Harnessing of Biotechnology Techniques in Animal Disease Control

AUTHORS DETAIL

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Abstract

Biotechnology with its cutting-edge tools and techniques, has become a potential field in the battle against animal diseases. Infectious diseases become a serious issue for veterinary animals and biotechnological approaches helps to overcome these diseases. It has greatly improved the veterinary care by providing novel approaches in diagnosis, prevention, and treatment. Additionally, different sequencing techniques can help in the detection of infectious causative agents with the help of biotechnology. Moreover, the modern biotechnological techniques give lesser chance of false positive results, real time PCR (RT-PCR) gives easy and accurate detection of pathogens and advanced techniques of sequencing provides efficient detection of disease causing microorganisms. Current chapter explores the some of ways in which biotechnology is used to control animal diseases, emphasizing how it is revolutionary effect on the health and welfare of animals. Biotechnology has a big impact on veterinary medicine, helping to improve animal diet, health, and genetics.

Keywords: Biotechnology, Veterinary medicine, Gene editing, Vaccines, Diagnostics, Infectious diseases

1. Introduction

Among the agricultural industries that are developing at the fast pace, to meet the demands of the world's burgeoning population are livestock, poultry, and aquaculture. Nonetheless, this industry's expansion is hampered by the persistent rise in global risks of infectious diseases. The globalization of the animal trade for a variety of uses exacerbates this threat even further. The abrupt arrival of the infectious disease in a new region may cause a quick spread among the vulnerable animal population, making a delay in diagnosis. Globally, vector-borne illnesses are also rising in response to climate change (Abd El Wahed et al. 2013). Quick, precise, and extremely sensitive detection of infection organisms is one of the fundamental and crucial conditions set forth to prevent the transmission of infectious illnesses by the World Organization of Animal Health (OIE). Biotechnological applications have substantially aided in the creation of novel, powerful diagnostic assays for the efficient diagnosis and treatment of infectious diseases in animals (Vidic et al. 2017).

2. Impact of Infectious diseases

Infectious diseases have a huge impact that is felt everywhere. The entire political system, economy, and society have been impacted by infectious diseases. Vital sectors are experiencing constant development and economic loss. Both humans and animals have suffered greatly as a result of infectious diseases (Bhatta et al. 2012). Humanity has been under pressure from this, and significant financial, social, and psychological losses have resulted. Therefore, investing in methods to combat and control infectious diseases is beneficial for economy and health for animals (Ellwanger et al. 2021).

The emergence of various variants of the pathogen is creating additional difficulties, prompting people to consider new tactics and driving researchers to seek out novel ones. Pathogens that have recently evolved are always more sophisticated, lethal, and resistant than their predecessors. These pathogens are 'the fittest' from an evolutionary standpoint, and it is unlikely that human ingenuity will ever defeat them. The rate of pathogen discovery has accelerated as our understanding of infectious illnesses and science has grown. New methods and technologies must continue to develop to stay up to date and improve diagnosis (Bonot et al. 2014). This is to generate forecasts with likely and feasible outcomes in addition to promptly identifying the infections outbreaks (Woolhouse et al. 2011).

It is also necessary to study epidemiology and pathogenic etiology in order to comprehend the situation and draw a firm judgment. This will make it easier to comprehend the pathogen's lineage and offer a mechanism and insight into the pandemic, endemic, or epidemic. Additionally, the describing method aid comprehension of the directional flow and interface transmission of zoonotic infectious illnesses (Caliendo et al. 2013). Therefore, the goal of epidemiology and phylogenetic analysis would be to plan for the difficulties that arise while monitoring and detecting pathogens. In 2003, a coronavirus called SARS caused a pandemic. However, Epidemiology and microbiology prevented its catastrophic effects, and the SARS causative agent was identified. Fecal bacteria, viruses, and parasites pollute food, infect humans and animals, and cause sickness (Yang et al. 2020). Antibiotics are commonly used to boost animal productivity and maintain their health, which leads to the development of bacteria that are resistant to the drugs. This makes the situation even worse and exacerbates the illness. It was also discovered that pets acquired from overseas can spread the illnesses to people (Manyi-Loh et al. 2018).

Examples of biotechnological methods applied in veterinary medicine include genetic engineering, gene editing, gene therapy, sterile insect techniques, and bioinformatics (Dhama et al. 2013). Genome editing techniques such as clustered regulatory interspersed short palindromic repeats/associated protein 9 (CRISPRs/Cas9) have been used in biological systems and animals to detect and eliminate possible inherited illnesses. In order to treat cancer and cystic fibrosis, gene therapy is being used (Ferris et al. 2010). Among the areas where biotechnology has been applied to enhance animal health include the creation of virus-vectored immunizations, DNA vaccine technology, biosensors, proteomics, and molecular diagnostics (PCR, RT-PCR, and nanoPCR). Consequently, this article covers the recent advancements and in biotechnological approaches for animal health care medicine.

