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REVIEW ARTICLE

The role of nano-vaccines in animal science and health

Masoumeh NIAZIFAR [1], Akbar TAGHIZADEH [1*], Valiollah PALANGI [2]

[1] Department of Animal Science, Faculty of Agriculture, University of Tabriz, Tabriz, Iran

[2] Department of Animal Science, Faculty of Agriculture, Atatürk University, 25240, Erzurum, Turkey

Corresponding author E-mail: a_tagizadeh@tabrizu.ac.ir

HIGHLIGHTS

> Nanotechnology is the practical science of fabrication and utilization of substances at a tiny scale in a variety of 1-one hundred nm.
> The use of nanotechnology in the preparation of nano-vaccines for animal health was discussed.
> Purification and modification of minerals to prepare nano-vaccines were investigated.

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ABSTRACT

In recent years, researchers from various fields have tried to use them because of the increasing growth of nanotechnology. Technological applications in animal health have been a significant problem. However, it has overturned into a recent enabling technique over the years, with the vast possibility of transformation, and has potentially developed solutions. Nanotechnologies offer a wide range of prescription drugs for the diagnosis and treatment of diseases and reproduction. Nano-vaccines have emerged as a novel method of vaccination and are many more effective than traditional vaccines. Nano-vaccines trigger immune responses in the bloodstream and cells and prevent the spread of infection by destroying infectious agents by controlling the immune system. Also, advances have been reported in developing DNA-based vaccines for many diseases compared to conventional therapies. Objective: This review article aims to gather the materials and research that has been done to clarify the potential roles of nano-vaccines on animal health and their potential benefits and risks.

1. Introduction

Nanotechnology in animal science, is a powerful technology that can create a revolution and significant changes in the food and livestock supply system worldwide. Security of food and agricultural systems, enrichment and improvement of quality agricultural products, new cellular and molecular biology tool, intelligent transmission systems to animal diseases, and new materials to detect pathogens and protect the environment are examples of potential nanotechnology in the agricultural sciences. Nanotechnology addresses issues on a scale equal to those of viruses and other pathogens. Therefore, it has a high potential for identifying and eradicating pathogens; it also allows the use of drug delivery systems that can remain active for a long time. Designing drug-releasing systems have always been researchers' dream for drug-releasing systems, nutrients, and probiotics [1]. Today, one of the scientific challenges is using alternative food additives that do not produce antibiotic-resistant microbial species and increase resistance to stress and growth. Nanoparticles have various physiological and morphological properties, increased reflexive characteristics, bio-accessibility, persistence, regulated particle length, controlled delivery of medications, site-specific targeting, and managed pharmaceutical liberation. In addition, Nanoparticles can penetrate the cell, muscles, and limbs, creating a practical tool for medical performance [2]. In fact, vaccines are bioactive compounds that stimulate immune responses by delivering antigens to the immune system and equipping the body with more robust immune responses in the face of the primary pathogen. The use of nanotechnology in vaccine production science has found its way into areas ranging from ancient diagnostic methods to disease treatment, and it provided a new horizon to resolve the past challenges of developing effective vaccines. Nanotechnology has allowed different nanoparticles to develop in measure, composition,

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form, and surface properties for pharmaceutical applications. Therefore, Nanometer size feeds can increase the bioavailability of feeds, production performance, and safety status of an animal [3].

2. The place of nanotechnology in disease recognition

The economies of many countries depend on the livestock industry, and the emergence of several viral diseases requires new disease prevention systems. Nanotechnologies must have the potential to enhance the supply of medicine and vaccines in veterinary medicine. By increasing the growth of the range of nanoparticles, new therapies will develop to treat viral or bacterial diseases and enhance the healing of deep wounds [4]. Nanotechnology has allowed different nanoparticles to originate in measure, composition, form, and surface properties for pharmaceutical applications [4].

Vaccines produced using recombinant DNA technology are a set of DNA-related techniques that make up the core gene replication. In this method of making a vaccine, after identifying the antigenic epitopes of the pathogen, the genes encoding these antigens are found. They are then introduced into cellular expression systems such as bacteria, viruses, mammalian cells, or even plants to produce large amounts of the active substance. These materials are used as recombinant vaccines after isolation and modification. Nano-sensors and nano-chips can detect diagnosis at the molecular level and on a single cell, enabling the diagnosis, information, and treatment of infections. Furthermore, nanoparticle delivery systems may have numerous distinguishing characteristics, containing excessive drug loading capacity, controlled clearance rate, and decreased drug toxicity within the body. Therefore, approaches based on nanoparticles as the release or assistive systems offer new possibilities to improve innate immune activation and induce a robust immune response to minor toxicity [5].

