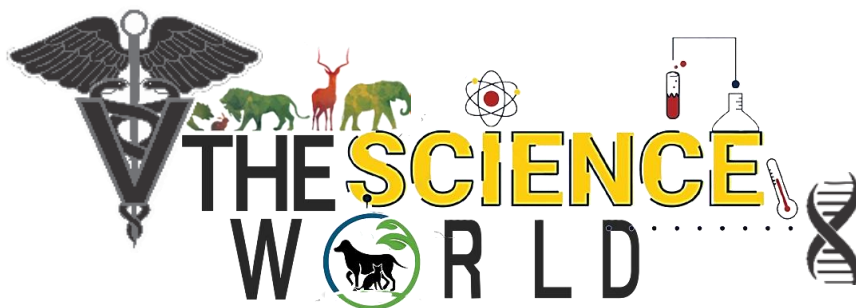




A Monthly e Magazine
ISSN:2583-2212

Popular Article

Sept, 2026 Vol.6(9), 2830-2833

The Genomic Revolution: Breeding Resilient Livestock for a Changing World

Rakesh Nehra¹, Pallavi Choudhary²

¹PhD scholar, Department of Animal Genetics and Breeding, LUVAS, Hisar, Haryana, 125004.

²Assistant Professor, Sri Ganganagar Veterinary college, Tanta University, Sri Ganganagar, Rajasthan, 335002.

doi.org/10.5281/ScienceWorld.23140660

Introduction

The livestock sector is currently under intense pressure to meet a surging global demand for animal products while simultaneously improving animal health and reducing its environmental footprint (Liu, 2026; Wang, 2024). This dual challenge has pushed the industry beyond traditional phenotypic selection toward a "systems biology" approach that integrates advanced technologies like genomic selection, CRISPR gene editing, and epigenetics (Wang, 2024; Kanaka et al., 2021).

Genomic Selection and the Rise of Integrative Omics

Traditional breeding relied on observable traits like size or milk yield that only manifest as an animal matures (Young, 2024). Modern genomic selection (GS) has revolutionized this by using thousands of genetic markers to calculate Genomic Estimated Breeding Values (GEBV), allowing breeders to predict an animal's potential at birth or even as an embryo (Wang, 2024; Young, 2024).

Ireland has emerged as a global leader in this field, with the Irish Cattle Breeding Federation (ICBF) managing a database of over 6.2 million genotypes (ICBF, 2025). In 2025 alone, ICBF genotyped nearly 42% of all Irish calves born, an achievement unmatched by any other country at a national level, which facilitates shorter generation intervals and more accurate herd management decisions (ICBF, 2025).

The next frontier is integrative omics, which combines genomics with transcriptomics (gene expression), proteomics (protein levels), and metabolomics (metabolic snapshots) to



provide a holistic view of animal biology (Wang, 2024). For example, researchers are now mapping the intricate regulatory networks that drive complex traits like disease resistance and meat quality through initiatives like the Functional Annotation of Animal Genomes (FAANG) project (Wang, 2024).

Epigenetics

While the DNA sequence provides the blueprint, epigenetics determines how that blueprint is actually read (Kanaka et al., 2021). Epigenetic mechanisms, such as DNA methylation and histone tail modifications, act as chemical switches that turn genes on or off in response to the environment without changing the underlying DNA sequence (Kanaka et al., 2021).

This field helps explain "**missing heritability**"- phenotypic variations that traditional genetics cannot account for (Kanaka et al., 2021). Research indicates that environmental triggers like nutrition and climate can leave "**epigenetic marks**" that affect productivity (Kanaka et al., 2021). For instance, feeding dairy cows a diet rich in corn straw has been shown to alter the methylation of genes involved in milk fat synthesis (Kanaka et al., 2021). More significantly, across-generation epigenetic inheritance suggests that acquired traits, such as a mother's response to stress or heat, can be passed down to future generations as "**soft inheritance**" (Kanaka et al., 2021).