3. Biotechnological approaches to overcome animal diseases

In veterinary medicine, biotechnology is essential because it offers creative answers to a range of problems. It aids in the development of vaccinations, improves disease diagnosis, and advances therapeutic approaches (Finstad et al. 2012). Veterinarians are better able to recognize and treat animal health problems because to biotechnology, which improves results and animal welfare. One significant advancement in the prevention and management of infectious illnesses in animals has been the development of vaccines. New vaccinations that are safer, more effective, and more targeted have been made possible by biotechnology. Scientists can create vaccinations that precisely target the pathogens causing a given disease using genetic engineering techniques, which lowers the possibility of side effects and increases overall efficacy (Adam et al. 2009).

Additionally, biotechnology has significantly improved veterinary illness diagnosis. Veterinarians may identify diseases with great accuracy and precision because to molecular diagnostics like DNA sequencing and polymerase chain reaction (PCR). These methods can detect the existence of infectious organisms, identify the genetic variations at play, and even forecast the likelihood of developing medication resistance (Fu et al. 2013).

In the creation of innovative therapeutic approaches, biotechnology has performed a major role. For instance, gene therapy has enormous potential in the field of veterinary medicine (Gambari et al. 2014). Through the introduction of therapeutic genes into an animal's cells, researchers may be able to improve immune responses, fix genetic flaws, or target certain disease processes. This method has proven effective in treating some genetic illnesses and could open up new possibilities for treating complicated animal diseases. Biotechnology has a significant influence on food safety and animal productivity in addition to its direct effects on animal health (Goldenberg et al. 2015). Biotechnology has improved livestock output and quality through breeding programs and genetic selection. Breeders can create healthier and more productive animal populations by choosing animals with desired features and selectively propagating them via the use of assisted reproductive technology (Hernandez et al. 2023).

Genetic Engineering:

Genetic engineering is the process of introducing desired characteristics or modifications into an animal or biological system through the use of recombinant DNA technology (Goodwin et al. 2016). In other words, this approach legally controls, genetic material's modification and transfers from one organisms to another organisms by genes transferring and DNA fragments from one species to another species. According to (Gupta et al. 2021), the recombination of DNA produces recombinant DNA, created by the DNA of more than one species in lab. This contemporary method makes it possible to separate one or more genes from massive DNA masses and generate them in extremely large quantities (He et al. 2010).

4. Utilizing Transgenic Animals to Improve Animal Health in Diseases of Economic Importance:

New genes may not be incorporated into an animal's genome very regularly, and their different locations may often inhibit their expression. As a result, scientists believed that cloning was an effective way to produce transgenic animals (Keller et al. 2018). Here, bulk of cell line becomes a donor cell for cloning after successfully incorporating and expressing a transgene. The transgene will be integrated into the genome of the produced clones, allowing them to successfully pass it on to their progeny using conventional breeding techniques. As a result, a complete class of transgenic animals may express certain gene alleles for use in agriculture and biomedicine (Shakweer et al. 2023).

4.1. Pathogen's Diagnosis

Numerous traditional and traditional methods has been created and applied for in-vitro diagnosis of different infectious agents. Those techniques which are labor-intensive and time taking include serological, cell culture, and electron microscopy-based approaches. However, as biotechnology advances, new and reliable diagnostic technologies are constantly emerging and replacing traditional approaches (Oh et al. 2015). Many animal diseases are currently accurately diagnosed using molecular detection techniques like polymerase chain reaction (PCR) or its variations, as well as serological techniques like enzyme-linked immunosorbent assay (ELISA). Nevertheless, new high-throughput assays and point-of-care (POC) assays have just been created.

4.1.1. Hybridization-based methods:

In situ hybridization is the most popular hybridization-based technique, and it may make use of either fluorescent (FISH) or chromogenic (CISH) molecules. CISH-based assays are used for the quick identification of microorganisms in positive culture samples, including Mycobacterium species and dimorphic fungi (Parida et al. 2018). Mycobacterium tuberculosis complex may now be identified and distinguished from nontuberculous mycobacteria using a FISH-based approach (Perez et al. 2011).

4.1.2. Amplification-based methods:

One of the finest techniques for identifying pathogens in clinical samples with high sensitivity and specificity is nucleic acid amplification. Numerous adjustments to nucleic acid amplification techniques have produced robust technologies that together produce more precise and superior outcomes. These changes fall under two categories of amplification techniques: isothermal amplification techniques and PCR and its variations (Yamin et al. 2023).

a. Polymerase chain reaction and its variants: Around the world, these are the most often used instruments for pathogen detection. Multiplex PCR allows for the detection of multiple sequences: RT-PCR (reverse transcriptase PCR) converts RNA to cDNA. Further this cDNA as a template for amplification; and real-time PCR, a modified form of conventional PCR, allows for the quantification of DNA sequence without the need to run the amplified product on an agarose gel (Sharma et al. 2018). Several fluorescent chemistries, including SYBR green and TaqMan can be used in real-time PCR. To quickly identify and measure the Japanese encephalitis virus in pig blood and mosquito vectors, a TaqMan real-time RT-PCR test was recently developed.

