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Popular Article

Breeding for Success: The Latest Innovations in Animal Genetics

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Abstract

Recent breakthroughs in animal breeding are transforming the agricultural landscape. Advances in genetic selection, genomics, and reproductive technologies have enabled farmers and breeders to produce healthier, more productive, and resilient livestock. This review highlights the latest innovations in animal breeding, including precision breeding, gene editing, and artificial intelligence. These advances hold promise for improving food security, reducing environmental impact, and promoting sustainable agriculture practices.

Keywords: Breeding, Marker Assisted Selection,

Introduction

Animal breeding has undergone significant transformation over the years. Traditionally, skilled breeders controlled the process. However, with the advent of science and technology, the industry has shifted towards a more data-driven approach. Large corporations now play a significant role in animal breeding, diminishing the influence of individual breeders. The adoption of scientific principles, biotechnology, and reproductive technologies has driven this change. Advances in molecular genetics, artificial insemination, and DNA marker-based selection have significantly impacted genetic improvement in dairy cattle and breeding program design. Technologies like ovum collection, in vitro fertilization, and embryo transfer are now commonplace.

The rapid evolution of computer and information technology has revolutionized data collection and genetic evaluation methods in livestock populations. Effective introduction of breeding methods requires a delicate balance between technological capabilities and user acceptance.

Marker-Assisted Selection (MAS) is a powerful tool that combines genomic information with phenotypic data to enhance selection response. This indirect selection process selects a trait of interest

based on a linked marker, rather than the trait itself. Ultimately, successful animal breeding programs must strike the optimal balance between technological innovation and practical feasibility to remain competitive, considering consumer preferences, economic factors, and production efficiency

1. Marker Assisted Selection

Marker-Assisted Selection (MAS) combines genomic information with phenotypic data to enhance selection response. This approach offers several advantages over traditional methods. By analyzing genes, breeders can identify traits an individual will pass on to the next generation, regardless of environmental conditions. MAS enables selection for traits that are difficult to evaluate (Wakchaure *et al.*, 2015).

MAS accelerates the selection process, allowing for early prediction of an individual's phenotype. This approach is particularly beneficial for sex-limited traits, low heritability traits, and traits that are difficult or expensive to measure.

MAS can be used to select for carcass traits, disease resistance, and fertility. It can also reduce generation intervals, enabling breeders to make selections earlier in an individual's life.

To fully harness the potential of MAS, large-scale genotyping methods and infrastructure are needed. This will enable breeders to generate vast amounts of molecular data at a reasonable cost, leading to improved genetic evaluation and selection.

2. Genomic selection

Genomic selection (GS) is a type of marker-assisted selection that estimates an animal's breeding value using a dense chromosome map. This method doesn't require knowledge of the animal's phenotype or its relatives. GS reduces generation intervals and the cost of proving bulls, increasing animal production. Unlike traditional MAS, GS assumes all markers may be linked to a gene affecting the trait and estimates their effects without testing significance (Meuwissen *et al.*, 2016).

Three technological breakthroughs have enabled the widespread use of DNA information in animal breeding: GS technology, the discovery of thousands of genetic markers (SNPs), and high-throughput genotyping technologies. In GS, the effects of all SNPs are estimated simultaneously using a reference population. Selection candidates are then genotyped, and their genotypes are combined with estimated effects to predict genomic EBV. The use of GS has several advantages, including selecting for complex traits determined by thousands of genes with small effects. GS also doesn't require pedigree recording, and elite breeding animals don't need to be trait-recorded. The 1,000-bulls sequencing project has revealed over 30 million SNP markers in cattle. SNP-chip genotyping technologies have made it cost-effective to genotype animals for thousands of SNPs.

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3. Non-invasive techniques for exact phenotypic assessment of carcass composition

Historically, scientists used destructive methods like dissection and chemical analysis to study animal body composition. However, over the past 30 years, non-invasive methods have emerged.

Techniques like ultrasound, computer tomography (CT), dual-energy X-ray absorptiometry (DXA), and magnetic resonance imaging (MRI) enable accurate body composition analysis in domestic animals. CT has been widely used in farm animals, including sheep, rabbits, beef, and pigs, to measure body composition. DXA has also been employed in pig body composition analysis with high accuracy. MRI has demonstrated better results than DXA in some studies, particularly in humans. Non-invasive techniques allow investigation of living animals without harm, making them suitable for sequential studies (Kušec *et al.*, 2016).

