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Applications of nanoparticles in veterinary science: A promising technology for animal health

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ABSTRACT

Objective: To revise and describe the importance of nanoparticles in veterinary sciences to improve the health and welfare of animals.

Design/methodology/approach: The use of nanoparticles in veterinary sciences has the aim of using the unique properties of these structures at the nanometer level in order to solve medical and therapeutic problems in the field of veterinary medicine.

Limitations on study/implications: Although the nanoparticles have great potential in veterinary medicine, they also have certain limitations that must be considered in their application, among which the following stand out: bioavailability, distribution, toxicity, immunologic interactions, and costs.

Conclusions: The field of veterinary medicine is in constant evolution, which is why nanoparticles have become a cutting-age tool with transforming potential. Their application in the diagnosis, treatment and prevention of diseases offers ways to improve animal health and welfare. The continuous search for solid research and solutions to overcome the limitations will allow taking advantage of all the potential of these technologies.

Keywords: nanoparticles, veterinary sciences, animal health.

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INTRODUCTION

In a world in constant evolution, where science and technology come together to improve life, nanotechnology is the manipulation and use of materials at a nanoscale, which has opened new horizons in several fields of science, including veterinary medicine (Ali *et al.*, 2021). Nanoparticles have become a fascinating innovation frontier. These small structures vary in size between 1 and 100 nanometers, and they have unique physical and chemical properties that have allowed them to supply minerals, vitamins, medications and other compounds, providing innovative approaches for the management of animal health (Cervera *et al.*, 2023).

Veterinary medicine, responsible for the care and welfare of animals, constantly seeks to solve medical problems, improve the diagnosis, optimize the treatment, and prevent diseases. Therefore, nanoparticles have become a promising tool to change the way in

which animal health is approached (Scott, 2005). Nanoparticles have a series of unique characteristics due to their size at nanometer scale, such as a special surface-volume relationship and optical, magnetic and chemical properties (Urrejola *et al.*, 2018). These characteristics allow them to interact with biological systems in a specific and accurate way, which opens up a series of possibilities in veterinary medicine and zootechnics. From an early detection of diseases to specific treatment, nanoparticles have become a multifaceted tool useful to improve animal health (Reséndiz and Arvízu, 2020). This review has the objective of understanding some applications of nanotechnology in the field of veterinary medicine, as well as considering ethical safety and the balance necessary to take advantage of the entire potential of this emerging technology.

Applications of nanoparticles in veterinary medicine

Diagnostic application

Nanoparticles were used to improve diagnostic procedures in animals. Their capacity to interact with specific biomarkers allows a detection of highly sensitive and specific diseases (Tyler and Kang, 2015). This makes the early detection of diseases easier, which at the same time leads to more effective interventions and more positive results. The tests based on nanoparticles can detect certain biomarkers in a faster and more sensitive way (Kyle and Saha, 2014). For example, gold nanoparticles used with antibodies can bond with specific antigens allowing the early detection of infectious diseases or cancer in animals (Guo *et al.*, 2017). This test also has the potential to be used in diagnostic tests of zoonotic diseases, so it is important both for animal health and for public health.

Administration of medications

The accurate administration of medications is a challenge in veterinary medicine. Nanoparticles can be loaded with drugs and they can be liberated in a controlled way, which allows a prolonged and specific liberation in the animal's body (Irache, 2008). This is particularly useful in prolonged treatments or to minimize the secondary effects of the medication. Nanoparticles can also go through biological barriers such as the blood-brain barrier, which allows the treatment of disorders of the central nervous system in animals. Nanoparticles offer a series of advantages in comparison with the formulation of traditional drugs (Murthy, 2007). Their nanometric size allows a better penetration in specific tissues and cells, thus improving the bioavailability of the drug. In addition, the superficial properties of nanoparticles allow the conjugation with target cells, permitting a controlled and specific liberation of the medication in the site of action. This reduces the necessary dose and minimizes side effects (Masri *et al.*, 2018).

Prevention and control of diseases

Nanoparticles were also used in the prevention and control of diseases in animals, such as increasing the immunogenicity of cows, which results in a stronger and more lasting immunity response (Durán *et al.*, 2020). In addition, antimicrobial nanoparticles are being researched as an alternative to combat infections that are resistant to antibiotics, of great importance in the livestock industry. Nanoparticles offer a new way of preventing infectious

diseases in animals. It has been proven that antimicrobial nanoparticles, such as those from silver and copper, have strong bactericide and antiviral properties (Alvarracin *et al.*, 2021). These nanoparticles could be incorporated to equipment and lining of surfaces in livestock facilities, reducing the propagation of pathogens and the need for treatment with antibiotics.