Nanoparticles designed with polyethylene glycol (PEG) can delay the release of the drug from the body. It makes the systematic circulation of the drug in the body longer than the free drug state and can eventually be helpful in further accumulating the medicine at the site of the disease. Using bio-degradable nanoparticles in vaccine formulations has improved antigen shelf life and immunogenicity, regular delivery to target tissues, and slow release. Therefore, nano-drugs are very useful in preventing and treating diseases. Vaccine delivery methods have developed, from intravascular and intramuscular injections to oral, inhaled, and dermal injections. However, some vaccines have commercials for oral administration [6].

3. Nanotechnology in safety system

In particular, nanotechnology in vaccinology has emerged hastily in recent years, leading to the creation of "nano-vaccinology." Recent decades have introduced a growing number of proteins and peptides as potential new medicine [7]. Although these Biopharmaceutical has revolutionized medicine by introducing new therapeutic opportunities, their poor bio-pharmaceutical properties and inadequate patterns of drug release rates are a difficult stage in their development as a drug that significantly affects their widespread use. Their appeal was improved drug stability, enhanced targeting capacity, and controlled drug release. Antigen-carrying nano-particles' can affect the immune response and substantially enhance the T-cell cytotoxic response against antigens fused to nanoparticles because of the specialized ability of some antigen-expressing cells, which can deeply absorb foreign particles such as micro-particles and bacteria [7]. Attribute this advantage are to the nanoscale particle size, associated lymphoid tissues, and effective antigen diagnosis and production. The interaction of immunogen with Nanoparticles, which is the central portion of a nano-vaccine for the connection of Nanoparticles, includes three distinct tracks: conjugation, sorption, and encapsulation (within the Nanoparticles) (Figure 1) [8]. This cellular nutrition process is carried out by detecting antigen material to analyze and express antigens foreign to other cells in the immune system. Nano-metric materials can enhance the effectiveness of vaccines because of their biomedical benefits. The nanoparticles also have many properties as helpers for vaccines; However, there are limitations such as nonspecific uptake through the intracranial turbine system and toxicity to the immune system with these compounds [9]. Nano-technology offers opportunities to increase substances for scientific usage, where traditional techniques can attain their limits.

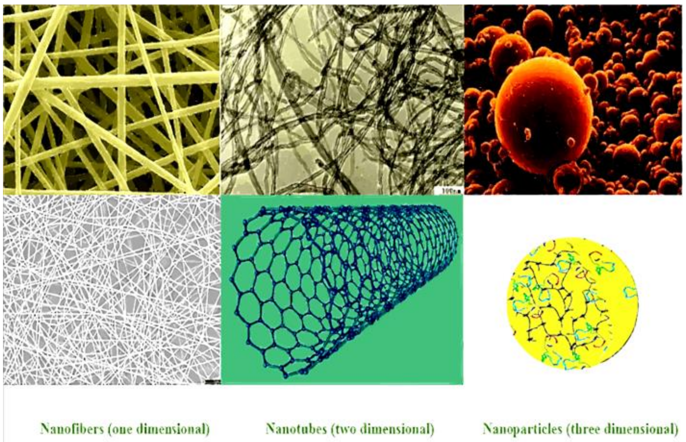

Figure 1. According to the proportions of the structural components, nanostructure substances are classified into three major types: nanofibers, nanotubes, and nanoparticles [9].

4. The emulsions of nano-vaccines

Can be used Nanoscale emulsions between 50 and 600 nm in size as an aid in vaccines. These nanoparticles may be present as oil in water or water-in-oil, in which an adequate surfactant stabilizes the nanoparticles. Emulsions disband polymers in the primary phase and form an emulsion with the aqueous phase. Dependent on the hydrophobicity of the vaccine, it may be the essential or aqueous phase of the emulsion. Polymer-encased emulsions act as nanocapsules by shaping a nucleus-envelope nanostructure [9]. The emulsions wil l be Trappe combining with antigen or pulling antigen into their nucleus to achieve the effective release of the vaccine. Emulsions present great potential in vaccine production science through nanotechnologies [10].

