Modern Research and Modern Tools to Match Cattle Genetics to the Environment

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Introduction

Matching cattle genetics to the environments they produce in is an important goal in beef production systems, as it maximizes efficiency, productivity, and animal welfare. However, achieving this goal requires an understanding of the interplay between genetics and the environment. My group's research explores the genetic basis of environmental adaptation in beef cattle, with a focus on identifying local adaptation, enhancing environmental resilience, and creating selection tools for sustainable beef production.

Genetics and Environment

Early research efforts, such as the Montana and Florida Hereford line-by-location studies conducted from 1966 to 1974 (Burns et al., 1979; Koger et al., 1979; Pahnish et al., 1983; Pahnish et al., 1985), demonstrated that genotype-by-environment interactions have an important impact on beef production. However, after the 1980s, this research was mostly ignored, especially as more emphasis was placed on the prediction of genetic merit. Further, beef genetics were more easily moved around the country with increased use of artificial selection. Troy Rowan, as a graduate student in my group, researched associations between genotype and time, which indicate changes in allele frequency due to selection. He looked at this not just on a national level, but also selection that was specific to individual eco-regions. In every case for which he found eco-region specific selection, the allele frequencies were converging towards breed averages. This result indicates the loss of local, environment-specific genetic adaptation (Rowan et al., 2021). Farmer and ranchers should not be blamed for the loss of this environmental genetic adaptation, because there simply were not tools available to select for environmental adaptation. To address this challenge, my group's research works to identify region-specific loci associated with environmental selection and develop genomic prediction models tailored to diverse environmental and management contexts.

Low Tech Approaches

Typical selection criteria often fail to capture the response of cattle to environmental stressors. However, by prioritizing traits that exhibit rapid deterioration under adverse conditions, such as reproduction, body condition, and metabolism, breeders can enhance the resilience of their herds to environmental challenges. Utilizing Expected Progeny Differences (EPDs) for reproductive traits, such as Heifer Pregnancy and Stayability, enables breeders to make informed selection decisions that increase baseline genetic merit for fertility and longevity.

Another low-tech approach to select for environmentally adapted cattle is to purchase seedstock bred and developed in the same eco-region and under similar management as your farm or ranch.

It is important that those cattle are developed under similar management as your operation, because increased management and inputs are often used to mask environmental stress.

High Tech & Direct Approaches

Genomics allows us to create tools so that farmers and ranchers can actively select for cattle adapted to the environment.

While the development of ecoregion-specific genomic prediction models holds promise for tailoring selection to local environments, challenges remain in accurately capturing genotype-by-environment interactions in these models. In plant breeding identical genotypes are replicated across environments, which is a powerful data structure to analyze genotype-by-environment interactions. However, an animal's genotype is a unique sample of the genes and chromosomes within a population (The Random Shuffle of Genes: Putting the E in EPD | MU Extension), thus an animal's genotype is not replicated across environments. In other words, an animal model cannot accurately disentangle genotype-by-environment interactions. However, a sire's genetics are represented across many environments, especially in the case of popular artificial insemination sires. Thus, going back to older methods, a sire model may be a practical way to investigate genotype-by-environment interactions in beef cattle.

New Traits for Environmental Resilience

New research initiatives, such as the Mizzou Hair Shedding Project, offer insights into the genetic basis of environmental resilience, particularly in traits related to heat tolerance and response to the environment. By integrating genomic data with phenotypic observations, researchers can identify novel traits for environmental resilience.

The incorporation of novel traits, such as Pulmonary Arterial Pressure (PAP) and Winter Hair Shedding, into selection indices holds promise for enhancing the environmental resilience of beef cattle. The Mizzou Hair Shedding Project, supported by USDA Grant No.2016-68004-24827, industry partners, and collaborating breeders, has yielded valuable data on the heritability and predictive accuracy of hair shedding scores (Durbin et al., 2020; Durbin et al., 2024). Hair shedding is an important trait not only for its direct relationship with heat tolerance, but also because it affects maternal performance and reflects an animal's ability to sense and respond to the environment. Furthermore, advances in reproductive trait prediction, such as when in the breeding season a heifer conceives (Days Open), offer new avenues for improving fertility and calving efficiency in diverse environmental conditions.

Rules and Laws

Principles of ecological adaptation, such as Bergmann's Rule (Brown and Lee, 1969; Geist, 1987) and the Surface Law (Rubner, 1883; Richet, 1889; Kleiber, 1961), provide theoretical frameworks for understanding the evolutionary drivers of phenotypic variation in beef cattle. By elucidating the underlying mechanisms governing nutrient utilization, metabolism, and thermoregulation, researchers can refine selection strategies to optimize performance traits across varying environmental gradients and management strategies. Researchers at the University of Missouri

have created a technology that creates an accurate 3-D image of cattle (Omotara et al., 2024) and use this technology to identify the metabolic rate and other features of commercial importance in cattle (Patent Application PCT/US2024/041452). In livestock production, often the traits we predict are out of convenience; they are easy to measure. What is needed to move the industry forward is to measure traits with direct relationships to actual biology. An example of this is the direct relationship between surface area and volume with basal metabolic rate, rather than the indirect relationship between weight and basal metabolic rate.

Conclusion

In conclusion, modern research and cutting-edge tools offer unprecedented opportunities to match cattle genetics to the environment in a manner that enhances sustainability, resilience, and productivity in beef production systems. By integrating traditional selection criteria with novel traits for environmental resilience and leveraging genomic and high throughput phenotyping technologies to tailor selection to local environments, breeders can optimize the genetic potential of their herds while minimizing environmental impacts.

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