In parasitology, nanoparticles can be loaded with antiparasite drugs and administered through feed or topical formulations to control endo and ectoparasites in the livestock.

Applications in food safety

In addition, there are many applications for nanoparticles to improve food safety. They can be used as antimicrobial lining on surfaces and food containers, limiting the growth of bacteria and other pathogens (Villamizar and Monroy, 2015). The nanoparticles from silver, zinc and copper have shown efficient antibacterial properties against various pathogens transmitted in food. Biosensors based on nanoparticles can quickly detect pathogens and contaminants in foods, allowing early detection and a timely response to the problems of food safety. Similarly, they can be used to control the liberation of antimicrobial and antioxidants to help extend the useful life of perishable foods (Khaliefa *et al.*, 2017).

Application in animal nutrition

Studies have shown that nanoparticles are valuable to improve the absorption and bioavailability of essential nutrients in animal feed (Cuca, 2018). Minerals such as zinc and iron tend to have low bioavailability in the diet of animals. Encapsulating these nutrients in nanoparticles could increase their solubility and absorption in the digestive tract, allowing a better availability (Kociova *et al.*, 2020). The digestive tract plays an important role in animal health and the absorption of nutrients; nanoparticles can have beneficial effects on intestinal health by modulating the microbiome and the integrity of the mucosa (Cano, 2022). Some nanoparticles act like prebiotics, promoting the growth of beneficial bacteria in the intestine, improving the digestion and absorption of nutrients. Oxidative stress is a factor that can affect negatively the yield and the health of animals, and some nanoparticles have antioxidant properties that can neutralize the free radicals and reduce the oxidative stress in animal tissues (Flores *et al.*, 2022). This is important, particularly in the case of animals subjected to stressful conditions, such as intensive breeding.

Importance and advantages of nanoparticles

The introduction of nanoparticles in veterinary medicine has changed the definition of animal health. The benefit is clear, since an early and accurate detection of diseases can be achieved thanks to their capacity to interact with specific biomarkers (Rodríguez *et al.*, 2021). In addition, customized therapy has become a reality, helping to control medications and to reduce the side effects. Disease prevention has also been improved by making vaccines more effective and combating infections that are resistant to antibiotics (Gómez *et al.*, 2016).

The use of nanoparticles in veterinary medicine has proven to be an innovative and promising strategy to address various animal health and welfare challenges, from the

accurate diagnosis to customized therapy and the improvement of livestock (Aguilera *et al.*, 2021). As research in the field of nanotechnology advances, it is important to face the challenges and maximize the potential of this technology in benefit of the animals.

Challenges and disadvantages

However, these opportunities entail challenges. The bioavailability and distribution of nanoparticles in animals can be unpredictable, which can affect their efficacy. The safety and toxicity of these particles must be evaluated carefully to avoid adverse effects (Chavez, 2018). Although there can be beneficial effects for the animal, they can also cause inflammatory reactions and even toxic ones at cellular level. The biodistribution of nanoparticles in animals is a reason for great worry because they can be accumulated in certain organs and have long-term effects that are not completely understood yet. Immune interactions and differences between species are also problems, since the administration and approval of therapies based on nanoparticles could be a complex and costly process. In addition, the issues of ethics and sustainability require continuous evaluation (Lozano, 2022).

The future of nanoparticles in veterinary medicine

Despite these problems, the balance between advantages and disadvantages suggests that the use of nanoparticles in veterinary medicine has great potential. Studies indicate that it is possible to attain reliable solutions to overcome these limitations, with which greater benefit will be obtained from these technologies (Grande, 2007). We must remember that all scientific achievements are associated with ethical responsibilities and the need for a careful application (Wing, 2006). On the other hand, it is important to consider that nanoparticles offer great potential to improve the diagnosis, treatment and prevention of diseases which allows a more customized and efficient care and treatment for the animals (Betancur, 2016).

CONCLUSIONS

Nanoparticles have proven to be versatile and promising tools in veterinary medicine. Nanoparticles are an innovative tool to enhance animal nutrition, improving the bioavailability of nutrients, promoting intestinal health, and reducing oxidative stress. They also enhance the capacity to improve early diagnosis, therapeutic efficacy and disease prevention in animals, which has the potential of changing the veterinary practice. However, more research is needed to understand the problems of safety and efficacy, and to maintain high ethical standards when these technologies are used in animal care. This is why it is necessary to continue the research in this area, as well as to analyze their advantages and disadvantages to ensure that their use in the practice of veterinary medicine can be a supporting tool in animal science.

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