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ISSUES IN GENETIC EVALUATION OF DAIRY CATTLE FOR HEAT TOLERANCE

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INTRODUCTION

In many parts of the world, Holsteins are exposed to heat stress at least seasonally. During heat stress, production and fertility decline while health problems increase. Heat stress can be managed by physical modification of the environment (shade, sprinklers and fans). Cooling is extremely effective in dry environments but less so in humid conditions. When humidity reaches 100% at night, evaporative cooling loses efficiency.

Ravagnolo *et al.* (2000) introduced a method to analyze heat stress with information from public weather stations on test days. Decreases in performance are considered to be a function of a temperature-humidity index (THI), which is the temperature equivalent to 100% humidity. Animals with less decline in performance at high THI are considered to be more heat tolerant. Analyses (Ravagnolo *et al.*, 2000; Ravagnolo and Misztal, 2000) revealed that 1) heat stress starts at about 19–21 °C at 100% humidity, 2) heat tolerance has a substantial genetic component, and 3) correlation between milk yield under mild temperatures and rate of yield decline under high THI is about −0.4. Consequently, animals that were continually selected in cold climates would gradually show worsening performance under heat stress. Similar results have been reported for dairy sheep (Finocchiaro *et al.*, 2005).

Previous studies raised many questions. Do public weather stations provide accurate information? Could more genetic variance be captured with on-farm measurement of THI? What level of heat stress occurs in various geographical locations? What influence do differing management systems have? Can genetic evaluation for heat stress be implemented on the national scale? How would heat-tolerant bulls be profiled? Does heat stress explain regional differences in U.S. bull evaluations? This paper discusses research conducted at the University of Georgia since 2002 on genetics of heat tolerance in dairy cattle.

NEW STUDIES

Loss of information with weather stations. West *et al.* (2003) studied rates of decline in milk yield at high THI based on on-farm measurements. Cows were at a similar lactation stage for the same parity. Daily THI was recorded over 3 months during the summer. Decline in milk yield was about 0.9 kg/THI unit (based on Fahrenheit temperature) over the THI threshold for heat stress compared with the decline of 0.2 kg/THI unit reported by Ravagnolo *et al.* (2000), who used test-day records from cows at different lactation stages on different farms and weather data from public weather stations. Freitas *et al.* (2005) reanalyzed the data of West *et al.* (2003) with added information from public weather stations that were 3 to >400 km from the farm (figure 1). The decline in milk yield relative to THI based on data from the nearest weather station was 1.1 kg/THI unit, which was larger than the decline relative to THI from on-farm measurements. Declines based on data from more remote weather stations were all >0.7 kg/THI unit. If the terrain is flat, data from well-managed weather stations can be as (or more) informative as on-site measurements. Data of Freitas *et al.* (2005) were expanded to include test days over 10 years and test days from a cluster of farms. In both cases, the decline in milk yield was <0.5 kg/THI unit. Only a fraction of response to heat stress is captured with test days as opposed to more frequent measurements, especially if cows are in different lactation stages. Test days provide only a few observations per year per herd, and accounting for past events that influence test-day milk yield, including daily heat fluctuations, is difficult.

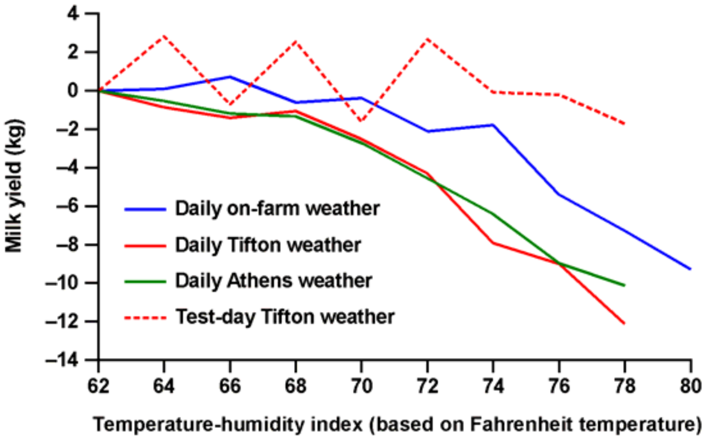

Figure 1. Change in milk yield as a function of a temperature-humidity index based on daily weather data from on farm, Tifton weather station (3 km away from farm) or Athens weather station (350 km away from farm) or on test-day weather station data from Tifton

Heat stress and management. Data from states with seasonal heat stress, such as South Dakota and parts of California, were studied. Milk yield of small herds (<100 cows) declined with increasing THI; however, smaller or no decline was found for large herds. In regions with less heat stress, usually only larger farms have cooling devices. In regions of low humidity, such devices are so efficient that effect of heat stress on milk yield is difficult to detect.

