Measuring Heat Adaptability in Bos Indicus Cattle

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Heat stress is a principal factor limiting production of animal protein and negatively affecting health and welfare of cattle in subtropical and tropical regions. Detrimental effects on livestock productivity associated with heat stress are expected to intensify dramatically and expand into currently temperate zones upon the realization of predicted climate change (IPCC, 2007). Most animal-producing areas in the US are predicted to experience extreme summer conditions (Luber and McGeehin, 2008) and by 2100, average temperatures in the US are projected to increase 2° to 6°C, depending on the emissions scenario and climate model applied (USGCRP, 2009). The number of days with maximum temperatures above 32°C (90°F) is also expected to increase. The SE and SW areas of the US currently average 60 such days per year but are projected to experience at least 150 such days a year by the end of the century.

Development of effective strategies to improve the ability to cope with heat stress is imperative to enhance productivity of the US livestock industry and secure global food supplies. Substantial differences in thermal tolerance exist among breeds and among animals within breeds indicative of opportunities for selective improvement. For example, *Bos indicus* cattle exhibit increased resistance to many environmental stressors relative to *Bos taurus*, but tend to have slower growth, lower fertility and poor meat quality as they have not been as intensively selected for these traits as specialized *Bos taurus* breeds. Use of genomic tools to produce an animal with superior ability for both thermal adaptation and production represents an energy-efficient sustainable approach to meet the challenge of global climate change.

Thermoregulation is a process in which environmental information provokes a cascade of appropriate responses to maintain body temperature within the narrow range necessary for optimal cellular and molecular function. This is accomplished by jointly regulating heat production and heat loss. To reduce internal *heat production* beef cattle will decrease physical activity; reduce feed intake and downregulate biological functions associated with growth, reproduction, and immunity. Cattle will also increase blood flow to the skin and increase evaporative heat loss through sweating, panting, and behavioral wetting of the skin to increase the *heat exchange* with the environment. Hyperthermia results when body temperature increases above normal range despite these adjustments. Improvements in production, such as increased growth rate, lead to increased metabolic heat production, and exacerbate the problem of thermoregulation and a good example is the negative genetic correlation between milk yield and ability to regulate body temperature during heat stress in dairy cattle. Unless accompanied by changes that increase heat loss capacity, improvements in production make animals more susceptible to hyperthermia during heat stress.

Quantitative measures of the thermal environment and the animal's responses to heat stress are needed to assess thermal tolerance. Commonly used measures of the thermal environment are temperature, humidity, solar radiation, and wind, while coat characteristics, body temperature, skin temperature, respiratory rate and sweating rate describe thermal environment from an animal perspective. Riley et al. (2012) reported heritabilities of 0.19 and 0.27 for rectal temperature and coat score in a Brahman x Angus crossbred population, and a genetic correlation of 0.24 between these traits. Dikmen et al. (2012) reported heritability of 0.17 for rectal temperature in dairy cattle. Both studies were conducted during hot and humid summers in Florida. These heritabilities demonstrate genetic variation and supports the hypothesis that selection for improved thermal tolerance is possible if animals with genetically superior core body temperature regulation when exposed to environmental thermal stress can be identified. Selection for improved thermal tolerance using classical approaches is not feasible due to cost and difficulty of collecting appropriate phenotypes on large numbers of animals. To determine an animal's response to heat stress (and therefore to assess its thermal tolerance), high frequency measurements of relevant traits are required, hence the importance of fine-scale high-throughput phenotyping.

An exploratory study was conducted at the University of Florida (UF) Beef Research Unit in summer 2015 to demonstrate the feasibility of using iButtons devices to record vaginal temperature over a period of 5 consecutive days and assess the phenotypic variation in the UF multibreed population. Vaginal temperature was measured at 5-min intervals for 5 days on 191 cows which ranged in breed composition from 100% Brahman to 100% Angus. Ambient environmental conditions were monitored using HOBO data loggers, which continuously record temperature, humidity, solar radiation, black globe temperatures, and wind speed. The temperature humidity index was calculated as: $THI = (1.8 \times T + 32) – [(0.55–0.0055 \times RH) \times (1.8 \times T – 26)]$, where T = air temperature (°C) and RH = relative humidity (%). The hourly average THI was used to assess the heat stress level cows were exposed to, based on the intensity and duration of THI

