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REVIEW ARTICLE

Application of nanomaterials in animal sciences

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HIGHLIGHTS

> The purpose of this article is to review the use of nanotechnology in the livestock industry and the effect of nanomaterials on ruminant nutrition.

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ABSTRACT

Nanoscience is one of the newest technologies in the world that is widely used in all fields of science and technology such as agriculture, medicine, pharmacy, environment, etc. One of the reasons for the pervasiveness of this technology in all sciences is related to its cross-science nature. This technology has received more attention in recent years due to its low cost, better and faster performance, high stability, and high repeatability. With this technology, farmers can have animals of superior breed and high production and experience the best performance by minimizing various diseases and have a high efficiency of milk and meat production at a lower cost.

1. Introduction

Nanotechnology is the science of controlling matter in nanometers. Nanomaterials have unique properties due to their small size (1-100 nm) and have many applications in industries and sciences various, including animal sciences. Applications of nanomaterials in animal sciences include health, drug delivery, higher production, and better quality milk and meat. Mineral nanomaterials are also used in the feed of livestock. Inorganic nanomaterials, due to the small size [1], stability at high pressure and temperature [2], small size and less space occupation, and larger impact area [3] (current perspective and future), have a high absorption capacity in the gastrointestinal tract [4]. The properties of mineral nanomaterials are known by their size, shape, and crystal structure [5]. Some nanomaterials with a surface function can bind to toxins and pathogens and cause their removal [6]. Nanomaterials (nano silver, nano zinc, and nano selenium) can also be effective in health and improving product quality [5].

2. Types of nanoparticles

Nanoparticles can be classified into metals, polymers, natural compounds, and nanostructured materials. Due to the fact that each group has different engineering processes, they perform different biological functions through various mechanisms. Metal nanoparticles are used in imaging and antimicrobial therapy. Metal nanoparticles in the treatment of antimicrobial kill gram-positive and negative bacteria and in this regard have been considered in medicine. However, the accumulation of metal nanoparticles in the body should be avoided because it may have harmful effects [7]. With the spread of magnetic nanoparticles in different parts of the body, MRI imaging is possible. In Feed additives in the form of nanoparticles in animals due to their availability, better performance and absorption in the intestine. Nanopolymers are synthesized polymers of nanometer size that have the ability to bind to other materials and have a positive effect on their biocompatibility and degradability. These properties of nanopolymers are considered in medicine because they have few harmful effects on patients. Nanopolymers destabilize bacterial cell walls to kill bacteria, greatly damaged bacterial function. Nanostructured materials are derived from various nanoparticle-based compounds such as lipids and proteins. These substances act as carriers of nutrients or drugs in the body. Damaged sperm can also be identified and removed by antibodies attached to nanoparticles. Natural nanoparticle-based compounds are also naturally obtained with little modification, like proteins. Natural nanoparticles and nanostructures can act as carriers

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of functional groups such as nutrients. Natural nanoparticles can be safer. Dietary supplements in the form of nanoparticles can increase the bioavailability of nutrients and also prevent the breakdown of nutrients in the stomach by encapsulation [6].

3. Nutrient delivery

Manipulation of nanoparticles such as casein micelles naturally present in milk and the accumulation of some casein forms around calcium and proteins, etc., can lead to the synthesis of hydrophobic nutrients [8]. Researchers have found that vitamin D in these nanoparticles increases their bioavailability due to proteolytic breakdown in the stomach and the release of vitamins [9]. This increase in bioavailability can lead to high growth in young animals, which can become overweight and highly productive animals in the future. Due to the fact that the different parts of the gastrointestinal tract of ruminants have unique properties, nanoparticles must be able to act according to the conditions of different parts of the gastrointestinal tract to increase their impact and absorption. Nanoparticles pass hydrophobic and hydrophilic compounds through the stomach in a protected manner to reach the intestines and must function as if they originate from the feed. Digestible nanoparticles are digested in the gut and otherwise excreted naturally from the body [6].

We briefly mention the mechanism of action of nanoparticles in animals:

1. Increased surface for binding to biological agents
2. Increased long-term storage of compounds in the gastrointestinal tract
3. Orientation of active components to the desired targets in the body
4. Significant reduction in gut cleanse
5. Allowing cells to absorb effectively
6. I Perforation of the cross-section of the epithelial coating in tissues, e.g., liver
7. Penetrating deep-rooted into the tissues through thin capillaries

4. The effect of nanoparticles on ruminal fermentation and growth performance in ruminants

Nanoparticles such as nano-minerals (selenium nanoparticles and zinc nanoparticles) positively affect ruminal fermentation and nutrient digestibility by increasing the surface to volume ratio, nanoparticle size, and catalytic and rapid efficacy. It also improves the bioavailability of mineral nanomaterials in the gastrointestinal tract. Mineral nanomaterials promote better growth of the animal by positive changes in the intestine and improvement of ruminal fermentation (increased fiber digestion and redox reaction). The researchers [10] stated that zinc nanoparticles (200-100 mg/kg) increased volatile fatty acids, microbial crude protein, and decomposition of organic matter in 6 to 12 hours after incubation in vitro ruminal fermentation conditions. Similarly, zinc nanoparticles in experiments [5,11] and selenium nanoparticles [12] increased the digestibility of dry matter, organic matter, crude fiber-free extract, and finally increased the weight of lambs.

