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Analysis of Animal Vaccine Classification and Current Status

Caijuan Shou, Xiaopin Cai

Xiongcheng Jianmin Med. Ltd., Zhuji, 31180, Zhengjiang, China

Corresponding author: 2985757244@qq.com

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Shou C.J., and Cai Z.P., 2024, Analysis of animal vaccine classification and current status, Journal of Vaccine Research, 14(1): 10-16 (doi: 10.5376/jvr.2024.14.0002)

Abstract Animal vaccines refer to biologics prepared artificially using one or more pathogens, with the aim of preventing and controlling animal diseases. These biologics are administered into animals through methods such as injection, introducing the pathogens or their corresponding antigens into the animal's body. This stimulates the host's immune response, leading to the development of immunity, ultimately preventing and controlling animal diseases. Animal vaccines are a crucial tool for preventing and controlling animal diseases. They can reduce disease incidence in animals, minimize the occurrence and spread of epidemics, safeguard animal health and production, and also have significant implications for human health and safety. With advancements in technology and an increasing focus on animal health and welfare, research and application of animal vaccines are receiving growing attention. This study aims to explore various aspects of animal vaccines, including their definition, classification, and current developments, aiming to gain a deeper understanding of the importance and application value of animal vaccines, as well as the necessity of vaccine research and development.

Keywords Animal vaccines; Immune response; Vaccine development status

Animal vaccines are biological preparations used to prevent and control infectious diseases in animals. They can stimulate the immune system of animals to produce antibodies, thereby providing protection. The preparation of animal vaccines involves a series of complex processes, including pathogen isolation and cultivation, inactivation or attenuation, and purification steps. Ultimately, the prepared vaccine can be administered to animals through methods such as injection, oral administration, or spraying.

The application of animal vaccines is extensive and includes areas such as agriculture, livestock farming, and wildlife conservation. In agriculture and livestock farming, animal vaccines are widely used to prevent and control common diseases such as avian influenza, swine fever, and foot-and-mouth disease. This not only helps protect the health of farm animals but also reduces the spread of diseases on farms, ensuring food safety and improving economic benefits. In addition, animal vaccines play a crucial role in the protection of wildlife. Many wildlife populations are at risk of disease transmission, and once a species is affected by an epidemic, its survival and reproductive capacity may be severely threatened. Therefore, developing and implementing vaccine plans for endangered species is crucial for protecting wildlife diversity and ecological balance.

Animal vaccines also have significant implications for human health. Many animal pathogens can be transmitted to humans through the food chain, leading to zoonotic diseases. Therefore, by preventing and controlling animal diseases, animal vaccines can reduce the risk of humans being infected with animal pathogens, thus maintaining public health. Despite the significant achievements of animal vaccines in preventing and controlling animal diseases, they still face some challenges. Issues such as pathogen variation, inadequate vaccine coverage, and vaccine safety require continuous research and innovation to address. This study explores definitions, classifications, development status, and more, aiming to increase awareness of the importance of animal vaccines and contribute to the protection of animal and human health.

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1 Definition of Animal Vaccines

Animal vaccines are biologics used to prevent and control infectious diseases in animals. They are composed of one or more microbial components and can stimulate the immune system of animals to produce antibodies against specific pathogens, thereby providing protection. Animal vaccines are typically administered to animals through injection, but they can also be given orally or via spray.

Pathogens (such as viruses, bacteria, or parasites) must be isolated from infected animals and cultured in the laboratory to obtain a sufficient quantity of the pathogen for vaccine preparation. To create safe and effective vaccines, the pathogens need to be inactivated or attenuated. Inactivated vaccines use chemical substances or physical methods (such as heat treatment) to kill the pathogens, rendering them non-pathogenic while still eliciting an immune response. Attenuated vaccines are achieved by reducing the pathogenesis of the pathogen.

The primary purpose of animal vaccines is to prevent animal infections and reduce the spread of diseases. They are widely used in agriculture and livestock farming to protect farm animals from common diseases. Animal vaccines are also crucial for the protection of wildlife populations, particularly for endangered species. The use of animal vaccines has significant implications for human health since many animal pathogens can be transmitted to humans through the food chain, thereby reducing the risk of zoonotic diseases.

