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EVALUATION OF AUSTRALIAN BREEDING VALUES FOR HEAT TOLERANCE UNDER US CONDITIONS

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SUMMARY

Reduced milk production and reproductive losses are common consequences of heat stress in dairy cattle and are likely to increase because of global climate change. The objective of this study was to compare body temperature regulation during heat stress between genetically heat-tolerant and heat-sensitive cows in peak summer (August 2020) on a California dairy farm. Genomic ABVs (ABVHT) were calculated for 12,487 cows from a single U.S. dairy farm. The herd had an average ABVHT of 102.5 with a standard deviation of 3.6. Rectal temperature was measured in 626 lactating cows with ABVHT ≥ 102 (heat tolerant) or <102 (heat sensitive) using a rectal thermometer. Vaginal temperature was measured in 118 cows with ABVHT ≥ 108 or <97 at 15-min intervals for five days in 118 cows using iButtons placed in blank CIDRs. Heat-tolerant cows had a 0.12°C (P=0.032) lower rectal temperature and a 0.07°C (P<0.001) lower vaginal temperature than heat-sensitive cows. The ABVHT can be used to select cows for resistance to heat stress under U.S. conditions.

INTRODUCTION

Heat stress is one of the most significant environmental determinants of livestock productivity. In cattle, heat stress decreases milk production, reduces growth, diminishes sexual behavior, compromises female fertility, alters fetal development, and disrupts spermatogenesis (Hansen 2020). Global climate change means that limitations to sustainable livestock production caused by heat stress will become even more important than today (Battisti and Naylor 2009; Gauly and Ammer 2020). A breeding value for heat tolerance (ABVHT) in Holsteins and Jerseys based on the magnitude of the decline in milk, fat and protein yield per unit increase in temperature-humidity index for cattle is available for on-farm selection decisions in Australia (Nguyen *et al.* 2017). Inclusion of thermotolerance in selection indices for cattle present in hot climates may represent a useful approach for minimizing current and projected effects of heat stress on production and reproduction of dairy cows. The extent to which the breeding value is useful for other countries and systems, depends on whether the trait, measured in cattle under Australian conditions, also identifies dairy cattle in other countries that are genetically predisposed to be resistant or susceptible to heat stress. Given differences in management, including housing and feeding, this may or may not be the case. Accordingly, the purpose of this study was to evaluate the effectiveness of the genomic estimates of ABVHT for predicting resistance of lactating Holstein cows in the USA to heat stress. It is hypothesized that core body temperature is lower for females with high ABVHT than for females with low ABVHT.

MATERIALS AND METHODS

The trial was approved by the University of Florida animal ethics committee. Data were collected from a commercial dairy farm in Riverdale, California. There were 3,613 lactating Holstein cows milked two times per day. The cows were housed in free-stall barns with shade cloth, fans, and sprinklers for heat abatement, and had access to dirt lots. In August, average daily milk yield was 38.1 kg.

Climate data. Dry bulb temperature and relative humidity were measured every 15 minutes for the duration of the study using HOBO U23 Pro v2 temperature and relative humidity data logger (Onset, Bourne, Massachusetts, USA) from three locations at the farm: exterior parking lot, the barn identified as the hottest by the farm manager and the barn identified as the coolest.

Genotypes. Genotypes (n=12,684) and pedigrees were sent to DataGene (Melbourne, Australia) and included in the August 2020 official genetic evaluation run. Standard procedures used by DataGene to edit and impute genotypes were applied (Nieuwhof *et al.* 2010). Samples with a call rate less than 0.9 or with more than 40% of markers heterozygous were removed. Animals with parentage or sex inconsistencies between the pedigree and genotype were also excluded. As many commercial providers provide genotypes to DataGene, a standard set of 45,685 SNP genotypes is used for routine evaluations (Nieuwhof *et al.* 2010) and missing genotypes were imputed by DataGene to satisfy this requirement. After quality control, genomic ABVHT were calculated for 12,487 cows following the methodology of Nguyen *et al*. (2016). The ABVHT is calculated to have a breed mean of 100 and a standard deviation of 5.

