Genetic Control of Heat Stress in Dairy Cattle

P.J. Hansen
Department of Animal Sciences
University of Florida
Gainesville, FL 32611
Hansen@animal.ufl.edu

The Growing Problem of Heat Stress and the Possible Role for Genetic Strategies to Mitigate Its Effects

Heat stress is a big problem for the lactating cow. Cows exposed to heat stress experience a 15-25% reduction in milk yield, reduced expression of symptoms of heat and lower fertility after insemination. In one study in Florida, only ~20% of heats were detected in summer (Thatcher and Collier, 1986). Conception rates in Florida can be as low as 10-20% (Hansen and Aréchiga, 1999).

Much of the world has to deal with heat stress. There are three billion people who live in the tropics and subtropics. Moreover, it is expected that regions of the world where heat stress is an issue will increase because of global climate change. By 2050, much of the world will experience median temperatures in the summer that are warmer than the warmest temperatures on record (Figure 1).

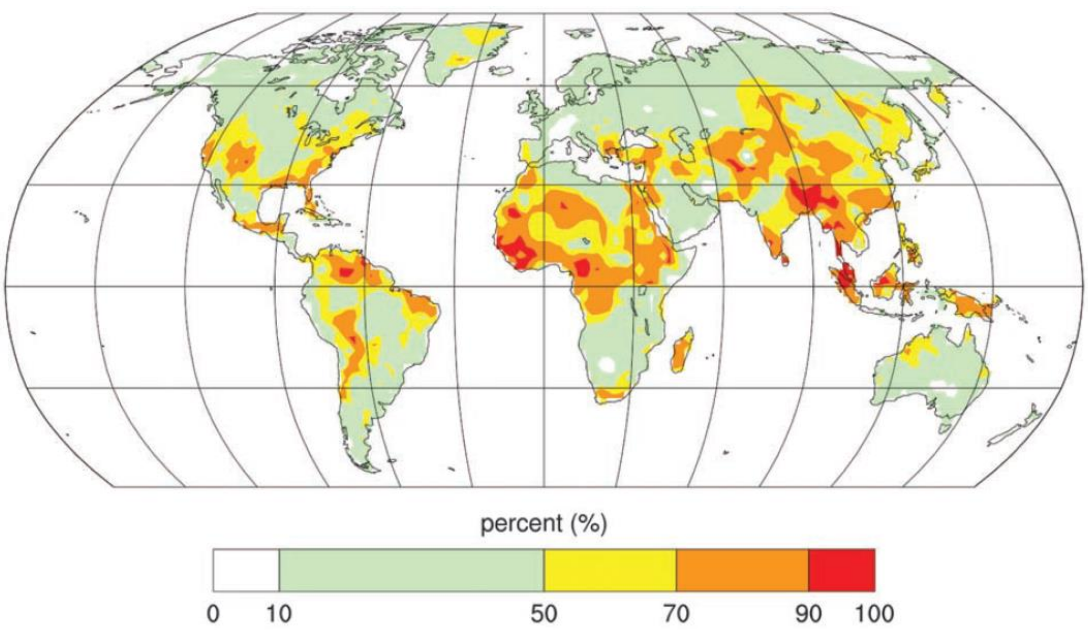

Figure 1. Likelihood (in percent) that median summer temperatures in 2050 will be higher than the highest median summer temperature observed from 1900-2006. For example, there is a greater than 90% change that areas in red will have summer temperatures higher than the highest on record from 1900-2006. The figure is from Battisti and Naylor (1999) and is reproduced with permission of the publisher.

Even if climate change was not to occur, it is likely that heat stress will increase in importance. That is because increases in production make cows more susceptible to heat stress. The modern dairy cow, with its high levels of productivity, begins losing the ability to regulate its body temperature at air temperatures as low as 25-29°C. Heat stress causes a decline in fertility in the summer in all regions of the United States (Pszczola et al., 2009).