5. Nano-vaccines intervention in animal science

Nanoparticles have received much attention in recent years because they use a release system or immune system enhancers. Nano-vaccines have emerged as a novel method for vaccination. Nano-vaccines are more efficient than conventional vaccines and trigger blood and cell immune reactions. Vaccines inhibit infection by killing infectious agents controlling the immune system [11]. Vaccines advantage significantly from nanoparticle formulations, enhancing antigen perception and targeted APCs administration and enhancing immunogenicity and slow release of antigens. Because of their biodegradability, bioavailability, and minimal toxicity, most vaccine models containing these particles can be safe and effective alternatives to traditional vaccine formulas. It produced this new generation of vaccines with nanoparticles as vectors or adjuvants. Because of the similar size of nanoparticles and pathogens, they effectively stimulate the immune system. The activation of each cellular and humoral immune response followed the use of these vaccines [12]. The benefits of nano-vaccines include: Their best stability is in blood flow, Enhanced immune system stimulation, no boosters, and cold chain. Using nanoparticles' in vaccines offers two significant benefits. Firstly, nanoparticles act as adjutants, increasing the antigenicity of adsorbed or conjugated antigens and act as an antigen themselves. In this way, they can mimic the properties of pathogens such as viruses.

Secondly, the production of inflammatory cytokines intercedes many immunostimulatory responses initiated by NPs. Therefore, several nanoparticle structures are currently advanced for many applications. These structures can be both engineered or found naturally in the environment, and engineered Nanoparticles can specifically be designed to avoid interactions or target the immune system. This advantage is attributed to the nanoscale particle size (which facilitates uptake by phagocytic cells), associated lymphoid tissues, and efficient recognition and presentation of antigens. The interplay of immunogen with Nano-particles, which is the central piece of a nano-vaccine for Nano-particles incorporation, consists of three different ways: conjugation (covalent attachment), adsorption (on the surface of the NPS), and encapsulation (within the NPS) [13]. The other structures contain unique components that have gained much attention in the medical sciences, particularly in vaccines, such as liposomes, virus-like particles (VLPs), polymeric Nanoparticles, inorganic Nanoparticles, and the emulsions capability of Nanoparticles to fabricate synthetic vaccines to improve relating immune response and to act as vaccine delivery structures for a variety of substances (Figure 2).

It can induce an adaptive immune reaction and natural responses. Due to their high specific surface space and functionality, they are used as antigen carriers to improve antigen processing and offers. These qualities of Nano-particles have resulted in efficient cell targeting and the controlled release of antigens. Nanoparticles have abilities to both release antigens in a controlled manner and extend the half-life of most vaccines [13]. In addition, they can also act alone as immune potentiators. Added together are Resistant potentiators with adjuvants to influence T cells directly and their activation and improve antibody tigers. Nevertheless, in combination with immune potentiators, classical adjuvants have more complexity than improved immunogenicity [14].

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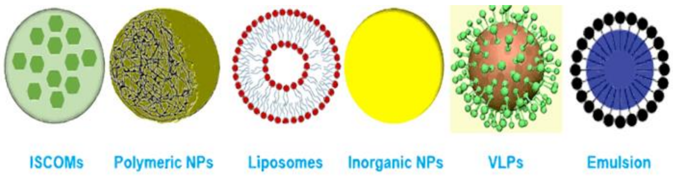

Figure 2. Structure of nanocarriers for vaccine antigen delivery [6].

6. Nano-vaccines intervention in animal health

The antigen-loaded nanoparticles can also target the lymph tumor, improving vaccine efficiency. There are many milestones in improving various types of veterinary nano vaccines, such as

1. Nano-emulsion vaccines, e.g., recombinant Bacillus anthracis spore-based and influenza virus vaccines, develop mucosa immunity after intranasal administering [16].
2. PLGA nanoparticles, e.g., Helicobacter pylori vaccine, Bovine parainfluenza type 3 vaccine, Tetanus toxoid, Bordetella pertussis vaccine, Rotavirus capsid vaccine, delivers IgG and IgA immune resistance after their oral management.
3. Chitosan nanoparticles (glucosamine biopolymer) can be distributed intranasal or pulmonary (e.g., TB vaccine) and S/C (e.g., recombinant Leishmania SOD vaccine) [16].