Furthermore, animal vaccines provide important information and platforms for the development and testing of human pathogen vaccines. Animal vaccines serve as essential tools for preventing and controlling infectious diseases in animals. By stimulating the immune system of animals, they offer long-term immune protection, reducing the occurrence and transmission of animal diseases. This is crucial for maintaining the health of both agricultural and wildlife animals and protecting humans from the threats posed by animal pathogens.

2 Classification of Animal Vaccines

According to the use of the vaccine and the type of disease, animal vaccines can be divided into two categories: preventive vaccines and therapeutic vaccines

2.1 Preventive vaccines

Preventive vaccines are vaccines administered to animals when they are in good health to enhance their immunity and prevent the occurrence and spread of a specific disease. Preventive vaccines can be further categorized into primary vaccines and secondary vaccines. Primary vaccines are prepared from pathogens that are either naturally occurring or artificially cultured, such as rabies vaccines, foot-and-mouth disease vaccines, and avian influenza vaccines. Secondary vaccines refer to administering the same or different vaccines to animals after receiving the primary vaccine, in order to enhance their immunity and enhance vaccine efficacy. For example, multiple doses of foot-and-mouth disease vaccine are required to establish effective immunity (Figure 1).

Figure 1 Animal vaccine reagents

2.2 Therapeutic vaccine

Therapeutic vaccines refer to vaccines administered to animals after they have already contracted a specific disease. These vaccines are intended to boost the animal's immunity and accelerate the recovery from the disease. While the efficacy of therapeutic vaccines may not be as high as preventive vaccines, they can, to some extent, shorten the course of the disease and alleviate its severity.

Therapeutic vaccines are designed for individuals that have already been afflicted by a disease. Unlike preventive vaccines, which aim to provide immunity before infection, therapeutic vaccines are intended to promote treatment and recovery after infection. The design and application of therapeutic vaccines are based on the capacity of the immune system to activate and modulate the body's immune response. They typically contain components capable of eliciting an immune response against specific pathogens or disease-related antigens. These components can include pathogen proteins, peptides, nucleic acids, or other specific antigens.

The goal of therapeutic vaccines is to enhance the treatment outcomes by triggering an immune response. These vaccines stimulate the immune system to produce antibodies, cytotoxic T cells, or other immune cells, thereby strengthening the host's ability to combat the pathogen. These immune cells can recognize and attack the pathogen, leading to its clearance or control (Guerrini, 2001; Garg et al., 2017).

2.3 Common types of animal vaccines

Common classifications of animal vaccines each have their unique advantages and applicability. Selecting the appropriate vaccine type based on the specific animal species, disease type, and immunological requirements is a crucial factor in ensuring effective prevention and control of animal infectious diseases.

2.3.1 Inactivated vaccines

Inactivated vaccines use pathogens that have been rendered non-replicative and non-infectious. These pathogens are inactivated through methods such as chemical treatment, heat treatment, or radiation. Although inactivated vaccines have high safety and stability requirements during the vaccine preparation process, they pose lower risks and are suitable for animals with weaker immune systems.

2.3.2 Live attenuated vaccines

Through the use of attenuated pathogens, their pathogenic capacity has been significantly diminished but still able to activate the host immune system They can provide long-lasting immune protection because they mimic real pathogen infections, activating both cellular and humoral immune responses in the host. However, since live attenuated pathogens are present in the vaccine, special handling and precautions are required during vaccine preparation, storage, and administration.

2.3.3 Subunit vaccines

Subunit vaccines contain only specific components of pathogens, such as proteins, peptides, polysaccharides, or nucleic acids. By selecting specific antigenic components of the pathogen, subunit vaccines can provide targeted immune protection against specific pathogens, avoiding adverse reactions associated with the use of complete pathogens. The development and production process of subunit vaccines may be more complex, but they offer advantages in terms of safety and purity.

2.3.4 Recombinant vaccines

Recombinant vaccines use genetic engineering techniques to introduce specific genes from the pathogen into host cells, enabling them to produce antigenic proteins of the pathogen. These antigenic proteins can serve as components of the vaccine, activating the host's immune system. Recombinant vaccines have high safety and purity and can be customized as needed. Furthermore, they can avoid the use of live pathogens, reducing the risks of infectivity and adverse reactions.