Cow design and sampling. Of the 12,487 cows with ABVHT, 2,925 cows were in the current herd. Rectal temperatures were measured daily using digital rectal thermometers across a random sample of cows (n=1078) once they had returned from milking in the afternoon (range of sampling time was 11:00 – 20:45 H). Of the 1,078 cows, 626 animals with ABVHTs ranging from 102 to 109 (termed HTR, n=354) or 95 to 101 (HSR; n=272) were used for statistical analysis. The most heat tolerant cows on the farm (ABVHT ≥ 108; termed HTV) and least heat-tolerant cows (ABVHT ≤ 97; termed HSV) were selected for vaginal temperature analysis. A blank CIDR containing an iButton 1922L (Maxim Integrated, San Jose, California, USA) was placed intravaginally for five days to record temperature every 15 minutes. The experiment was performed with 40 HTV and 23 HSV cows in week 1 and with a separate 26 HTV and 29 HSV cows in week 2. Herd records were obtained from the farm and accessed using DHI-Plus (Amelicor, Provo, Utah, USA).

Statistical analysis. Statistical analysis was performed using R (4.0.3). The model $y = \mu + X\beta + \varepsilon$ was used to analyze rectal temperature, where y is a vector of rectal temperature, β is a vector of fixed effects including close barn temperature (barn closest to the location of the cows), test day milk yield, parity (primiparous or multiparous), day of calendar year, and ABVHT, and X is a design matrix of the fixed effects. Vaginal temperature was analyzed using the model, $y = \mu + X\beta + \varepsilon$, where y is a vector of vaginal temperature averaged across 5 days, β is a vector of fixed effects including ABVHT, week, pen, milk yield, parity (primiparous or multiparous), and days in milk, and X is a design matrix for fixed effects. Week one and two were analyzed separately using the mixed model: $y = \mu + X\beta + Zg + \varepsilon$, where y is a vector of vaginal temperature, β is a vector of fixed effects including ABVHT, date, time, date by ABVHT, time by ABVHT, milk yield, parity (primiparous of multiparous), and days in milk, g is a vector of random effects including cow nested within ABVHT, and X and Z are design matrices for fixed and random effects respectively.

RESULTS AND DISCUSSION

Cows designated as HTR (ABVHT ≥102) had lower (P=0.032) rectal temperatures than cows designated as HSR (ABVHT <102) (Figure 1A). The mean rectal temperature was 38.46°C and 38.58°C for HTR and HSR cows, respectively (Figure 1B).

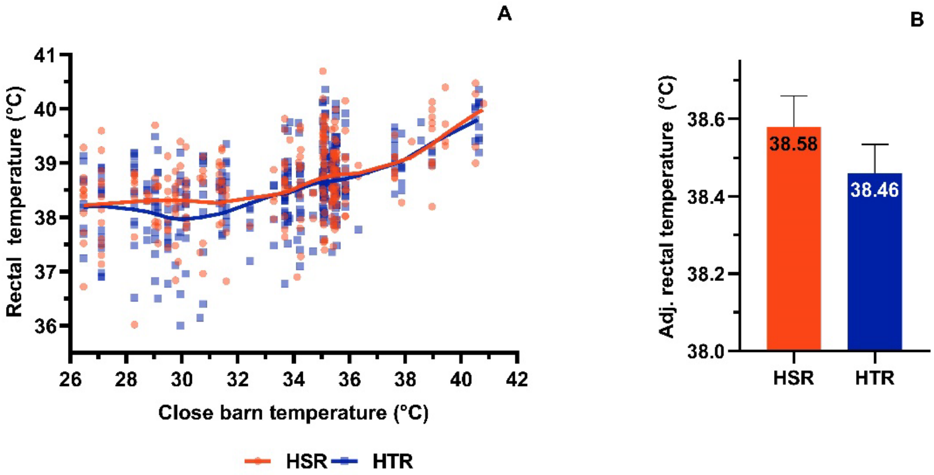

Figure 1. Differences in rectal temperature between heat-sensitive and heat-tolerant cows as affected by dry bulb temperatures measured at the barn closest to the cow (n=626). Heat-tolerant (HTR) cows had an ABVHT ≥102 and heat-sensitive (HSR) cows had an ABVHT <102. (A) Data points are rectal temperatures for individual cows. (blue = HTR; orange = HSR). The line shows the group average at each barn temperature. (B) Mean rectal temperature ± SEM for each ABV class after adjustment for close barn temperature, milk yield, parity, and day

