CURRENT PROSPECTS OF NANOTECHNOLOGY USES IN ANIMAL PRODUCTION AND ITS FUTURE SCENARIO

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ABSTRACT: The usage of nanoparticles in veterinary/animal production is still relatively new, yet they have long been used as therapeutic and/or diagnostic tools in human medicine. At the moment, improvements and breakthroughs in animal production are being made using nanotechnology advancements. Therefore, the goal of the current review is to provide a data-ailed classification and uses of nano-particles in animal science. By increasing therapeutic benefits and minimizing side effects, the creation of an alternative medicine delivery system based on nanoparticles is thought to be beneficial for treating microbial illnesses. The increasing applications of nanoparticles in veterinary medicine, reproductive technology, food delivery, biocide, and as a factor in meat, egg, and milk quality has been widely studied and found to be a noteworthy effect. Recently, the introduction of novel, small-scale technologies, and materials that are advantageous to livestock species has revolutionized practically most aspects of veterinary care and animal research. This review will cover information about varying types of nanoparticles, the benefits of using nanomaterials over their alternatives, and the nanotechnology role and applications in veterinary science. The use of nanoparticles to create nano-vaccines and nano-adjuvants, and their usage in gene therapy and cancer treatment has ushered in a new era of medicine. Moreover, there is also limited literature available on the use and possible effects of nanoparticles in poultry feed, hence, this review will highlight the promising effect of various mineral nanoparticles (NPs) or mineral supplements on the production performance of broiler and commercial layers.

Keyword: Nanotechnology; Nanoparticles; livestock; animal science; nano-vaccines; biocide

(Received 15.01.2022 Accepted 18.05.2022)

INTRODUCTION

The science of materials at the nanoscale (microscopic) is known as nanotechnology. Nanomaterials are best described as particles with at least one dimension range between 1 and 100 nm averaging 109 – 107 nm (Hill and Li, 2017, Liang *et al*., 2006, Savithramma *et al*., 2011, Sailor and Park, 2012). The use of nanotechnology has an important place in veterinary science and other aspects of animal science/production, as well as in the administration of drugs through the development of smart systems to cure different fatal diseases. One of the most important advantages of nanotechnology is that it bridges the gap between microscopy and macroscopy, with nanoparticles serving as an ideal channel for communicating with biological systems. Large and active surfaces, certainly adjustable surface chemistry, and ligands i.e., nucleic acid, peptide and antibody are some of the characteristics that distinguish nano particles from bulk materials (Woldeamanuel *et al*., 2021, Mohanraj and Chen, 2006, Moudgil and Ying, 2007, Raghuwanshi *et al*., 2020).

Physical and chemical changes in particles size may affect their solubility and reactivity, as smaller size has higher solubility and reactivity as compare with larger size particle. Nanotechnology is important in every aspect of life (Khan *et al.,* 2019; Jeevanandam *et al.,* 2018). It is regarded as the most cutting-edge fields of scientific study. It has various uses in a variety of disciplines, however its application for treatment and production in veterinary sciences still in the experimental stage (Scott, 2007). However, in recent years, nanotechnology's contribution in the aforementioned domains of scientific investigation has made significant development. Nanotechnology is now being used to transform drug delivery methods and diagnosis unusual diseases. Nanoparticle technology has been used in animal reproduction, as well as in the development of effective vaccinations (Ali *et al.,* 2021).

Nanotechnology and nano-medicine have recently made significant contributions to clinical therapeutics by using biocompatible nano scale drug carriers including metal-, polymeric-, dendrimer-, micelle- and liposomes-nanoparticles to deliver various anticancer drugs more efficiently and safely (Bai *et al*., 2018, Youssef *et al*., 2019b). Nanoparticles can be used to kill a variety of animal pathogens, including those that cause robust chronic infections, intracellular pathogens, and blood parasites. The combined compounds can be employed for both therapeutic and diagnostic reasons due to their stronger affinity for antibodies (Jain and chemistry, 2005). Nanoparticles can also bind to antigens/proteins to create improved nano vaccines. Nano vaccines could replace the adjuvant and extend the duration of vaccine protection by controlling the release of bound antigens (Num and Useh, 2013, Maina *et al.,* 2020). Nanotechnology improves performance in a variety of dosage forms.