4.1.3. Novel and high throughput assays

a. Biosensors: Biosensors can be very particular with a lower chance of a false positive, and they are portable, rapid, easy to use, and ultrasensitive. Detecting changes in pH, ion concentrations, mass through particular hybridization, enzymatic reaction, loss of functionality, electrical potential change, color change, and temperature are some of the concepts that biosensors operate on. Many biosensors have been created for the detection of animal diseases based on these concepts. For example, an extended-gate field-effect transistor for the direct potentiometric serological diagnosis of the BHV-1, and a nanowire-based immunosensor for the bovine viral diarrhea virus (BVDV) (Shimaa et al. 2015; Shunxiang et al. 2017).

b. Next-generation sequencing: The diagnosis of microbial disease has become easier due to the restricted ways for detecting microbial signatures and the introduction of new technology that allows for rapid and parallel gene expression capacity. The use of next-generation sequencing (NGS) to comprehend the molecular epidemiology, transmission, and characterization of animal diseases is growing. Large deposits of genes present in the clinical sample can be found in a single test rather than requiring gene-by-gene examination. NGS applications are thought to be more inventive. As a result, it is widely used as a diagnostic tool, rapidly replacing the majority of existing molecular diagnostic methods, and has revolutionized pathogen diagnosis (Nafea et al. 2024).

The sequencing and identification of genomes has changed significantly as a result of numerous advancements and changes. It all starts with Roche 454 pyrosequencing, which had shorter read lengths and lower efficiency. Recent advancements in nanopore technology have resulted in amazing efficiency of using new science and technology. Real-time viral genome sequencing is possible with nanopore technologies for both DNA and RNA. The principle of this technique is based when a DNA or RNA strand is permitted to flow with the help of nanopore, the flow of current changes as the strands (G, T, C, and A) pass by the tiny hole in various configurations. The above described solutions enable on the high-throughput sequencing, high-sample number PromethION, the benchtop GridION, and the portable MinION instrument. In the detection of influenza viruses, nanopore sequencing has recently proven to be a groundbreaking diagnostic technique (Singh et al. 2017).

c. Microarray: Microarray is the multiplex lab-on-a-chip test. It involves setting up a lot of biological materials for screening using detection-based assays on a solid platform, usually a glass slide. High-throughput screens and the discovery of the root causes of epidemics have benefited greatly from microarray technology. The most important advancements in the study of infectious diseases in endemic areas is the simultaneous detection of coinfections and other more remarkable alterations during outbreaks (Smith et al. 2012). As a result, novel kits for liquid microarrays, bioelectric arrays, and point-of-care detections are being developed. For specific probe and target combinations with precise detections, this is a simple and enhanced hybridization technique. As a result, less work will be required to go from diagnosis in clinics to the single organism diagnosis. All of them, assist in reducing time required to comprehend the appropriate and prevalent infections (Miller et al. 2009).

5. Applications of biotechnology in detection of infectious agents in animal diseases

Animal products are rapidly spreading around the world as a result of globalization, endangering human health. Foot-and-mouth disease and classical swine fever are two examples of transboundary animal diseases (TADs) that can spread swiftly across national boundaries. These illnesses have a terrible effect on animal husbandry and the animal trade (Song et al. 2012). Humans can be infected by zoonotic infections from some animal diseases that transcend the species barrier. As a result, proper techniques must be used to diagnose these illnesses. This will aid in the development of specific preventative measures, such as immunizations and quarantines (Rahman et al. 2020).

PCR has the advantage of high specificity. PCR is very sensitive test that can identify infectious pathogens at the molecular level. Amplification of the genetic material, including DNA and RNA, is made possible by PCR because each bacterium has a distinct genome. There are numerous variations of the real-time PCR technology, such as TaqMan tests and FRET-based assays. Because SYBR Green does not require the use of probes, it is an economical approach (Ye et al. 2014). Because PCR techniques are inexpensive, they are used in portable, lightweight equipment for on-site detection of infection. The use of innovative isothermal amplification techniques makes it even easier to diagnose animal diseases on-site. Loop-mediated isothermal amplification (LAMP), for instance, produces results that are visible to the human eye and operates at a single temperature level. Several technical methods, like the use of padlock probes and distinct liquid microarray are the common readouts of PCR findings. This also enable the simultaneous identification of multiple infectious pathogens (Wong et al. 2018).