2.3.5 DNA vaccines

DNA vaccines trigger an immune response by introducing the DNA sequence of the pathogen into host cells. DNA vaccines can deliver the pathogen's DNA directly into host cells through methods like injection, electroporation, or gene gun. Once the DNA enters the cells, host cells begin producing antigenic proteins of the pathogen, thereby activating the immune system. DNA vaccines have advantages in terms of ease of synthesis, storage, and the ability to elicit both cellular and humoral immune responses (Shin and Yoo, 2013).

2.3.6 Viral vector vaccines

Viral vector vaccines use viruses as carriers to introduce the antigenic genes of the pathogen. Once the virus enters host cells, it releases antigens of the pathogen, activating the immune system. Viral vector vaccines can simulate the actual virus infection process, triggering long-lasting immune protection. Some common viral vectors include adenoviruses, herpes viruses, and recombinant Newcastle disease viruses, among others.

2.3.7 Combination vaccines

Combination vaccines combine antigens from multiple pathogens to provide immune protection against several diseases. Combination vaccines can reduce the number of vaccinations needed and simplify management while offering comprehensive immune protection. For example, some canine distemper vaccines also include antigens for canine infectious hepatitis and canine parvovirus.

2.3.8 Others

Adjuvanted vaccines have adjuvants added to enhance immune responses. Adjuvants can facilitate antigen absorption and transport, activate immune cells, and increase the vaccine's duration. Commonly used adjuvants include aluminum salts, oil emulsions, and aluminum hydroxide, among others.

Glycoprotein vaccines use surface glycoproteins of pathogens as antigens. Glycoproteins play crucial roles in many pathogens, such as the hemagglutinin protein in influenza viruses. Glycoprotein vaccines can activate humoral immune responses and possess broad immunogenicity.

Oral vaccines are administered to animals through oral ingestion, activating the immune system via the host's intestinal mucosa. Oral vaccines can mimic the actual pathogen infection route and offer the advantages of convenience, ease of use, and dissemination.

3 Research Status and Challenges of Animal Vaccines

3.1 Current status of animal vaccines

The research and development of animal vaccines have a long history, and traditional techniques mainly include inactivated vaccines, live vaccines, and subunit vaccines preparation technologies. The current research status of animal vaccines exhibits characteristics such as technological innovation, application innovation, regulation, and standardization. In the future, with advances in technology and changes in societal demands, research on animal vaccines will also present new trends and opportunities (Wang et al., 2010).

Research on animal vaccines has always been an important focus in the fields of animal health and human food safety. Currently, new technologies such as genetic engineering, nanotechnology, and adjuvant technology are widely applied in the development of animal vaccines. For example, genetic engineering technology allows the insertion of foreign antigen genes into pathogens, enabling the pathogens to produce more antigens and thereby enhance the vaccine's efficacy. Simultaneously, nanotechnology can encapsulate pathogen antigens within nanoparticles, improving the stability and immunogenicity of the vaccine. Additionally, adjuvant technology can enhance the immune effectiveness of vaccines and improve their safety (Meeusen et al., 2007; Akkermans et al., 2020) (Figure 2).