Effects of heat stress in many species of livestock have been reduced by developing strains that are genetically resistant to heat stress. A beef cow of the Brahman or Nelore breed can maintain productivity in hot environments because it contains genes that allow animals to regulate body temperature during heat stress. For various reasons, this approach has not been widely utilized in the dairy industry. While there are some dairy breeds like the Gir and dairy crosses like the Girolando that are used in the tropics, the predominant breeds of dairy cattle in much of the world arose in Northern Europe and are not adapted to hot climates.

Nonetheless, there are some genes in Northern European dairy cattle that confer animals with some resistance to heat stress. In this paper, we will examine the prospects for selection for those genes to produce genetically-thermotolerant dairy cattle and discuss the advantages and disadvantages of doing so.

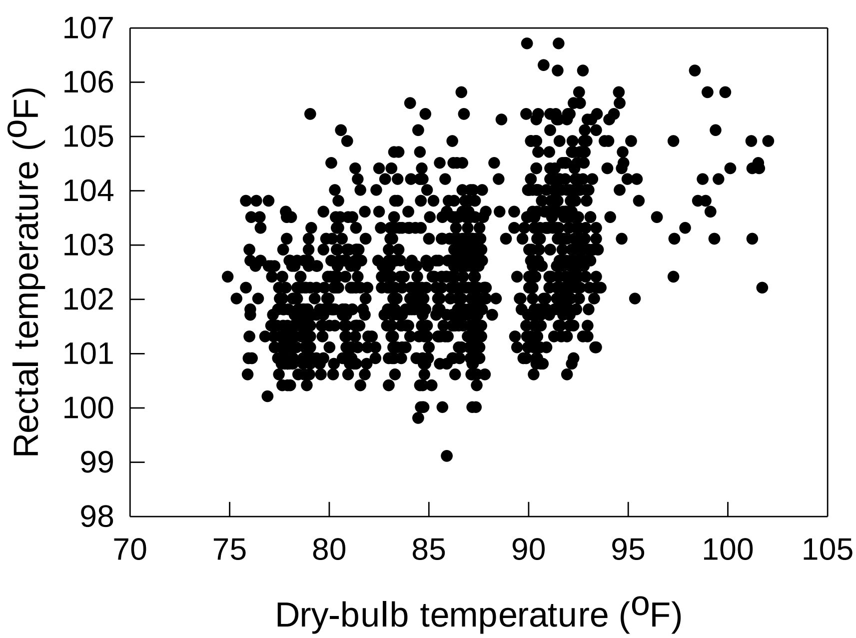

Figure 2. Rectal temperatures for individual cows in Florida. Temperatures were recorded between 3:00 to 5:00 PM. Data are redrawn from Dikmen and Hansen (2009).

Is Resistance to Heat Stress Controlled Genetically?

Shown in Figure 2 is a graph of afternoon rectal temperatures for 1016 lactating dairy cows. Two things are easily noticeable. The first is that as it gets hotter, the rectal temperature tends to increase. The second is that there is great deal of variation in rectal temperature among cows exposed to the same dry-bulb temperature. For example, on a day when the dry-bulb temperature was 90°F, rectal temperatures varied from 101.1°F to 104.0 °F. Clearly, some cows are better at regulating their body temperatures than others. The question is to what extent is that variation due to genetics?

Recently, Dikmen et al. (2012) and Dikmen, Cole, Null and Hansen (unpublished) estimated the heritability of rectal temperature under heat stress conditions. The values ranged from 0.13 to 0.17. This means that about 13-17% of the variation among cows in rectal temperature during heat stress is the result of variation in genetics. This value is relatively low compared to a trait like milk yield, where heritability is ~0.30 (Pritchard et al., 2013), but it is high enough to allow selection for rectal temperature.