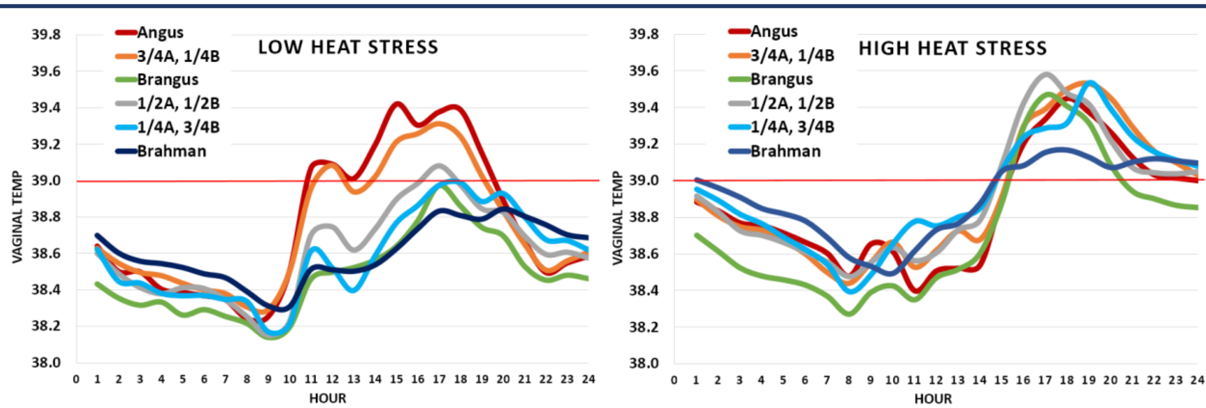

Figure 1. Daily variation in vaginal temperature in UF cows of different breed composition presented as average temperature over a 5-day period for each breed group during low heat stress (low intensity and short duration THI throughout the day) or high heat stress conditions (high intensity and long duration THI).

during the day and that measure was used to classify each replicate as low heat stress (low intensity and short duration THI), medium heat stress (lower intensity and long duration) or low heat stress (lower intensity and short duration). The hourly vaginal temperature was analyzed using an autoregressive model where cows within replicate and breed group were treated as repeated observations was used to estimate the effect of breed group for each heat stress level. **Figure 1** shows the pattern of hourly variation in vaginal temperature for Angus, 3/4Angus x 1/4Brahman (3/4A, 1/4B), Brangus, 1/2Angus x 1/2Brahman (1/2A, 1/2B), 1/4Angus x 3/4Brahman (1/4A, 3/4B) and Brahman cows under low heat stress (left panel) and high heat stress conditions (right panel). Angus and 3/4 Angus cows had a vaginal temperature higher 39°C even during lower heat stress conditions while Brahman cattle were the only ones able to maintain a lower vaginal temperature throughout the 24h-day during high heat stress conditions.

A large research project to identify causal genetic variants controlling thermal tolerance was initiated during Summer 2016 using 725 two-year old Brangus heifers from the Seminole Tribe of Florida. The heifers were evaluated in four groups under hot and humid conditions at the

Seminole Ranch on the Brighton Reservation, west of Lake Okeechobee between August 15 and Sept 15, 2016. Phenotypes describing thermal tolerance were collected and included vaginal temperature at 5-min intervals for 5 days, sweating rate, hair coat color and coat score, and temperament (chute and exit score). Ambient environmental conditions were monitored using HOBO data loggers, which continuously record temperature, humidity, solar radiation, black globe temperatures, and wind speed. Several parameters to describe animal's response were developed, such as minimum and maximum vaginal temperature, the difference between minimum and maximum vaginal temperature, and time between minimum and maximum vaginal temperature. Preliminary data from this ongoing research trial are summarized in **Table 1**.

Variable	Mean	Std Dev	Minimum	Maximum
Minimum vaginal temp, °C	38.42	0.29	36.36	39.36
Maximum vaginal temp, °C	40.05	0.54	38.77	42.30
Minimum THI	75.05	1.40	73.04	76.44
Maximum THI	86.60	1.91	84.00	89.14
Max-Min vaginal temp, °C	1.56	0.44	0.56	2.99

Table 1. Summary statistics including mean, standard deviation, minimum and maximum values on 725 two-year old Brangus heifers exposed to heat stress during Summer 2016. Minimum and maximum vaginal temperature during 3 consecutive days, minimum and maximum temperature-humidity index (THI) during the same 3 consecutive days, and the difference between the minimum and maximum vaginal temperature for each cow.