The development of non-invasive methods has revolutionized animal body composition research, enabling accurate and humane analysis. These techniques have opened up new avenues for research in animal science, particularly in growth, development, and nutrition.

4. Epigenetics

Epigenetics refers to heritable changes in gene expression that occur without altering the DNA sequence. This process bridges the gap between genotype and phenotype.

Epigenetic regulation enables cellular differentiation, where cells with identical genetic material exhibit distinct phenotypic characteristics. Other fundamental epigenetic processes include gametogenesis, aging, and genomic imprinting. The epigenome, a regulatory layer independent of the DNA sequence, plays a crucial role in these processes. Aberrations in the epigenome have been linked to developmental disorders and late-onset diseases (Zeric, 2012).

The application of epigenetics in livestock production holds promise for enhancing commercially valuable traits. Further research is necessary to explore the potential of imprinted and X-linked QTL in livestock production.

5. Gene editing technology and CRISPR-Cas9

Genome editing technology has revolutionized genetic research by enabling precise manipulation of living organisms' genomes. This technology emerged in the 1990s with various methods developed for targeted gene editing. Three widely used systems are transcription activator-like effector nuclease (TALEN), zinc finger nuclease (ZFN), and clustered regularly interspaced short palindromic repeats (CRISPR). CRISPR-Cas9 has become a powerful tool due to its simplicity, efficiency, and speed. The CRISPR-Cas9 system consists of two main components: the Cas9 protein and guide RNA. This system allows for precise modification of genomic sequences by cutting the DNA at a targeted location. CRISPR-Cas9 has been widely used in various scientific fields, including medical science, therapeutics, plant science, and animal science. Its potential applications are vast, and

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ongoing research is exploring its use in treating genetic diseases and improving crop yields (Tavakoli *et al.*, 2021).

With its ease of use, efficiency, and precision, CRISPR-Cas9 has revolutionized the field of genome editing and is poised to make significant contributions to various fields of research.

6. Embryo transfer technology

Efficient reproductive performance is crucial for sustainable livestock production. Modern reproductive technologies like Embryo Transfer (ET) offer innovative solutions. ET involves collecting an embryo from a donor female and transferring it into a recipient female.

ET offers significant advantages, including: Up to 32 embryos per cow per year, producing more calves from superior females and non-surgical embryo collection procedures. ET has become a cornerstone for achieving real genetic gains, producing high-quality animals, and increasing offspring numbers through twins (Mebratu *et al.*, 2020).

7. **Sex Shorted Semen**

The dairy industry's demand for female calves drove the development of sperm sorting technologies. High-speed flow cytometry emerged as the most successful technique, producing populations of X or Y sperm with over 90% purity. This technology, known as the "Beltsville Sperm Sexing Technology," is applicable to almost all animals. Despite its benefits, sex-sorted semen accounts for only 5% of the AI industry due to high costs. Its adoption is expanding rapidly, particularly in dairy herds, to improve genetic progress and profitability. Bovine spermatozoa are well-suited for high-speed sorting due to their high sorting index (Vishwanath *et al.*, 2018). However, using sexed semen can be challenging in herds with low fertility, and continuous use can lead to decreased genetic diversity and effective population size.

8. Precision animal breeding

Precision livestock breeding combines genomic, proteomic, transcriptomic, metabolomic, and epigenetic data for accurate breeding value prediction. This approach enables precise selection of top-performing individuals, driving rapid genetic improvement.

To uncover genetic factors influencing economically important traits, breeders use linkage and association analyses. However, most genomic variable sites are population-specific, and breeding value estimation methods are often not transferable across populations. Achieving precision breeding requires population-specific variation information and personalized markers. The accuracy of genomics-assisted selection is also influenced by the size and structure of the reference population. Livestock breeding has evolved into a complex, multidisciplinary field, incorporating various disciplines. The advent of big data has unleashed genomic information, empowering breeders to unravel genetic underpinnings of complex economic traits (Yang et al., 2017). The future of livestock

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breeding holds promise, with the anticipated realization of precision, population-personalized multi-omics breeding. This will enable breeders to achieve rapid, accurate, and targeted selection of livestock.

Conclusion

In conclusion, the latest innovations in animal genetics are revolutionizing the livestock industry, enabling breeders to produce healthier, more productive, and more sustainable animals. From genomic selection and gene editing to precision breeding, these pioneering technologies are renovating the way we approach animal breeding. As the global demand for animal products continues to rise, the importance of leveraging these innovations to improve the efficiency, productivity, and sustainability of animal agriculture cannot be overstated.

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