The beneficial effects of nano-silver on production have been reported by Albanese [3] and Elkloub [13]. These positive effects can be attributed to the strong antibacterial, antifungal, anti-protozoan, and even antiviral activity of silver nanoparticles. It is also possible that under conditions of commercial farm stress, the concentration of pathogenic bacteria will increase, and as a result, the effect of silver will be greater. These positive effects can be attributed to the strong antibacterial, antifungal, anti-protozoan, and even antiviral activity of silver nanoparticles. It is also possible that under conditions of commercial farm stress, the concentration of pathogenic bacteria will increase, and as a result, the effect of silver will be greater. Arshad et al. [14] reported that selenium improves GSH-Px activity in microorganisms. Selenium is used to synthesize microbial proteins and cell wall components. Increased microbial protein production improves the production of volatile fatty acids, microbial population and decreases ammonia nitrogen.

Shi et al. [15] and Xun et al. [4] have reported that Se NPs improve the function of bacterial degrading proteins and the production of protein degrading enzymes.

Rumen pH balance and microbial population are critical for balanced rumen fermentation. Acidic pH impairs fiber digestion because it prevents bacteria from attaching to the plant cell wall. Studies by Shi et al. [15] found that the use of nano-selenium increased ruminal fermentation by improving and balancing microbial fermentation and ruminal pH in sheep.

5. Application of nanomaterials in the health of ruminants

Mineral nano-materials reduce free radicals and increase antioxidant activity by increasing the surface area and improving the health status of animals. Experiment [12] in male goats receiving selenium nanoparticles showed a significant increase in serum selenium and SOD superoxide, catalase, and glutathione peroxidase. These enzymes have an antioxidant role and eliminate oxidative stress factors such as malondialdehyde (MDA) [12]. Nanomaterials can also play a protective role against physiological disorders [16]. Selenium nanoparticles have been shown to protect cardiac cells against abnormalities and have positive effects [16]. Zinc oxide nanoparticles can also have antibacterial activity and effectively treat bacterial diseases.

6. Application of nanomaterials in animal reproduction and breeding

Finding estrus on the farm is difficult, costly, and time-consuming for industrial livestock. During estrus, estradiol changes in the blood can be used to identify estrus animals to be inseminated at the appropriate time. Today, specialists use nanotubes implanted under the skin to detect estradiol levels in the blood and track estrus animals [15]. Other nanomaterials include biological chips, which are used to physically classifysperm and ovum, allowing dysfunctional genomes and genetic diseases to be identified and removed as quickly as possible. Therefore, farmers can identify animals of a superior breed that have high production [17].

Recent research suggests that some nanoparticles increase fertility and protect sperm. Artificial insemination in livestock production is considered due to the lack of risks due to natural insemination for animals and breeders due to the selection of superior livestock traits. Nanotechnology can enhance this method (non-invasive bioimaging of gametes, nanofiltration, and preservatives in sperm freezing). In this regard, mineral nanomaterials are preferred to organic fluorescent molecules due to their high biocompatibility, high stability, and high signaling intensity [18,19]. Quantum dots are another method that detects and images molecular and cellular processes during fertilization and at a greater depth in the tissue, which is a function of the size, wavelengths, and probability of ovum and sperm mating [18,20]. Appropriate concentrations of quantum dots should be used to reduce cytotoxicity.

Defective sperm can be isolated in the reproductive cycle by seminiferous semen filtration. Several methods have been identified for nanofiltration, including antibody and lectin techniques. With this method, more female animals can be inseminated using diluted semen, which improves fertility [21].

Shahin et al. [22] stated that gene transfer was made possible by using silica nanoparticles. In this method, nanoparticles have a strong relationship with sperm and have no adverse effect on sperm, and ultimately improve its fertility [23]. Despite the many applications that nanoparticles have in reproduction, they can also be harmful and reduce sperm quality. Toxic nanoparticles include zinc oxide and titanium oxide nanoparticles, which increase sperm death by weakening membranes and fragmenting DNA [6]. To this end, [24] conducted an experiment using zinc oxide nanoparticles on human sperm and found that this substance reduced sperm survival by 50%. Therefore, it is necessary to be careful when using nanoparticles when using them [6].

7. Application of nanomaterials in improving the quality of animal meat

There are various methods to improve the quality of livestock meat using nanotechnology, such as encapsulation, spray drying, melt extrusion, coagulation, grease coating, and spray cooling. These systems cause changes in taste, delivery of several active ingredients, and long shelf life of meat. Today, researchers produce meat in the laboratory that has the potential to be even richer in nutrients than ordinary meat obtained by slaughtering animals [25].

8. Application of nanotechnology in milk production and safety

Milk can be contaminated by endogenous and exogenous agents and can cause disease in humans and newborn animals when consumed. Among the pathogens in milk, we can mention Staphylococcus, Streptococcus, Bacillus species, and Escherichia coli [26]. These pathogens contaminate milk and eventually cause disease by producing toxins. Therefore, it is necessary to identify these pathogens in milk before consumption, and special attention should be paid to it. Researchers [27] used hydrogenated castor oil solid lipid nanoparticles to identify Staphylococcus aureus pathogens. According to the experiment, the researchers said that by balancing the dose of nanocarriers and their half-life, milk loss could be minimized [6]. Other nanomaterials used to identify pathogens in milk are nanocomposites (gold nanoparticles and magnetic nanoparticles) containing antibodies. The unique feature of these nanocomposites is related to antibodies that can absorb pathogens.

9. Conclusion

Nanotechnology is a creative science that has a lot of potential and can affect society, the environment, animals, and many other issues in the world. In the near future, this technology in the discussion of diagnosis and treatment of diseases will make significant progress compared to the past and reduce costs and waste time. Also, the use of nanomaterials in animal nutrition by affecting ruminal fermentation, digestibility, and antioxidant activity improves milk and meat production compounds. Consequently, human health is guaranteed by consuming these products.

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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