There was a good level of variation in the THI over the time period evaluated, ranging from a minimum of 73 to a maximum of 89. Previous studies suggest that 72 to 79 THI corresponds to mild level of stress, 80 to 89 THI represents moderate level of stress, and a THI greater than 90 is indicative of severe heat stress level. There was also a high level of variation in the vaginal temperature, which ranged overall from 36.6°C to 42.3°C. Most importantly, the variation in the maximum vaginal temperature between 38.8°C and 42.3°C is suggesting that genetic variants controlling body temperature are segregating in Brangus cattle.

A repeated measures model was used to investigate the effect of the coat score and body temperature. The coat was scored as excessively smooth (score 1, n = 526), fairly smooth (score 2, n = 189) or long coat (score 3, n= 7). The fairly smooth and long coat classes were combined into one due to the small number of long coat scores. The coat score had a significant effect on body temperature, where cows with excessively smooth coat had lower body temperatures throughout the 3 days of continuous body temperature measurements (**Figure 2**) indicating that coat type plays an important role in the control of body temperature. A slick dense coat provides a greater resistance to heat transfer to the skin and therefore reduces the heat gain from the environment when the animals is in sunlight.

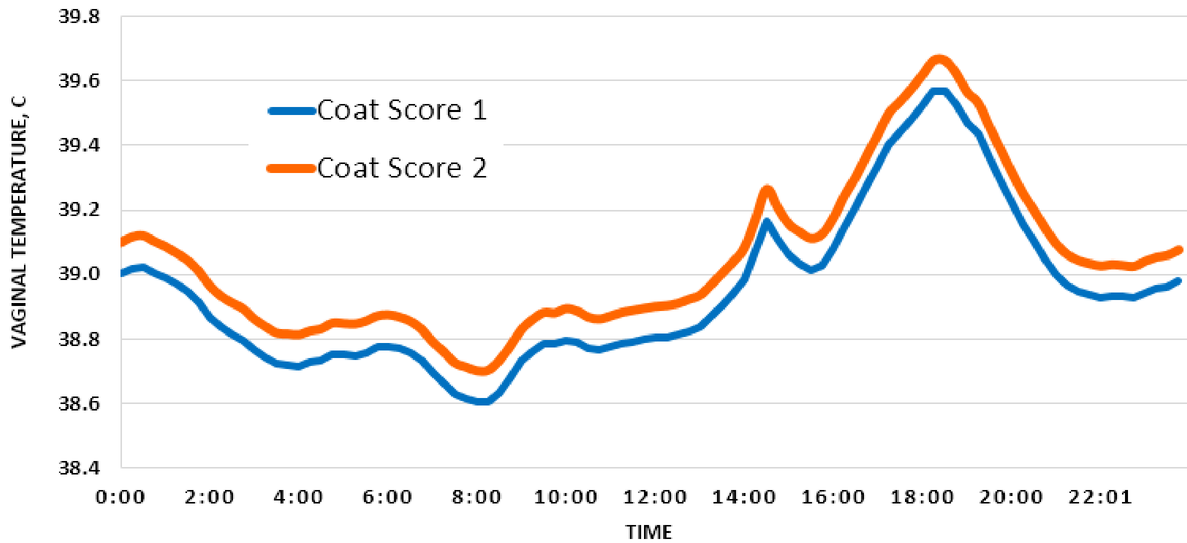

Figure 2. Effect of coat score (1 = excessively smooth, 2 = smooth) on average hourly vaginal temperature Brangus cows. Vaginal temperature was average over a 3-day period within each cow for 724 cows evaluated in four replicates. A repeated measures model showed a statistically significant effect of coat score on vaginal temperature.

We are in the process of collecting body temperature data and other relevant phenotypes on another set of 2,000 animals. The ultimate goal is to integrate all detailed phenotypes collected with high-density genotyping and gene expression analysis to understand the genetic architecture of thermal tolerance. Critical genomic regions targeted through this process will be sequenced to identify causal genetic variants controlling thermal tolerance. We will use this information to develop tools to be used in selection and management programs designed to mitigate the effect of heat stress in indicine-influenced beef cattle populations that predominate in hot and humid regions of the US and globally. These regions in the US contain approximately 50% of beef cow-calf producers and 42% of beef cows, for which a substantial fraction are *Bos indicus* influenced (Morrison, 2005). Economic losses from heat stress in the US beef industry were estimated over a decade ago to average $369 million (St-Pierre et al., 2003).