Approaches for Selection of Thermotolerance

It will not be practical to select cows for thermotolerance based on rectal temperature directly because this trait that is not recorded frequently on dairy farms. However, data on variation in rectal temperature has been used to identify genetic markers that predict thermotolerance on the Illumina Bovine SNP50 BeadChip (Dikmen, Cole, Null and Hansen, unpublished). The Bovine SNP50 BeadChip is a genetic tool to estimate an animal's inheritance of specific mutations at 50,000 places on its chromosomes. With this information, obtained from a single sample of blood or hair, one can estimate genetic merit for milk yield, net merit, etc. Our data indicates it should also be possible to use the SNP5 BeadChip to estimate genetic merit for resistance to heat stress.

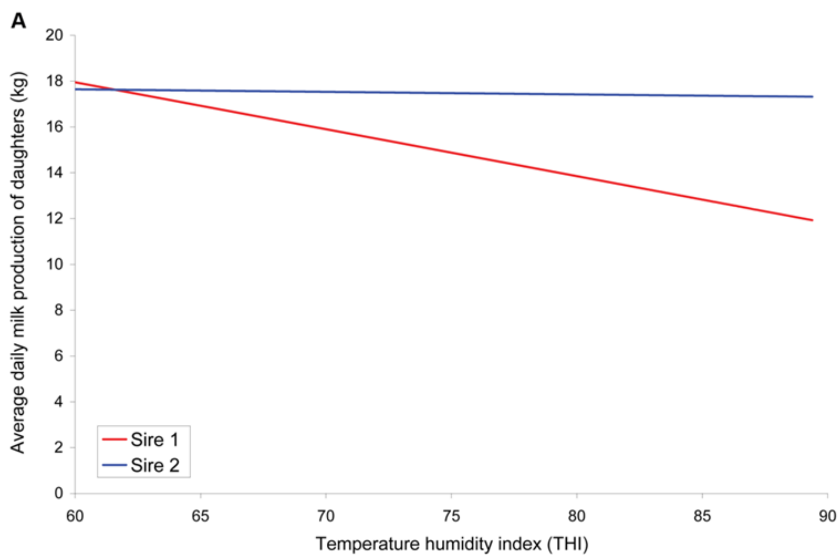

Figure 3. Example of sire differences in response of their daughters to changes in heat stress. Daughters of 798 sires in Australia were evaluated for effects of heat stress (quantified as temperature humidity index) on milk yield. Shown are the two most extreme sires. Note that as THI goes from 60 to 90, milk yield in Sire 1 declines from about 40 lb/day to 28 lb/day. In contrast, there was no change in milk yield for daughters of Sire 2. The figure is reproduced from Hayes et al. (2009).

Another approach to estimate genetic merit for thermotolerance was developed by Hayes and colleagues (2009) in Australia. They evaluated records on daughters from 798 sires to determine the degree to which milk yield was depressed by heat stress. There was substantial variation between bulls (Figure 3). A heat stress index based on these measurements could also be used to select bulls for thermotolerance.

Should We Select for Thermotolerance?

The advantage of selection for thermotolerance is that the reduction in milk yield and fertility during the summer would be minimized. Against those benefits must be weighed two disadvantages. First, it is to be expected that cows that are more resistant to heat stress will also be less resistant to cold stress. Thermotolerant cows would not be very desirable in states to the north of Florida where winter temperatures can be extreme. The second possible disadvantage is that selection for thermotolerance could accidentally lead to selection against milk yield. An increase in milk yield causes cows to produce more heat and that might make them less thermotolerant. Indeed, Dikmen et al. (2012) found a small but significant genetic correlation between rectal temperature and milk yield. As genetic merit for milk yield increased, so did genetic merit for rectal temperature (i.e, cows were less thermotolerant).