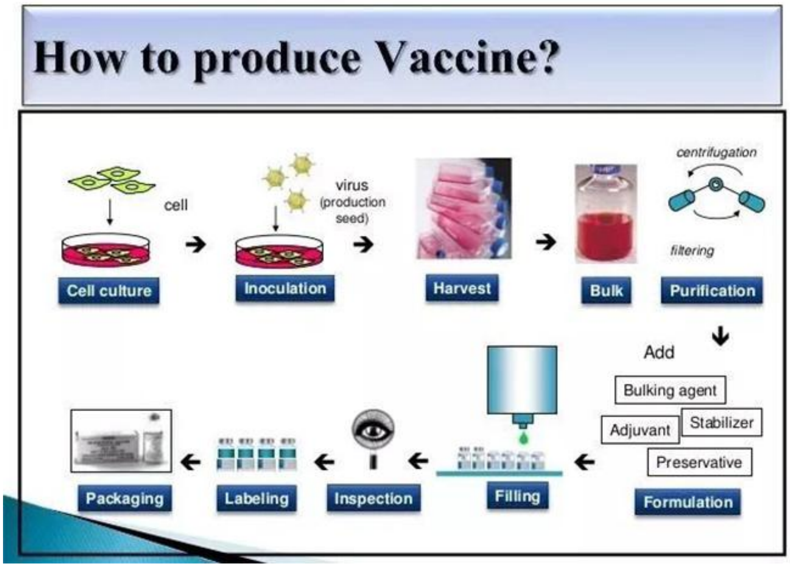

Figure 2 The process of vaccine research

3.2 The challenges faced in researching animal vaccines

With the influence of factors like globalization and climate change, the production and distribution of vaccines are facing new challenges. Currently, new technologies such as information technology and logistics technology are being applied to vaccine production and distribution. For example, information technology enables end-to-end tracking and management of the vaccine production process, enhancing vaccine quality and safety. At the same time, advancements in logistics technology can improve the efficiency and precision of vaccine distribution, better addressing situations like disease outbreaks.

As the use of animal vaccines becomes more widespread, regulatory oversight and standardization have also become increasingly important. Currently, countries and international organizations are strengthening their regulation and standardization of animal vaccines, developing relevant laws, regulations, and standards to ensure vaccine quality and safety. Efforts are also being made to enhance research in areas such as pathogen detection and vaccine efficacy evaluation, improving vaccine quality and efficacy.

Animal vaccines play a crucial role in safeguarding animal health, controlling disease transmission, and ensuring human food safety. However, in the processes of research, development, production, and application, they still face several challenges. Vaccine development requires substantial human resources, materials, and financial investment, along with adherence to strict safety and effectiveness standards. Due to the uncertainty and risks involved in vaccine development, the costs are often high, which is a major factor. Additionally, vaccine production and distribution require significant resources. The production and distribution of vaccines also require a lot of human, material and financial resources. Especially in some remote areas and developing countries, the cost and difficulty of vaccine distribution are also very high due to inconvenient transportation and poor climate.

Animal vaccines continue to face challenges in their research, development, production, and application. It necessitates collaborative efforts, innovation, improved research efficiency, reduced production and distribution costs, enhanced vaccine quality and safety management, and increased vaccine coverage to better safeguard the health of animals and humans (Bhatt and Nimesh, 2021).

4 Future and Outlook

The future outlook for animal vaccines is promising, with the potential to play an even more significant role in safeguarding animal health, controlling disease spread, and maintaining human food safety. As technology advances and societal needs evolve, animal vaccines also face new challenges and opportunities. With population growth and economic development, the scale of the livestock and pet markets continues to expand, increasing the demand for animal vaccines. Additionally, factors such as globalization and climate change lead to the emergence of new animal diseases that traditional vaccines may not effectively combat, necessitating the development of more efficient, safe, and comprehensive novel vaccines.

At the current stage, improving vaccine research and enhancing related regulations and personnel training are imperative. Establishing comprehensive animal vaccine management systems is essential for efficient vaccine administration. Government departments should enact robust vaccine management regulations, aligning with national legal requirements, and ensure that vaccine responsibilities and tasks are assigned at the individual level, ensuring dedicated management at every step. It is crucial to raise public awareness and capacity for self-protection, encouraging active cooperation with preventive measures. In regular practice, strengthening the training of personnel responsible for vaccine management enhances their sense of responsibility, thereby ensuring the safety and quality of vaccines. With the development of information technology, vaccine management should prioritize informatization. Traditional management methods often lack efficiency, and utilizing information-based management can significantly enhance the quality of vaccine management (Hao, 2012).

With rapid developments in biotechnology, information technology, and related fields, the research and development of animal vaccines will encounter new opportunities. For instance, gene engineering, molecular biology, and other technologies help scientists better understand the characteristics of pathogens, enabling the development of more precise vaccines. New adjuvant technologies, nanotechnology, and other innovations can enhance vaccine efficacy and safety. Information technology can improve the efficiency and precision of vaccine production and distribution. The future research and development of animal vaccines will emphasize technological and application innovations. Furthermore, the research and production of animal vaccines will require a more globalized, collaborative, and standardized approach. Countries should strengthen information exchange and cooperation, collectively addressing global animal disease challenges, while enhancing the regulation and standardization of animal vaccines to ensure quality and safety (Luo et al., 2009).

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Conflict of Interest Disclosure
The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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