Published March 2, 2017

BREEDING AND GENETICS SYMPOSIUM: Resilience of livestock to changing environments[1]

J.B. Cole,*[2] J.M. Bormann,† C.A. Gill,‡ H. Khatib,§ J.E. Koltes,# C. Maltecca,|| and F. Miglior¶**

*Animal Genomics and Improvement Laboratory, ARS, USDA, Beltsville, MD 20705; †Department of Animal Sciences and Industry, Kansas State University, Manhattan 66506; ‡Department of Animal Science, Texas A&M University, College Station 77843; §Department of Animal Science, University of Wisconsin-Madison 53706; #Department of Animal Science, University of Arkansas, Fayetteville 72701; ||Department of Animal Science, North Carolina State University, Raleigh 27695; ¶Centre for Genetic Improvement of Livestock, Department of Animal BioSciences, University of Guelph, ON, Canada; **Canadian Dairy Network, Guelph, ON, Canada

J. Anim. Sci. 2017.95
doi:10.2527/jas2017.1402

The Breeding and Genetics Symposium titled "Resilience of Livestock to Changing Environments" was held at the Joint Annual Meeting, July 19–24, 2016, in Salt Lake City, UT. The objective of the symposium was to provide a broad overview of recent research on the effects of changing environmental conditions on livestock. Topics covered by the speakers included a review of the variation in response to heat stress and its effects on metabolic parameters and energy demands in pigs and cattle, production and reproduction in livestock and aquaculture species, the development of genetic improvement programs to produce more robust animals, and the use of gene introgression to develop heat-resistant animals. Substantial discussion focused on the tradeoffs involved in producing robust, high-producing livestock. The symposium included 6 invited presentations, each of which is discussed below.

Modern livestock have been selected to efficiently convert feed into food and fiber for human use, but the most productive breeds generally require intensive management to maintain high levels of production. Most major livestock breeds in the U.S. are derived from animals that evolved in temperate climates, such as Holstein dairy cattle. Unfortunately, the climate in the southern states is hot enough to cause several months per year of heat stress. Heat stress occurs when the environmental temperature exceeds an animal's thermoneutral point, and its effects include decreased dry matter intake, reduced water consumption, depressed production, and impaired fertility (e.g., West, 2003). These effects will become more common in areas that have not previously experienced heat stress as global temperatures continue to rise (IPCC, 2014). Technological interventions, including fans, sprinklers, and shade structures, can be used to ameliorate many of the effects of heat stress, but they provide only temporary relief. Genetic selection for greater thermotolerance is possible and will result in cumulative, permanent gains (Aguilar et al., 2009; Dikmen et al., 2012, 2015).

The opening speaker in the symposium, Dr. L.H. Baumgard (Iowa State University, Ames), presented a talk titled "Production, biological, and genetic responses to heat stress in ruminants and pigs". This set the stage for the rest of the symposium by reviewing the current state of knowledge of bioenergetics and metabolic changes in ruminant and monogastric species in response to heat stress (Baumgard et al., 2016). There is now an extensive literature on physiological changes at the tissue and cellular levels in response to high temperatures. Of particular interest were the results that thermoregulatory and production responses to heat shock are only marginally related to one another, and changes in feed intake under heat stress are poor predictors of production losses. Such solid grounding in physiology and metabolism is necessary to ensure that effective strategies are used to reduce the effect of heat stress.

The second speaker was Dr. M.J. Carabaño (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Madrid, Spain), who gave a presentation titled "Breeding for resilience to heat stress

[1]A symposium held at the Joint Annual Meeting, July 19–24, 2016, Salt Lake City, UT. The symposium was sponsored, in part, by Neogen Corporation (Lansing, MI), with publication sponsored by the American Society of Animal Science and the *Journal of Animal Science*.

[2]Corresponding author: john.cole@ars.usda.gov

Received January 17, 2017.
Accepted January 18, 2017.

effects: A comparison across dairy ruminant species". Her talk reviewed the use of meteorological and production data to select for more heat-tolerant dairy cows, biomarkers and physiological parameters, and genes associated with heat stress to select for more heat-tolerant dairy cows (Carabaño et al., 2017). Although production and temperature data are abundant, they may not provide very precise selection criteria, which is consistent with the opening presenter's comments on the relationships of thermoregulatory responses to changes in production. The best approach to genetic improvement may be to combine imprecise-but-cheap and precise-but-expensive phenotypes in a selection index.

