

Transgenesis: A New Era of Genetic Innovation and Its Applications

Bula Das¹, Arundhati Phookan¹ and Olympica Sarma²

¹Department of Animal Genetics and Breeding, College of Veterinary Sciences, Assam Agricultural University, Khanapara, Guwahati, Assam

²Department of Animal Genetics and Breeding, College of Veterinary and Animal Sciences, G B Pant University of Agriculture & Technology, Pantnagar, Uttarakhand

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Abstract

Transgenic animals are genetically modified organisms that incorporate genes from other species, enabling them to exhibit specific desirable traits. The rise of transgenic technology has expanded opportunities for advancements in livestock development. Transgenesis is the process of incorporating foreign genes into an organism's genome to confer new traits or functions. Various techniques have been developed for this purpose, including pronuclear microinjection, embryonic stem cell technology, viral vector-mediated transfer, electroporation, and CRISPR-Cas9. The development and use of transgenic animals leads to advancements in medicine, agriculture, and research. Balancing innovation with ethical responsibility is crucial for the sustainable and humane application of transgenesis. Transgenic animals have revolutionized various fields by offering significant advancements in agriculture, medicine, and scientific research. They are engineered to enhance productivity, improve disease resistance, and produce valuable pharmaceutical proteins. In biomedical research, transgenic models help in studying human diseases and developing new treatments. Additionally, genetically modified livestock contribute to sustainable farming by reducing environmental impact. Although transgenesis raises a various ethical concern, this article focuses on the fundamentals of animal transgenesis and its applications in industry, medicine, and agriculture.

Keywords: Gene, Transgenesis, Transgenic Animals, Vectors

INTRODUCTION

Transgenic animals are those that have been genetically modified to carry genes from other species, resulting in specific desired traits. This groundbreaking biotechnological advancement has transformed scientific research, agricultural practices, and medical applications. By introducing foreign DNA into an animal's genome, transgenic technology enables the study of gene functions, the improvement of agricultural productivity, and the development of pharmaceuticals. Transgenic animals with germline modifications can pass these genetic changes to future generations within the herd, offering the potential for sustained productivity improvements over time. Applications of

transgenic animals span diverse fields. In agriculture, these animals can be engineered for enhanced milk production, improved meat quality, or environmental benefits, such as reducing waste from livestock farming. In biomedicine, transgenic animals play a pivotal role in producing human therapeutic proteins and serving as models for studying human diseases. Additionally, they contribute to xenotransplantation research, providing organs for potential human transplantation.

However, the use of transgenic technology raises ethical, regulatory, and environmental concerns. Factors such as the welfare of genetically modified animals, the safety of their products, and the potential ecological impact must be carefully evaluated. Despite these challenges, the ongoing refinement of transgenic techniques offers immense potential for societal benefits, with advancements continuing to shape the future of this innovative field.

Methods of Transgenesis

Transgenesis involves introducing foreign genes into an organism's genome to endow it with new traits or capabilities. Several methods have been developed to achieve this genetic integration, each with distinct advantages and applications:

1. Pronuclear Microinjection

In this technique, foreign DNA is directly injected into the pronucleus of a fertilized egg. The modified embryo is then implanted into a surrogate mother, leading to offspring that carry the transgene. This method has been widely used in creating transgenic animals, especially mice.

2. Embryonic Stem Cell (ESC) Method

Here, foreign DNA is introduced into cultured embryonic stem cells. These modified cells are then incorporated into an early-stage embryo, resulting in a chimeric organism. Breeding of these chimeras can produce fully transgenic offspring.

3. Viral Vector-Mediated Transfer

Viruses are engineered to carry and insert foreign genes into the host genome. This method benefits from the virus's natural ability to infect cells but requires careful handling to ensure safety and specificity.

5. Electroporation

By applying an electrical field, cell membranes become temporarily permeable, allowing foreign DNA to enter. This technique is often used in conjunction with other methods to enhance DNA uptake.

6. Somatic Cell Nuclear Transfer (SCNT)

The technique involves transferring a somatic cell nucleus into the cytoplasm of an enucleated egg, where the egg's cytoplasmic components reprogram the nucleus, transforming it into a zygote. In mammals, the zygote must be artificially implanted into the uterus of a surrogate mother.





One of the most famous examples of SCNT is the cloning of "Dolly sheep" in 1996, which demonstrated that adult cells could be reprogrammed to create a new organism.

7. CRISPR-Cas9 and Other Genome Editing Tools

Recent advancements have introduced precise genome editing techniques like CRISPR-Cas9, which can target specific genomic locations for gene insertion, deletion or modification. This method offers higher specificity and efficiency compared to traditional transgenesis techniques.

Each of these methods has its own set of advantages and limitations, and the choice of technique often depends on the specific goals of the transgenic experiment, the species involved, and the desired precision of genetic integration.



