Studies on heat stress in dairy cattle and pigs

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Introduction

Under heat stress, production decreases, fertility decreases even more, and animals have a decreased chance of survival (St. Pierre et al., 2003). Heat stress can be mitigated in two ways: by environmental management, such as cooling devices or timing of reproduction West, 2003), or by genetic selection (Misztal et al., 2002). Heat stress in farm animals is likely to become a bigger problem due to global warming.

Ravagnolo et al. (2002) developed a model to evaluate the genetics of heat stress in dairy cattle. This model utilizes phenotypic data augmented by daily records from public weather stations. It assumes that heat stress reduces performance after a fixed threshold of a temperature-humidity index (THI) and that this reduction is linear with THI. Such a threshold was estimated at 19°C THI for reproduction and 22°C for production. The genetic components for heat tolerance were sizeable at higher temperatures, and the genetic correlation between performance at low temperatures and rates of decline at high THI was negative. The last finding means that the current selection for (re)production in colder regions decreases heat tolerance.

Research on heat stress at the University of Georgia was summarized at WCGALP '02 and '06 (Misztal et al., 2002; Misztal et al., 2006). The purpose of this paper is to present new research.

Material and methods

Heat stress in first three parities in Holsteins. Studies by Ravagnolo et al. (2002) involved only the first parity. Aguilar et al. (2009) looked at the genetics of heat stress in three parities. Estimates of genetic parameters are summarized in Table 1.

Table 1. Variance component estimates for the first, second, and third parities of milk, fat and protein using a multiple trait repeatability test-day model

Parameter	Milk			Fat (kg*100)			Protein (kg*100)		
	1	2	3	1	2	3	1	2	3
REG	5.6	7.5	6.5	74.0	93.9	109.0	42.5	56.8	52.2
HEAT	3.7	7.2	8.9	37.0	74.9	141.7	21.7	47.8	107.8
CORR	-0.46	-0.38	-0.47	-0.39	-0.39	-0.30	-0.43	-0.36	-0.50

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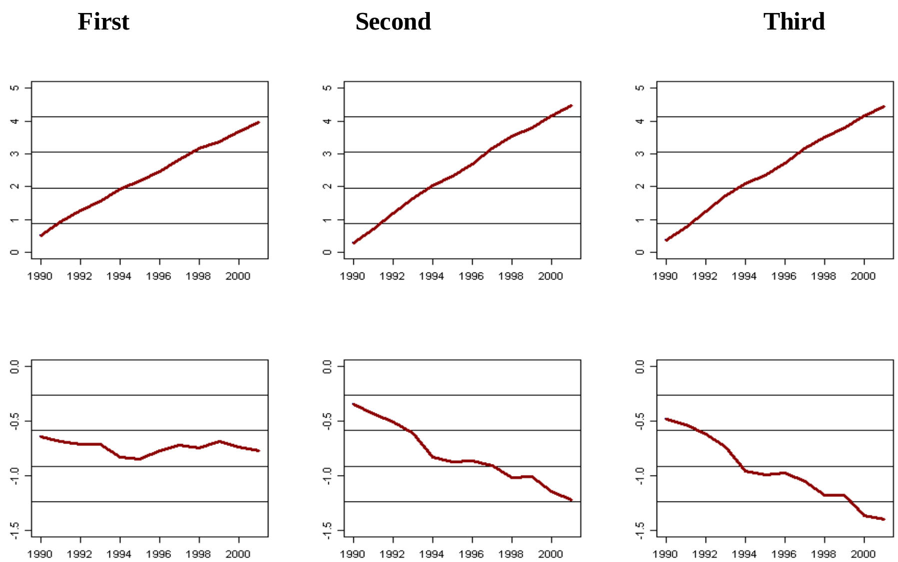
REG = = regular genetic variance; HEAT = heat tolerance variance at 5C over the threshold; CORR = correlations between REG and HEAT.

While the regular genetic variance increased from parity 1 to 3 by up to 50%, the variance due to heat stress increased up to five times. Much higher sensitivity of later lactation cows due to heat stress may be a reason for strong culling from parity to parity; in the analyzed data, only 25% of first parity cows had third parity records.

Trends for heat stress for milk and DO. Aguilar et al. (2010b) applied the same model to a U.S. national data set for Holsteins. Trends for regular and heat stress effects are in Figure 1. While the trends for milk are all favorable, the trends for heat stress are flat in the first parity and declining in the subsequent parities. While negative selection for heat stress in the first parity is compensated by selection for fertility and survival in the first parity, such compensation is insufficient in later parities due to higher genetic component for heat stress. Negative trends for Days Open under heat stress were observed by Pszczola et al. (2009). Their study of "heat-tolerant" bulls found that a disproportionate fraction of bulls used during the hot season were those with low semen price, indicating a specific management of heat stress for reproduction that also could cause underestimation of the real effect of heat stress.