Nanomaterials and nanodrug delivery systems are new technologies in human and veterinary medicine. Nano-drug delivery systems provide a number of advantages, including increased stability, increased bioavailability, and reduced toxicity (Boulaiz *et al.,* 2011). Although nano-drug delivery technologies have mostly been used in human medicine, they are increasingly being applied in veterinary medicine. This brief review looked at common nano-drug delivery techniques and their applications in veterinary medicine (Koo *et al.,* 2005). In terms of enhancing diagnosis and treatment, as well as giving new tools to the field, veterinary nanotechnology holds a lot of promise. This study looks at some of the most significant nanoparticle applications in animal production, as well as their future potential (Patra *et al.,* 2018). When we talk about the main advantages of nanosizing it includes, decreased fed/fasted variability, decreased patient-to-patient variability, enhanced solubility, enhanced surface absorption, increased oral bioavailability, increased rate of dissolution, increased surface area, less amount of dose required and more rapid onset of therapeutic action as discussed by (Bhatia, 2016).

Nanotechnology has made significant development and has enormous potential in recent years. The current review focused on how nanotechnology has changed animal production and healthcare, both in terms of diagnosis and treatment. Nanomaterials such as carbon nanotubes, quantum dots, liposomes, polymeric nanoparticles, magnetic nanoparticles and other types of nanoparticles are being studied for their potential utility in illness diagnosis and therapy. In the future, it is possible to imagine bacterial infections being eradicated from a patient in minutes rather than weeks of antibiotic treatment (Meena *et al.,* 2018).

It is fair to expect that nanotechnology research will change animal health science and technology in the coming years, assisting in the increase of livestock production. Diseases of livestock such as helminthiasis, trypanosomiasis, tick and tick-borne diseases, influenza, clostridial infections, just to mention a few have made news headlines all over the world, because of their devastating effects on livestock population and the potential for some of these to be transmitted to human beings (Kroubi *et al.,* 2010).

Classification of Nano particles: Nanoparticles are classified in a variety of ways depending on their administration, structure, shape and origin as shown in figure 1.

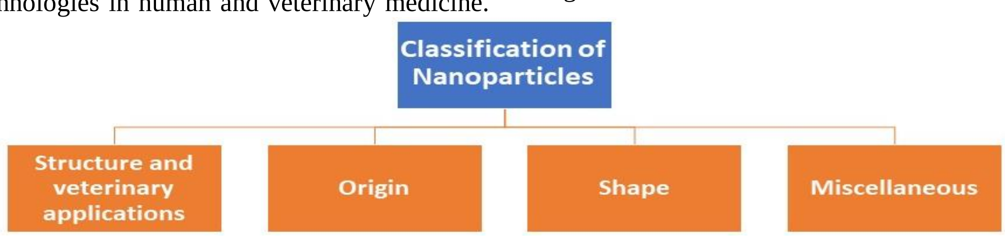
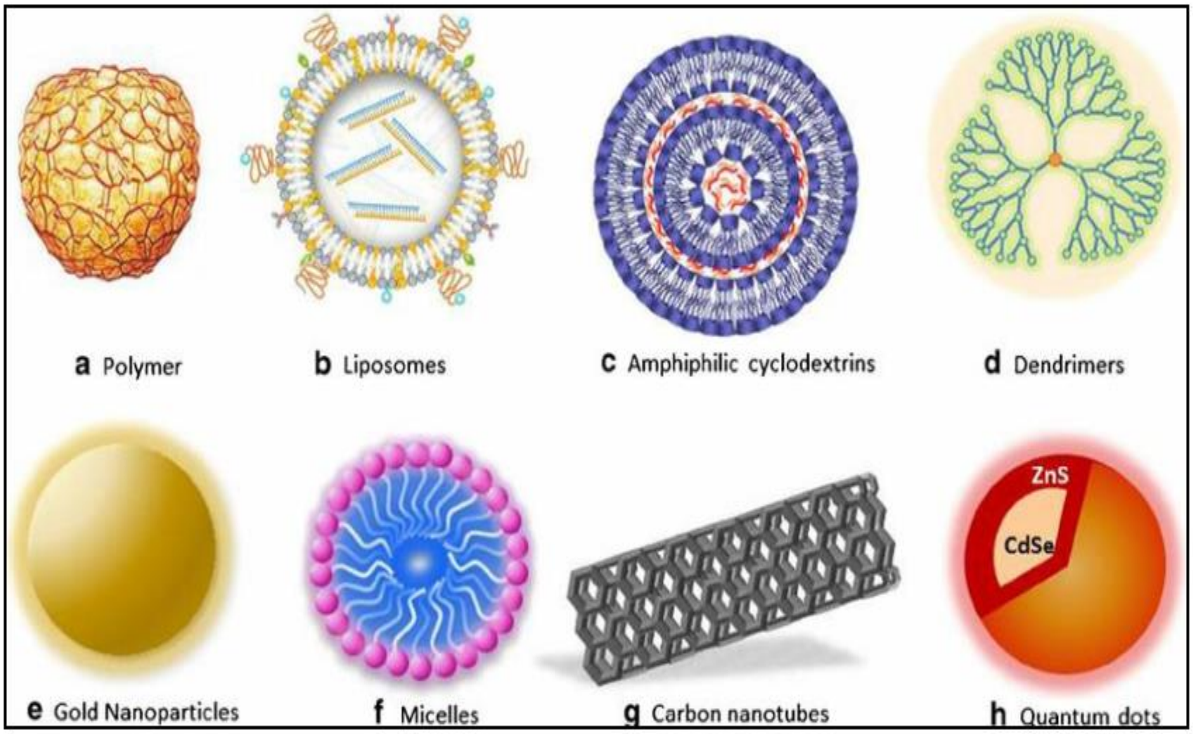


