

Mini Review

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Radiation and Genome Integrity: A Cornerstone of Sustainable Livestock Productivity

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Received: July 08, 2026; **Accepted:** July 13, 2026; **Published:** July 22, 2026**Introduction**

Over the past few decades, the concept of livestock productivity has undergone a profound transformation. Productivity is no longer measured solely by increased meat or milk yield; instead, it is increasingly evaluated through the lens of sustainability, resource-use efficiency, environmental stewardship, and long-term genetic resilience. At the heart of this transformation lies the animal genome, the biological blueprint that governs growth, fertility, feed efficiency, disease resistance, adaptation, and overall production performance.

While nutrition, health management, and environmental conditions are recognized as major determinants of livestock productivity, an equally critical but often overlooked factor is the integrity of the genome itself. Environmental stressors capable of disrupting genomic stability may compromise the very foundation upon which genetic improvement programs are built. Among these stressors, ionizing radiation occupies a unique position because of its well-established ability to alter DNA structure through both direct and indirect mechanisms.

The Genome: The Biological Capital of Livestock Production

The genome represents far more than a collection of genes. It is the biological capital that determines the genetic potential of every animal. Traits of major economic importance including growth rate, reproductive efficiency, milk production, feed conversion efficiency, carcass quality, and disease resistance are all encoded within the genome and transmitted across generations.

Modern breeding programs aim to accumulate favorable alleles over successive generations through selection, genomic evaluation, artificial insemination, embryo transfer, and advanced reproductive technologies. However, the success of these programs ultimately depends on one fundamental requirement: genome stability.

Without genomic integrity, the reliability of inherited traits declines, reducing the efficiency of long-term genetic progress.

Radiation as a Genomic Stressor

Ionizing radiation possesses sufficient energy to remove electrons from atoms and molecules, initiating a cascade of biological events within living cells. Its biological effects primarily arise through two pathways.

The direct effect occurs when radiation interacts directly with DNA molecules, causing single-strand breaks, double-strand breaks, base modifications, or chromosomal rearrangements.

The indirect effect, which accounts for a substantial proportion of radiation-induced damage, results from the ionization of intracellular water molecules. This process generates highly Reactive Oxygen Species (ROS) and free radicals capable of attacking DNA, proteins, and cellular membranes, thereby amplifying genomic injury. The biological consequences of radiation exposure are influenced by several factors, including radiation type, absorbed dose, exposure duration, dose rate, tissue sensitivity, and the efficiency of cellular DNA repair mechanisms. Although cells possess sophisticated repair pathways, persistent or excessive DNA damage may overwhelm these mechanisms, leading to mutations, chromosomal instability, apoptosis, or impaired cellular function.

Why Does Genome Integrity Matter for Livestock Productivity?

From a livestock production perspective, genome integrity extends beyond molecular biology; it directly influences animal performance and breeding efficiency. Stable genomes ensure the faithful transmission of desirable genetic traits from one generation to the next. Conversely, genomic instability may compromise reproductive performance, embryonic development, immune competence, growth potential, and overall biological efficiency.

Even subtle genomic alterations accumulated over multiple generations may reduce the effectiveness of breeding programs, limiting the expected response to genetic selection. Consequently, protecting genome integrity should be regarded as an essential component of sustainable livestock development rather than merely a laboratory concern.

Environmental Exposure and Food Chain Implications

Radiation is naturally present in the environment through cosmic rays, terrestrial radionuclides, and naturally occurring radioactive materials. However, anthropogenic sources including nuclear accidents, industrial contamination, and improper waste disposal may introduce additional radionuclides into agricultural ecosystems. In grazing systems, radionuclides deposited onto soil may be absorbed by forage plants, subsequently entering livestock through feed and water. Depending on their physicochemical properties, certain radionuclides may accumulate in specific tissues or be transferred into edible products such as milk or meat.

Therefore, livestock may serve not only as food-producing animals but also as biological indicators of environmental quality, reflecting contamination within agricultural ecosystems.

This highlights the importance of environmental monitoring programs aimed at safeguarding both animal production systems and public health.

Genome Integrity and Sustainable Livestock Systems

The concept of sustainability has traditionally focused on reducing greenhouse gas emissions, improving water-use efficiency, and minimizing environmental footprints. However, genomic sustainability should be recognized as an equally important pillar. A genetically stable population demonstrates greater resilience to disease, improved reproductive performance, enhanced adaptability to climate variability, and more efficient utilization of feed resources. These characteristics ultimately reduce production losses, improve resource efficiency, and decrease the environmental impact per unit of animal product. Thus, protecting genome integrity contributes simultaneously to environmental sustainability, economic efficiency, and food security.

Toward an Integrated Vision of Livestock Sustainability

Future livestock production systems should adopt a broader definition of sustainability that incorporates genome protection alongside traditional environmental indicators.

This integrated framework should include:

- Conservation of genetic resources.
- Monitoring environmental factors capable of affecting genomic stability.
- Minimizing exposure to environmental pollutants, including ionizing radiation.
- Strengthening genomic surveillance within breeding programs.
- Integrating genome health into livestock sustainability assessments.

Such an approach recognizes that sustainable livestock production depends not only on producing more animals, but on preserving the biological quality of future generations.

Conclusion

The future of livestock production depends not only on selecting genetically superior animals but also on preserving the integrity of the genomes that define their biological potential. Radiation represents one of several environmental stressors capable of compromising genomic stability. Although its role in commercial livestock production is often underestimated, protecting animals from environmental factors that threaten DNA integrity should be considered an essential component of sustainable breeding strategies.

Ultimately, genome integrity is not merely a genetic issue it is a cornerstone of productive efficiency, environmental sustainability, and global food security. Protecting the genome means protecting the biological foundation upon which every future generation of livestock and every future gain in productivity will depend [1-5].

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