STUDIES ON GENETICS OF HEAT TOLERANCE IN HOLSTEINS

I. Misztal[1] and O. Ravagnolo[2]

[1] University of Georgia, Athens, 30602, USA
[2] INIA, Las Brujas, Uruguay

INTRODUCTION

One of the limiting factors in dairy production in hot climates is heat stress (Costa *et al.*, 2002). Under heat, animals produce less and have lower reproduction rates (Kadzere *et al.*, 2002). Management devices that reduce the impact of high temperature and humidity on the animal are available, but they are not fully efficient and not all production systems can afford them. Higher heat tolerance can be achieved by selecting or crossbreeding more heat-tolerant animals. Crossbreds in dairy cattle have been successful under extensive, but not intensive, management because of much lower production levels than purebreds (McDowell *et al.*, 1996). Therefore, the remaining option is to select more heat resistant purebreds, predominantly Holsteins.

Past studies on genetics of heat tolerance depended on measurements of individual animals for rectal temperatures, respiration rates or volumes of air inhaled and other physiological functions. Because of high cost of measurements and subsequently small volume of data from experimental studies, selection for heat tolerance could not be successful. Also, national genetic evaluation for heat tolerance using data from measurements on individual animals is unrealistic.

The purpose of this paper is to present methodology and results for genetic analyses of heat tolerance in dairy cattle using inexpensive weather information.

MATERIALS AND DATA

Heat Stress Model. The basic assumption of a model for heat stress is illustrated in Figure 1. It is assumed that that a trait is influenced by a temperature-humidity index (THI) around the day of recording. That influence is only above THI > t_0, and the slope past the threshold is assumed to be linear. There exists variation, both for the value of the trait at low THI, which can be called a regular effect, and for the slope, which can be called a heat-tolerance effect. The variation is partly environmental and partly genetic.

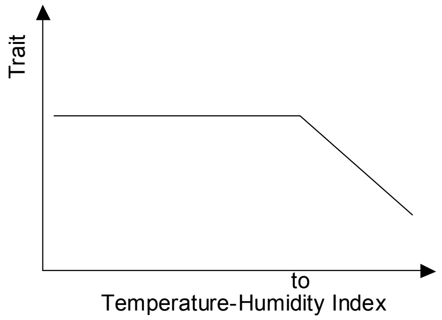


Figure 1. Relation between performance and heat stress

The assumptions above correspond to the following model:

$y_{i..mn}$ = "fixed" + a_m + $f(i)*v_m$ + p_m + $f(i)*q_m$ + $e_{i..mn}$

where y_{ijklmn} = records of an animal m in herd-year-day i and a set of "fixed" effects; a_m = regular additive effect of cow m, f(i) = heat stress function for herd-year-day i, v_m = additive effect of heat tolerance of cow m, p_m = regular permanent environmental effect of cow m, and q_m = permanent environmental effect of heat tolerance of cow m. The permanent environment effects are present only if there are repeated observations per animal. Regular and heat tolerance effects are assumed to be correlated :

$$Var\begin{bmatrix} a \\ v \\ p \\ q \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & A\sigma_{av} & 0 & 0 & 0 \\ A\sigma_{av} & A\sigma_v^2 & 0 & 0 & 0 \\ 0 & 0 & I\sigma_p^2 & I\sigma_{pq} & 0 \\ 0 & 0 & I\sigma_{pq} & I\sigma_q^2 & 0 \\ 0 & 0 & 0 & 0 & I\sigma_e^2 \end{bmatrix}$$

Under the heat-stress model, the genetic merit at heat-stress level f(i) for animal m is a function of heat stress:

$u_m [(f(i)] = a_m + f(i)*v_m$

The total genetic variance under heat stress level f(i) is:

$\mathrm{var}(a_m + f(i)*v_m) = \sigma_a^2 + 2f(i)\sigma_{av} + f(i)^2\sigma_v^2$,

The genetic correlation between regular and heat tolerance additive values can be computed as:

$$\mathrm{corr}(a, v) = \frac{\sigma_{av}}{\sigma_a \sigma_v},$$

and the genetic heritability for heat stress under heat stress level f(i) is:

$$h_v^2[(f(i)] = \frac{f(i)^2\sigma_v}{\sigma_a^2 + 2f(i)\sigma_{av} + f(i)^2\sigma_v + \sigma_a^2 + 2f(i)\sigma_{av} + f(i)^2\sigma_v + \sigma_e^2}$$

Also, the genetic correlation between cold and hot environments is a function of f(i):

$$\mathrm{corr}(a_m, a_m + f(i)*v_m) = \frac{\sigma_a^2}{(\sigma_a^2 + 2f(i)\sigma_{av} + f(i)^2\sigma_v)^{0.5}\sigma_a}$$

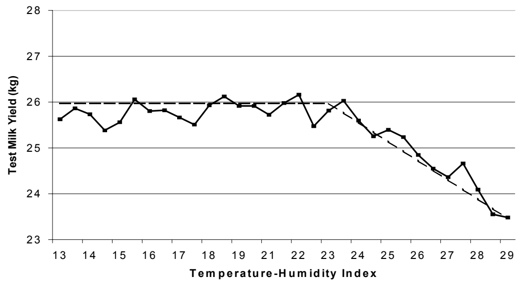
Data. Data were test day records for production from Holsteins in Georgia and Florida, and non-return (NR) information from Florida. The total number of animals in each state was approximately 15,000 with an average of 5 test days per cow. Additionally, daily temperature and humidity information was available from over 21 public weather stations in GA and FL. Initially, farms were matched to the closest weather station manually. Later, the assignment was automatic and was computed based on postal codes. Following fixed-model analyses by Ravagnolo *et al.* (2000), THI was computed as:

$\mathrm{THI}(t,h) = t - (1-h)(t-15)$

where t = maximum daily temperature in °C; h =minimum relative humidity. The heat stress function was defined as:

$$f(i) = \begin{cases} \mathrm{THI}(t_i, hum_i) - \mathrm{THI}(t_0, 100) & \text{if } \mathrm{THI}(t_i, hum_i) > \mathrm{THI}(t_0, 100) \\ 0 & \text{otherwise} \end{cases}$$

Analyses. Initially, all the data sets were analyzed with fixed models with THI as a class effect. Then, test days for production from Georgia were analyzed by single-trait models. Fixed effects were herd-test-day, class of age, days in milk and milking frequency. Also, first lactation test days and non-return rate at 90 days from Florida were analyzed jointly. For NR90, herd-test-day was replaced by herd-year-season, milking frequency was eliminated, and a covariable was added for class of milk production. All analyses were by EM REML (Misztal, 1999).



Phenotypic curves. Least square means for classes of THI as computed by Ravagnolo and Misztal. (2000 b) are shown in Figure 2.

Figure 2. Least square means of test day milk yield as a function of Temperature-Humidity Index

Subsequently, the threshold point for the onset of heat stress was set to t_0=22, which would be equivalent to 22°C at 100% humidity. The rate of decline after the threshold was approximately 0.40 kg/ °C. A similar graph was constructed by West *et al.* (2000) using on-farm weather recording. They obtained a response rate over 2 times higher. Thus the weather information from public weather stations is not as accurate as from on-farm recording, but it can be obtained at a very low cost. Two times smaller estimate mean that effects of heat stress obtained with public weather stations may be underestimated 2 times and variances 4 times.

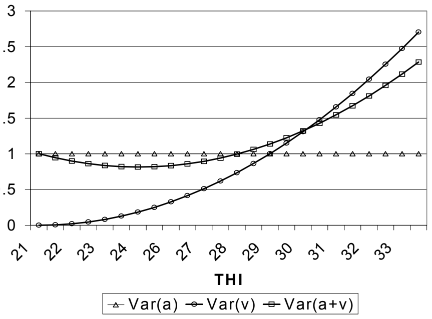


Figure 3. Regular, heat-tolerance and composite variances for Non Return 90 as function of THI

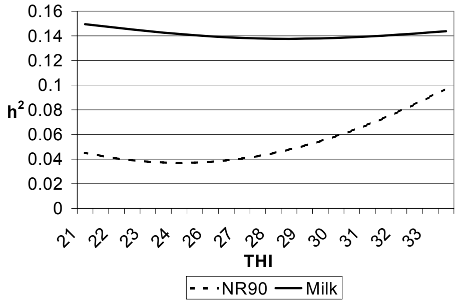


Figure 4. Heritabilities of Non Return 90 and test day milk as functions of THI

Genetic analyses. For milk, protein and fat, the genetic correlations between regular and heat tolerance effects were between -0.3 and -0.4 (Ravagnolo and Misztal, 2000 a; Ravagnolo and Misztal, 2002). This indicates that selection under temperate climates reduces heat tolerance.

Heritability of NR90 increased with THI indicating good selection potential for reproduction under hot temperatures. Similarity in performance across environments is usually shown by high genetic correlations. Such a correlation between milk yield in mild and hot environments is shown in Figure 5. The correlation is 1.0 for THI below the threshold but decreases to 0.8 at

THI corresponding to 30 °C, with the actual correlation possibly lower with on-farm temperature recording. High correlations reported in the literature (Weigel *et al.*, 2001) could be due to cows are exposed to heat stress for only part of the year, and because cows may be cycled to avoid production during the hottest period.

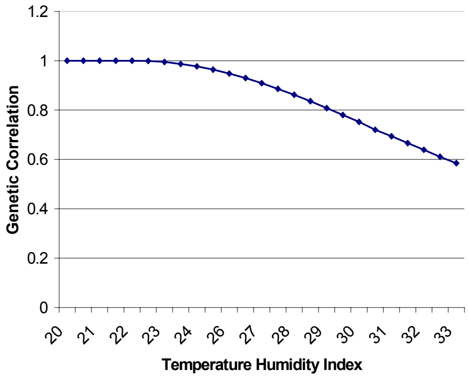


Figure 5. Genetic correlations between milk yield in milder climates and milk yield at given THI

Future work. The model for heat stress can be improved in many points. First, a repeatability model can be converted to a random regression model. Second, thresholds of sensitivity to THI can be estimated separately based on geographical regions, weather stations, or heat management. Linear regression on heat stress function can be converted to a higher order random regression to account for shapes of lactations (production traits only) and for nonlinear relationship between a trait and THI. The heat stress function may be modified to account for permanent effect of past heat stresses (Maltz *et al.*, 2000), and for different management practices on the farm.

CONCLUSIONS

Genetic effect of heat stress is high at higher temperatures indicating possibility of genetic selection. The genetic correlation between heat tolerance and regular effects for production and NR is antagonistic, meaning that selection for traditional proofs obtained with records from colder regions will decrease heat tolerance in hot regions. With the proposed methodology, national evaluation for heat tolerance is a possibility. Even herds located in temperate climates but briefly exposed to heat stress during the summer time would contribute to such an evaluation.

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