Other nano vaccines have additionally been advanced for veterinary use in opposition to FMD (gold nanoparticle-based vaccine), Newcastle disease (nano-capsule for oral administration), influenza virus (poly gamma glutamic acid vaccine for intranasal use, or Nano-patch TM for topical use), or herpes simplex (on calcium phosphate nanoparticles) and also African horse sickness virus (AHSV) vaccines with empty capsid and nucleus-like particles (CLPs) may be advanced the usage baculovirus-mediated co synthesis of African horse disease virus [17]. Such as (VLPs) of VP3 and VP7 (foremost middle proteins) and VP2 and VP5 particles (outer capsid proteins). The ensuing vaccine produces a weak immune response, requiring improvements in vaccine design [18].

7. Future Directions in nanovaccine

Vaccination includes a set of immunology, microbiology, molecular biology, investment and production costs and return on investment, and rules and regulations for vaccine use. The ultimate goal of any new vaccine is to produce a product needed for animal and human immunity against disease. Veterinary vaccines are involved in animals' health and high production, but they also play an influential role in human health [18]. Recently, vaccines have increased fertility, livestock production, and controlled livestock quantity in a particular group. Continuity of exchanges related to the rules and regulations for controlling animal and human diseases, scientific communication between researchers involved in animal and human diseases, and being prepared for the constant threat of emerging and re-emerging conditions are fundamental and essential [17].

A recent example of the emergence of the influenza virus of which poultry and wild birds are important vectors of the disease. Still, recent studies have shown that feral and domestic cats can also get the disease, and finally, the source may be the spread of the disease to humans. Pigs are susceptible to both human influenza virus and avian influenza virus. The simultaneous infection of pigs with the acute avian influenza virus and human influenza may cause the production of new strains of the virus that can be transmitted from human to human. Increasing the movement of animals from one region to another and the link between humans and wildlife, which is accelerated by global climate change, makes it essential to know about domestic animals and their products and nature, which play an indispensable role in spreading disease [17]. Human-transmitted has to take constant care. Significant progress has been made in producing effective vaccines and new types without side effects; however, we must add that many problems remain and are an incentive to use new technology in vaccine design. However, there are several new vaccines on the market. Still, they have less immunogenicity compared to living microorganisms, and identification of molecular and immunological properties of pathogens is required to increase the potency of killed and recombinant vaccines. Researchers need to do more research to find the pathogenic immunogenic antigens and increase their immunogenicity [19]. One of the best ways to increase the effectiveness of new and killed vaccines is to use new carrier systems, including plasmid DNA, nano- or microparticles, and living vectors. Essential points in immunology that are often overlooked in vaccine production are the critical role of innate immunity and the reactions of vaccine helpers. Intrinsic safety receptors for new compounds of active helpers and their associated ligands have been studied to enhance or enhance or regulate vaccine responses. The use of adjuvants in veterinary vaccines is not limited compared to human vaccines; in other words, in veterinary vaccines, there is more freedom in choosing helpers, and several helpers with different formulas are used in veterinary vaccines, but in human vaccines, only a few helpers are used [20].

On the other hand, in most cases, unfortunately, the details of the formula of veterinary assistants are not available to everyone due to their specificity. Information about helpers is not published, but there is hope that this case, in particular, will be reconsidered, and if possible, the formulation of helpers should be available to everyone. In general, existing barriers need to be removed for veterinary vaccines' success and commercialization [19].

8. Conclusion

The rapid improvement with the inside of the design and handling nano substances has endorsed the advancement of innumerable variations of the NPs. This service makes it possible to personify pharmaceutical operations. Nanotechnologies have led to unprecedented advances in all aspects of animal nutrition, including analysis, medicines, vaccination, animal composition and production, food, and health. Other applications of nanotechnology in animal science and animal health can be used in tissue engineering and the production of new tools for cellular and molecular proliferation, preservation and identification of animal reproductive processes, animal nutrition, the safety of animal food products, conversion of animal waste to feasible material consumption, and diagnosis of pathogens noted. The development of nanotechnology will revolutionize animal science and animal health and potentially enhance controlled practices, from nanocapsule vaccines to sex selection in reproduction. However, the economy and public opinion still need to focus on pharmaceutical nanotechnology and nanotechnology-based therapeutic advances to make them more prevalent in the future.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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