Daily variation in vaginal temperature was characterized by lower vaginal temperatures in the morning and higher temperatures in the late afternoon. There was variation between weeks that is likely due to milking schedule (Figure 2A). Mean vaginal temperatures across both weeks were lower for extreme heat-tolerant cows (ABVHT ≥108; designated HTV) than for extreme heat-sensitive cows (ABVHT ≤97; designated HSV). The average vaginal temperature was 39.02°C for HTV and 39.09°C for HSV($P<0.001$). These results are similar to those of Garner *et al.* (2016), working in environmental chambers in Australia, who found heat-tolerant cows (i.e. based on ABVHT) had significantly lower body temperatures during a heat challenge than heat-sensitive cows. There was a large effect of week on vaginal temperature. Analysis of vaginal temperature data to examine interactions between ABVHT and time of day were analyzed for week 1 separately from week 2. For week 1, there was a significant effect of ABVHT ($P<0.001$) but there was no interaction between time and ABVHT (Figure 2A). HTV cows had an average vaginal temperature of 39.11°C and heat-sensitive cows had an average vaginal temperature of 39.18°C. In week 2, there was an interaction between ABVHT and time of day ($P <0.001$) but no significant effect of ABVHT (Figure 2B). The difference between groups was more variable for week 2 throughout the day. In the evenings and early morning, there is a large difference in body temperature between HTV and HSV cows, while they become nearly identical between 12:00 AND 15:00. This result could indicate that HTV cows are more efficient at cooling their bodies when the environmental heat load is reduced than HSV cows. This idea is supported by the rectal temperature measurements where HTR cows maintained lower rectal temperatures than HSR cows until the dry bulb temperature reached ~33°C (Figure 1A). During both weeks, HTV cows maintained lower body temperatures than HSV cows throughout the day with the smallest difference in vaginal temperature from 12:00 to 15:00 when vaginal temperature declined for both groups. This time coincided with most cows returning from the parlor and drinking large amounts of water.

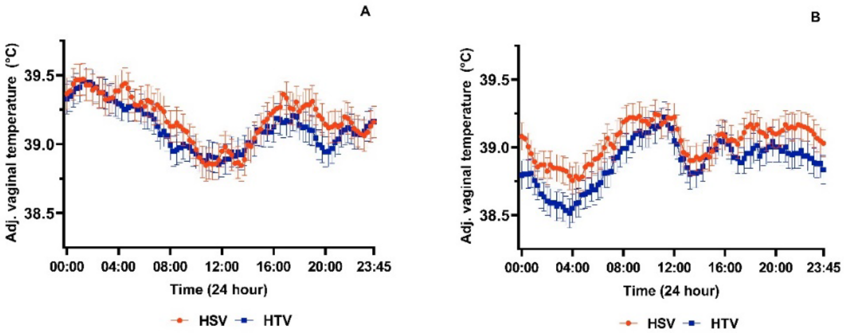

Figure 2. Mean daily vaginal temperature ± SEM adjusted for milk yield, days fresh, and parity (primiparous vs multiparous) in (A) week 1 and (B) week 2. Heat-tolerant (HTV) cows had an ABVHT ≥108 and heat-sensitive (HSV) cows had an ABVHT ≤97

Based on the literature, it is expected that genetically heat-tolerant cows which maintain lower body temperatures under heat stress conditions will sustain higher milk yields and better reproduction in the summer. The average difference in rectal temperature between heat-tolerant and heat-sensitive cows in the current experiment was 0.12°C and the average difference in vaginal temperature was 0.07°C. Future studies will determine whether differences in ABVHT are also reflected in genetically heat-tolerant cows having higher milk yield and conception rates under heat stress than their heat-sensitive counterparts.

CONCLUSIONS

Cows with a high heat tolerance breeding value had lower body temperatures under heat stress than cows with a low heat tolerance value. Thus, the ABVHT can identify heat tolerant cows with superior ability to regulate body temperature under US conditions.

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