Figure 1- Classification of Nano particles

➢ **According to their structure and veterinary applications**



i. **Liposomes:** They were described as non-destructive circular biodegradable PE Gylated particles containing phospholipid bilayers used to encapsulate poor water-soluble drugs. They can also be employed to cover a variety of antigens. Liposomes have a unique role in medication delivery since they are highly biodegradable and biocompatible substances with a great ability to stack molecules with the properties of both insoluble and soluble in water at the same time. Simple diffusion can be used to release the loaded medicines. In any case, their main stumbling block is their insufficient quantity, quick aggregation, and delivery of loaded pharmaceuticals (Torres-Sangiao *et al*., 2016, Riley and Vermerris, 2017, Bakker-Woudenberg *et al*., 2005).

ii. **Bucky tubes and Fullerenes:** Fullerenes containing carbon to form nano particles that have the shape of a little ball and can communicate with cells or pathogens. Bucky tubes structure are hollow and spherical. They can be used as biosensors for identifying various components, such as immunoglobulin's (Jurj *et al*., 2017, Meena *et al*., 2018, Manuja *et al*., 2012).

iii. **Respirocytes and Microbivores:** Respirocytes take on the characteristics of both red and white blood cells independently. Pathogens are caught by microbivores as they productively supply tissues with O_2 and forego the accumulated CO_2 employing extraordinary managerial sensors in a well-controllable method (Freitas Jr, 2005).

iv. **Nano shells:** They are spherical in shape with an exterior gold covering and are used to analyze malignant tumors using an infrared laser. Nano-shell reduce the X-force beam's and can therefore be used as a radiotherapy adjuvant. Furthermore, gold nana particles are biocompatible, as well as non-toxic to the human and animal (Freitas Jr, 2005, Manuja *et al*., 2012).

v. **Quantum dots:**They are extremely little diamonds that range in size from 2 to 10 nm. When exposed to light, these molecules exhibit semi conduction, allowing them to be employed in optoelectronic applications. The frame of semi-conductor parts is made up of cadmium, zinc, and selenium. They have an inorganic material centre and shell, as well as a fluid coating that can be conjugated to various biomolecules (Patil *et al.*, 2009, Torres-Sangiao *et al.*, 2016).

vi. **Solid lipid nanoparticles:** They have a lipophilic centre that allows them to be employed for cancer treatment. Different hydrophilic medications or antibodies can have their outer hydrophilic shell conjugated to them. The outer shell also increases the bio profitability of the medicine (Elgqvist, 2017, Mohantya *et al*., 2014).