Figure 1. Trends in milk yield in the first three parities for the regular component (upper) and the heat stress component (lower).

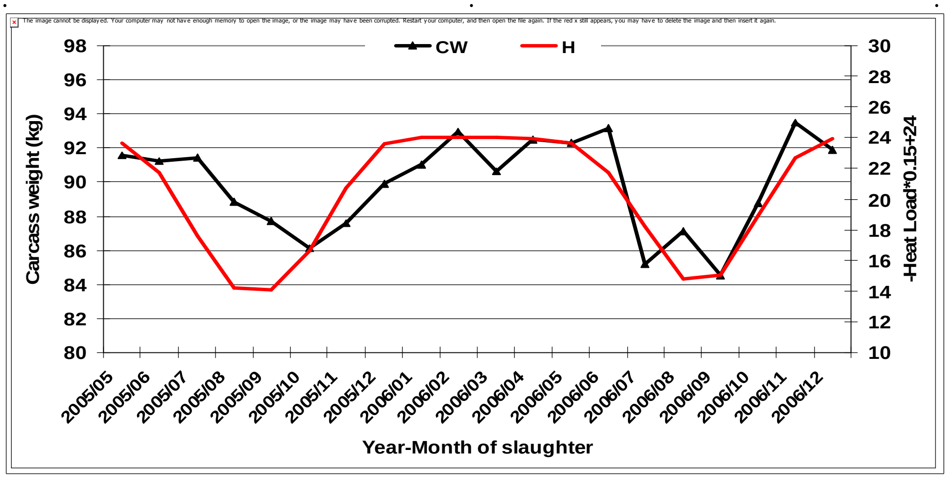


Heat stress and genomic information. In first parity records only old bulls with a large number of daughters can be accurately predicted for heat tolerance (Bohmanova et al., 2008). Use of later parities may increase accuracies due to a higher genetic component for heat stress in these parities; however, such accuracies may be insufficient for practical use, especially for young bulls. A dramatic improvement in accuracy could be obtained by the use of genomic information. The simplest and perhaps most efficient methodology in such a case would be the enhancement of pedigree-based relationships based on genomic information (Misztal et al., 2009; Aguilar et al., 2010a).

Effect of heat stress on growth in pigs. Heat stress has a negative effect not only for milk production but also for growth. However, modeling that effect is complicated because only the final weight is usually available and the animal grows continuously over various phases of heat stress.

Zumbach et al. (2008a) assumed that pigs are affected by heat stress only during the last n weeks of growth and that each degree of THI over a threshold reduced average daily gain by a proportionate amount. With field data they estimated n=10 weeks and a threshold of 20°C. Based on such assumptions, heat loads were constructed as a function of month of harvesting. The heat loads and average carcass weights are shown in Figure 2.

Figure 2. Estimated heat loads and average carcass weights in pigs.



Such a defined heat load was used in genetic analyses (Zumbach et al., 2008b). The heritability of carcass weight under the maximum heat load was twice as high (0.28) as under the minimum heat load (0.14), and the correlations between performances under the two extremes were only 0.4. Therefore, growth under mild and hot conditions are different traits, and selection for performance under hot conditions is likely to be efficient.

Variable threshold of heat stress

Studies by Ravagnolo et al. (2002) assumed a constant threshold of heat stress for different animals. Such an assumption was easy to model although it was not realistic. Sanchez et al. (2009) developed a Hierarchical Bayes model where both threshold of heat stress and rate of decline from heat stress could be estimated. Based on Holstein data, he found that both effects have large genetic components; however, their correlation was -0.9. This means that animals with a higher threshold of heat stress have lower rates of decline under increasing temperatures. Thus animals identified as having a lower rate of decline would almost automatically have a higher threshold of response to heat stress. Therefore a simple model assuming constant threshold is sufficiently accurate.

Conclusions

Intensive selection in moderate climates decreases heat tolerance. Drops in productivity due to decreased heat tolerance may intensify due to increased heat stress, particularly during heat waves. In dairy cattle, the susceptibility to heat stress strongly increases with parity and may be responsible for strong culling.

Methodologies exist to evaluate animals for heat tolerance. Such methodologies are applicable for traits measured at a specific time point (e.g., daily milk yield, success of insemination) as well as for traits averaged over a lifetime (e.g., carcass weight). Despite limitations and assumptions, these models may be sufficient to correctly rank animals for heat tolerance. Accuracy of selection of young animals can substantially be improved by incorporation of genomic information.

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