Ethical Considerations in Using Transgenic Animals

The development and use of transgenic animals raise several ethical concerns. While these technologies have revolutionized science and agriculture, they must be employed responsibly. The key ethical considerations are:

1. Animal Welfare

Transgenic procedures often involve invasive techniques such as microinjection or somatic cell nuclear transfer, which can lead to stress. Furthermore, unintended genetic modifications may result in health issues like deformities, immune disorders, or shortened lifespans in animals. The ethical principle of minimizing harm should be central to these practices.

2. Environmental Impact

The release or escape of transgenic animals into natural ecosystems may disrupt biodiversity. For example, genetically modified fish could outcompete wild species, leading to ecological imbalances. Strict containment protocols are essential to mitigate these risks.

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3. Human Health and Safety

Ethical concerns also extend to the consumption of transgenic animal products. Although these products undergo rigorous testing, there are ongoing debates about their long-term effects on human health. Transparent research and labeling are crucial to maintain public trust.

4. Balancing Benefits and Risks

The potential benefits of transgenic animals, such as advancing medicine, improving food security, and enhancing disease resistance, must be weighed against the ethical costs. Ensuring that research prioritizes genuine societal needs can help justify these interventions.

5. Regulatory Oversight

Ethical concerns demand stringent regulations to monitor transgenic animal research. These regulations should include welfare guidelines, environmental risk assessments, and frameworks for addressing unforeseen consequences.

Application of Transgenic Animal

Transgenic animals, engineered to carry genes from other species, have revolutionized research, medicine, and agriculture. Some of the notable applications of transgenic animals are:

1. Biomedical Research

Transgenic animals serve as models for studying human diseases. They mimic human conditions such as cancer, Alzheimer's and diabetes, allowing researchers to investigate disease mechanisms and test potential treatments. For example, *Oncomouse*, genetically modified to develop cancer, has been instrumental in cancer research.

2. Production of Biopharmaceuticals

Transgenic animals like goats, cows, and sheep produce therapeutic proteins in their milk. For example, antithrombin, a protein used to prevent blood clots, is produced in the milk of transgenic goats (*Atryn*).

3. Organ Transplantation (Xenotransplantation)

Transgenic pigs are modified to make their organs more compatible with the human immune system, reducing the risk of rejection during transplantation. This approach offers hope for addressing the organ shortage crisis.

4. Agricultural Improvements

Transgenic animals are developed to enhance productivity. For example, transgenic salmon



grow faster and reach market size quicker than non-transgenic salmon. These advancements improve food security and reduce resource use.

5. Conservation Biology

Genetic modifications in endangered species or similar surrogate animals are used to bolster population numbers and conserve biodiversity.

6. Disease Resistance

Transgenic livestock can be engineered to resist diseases like mastitis in cows or African swine fever in pigs, which improves animal welfare and reduces economic losses.

Transgenic Animals: Revolutionizing Agriculture and Biotechnology

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Transgenic animals, created through the introduction of foreign genes into their genomes, have significantly advanced agriculture, medicine, and scientific research. Some of the notable examples of transgenic animals:

1. AquAdvantage Salmon: AquAdvantage salmon are genetically modified Atlantic salmon that grow to market size in about half the time of conventional salmon. The primary benefits include increased production efficiency and reduced pressure on wild fish populations.

2. GloFish: GloFish are fluorescent zebrafish originally engineered to detect environmental pollutants. They contain genes from marine organisms that produce bright fluorescent colours. While their initial purpose was environmental monitoring, they have become popular in the ornamental fish trade, raising public awareness about genetic engineering.

3. EnviroPig: EnviroPig is a line of transgenic pigs engineered to produce the enzyme phytase in their saliva. This modification allows them to digest phytate, the principal form of phosphorus in their diet, reducing phosphorus pollution from pig farming by up to 75%. This environmental benefit addresses concerns about livestock production's impact on ecosystems.

4. Transgenic Cows Producing Human Proteins: Transgenic cows have been engineered to produce human proteins in their milk, such as alpha-lactalbumin. The first transgenic cow, Rosie, produced milk containing this human protein, offering a potential alternative to natural cow milk for infants and contributing to advancements in pharmaceutical development.

5. Transgenic Mice: Transgenic mice are extensively used in scientific research to study gene function and disease mechanisms. By introducing specific genes, researchers can model human diseases, test drug efficacy, and explore gene regulation, contributing to medical advancements and a deeper understanding of genetic disorders. These examples illustrate the diverse applications of transgenic animals, from enhancing food production and environmental sustainability to advancing medical research and biotechnology.



Conclusion

Transgenesis has revolutionized the fields of agriculture, medicine, and biotechnology by enabling precise genetic modifications in animals. Despite ethical and regulatory concerns, the potential benefits of transgenesis in improving food security, sustainability, and healthcare cannot be overlooked. With ongoing advancements in genetic engineering techniques like CRISPR, the future of transgenesis holds immense promise for addressing global challenges and enhancing the quality of life for both humans and animals.

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