vii. **Nanoparticles of Magnetic iron oxide:** This group can be distinguished by the presence of magnetic field externally that allows them to engaged the target cells via the circulation. They're better for things like drug delivery, thermal therapy, and imaging (Manuja *et al.*, 2012).

viii. **Dendrimer:** They are hyper-branched nano materials that are extraordinarily dissolved in aqueous solution and are made up of polymers that are exceedingly very small and even smaller than human cells (Rodríguez-Burneo *et al*., 2017, AWATE *et al*., 2013, Kareem *et al*., 2022).

ix. **Nano emulsions:** As bactericidal and virucidal drugs, nano emulsions offer a remarkable restorative potential. When oil drops in the animal body interact with viral or bacterial coats due to surface tension, the oil droplets attach to the layer/envelope and mix, causing the treatment to arrive within the microbial cells. Furthermore, nano emulsions can be used as antigen delivery vehicles. Various antigens can be mixed in a single nano particle (Rapoport *et al*., 2007, Torres-Sangiao *et al*., 2016, Kudela *et al*., 2015).

x. **Nano bubbles:** They are stable at ambient temperature, but when exposed to ultrasonic waves, they clump together to produce micro-bubbles. They are mostly employed in drug delivery, particularly drug administration into cancer tissues. Gene therapy also makes use of liposomal nano bubbles (Rapoport *et al.*, 2007).

xi. **Nanoparticles of Aluminosilicate:** Aluminosilicate are (poly-phosphate but short-chain that combined with nanoparticles of silica) that are used to speed up the natural clotting process, resulting in less bleeding (Kudela *et al.*, 2015).

xii. **Polymeric micelles:** They are made out of a hydrophobic core that allows hydrophobic medications to be transported more easily. A water-soluble coat, coats the hydrophobic core, making them highly water soluble. Paclitaxel and amphotericin B are examples of medicines that are less water soluble and are commonly utilized for targeted drug delivery(Erathodiyil and Ying, 2011, Jahanshahi and Babaei, 2008, Zaboli *et al*., 2013, Lee *et al*., 2013, Karimi *et al*., 2013, Prabhu *et al*., 2015, Youssef *et al*., 2019b).

xiii. **Nano crystals coated with Polymers:** Nanocrystals prevent aggregation for making it easier to organize a powerful nano suppression Macrophage-dependent HIV delivery and sequestration (Youssef *et al.*, 2019b).

xiv. **Polymeric Nanospheres:** Uniform circular frameworks with a size of less than a micron, made from bio-degradable or non-biodegradable polymers. It might be utilized to study "type-2 human/animal epidermal advancement factor receptor" and "in-vitro integrin cancer cell proliferation", which is a first for trans-dermal medicine delivery (McMillan *et al*., 2011).

xv. **Metallic nano particles:** A variety of metals are used in the nano systems, one of which is gold, which is commonly used in cancer treatment. Platinum, manganese, and silver nanoparticles are examples of metallic-nanoparticles with a metallic core that is shielded by a protective coating. In addition, metallic nano particles are loaded with antibodies and chelated radio nuclides (Mieszawska *et al*., 2013, Mishra *et al*., 2010, Landers *et al*., 2002).

The figure 2 show the classification of Nanoparticles used in veterinary sciences based on their applications and their structure

- **Depending upon their origin:** They are categorized as hybrid, inorganic and organic nanoparticles according to their origin as shown in figure 3.
- **Inorganic nano materials:** They are generally safe and bio-compatible, as well as less cytotoxic. These nanoparticles have unique optical and electrical properties that can be customised during assembly (Erathodiyil and Ying, 2011).
- **Organic nano materials:**

- **Proteins and peptide nano particles** are primarily used in measuring the quality delivery (e.g. gelatin) due to bio-resemblance, low creation efforts, and low lethality (Jahanshahi and Babaei, 2008, Zaboli *et al*., 2013, Lee *et al*., 2013, Karimi *et al*., 2013).
- **Hybrid nano particles** are made up of many nanoparticle sectors, such as a polymer-lipid hybrid system made up of polymeric NP and liposomes. The resulting chemical has a hydrophobic polymers (biodegradable) core that are loaded with hydrophilic medicines for simultaneous release (Prabhu *et al*., 2015, El-Sayed and Kamel, 2020b).
- **Depending on their shape:** Depending on the intended use (therapeutic, diagnostic, vaccine administration, nutritional), they are classed as spheres, tubes, or liquid drops (El-Sayed and Kamel, 2020b) as shown in figure 4.