National genetic evaluation for heat stress. Bohmanova *et al.* (2005) developed a national genetic evaluation for heat stress. The U.S. national data set consisted of 57 million first-parity test-day records of 7 million Holsteins that calved from 1993 through 2004. Hourly temperature and relative humidity records were available from 202 public weather stations across the United States. Herds were assigned by distance to the nearest weather station. The model was test-day repeatability with random regression on a function of THI. Heat-tolerance predicted transmitting abilities (PTA) of sires ranged from −0.48 to 0.38 kg milk/THI unit > 72/day; general milk-yield PTA for sires were between −8.9 and 7.9 kg/day. Official U.S. genetic evaluations from February 2005 were compared for the 100 most and 100 least heat-tolerant sires based on estimated PTA for heat tolerance (table 1). Sires that were most heat tolerant transmitted lower milk yields with higher fat and protein contents than did sires that were least heat tolerant. Daughters of the most heat-tolerant sires had better type, worse dairy form, better udder and body composites, higher Type-Production Indexes, longer productive life, and higher daughter pregnancy rates than did daughters of the least heat-tolerant sires.

Many dairy producers in the southeastern United States are paid based on fluid milk. This pricing scheme provides incentives to select for cows with high milk yield without advantage for high protein content. Based on results of Bohmanova *et al.* (2005), sires of such cows would be expected to transmit the least tolerance for heat stress. In a separate analysis, regional distribution of bulls was examined based on heat tolerance. Sires used in the southeastern United States had lower heat tolerance than the average U.S. bull. Problems of heat stress in hot climates may be compounded by selection of less heat-tolerant sires.

Table 1. Mean official February 2005 predicted transmitting abilities and Type-Production Indexes for the 100 most and 100 least heat-tolerant U.S. Holstein bulls based on estimated predicted transmitting ability for heat tolerance

Trait	Most heat Tolerant	Least heat tolerant	Difference between most and least heat tolerant
Milk yield (kg)[A]	−751	373	−1124
Fat (%)[A]	0.08	−0.02	0.10
Protein (%)[A]	0.03	−0.03	0.06
Type[B]	0.11	−0.46	0.57
Dairy form[B]	−0.49	0.96	−1.44
Udder composite[B]	0.15	−0.58	0.73
Body composite[B]	0.07	−0.25	0.32
Type-Production Index[B]	984	948	35
Productive life (mo)[A]	−0.22	−1.12	0.90
Daughter pregnancy rate (%)[A]	0.14	−1.49	1.62

[A] Official source: Animal Improvement Programs Laboratory, USDA, Beltsville, MD.
[B] Official source: Holstein Association USA, Brattleboro, VT.

Genotype-by-environment interaction due to heat stress in the United States. Data and models from Bohmanova *et al.* (2005) were used to calculate separate breeding values for the northeastern and southeastern United States. Breeding values for mild conditions (northeastern United States) were calculated with and without an effect for heat stress. For bulls with >300 daughters in each region, genetic correlation between regional evaluations was 0.86 when heat stress was not considered for northeastern evaluations and 0.87 when heat stress was considered. Although evaluations were slightly more accurate when effect of heat stress was included in the model, probably less than a quarter of the variation due to heat stress was accounted for in the evaluations. Also, the correlation of <1.0 resulted partly from reduced evaluation accuracy because information was available only from a limited number of daughters. In reality, heat stress may account for a large part of the genetic variation between the regions.

CONCLUSIONS

To assess the impact of heat stress on dairy cattle, data from public weather stations may be as accurate as from on-farm recording stations. Use of test-day weather records captures only a small fraction of variability due to heat stress because no consideration is given to variability between test days. The response to heat stress depends on environment and management. A national evaluation for heat tolerance is possible. In the United States, daughters of heat-tolerant sires have lower milk yields with higher fat and protein percentages and lower scores for dairy form but longer productive life and greater fertility than do daughters of bulls with low heat tolerance. Selection on fluid milk alone reduces heat tolerance, but selection on Type-Production Index does not. Heat stress is partially responsible for genotype-by-environment interaction between cold and hot regions. Continued selection for milk yield without consideration of heat tolerance results in greater susceptibility to heat stress.

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