The third talk by Dr. P. Sae-Lim (Nofima, Ås, Norway), which was titled "Climate change and selective breeding in aquaculture", provided a different perspective. Because of physiological differences between mammals and fish, and difficulties in affordably changing water conditions on a wide scale, rising water temperatures rise and other environmental changes (e.g., acidity) are particularly challenging for aquacultured species. Dr. Sae-Lim proposed a 3-pronged approach to these problems: 1) selection for robustness to produce fish that are less vulnerable to diseases while thriving in a wide range of temperatures; 2) selection for greater feed efficiency and reduced greenhouse gas emissions to reduce the impacts of aquaculture on climate change; and 3) increased adoption of breeding programs in aquaculture to result in more efficient use of feed, water, and land (Sae-Lim et al., 2017). This will ultimately reduce the input costs and environmental impacts per kg of fish produced. The techniques used to develop holistic breeding goals and increase the adoption of genetic improvement in fish can be applied to all species. The latter point is important because AI rates in both beef and dairy production are not as high as they should be, reducing genetic gain in herds that use natural service.

The fourth speaker, Dr. R.J. Spelman (Livestock Improvement Corporation, Hamilton, New Zealand), gave a talk titled "Introgression of genes conveying resistance to heat stress into cattle populations using the "Slick" genetic variant as a model". In contrast to the broad perspectives provided by the first 3 speakers, Dr. Spelman made a detailed case for the introgression of the so-called 'slick' allele into *Bos taurus* dairy cattle (Davis et al., 2017). The slick phenotype is the result of a frameshift mutation in the prolactin receptor in the Senepol breed that results in a truncated protein, and slick cattle have thinner coats and greater sweating rates than wild-type cattle. A 5-yr project is underway in New Zealand to introgress the slick allele from Senepol cattle into dairy breeds with the goal of producing homozygous bulls by inter-crossing F_2 lines. Gene editing may provide a faster alternative than traditional breeding schemes (e.g., Proudfoot et al., 2015), even faster than using advanced reproductive technologies to shorten the time required, but the regulatory environment around the use of that technology in food animals remains uncertain and consumer demand for adoption of such technologies is low. Regardless of the technology used, the introgression of the slick locus into dairy breeds will produce cattle that perform better in hot climates without environmental modifications or pharmacological interventions. This would be of great value to dairy farmers in the southern U.S., as well as tropical and subtropical regions around the world.

Dr. P.J. Hansen (University of Florida, Gainesville), the fifth speaker, focused on the topic of "Genetic solutions to infertility caused by heat stress". In cattle, heat stress negatively affects fertility in 2 ways: 1) through the physiological adjustments used to minimize hyperthermia during heat stress, and 2) the direct deleterious effects of elevated body temperature on the gamete and embryo (Hansen et al., 2016). In addition to the slick mutation discussed by the fourth speaker, other genetic variants confer cellular resistance to heat shock, including a mutation in the promoter of *HSPA1L* (e.g., Ortega et al., 2016). Selection for the beneficial allele of *HSPA1L*, as well as other genes controlling cellular resistance to heat shock, may reduce the damage to the oocyte and embryo caused by elevated body temperature. The harmful effects of heat stress begin at the embryonic stage in cattle, and continue throughout the lifespan. Genetic selection for alleles that confer resistance to these effects will provide life-long benefits.

The final speaker of the symposium, Dr. I. Misztal (University of Georgia, Athens), presented the important topic of "Resilience and lessons from studies in genetics of heat stress". After reviewing previous research on genetics of heat tolerance in cattle and pigs, Misztal suggested that current selection strategies may be adequate if they: 1) are accompanied by constantly improving management techniques; 2) make use of data from commercial as well as nucleus herds; and 3) include traits important under climate change (e.g., mortality; Misztal, 2017). He also began an interesting discussion about the language used to discuss desirable goals in selection programs, particularly 'robustness' and 'resilience', with the former focusing on current variation among environments and the latter on future variation. He concluded by recommending that we use management strategies to address short-term challenges from changing environments, and that we use genetic selection to address long-term problems.