- **Miscellaneous classification**

- **Immune-invigorating edifices** are classified as supra-molecular saponin adjuvant particles. Their primary function is to capture various viral antigens via hydrophobic interactions with viral wrap proteins(Grgacic and Anderson, 2006).

- **Virus-like particles** varies from smaller size (20 nm) to larger size (800 nm) with self-collecting properties. They can stimulate higher insusceptible reactions without activate contamination because of the lake of nucleic corrosive(Noad and Roy, 2003, Pushko *et al*., 2013)**.**
- **Self-gathering frameworks/proteins** encourage the use of higher concentrations of quaternary structures of protein in immunization of animals as well as in humans (Youssef *et al*., 2019a, Kanekiyo *et al*., 2013).

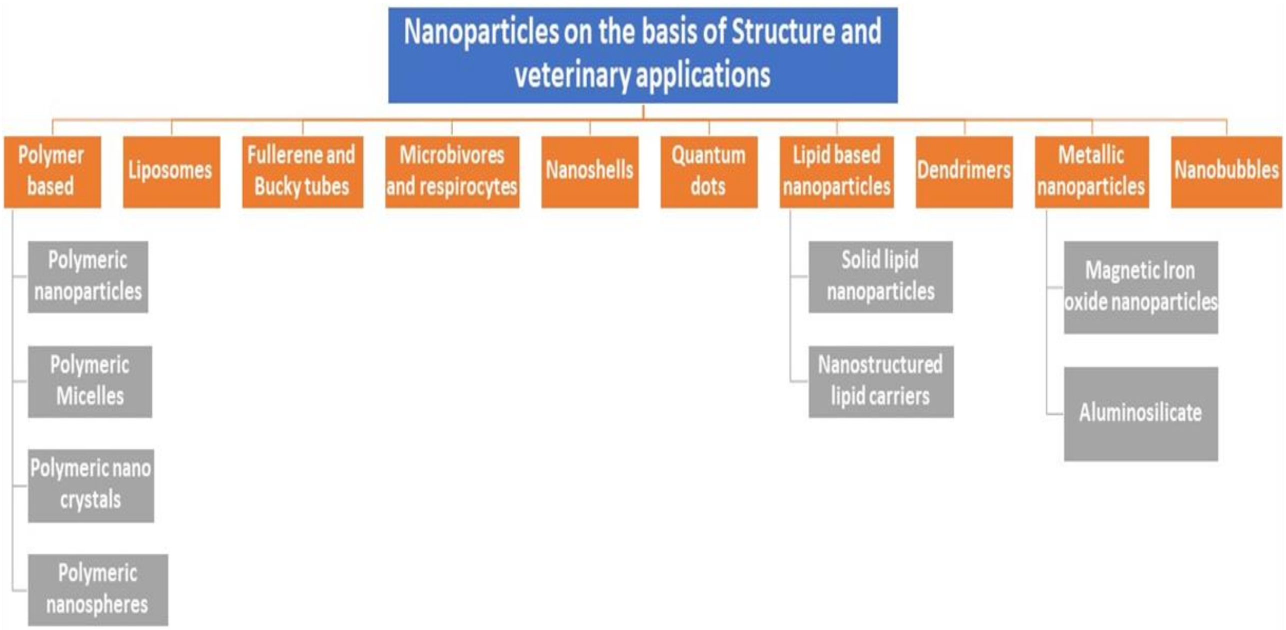


Figure 2-Classification of Nano particles on the basis of veterinary applications and their structure