DNA-binding moieties that attach to the amplified DNA and release fluorescence during the reaction are used in this assay to monitor the result without the need for the gel formation phase. The initial viral load determines the cycle number at which the fluorescence reaches its threshold level (Maan et al. 2018). Rapid two-way communication between laboratories and practitioners will guarantee the effectiveness of the control program.

Mycobacterium avium subspecies paratuberculosis (MAP) is the cause of Johne's disease (JD), a serious gastrointestinal illness that affects cattle (Deiman et al. 2002). Reduced milk output and early culling are the consequences of this disease. Conductometric biosensors, which combine immunomigration technology with electrical signal detection, can be used to control this disease. Direct serological analysis can be performed using the Field Effective sensor. This technique, which is quicker than ELISA and useful for disease intervention, can identify BHV-1, the pathogen that causes bovine respiratory illness. The biosensor assay, which offers quantitative measurement of antibodies in milk samples, can identify bovine herpes virus-1 antibodies (Dilbaghi et al. 2013).

Sr No.	Disease control approaches	Techniques/methods	Description
1	Molecular Diagnostics	Polymerase Chain Reaction (PCR)	By amplifying particular DNA or RNA sequences, this method makes it possible to detect pathogens even in trace amounts quickly and sensitively. For the diagnosis of bacterial, viral, and parasite infections, PCR-based assays are frequently employed (Kaminski et al. 2021)
		Real-Time PCR	Real-time PCR, a quantitative variant of PCR, provides important information for disease monitoring and outbreak investigations by enabling the real-time detection and quantification of pathogens (Artika et al. 2022).
		Loop-Mediated Isothermal Amplification (LAMP)	A rapid and simple technique that amplifies DNA under isothermal conditions, LAMP is suitable for point-of-care testing in resource-limited settings (Srivastava et al. 2023).
2	**Immunological Techniques**	**Enzyme-Linked Immunosorbent Assay (ELISA)**	A flexible method for identifying antibodies or antigens in biological materials is ELISA. Numerous infectious disorders, such as bacterial, viral, and parasitic infections, can be diagnosed using it (Celindo et al. 2013).
		Lateral Flow Immunoassay (LFIA)	A flexible method for identifying antibodies or antigens in biological materials is ELISA. Numerous infectious disorders, such as bacterial, viral, and parasitic infections, can be diagnosed using it (Ma et al. 2011)
3		**Recombinant Vaccines**	Certain genes from a disease are inserted into a harmless carrier organism to create these vaccines. This method makes it possible to produce vaccines that are both safe and effective against a variety of illnesses (Pollard et al. 2021).

	Development of Novel Vaccines	**DNA Vaccines**	DNA vaccines trigger an immune response by introducing DNA encoding certain antigens into the host. This technology offers benefits in terms of stability and ease of manufacture, and it may be able to produce immunity that lasts for a long time (Khan et al. 2013).
		Subunit Vaccines	Subunit vaccines contain only specific parts of a pathogen, such as proteins or glycoproteins. This targeted approach reduces the risk of adverse reactions and can be particularly useful for diseases caused by complex pathogens (Ghattas et al. 2021).
4	**Genetic Engineering for Disease Resistance**	**Gene Editing**	By precisely altering the DNA, methods such as CRISPR-Cas9 make it possible to introduce disease-resistant characteristics into livestock animals. Researchers can make animals more resistant to infections by focusing on particular genes linked to disease susceptibility (Sollner et al. 2021).
5	**Therapeutic Interventions**	**Gene Therapy**	In order to treat infectious diseases or genetic problems, gene therapy entails introducing therapeutic genes into cells. Diseases that are now incurable may be cured using this method (Goswami et al. 2019)
		Antimicrobial Peptide Therapy	Antimicrobial peptides are naturally occurring substances that have broad-spectrum antibacterial activity. Scientists can develop novel medicinal molecules to combat antibiotic-resistant bacteria by understanding the mechanisms of action of these peptides (Zhang et al. 2021).

Conclusion

Biotechnology has made a tremendous impact in controlling of animal diseases. We may strive toward a future where animal diseases are successfully managed and protecting the health of veterinary animals, by utilizing biotechnology. New diagnostic techniques for the quick and accurate identification of a variety of livestock and companion animal diseases have been made possible by biotechnological advancements. Conventional diagnostic techniques requires lots of labor, time-consuming, less sensitive, and challenging to adapt to the developing pathogen diagnoses. NGS, biosensors, and amplification methods will continue to exist in their continuously altered forms for extended periods of time. Recent approaches in diagnostics for improvement will continually be brought about innovations. Costs are associated with new technique applications, and unbroken funds will be used to test new potential procedures. For ease of use in the field itself, these methods ought to be made simpler without seeming for any skilled personnel and highly equipped laboratories.

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