cattle in Nebraska and Florida. J. Anim. Sci. 69:104-114.

Olson, T.A., C. Lucena, C.C. Chase Jr., and A.C. Hammond. 2003. Evidence of a major gene influencing hair length and heat tolerance in *Bos taurus* cattle. J. Anim. Sci. 81:80-90.

Paula-Lopes, F.F., C.C. Chase Jr., Y.M. Al-Katanani, C.E. Krininger III, R.M. Rivera, S. Tekin, A.C. Majewski, O.M. Ocon, T.A. Olson, and P.J. Hansen. 2003. Genetic divergence in cellular resistance to heat shock in cattle: differences between breeds developed in temperate versus hot climates in responses of preimplantation embryos, reproductive tract tissues and lymphocytes to increased culture temperatures. Reproduction. 125:285-294.

Rae, D.O., P.J. Chenoweth, M.A. Giangreco, P.W. Dixon, and F.L. Bennett. 1999. Assessment of estrus detection by visual observation and electronic detection methods and characterization of factors associated with estrus and pregnancy in beef heifers. Theriogenology. 51:1121-1132.

Rocha, A., R.D. Randel, J.R. Broussard, J.M. Lim, R.M. Blair, J.D. Roussel, R.A. Godke, and W. Hansel. 1998. High environmental temperature and humidity decrease oocyte quality in *Bos taurus* but not in *Bos indicus* cows. Theriogenology. 49:657-665.

Rodrigues, H.D., J.E. Kinder, and L.A. Fitzpatrick. 2002. Estradiol regulation of luteinizing hormone secretion in heifers of two breed types that reach puberty at different ages. Bio. Repro. 66:603-609.

Sherbeck, J.A., J.D. Tatum, T.G. Field, J.B. Morgan, and G.C. Smith. 1996. Effect of phenotypic expression of Brahman breeding on marbling and tenderness traits. J. Anim. Sci. 74:304-309.

Skinner, J.D. and G.N. Louw. 1966. Heat stress and spermatogenesis in *Bos indicus* and *Bos taurus* cattle. J. Appl. Physiol. 21:1784-1790.

Vajrabukka, C. and C.J. Thwaites. 1984. The relative influences of exercise and coat-type on the thermoregulatory responses of cattle. Int. J. Biometeor. 28:9-15.

Voisinet, B.D., T. Grandin, J.D. Tatum, S.F. O'Connor, and J.J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with exitable temperaments. J. Anim. Sci. 75:892-896.