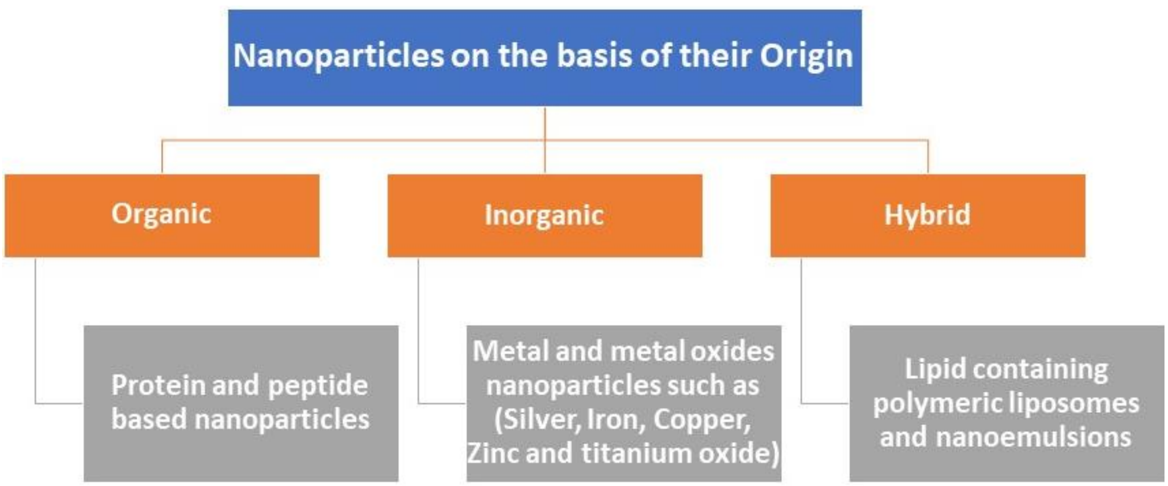


Figure 2- Classification of Nanoparticles on the basis of their origin

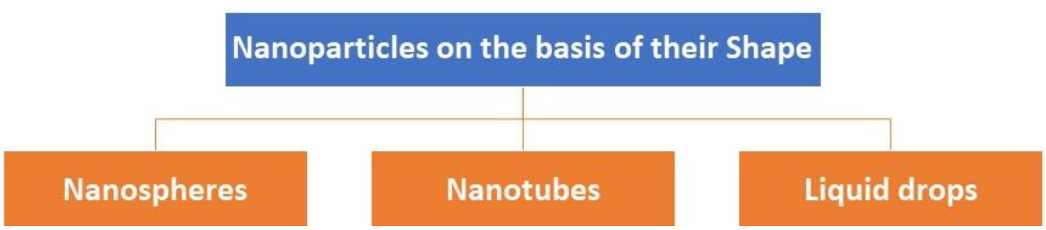


Figure 3- Classification of nanoparticle on the basis of shape

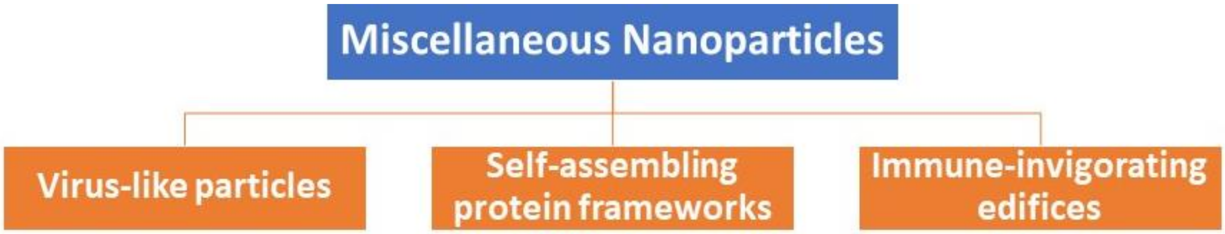


Figure 4- Miscellaneous classification of Nanoparticles.

Nanotechnology Importance in Pharmaceutical Medicine Development: Nanotechnology has a tremendous impact on medicine and medication delivery, owing to the considerable restrictions and issues that plague traditional pharmacological agents and older formulations and delivery systems (Halwani, 2022). In the realm of pharmacology, it's worth noting that nanotechnology allows for the development of new pharmaceuticals as well as the reworking of existing chemicals to improve efficacy. Drug delivery using nanoparticles has a number of advantages, including improving drug therapeutic efficacy and pharmacological characteristics. Nanoparticles have been proven to improve pharmaco kinetics, reduce undesirable side effects, and optimize transfer of drugs to disease locations in several nano-drug delivery systems (Woldeamanuel *et al.,* 2021). Some of the applications of nanotechnology in pharmaceutical sciences are summarized in figure 6.

