

Genetic evaluations for heat tolerance in meat animal species

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Summary

Climate change presents new problems for agriculture production such as heat stress. Heat stress causes a large economic impact in addition to animal welfare concerns across livestock industries. Heat stress solutions include management changes as well as genetic selection to improve heat tolerance. We investigated the existence of genotype-by-environment interactions based on heat stress for beef cattle and swine. Beef cattle data included 82,669 weaning and 69,040 yearling weights, and swine data included 207,233 170-d weights on purebreds and 228,191 hot carcass weights on crossbreds. An index of temperature and humidity characterized heat stress, and the cumulative heat stress after a threshold (heat load) was modelled as a reaction norm. Purebred swine had no genotype-by-environment interaction for heat stress because of the quality of the production environment, but genetic differences existed in the crossbred animals for heat tolerance. A similar interaction occurred for the direct component of cattle growth. Strong genetic correlations were present for the maternal component of cattle growth, which was unexpected because a genotype-by-environment interaction exists for milk production in dairy cattle. Improving thermal tolerance would be a step toward alleviating animal welfare concerns associated with heat stress. Global meat animal production would benefit from selection tools for improving heat tolerance and for developing a more resilient food supply. As climate variability increases, research will need to shift from assessing current conditions to incorporating the increasing variability of weather conditions.

Keywords: genotype-by-environment interaction, heat stress

Introduction

Climate change is a common factor affecting animal agriculture globally. Temperature and moisture variability are influencing livestock performance and crops used for livestock feed. Intense selection for production traits in developed countries has reduced the plasticity of livestock breeds in developing countries with less ideal environmental conditions. Germplasm is passing from developed to developing countries with greater frequency (Gollin et al., 2009) making vulnerability to climate change a global concern. Efficient use of genetic resources, such as using a tropically-adapted breed in a hot climate, is imperative to feed the world population. Possessing the biological knowledge and statistical tools to manage the adaptation of livestock is increasingly important, particularly for thermal tolerance.

One solution to improve livestock production in challenging environments is genetic selection where improvements can be accumulated across generations. Much research exists

for methods to select livestock and plants to better match genetics and environment. Reaction norms can be used to model genetic merit as a function of the environment. Ravagnolo and Misztal (2000) proposed using temperature-humidity index (THI) in a reaction norm for milk yield. This methodology has been used extensively to research heat tolerance in dairy cattle. Since then, these methods have been adapted for growth traits in swine (Zumbach et al. 2008; Fragomeni et al., 2016). The aim of this research was to investigate the presence of heat stress and to use existing methods to develop genetic predictions for heat tolerance in meat animal species.

Material and methods

We used beef cattle and swine data to address the objective of measuring heat tolerance in meat animals. The beef cattle population was a purebred black Angus population, which is the largest single beef breed in the US. Alternatively, the swine population consisted of purebred nucleus and crossbred commercial populations.

Beef cattle data

The American Angus Association (St. Joseph, MO) provided 82,669 weaning weights (WW; 205 d) and 69,040 yearling weights (YW; 365 d) for purebred Angus cattle born in the Upper South region of the US (Bradford et al., 2016b). This region was selected based on the hot, humid climate. Three-generation pedigrees were used in all analyses with 169,291 animals for WW and 149,963 animals for YW. Further details are provided in Bradford et al. (2016a)

Swine data

Smithfield Premium Genetics (Rose Hill, NC) provided 207,233 170-d weights on purebred, nucleus animals and 228,191 hot carcass weights on crossbred, commercial animals. The combined pedigree contained 553,442 animals. Purebreds were raised in North Carolina and Texas, and crossbreds were raised in Missouri and North Carolina. In each pair of states, genetic connections existed between states with 20% of animals having half siblings in the other state. Environmental conditions were more favourable for purebreds as they had greater space per animal and better barn cooling systems. Further details are provided in Fragomeni et al. (2016).

Heat load function

Temperature-humidity index (THI) based on maximum daily temperature and minimum relative humidity was used as the environmental descriptor for assessing heat stress. Weather information was extracted from public databases from airport weather stations, and was associated with records based on zip code and measurement date.

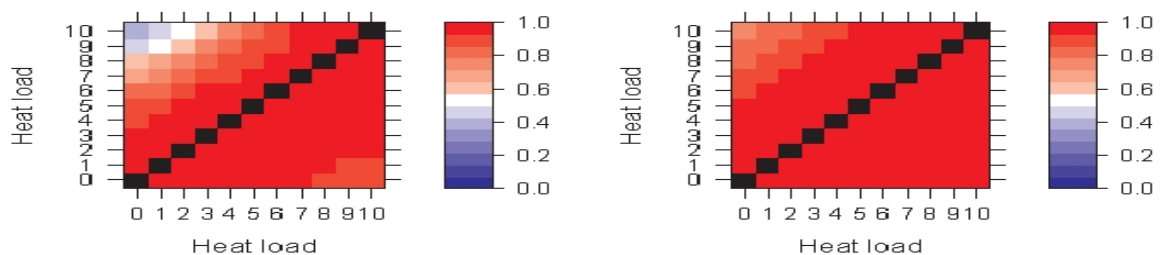
Heat load functions were developed for both species following the methodology of Zumbach et al. (2008). With this function, heat stress was assumed to be additive during a period prior to measurement dates. A break point was modelled such that THI less than the threshold did not contribute to heat load, and the degrees of THI greater than the threshold contributed to the total heat load.

For each species, the heat load was used in a reaction norm model. Each data point was associated with a heat load value, and genetic parameters were estimated as a function of heat load. Both species had models with random regressions on slope and intercept parameters. Genetic correlations are presented based on heat load.