Table 1. Differences in rectal temperature and milk yield between slick and normal-haired Carora x Holstein cows in Venezuela.[a]

Breed type	Number of cows	Hair coat type	Rectal temperature, ^{o}F	305-d milk yield, lb
Carora	9	Slick	101.2 ± 0.3[bc]	10,032 ± 1,012[b]
Holstein x Carora	288	Slick	101.1 ± 0.1[b]	12,157 ± 191[c]
Holstein x Carora	75	Normal	102.0 ± 0.1[d]	11,253 ± 363[bd]
75% Holstein: 25% Carora	30	Slick	101.4 ± 0.1[c]	14,056 ± 550[e]
75% Holstein: 25% Carora	39	Normal	102.8 ± 0.1[e]	12,274 ± 495[cdf]
Holstein	93	Normal	102.4 ± 0.1[de]	13,429 ± 350[ef]

[a] From Olson et al. (2003)

[bcdef] Means with different superscripts differ (P<0.05).

Use of genetic tests like the Bovine SNP50 BeadChip should make it possible to identify genetic markers that predict thermotolerance that are not related to milk yield. Selection for these markers could lead to an increase in thermotolerance without having adverse effects on milk yield.

Introduction of Specific Genes from Other Breeds

Another approach for improving resistance to heat stress in dairy breeds is to introduce thermotolerance genes from other breeds. One such gene is called the slick gene. This gene, which was first described in the Senepol breed of beef cattle that originated in the Virgin Islands, is a dominant gene that causes very short hair growth. The slick gene has been introduced naturally into some Holstein cows in Puerto Rico and into a dairy breed in Venezuela called the Carora. In addition, Tim Olson of the University of Florida used crossbreeding with Senepol and backcrossing to introduce the slick gene into Holstein cows in Florida. Slick Holsteins are better able to regulate body temperature during heat stress than cows with normal hair (Dikmen et al., 2008).

In Venezuela, Olson et al. (2003) found that Carora-Holstein crossbreds with the slick gene had lower rectal temperatures and higher milk yield than Carora-Holstein crossbreds with normal hair length (Table 1). Further work is needed to determine whether cows with the slick gene have superior milk yield in Florida.

Summary

The likelihood that progress can be made in improving genetic resistance to heat stress in Holsteins and other dairy breeds has been improved by discovery of specific genes and gene markers present within and outside the Holstein breed that are related to thermotolerance. What is needed now is a better understanding of how selection for resistance to heat stress will affect overall economic performance of dairies in hot regions like Florida.

Research conducted at the University of Florida reported in this paper was supported in part by funding from the Southeast Milk Inc. Dairy Check-off Program.

Southeast Milk, Inc.
Dairy Check-Off

References

Battisti DS, Naylor RL. Historical warnings of future food insecurity with unprecedented seasonal heat. Science 2009;323:240-244.

Dikmen S, Alava E, Pontes E, Fear JM, Dikmen BY, Olson TA, Hansen PJ. Differences in thermoregulatory ability between slick-haired and wild-type lactating Holstein cows in response to acute heat stress. J Dairy Sci 2008;91:3395-3402.

Dikmen S, Hansen PJ. Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? J Dairy Sci. 2009;92:109-116.

Dikmen S, Cole JB, Null DJ, Hansen PJ. Heritability of rectal temperature and genetic correlations with production and reproduction traits in dairy cattle. J Dairy Sci 2012;95:3401-3405.

Hansen PJ, Aréchiga CF. Strategies for managing reproduction in the heat-stressed dairy cow. J Anim Sci 1999;77 Suppl 2:36-50.

Hayes BJ, Bowman PJ, Chamberlain AJ, Savin K, van Tassell CP, Sonstegard TS, Goddard ME: A validated genome wide association study to breed cattle adapted to an environment altered by climate change. PLoS One 2009;4:e6676.

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

Pritchard T, Coffey M, Mrode R, Wall E. Genetic parameters for production, health, fertility and longevity traits in dairy cows. Animal 2013;7:34-46.

Pszczola M, Aguilar I, Misztal I. Short communication: Trends for monthly changes in days open in Holsteins. J Dairy Sci 2009;92:4689-4696.

Thatcher WW, Collier RJ. Effects of climate on bovine reproduction. In: D. A. Morrow (Ed.) *Current Therapy in Theriogenology 2*. 1986; pp 301−309. WB Saunders, Philadelphia.

NOTES