CRISPR: Genome Editing

One of the most powerful tools in precision genetics is CRISPR-Cas9, which acts as "molecular scissors" to delete or insert specific DNA sequences (Liu, 2026; Young, 2024). CRISPR is being deployed to solve the industry's most costly problems:

- **Disease Resistance:** Researchers successfully used CRISPR to "knock out" the CD163 gene in pigs, making them fully resistant to Porcine Reproductive and Respiratory Syndrome (PRRS), a virus that costs the U.S. industry \$664 million annually (Liu, 2026). Similarly, researchers identified the ANP32A gene as essential for bird flu replication and used CRISPR to reduce its replication in chickens (Liu, 2026).
- **Production Efficiency:** By targeting the MSTN (myostatin) gene, which naturally brakes muscle growth, scientists produced chickens with legs 55.3% heavier than wild-type birds and sheep with a 20–30% weight increase in their first two months (Liu, 2026).
- **Environmental Sustainability:** To combat climate change, CRISPR tools are being developed to target methanogens (methane-producing archaea) in the rumen of cattle, aiming for "climate-friendly" livestock (Liu, 2026).



Breeding for Climate Resilience

As extreme weather becomes more frequent, breeding for thermal tolerance is a necessity (Freitas, 2021). Scientists identify "signatures of selection"—genomic regions fixed by natural adaptation—in breeds like the Datong yak, which has developed specific genes for oxygen transport at high altitudes, or heat-adapted Zebu cattle (Freitas, 2021).

Modern breeding now pairs genomic data with high-throughput phenotyping, using automated sensors to collect real-time data on animal behavior and body temperature (Freitas, 2022). In Large White pigs, researchers found that the critical period for evaluating heat tolerance in growth and carcass traits is the 30 days prior to measurement, while for reproductive traits like weaning weight, the period from the last trimester of gestation until weaning provides the most accurate data (Freitas, 2021; Freitas, 2022). Direct physiological indicators, such as automatically-measured vaginal temperature, have proven to be heritable and can be used to select more resilient sows (Freitas, 2022).

Challenges

Despite these advances, the FAO (Food and Agriculture Organization) warns that the threat of genetic erosion is rising, with 29% of the world's recognized livestock breeds now at risk of extinction (FAO, 2024). High-tech breeding often prioritizes a few high-performing lines, potentially leading to a loss of the unique genetic resources found in traditional, locally adapted breeds (FAO, 2024).

Furthermore, ethical and regulatory hurdles persist. Public acceptance of gene-edited animal products varies, and concerns regarding animal welfare and irreversible genetic changes require rigorous oversight (Liu, 2026; Young, 2024).

Conclusion

The integration of genomic selection, epigenetics, and precision editing is redefining what is possible in livestock agriculture (Young, 2024). By blending these advanced sciences, the industry is moving toward a future where animals are more productive, resilient, and sustainable (Wang, 2024; Liu, 2026). Achieving this will require a critical balance between rapid technological innovation and the responsible conservation of global animal genetic resources (FAO, 2024; Wang, 2024)

References

FAO. (2024). Status and trends of animal genetic resources - 2024. Thirteen Session of the Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture, Rome, 20-22 November 2024 (CGRFA/WG-AnGR-13/24/4/Inf.1). Food and Agriculture Organization of the United Nations.



- FAO. (2025). Domestic Animal Diversity Information System (DAD-IS). Food and Agriculture Organization of the United Nations. (Accessed August 2025).
- Freitas, P. H. F. (2021). Improving livestock climatic adaptation through genomics [Doctoral dissertation, Purdue University].
- Freitas, P. H. F. (2022). Improving livestock climatic adaptation through genomics [Reprint/Published content in Chapters 3, 4, and 5]. Purdue University.
- ICBF. (2025, November 27). ICBF Advances Genomic Capacity with Major Upgrade Ahead of 2026 Evaluations. Irish Cattle Breeding Federation.
- Kanaka, K. K., Singh, S., Ganguly, I., Dash, A., Sukhja, N., Nandhini, P. B., & Dixit, S. P. (2021). Epigenetic mechanisms and their significance in livestock species. *Indian Agricultural Research Journals*.
- Liu, D. (2026). Applications of CRISPR-based gene editing in livestock agriculture. *American Journal of Student Research*.
- Wang, H. M. (2024). Integrative omics approaches for improving livestock breeding strategies. *Animal Molecular Breeding*, 14(2), 141-153. <https://doi.org/10.5376/amb.2024.14.0016>.
- Young, J. (2024). Innovations and advances in modern animal breeding. *Journal of Veterinary Science & Medical Diagnosis*, 13(3). <https://doi.org/10.4172/2324-83414.1000089>.