Results and Discussion

Beef producers modify calving seasons to fit different environmental conditions including forage availability and temperature. Despite the expectation of heat stress in the Southern US, no significant differences existed in weights from spring compared with fall calving, but fall calving was more common in this region to avoid heat stress during breeding and weaning (Bradford et al., 2016b).

Within the reaction norm in cattle, most genetic correlations were very strong (Figure 1). Direct WW had correlations less than 0.5 for large heat load differences. These results are indicative of a significant genotype-by-environment interaction for WW direct. Conversely, genetic correlations were very strong for YW and both maternal effects. Previous research found weaker maternal genetic correlations (Santana et al., 2015), and complexities of modelling maternal and maternal permanent environment effects may have contributed to the differing conclusions.



A.

B.

Figure 1. Heat map of direct (above diagonal) and maternal (below diagonal) genetic correlations from the reaction norm for weaning (A) and yearling (B) weights.

Weaker genetic correlations were expected for the maternal effect because a genotype-by-environment interaction exists for milk production in dairy cattle (Ravagnolo and Misztal, 2000; Bohmanova et al., 2008). One contributing factor is the difference in milk production between beef and dairy cows. A reduction in milk production for a low-producing beef cow may be less severe than that of a high-producing dairy cow. Additionally, the beef cow may be maintaining milk production while sacrificing reproduction and maintaining body condition. Maternal weaning weight is an indirect measure of milk production as the calf could be consuming forages to make up for any reduction in the dam's milk production and thus maintaining growth.

In purebred swine, no evidence existed for a genetic component of heat tolerance with genetic correlations across environments all greater than 0.95. Nucleus breeding animals were

raised in better environments with more space, better sanitation, and better cooling systems; hence, heat stress would be less in this controlled environment. Yet, these environmental modifications increase the cost of production making these systems too expensive for commercial production. Because of the lack of response to heat stress in purebred populations, heat tolerance should be assessed in commercial populations with a different production environment.

In contrast to the purebred swine results, genetic differences existed in the crossbred animals for heat tolerance (Figure 2). Genotype-by-environment interactions existed across states, within state, and between states. Genetic correlations decreased faster in Missouri than in North Carolina despite having more heat stress in North Carolina. Genetic correlations were less than 0.50 between heat-stressed conditions in North Carolina and Missouri indicating a need for region-specific predictions of crossbred performance.

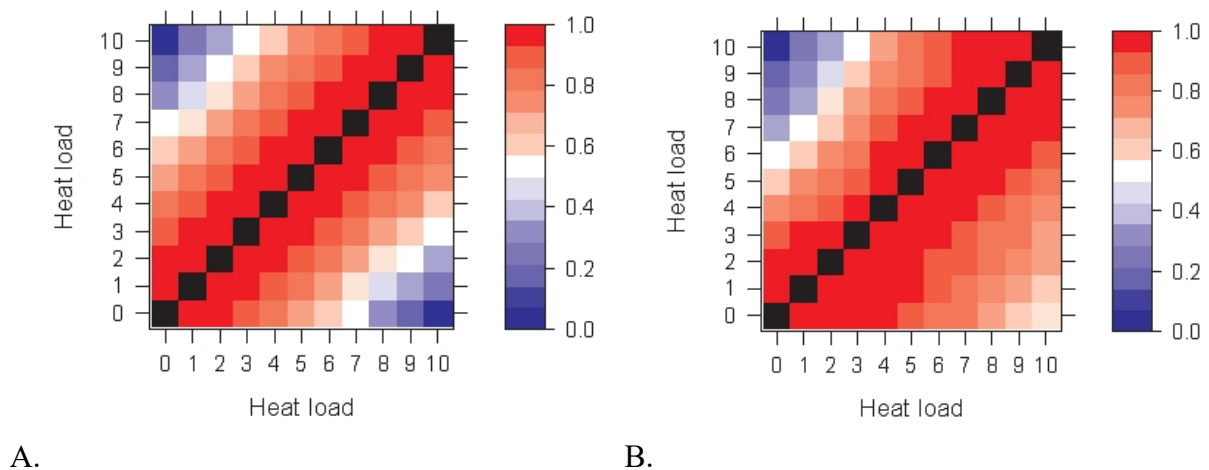


Figure 2. Heat map of direct genetic correlations from the reaction norm across states (A) and within states (B) for Missouri (above diagonal) and North Carolina (below diagonal).

Selection for improved heat tolerance requires recording phenotypes in challenging environments. Animals need to be given the opportunity to express genetic differences meaning environmental conditions should be less than optimal. Obtaining phenotypes from environments of interest is important for developing validation strategies for reaction norms because of the limited number of records for environmental extremes. Selection can be challenging when elite animals have better environments than typical in commercial production.

The livestock industry could benefit from environment-specific genetic predictions. Selecting the top sire using traditional selection tools may not result in the best offspring in hot environments. More targeted selection of genetics would be more profitable for the producer when marketing their final product. Yet, implementation is not straightforward for this type of genetic evaluation. Publishing the slope coefficients may cause confusion for producers using these tools. Publishing EBV at specific heat loads makes the number of published EBV more overwhelming for producers. In any case, the educational effort

associated with a heat tolerance evaluation will be the key factor for the successful uptake of the technology.

Conclusions

Selection for improved heat tolerance is feasible by using environment-specific genetic predictions in meat animals. Although purebred swine did not show signs of heat stress, heat stress was detected for crossbreds because animals were challenged more in the commercial environment. Improving thermal tolerance would be a step toward alleviating animal welfare concerns associated with heat stress. Further research is needed in other traits, breeds, and species to develop a holistic understanding of the genetic control of adaptability. Additionally, more research in diverse climates would contribute to the characterization of livestock resiliency and would help to target areas needing improvement. As climate variability increases, research will need to shift from assessing current conditions to incorporating the increasing variability of weather conditions.

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