This Breeding and Genetics symposium was developed for the purpose of providing a comprehensive overview of current knowledge about the effects of hot environments on livestock species, and the 6 speakers did an excellent job of doing that. Specific, actionable recommendations were made that can be addressed using existing tools, and important research questions that may lead to new tools were raised. Changing environments will force livestock and aquaculture producers and researchers to develop innovative solutions to adapt to those changes, and to continue providing high-quality, affordable food and fiber to a growing human population.

LITERATURE CITED

Aguilar, I., I. Misztal, and S. Tsuruta. 2009. Genetic components of heat stress for dairy cattle with multiple lactations. J. Dairy Sci. 92:5702–5711. doi:10.3168/jds.2008-1928

Baumgard, L. H., J. T. Seibert, S. K. Kvidera, A. F. Keating, J. W. Ross, and R. P. Rhoads. 2016. Production, biological, and genetic responses to heat stress in ruminants and pigs. J. Anim. Sci. 94 (E-Suppl. 5):190. (Abstr.) doi:10.2527/jam2016-0401

Carabaño, M. J., M. Ramón, C. Díaz, A. Molina, M. D. Pérez-Guzmán, and J. M. Serradilla. 2017. Breeding for resilience to heat stress effects in dairy ruminants. A comprehensive review. J. Anim. Sci. 95: (in press). doi:10.2527/jas.2016-1114

Davis, S.R., R.J. Spelman, and M.D. Littlejohn. 2017. Breeding heat tolerant dairy cattle: The case for introgression of the “slick” prolactin receptor variant into Bos taurus dairy breeds. J. Anim. Sci. 95: (in press). doi:10.2527/jas.2016-0956

Dikmen, S., J. B. Cole, D. J. Null, and P. J. Hansen. 2012. Heritability of rectal temperature and genetic correlations with production and reproduction traits in dairy cattle. J. Dairy Sci. 95:3401–3405. doi:10.3168/jds.2011-4306

Dikmen, S., X. Wang, M. S. Ortega, J. B. Cole, D. J. Null, and P. J. Hansen. 2015. Single nucleotide polymorphisms associated with thermoregulation in lactating dairy cows exposed to heat stress. J. Anim. Breed. Genet. 32:409–419. doi:10.1111/jbg.12176

Hansen, P. J., S. Dikmen, J. B. Cole, M. S. Ortega, and G. E. Dahl. 2016. Genetic solutions to infertility caused by heat stress. J. Anim. Sci. 94 (E-Suppl. 5):192. (Abstr.) doi:10.2527/jam2016-0405

IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core writing team. In: Pachauri, R. K., and L. A. Meyer, editors, IPCC, Geneva, Switzerland.

Misztal, I. 2017. Resilience and lessons from studies in genetics of heat stress. J. Anim. Sci. 95: (in press). doi:10.2527/jas.2016-0953

Ortega, M. S., N. A. Rocha-Frigoni, G. Z. Mingoti, Z. Roth, and P. J. Hansen. 2016. Modification of embryonic resistance to heat shock in cattle by melatonin and genetic variation in HSPA1L. J. Dairy Sci. 99:9152–9164. doi:10.3168/jds.2016-11501

Proudfoot, C., D. F. Carlson, R. Huddart, C. R. Long, J. H. Pryor, T. J. King, S. G. Lillico, A. J. Mileham, D. G. McLaren, C. B. A. Whitelaw, and S. C. Fahrenkrug. 2015. Genome edited sheep and cattle. Transgenic Res. 24:147–153. doi:10.1007/s11248-014-9832-x

Sae-Lim, P., A. Kause, H. A. Mulder, and I. Olesen. 2017. Climate change and selective breeding in aquaculture. J. Anim. Sci. 95: (in press). doi:10.2527/jas.2016-1066

West, J. W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:2131–2144. doi:10.3168/jds.S0022-0302(03)73803-X