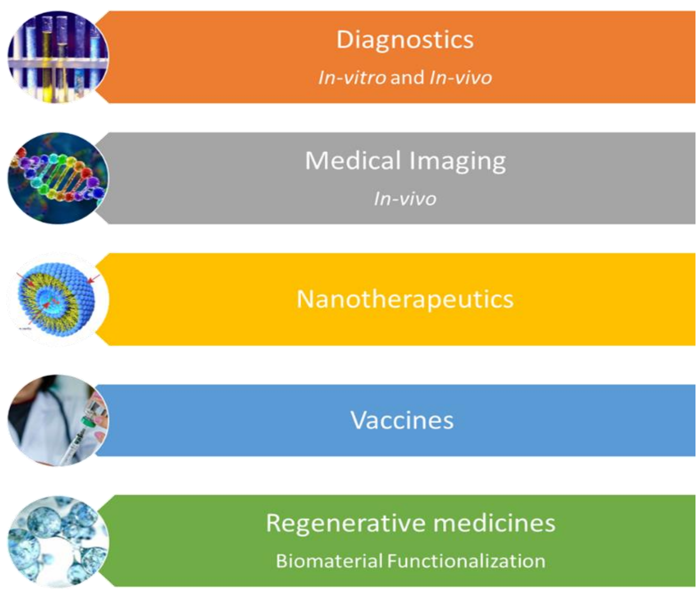


Figure 6-Importance of nanotechnology in Pharmaceutical Sciences

Nanotechnology in animal nutrition and health: The animal feed sector benefits from nano minerals synthesis in a number of ways (El-Sayed and Kamel, 2020a). Nano minerals are low-cost, used in smaller amounts, and operate as growth-promoting and immune-stimulating agents, resulting in numerous advantages for production of animal feed. They can also aid in the manipulation of feed pathogens and the improvement of the rumen fermentation process (Youssef *et al.,* 2019a). Finally, they can be employed to solve a variety of reproductive issues in herds/flocks. Many nonminerals, such as nano-ZnO, are now commercially accessible and help farm animals and birds grow faster, have better immune systems, and reproduce more successfully. It also reduces the incidence of diarrhea in young piglets. In dairy cows with subclinical mastitis, nano-Zn has been demonstrated to boost milk output and lower SCC (somatic cell count).

For poultry feed, nanotechnology-derived liquid vitamins are available. The nanosized nutrients travel through the GI tract and deliver vitamins and other nutrients directly into the bloodstream, increasing bioavailability. They hide unpleasant flavors while also improving the feed's nutrient dispersibility and durability. They also reduce the need for preservatives(El-Sayed and Kamel, 2020a)(figure 7).

Feed component microencapsulation is completed to shield them from process of oxidation and breaking down by oxidation and light, as well as lysis by digestive enzymes like proteases. It also promotes constancy at various pH levels, with better distribution and lipophilic additives mixingnan, and will extend their shelf life (Youssef *et al.,* 2019a). Mycotoxicosis is a dangerous disease that affects both humans and animals. Mycotoxins are found in roughly 25% of animal feeds, with the frequency being higher in developing nations. Nanotechnology enabled the production of a MgO-SiO_2 nanomycotoxin binder that effectively binds aflatoxins.

Better packaging materials with antibacterial properties (e.g., nano-zinc oxide), UV protection (nano-titanium dioxide), and extra strength are also possible using nanomaterials (nano-titanium nitride). Nanosensors have also enabled the recognition of any chemical or biological contamination, despite the level of concentrations (El-Sayed and Kamel, 2020a). The nanotechnology have showed major benefit in the field of animal production in areas such as reproduction, medicine, biocides, and delivery of nutrients (Hill and Li, 2017).

Several studies have demonstrated the potential of nano particles for removing heavy metals from the fresh water which can help us improve the health of fish in sea ports of Pakistan (Siddique *et al*., 2021, Wang *et al*., 2012)

- **Nutrient distribution:** Casein micelles are nanoparticles found naturally in milk, where casein phosphoproteins account for around 80% of the protein profile in cow's milk (Hill and Li, 2017),(Kareem *et al.,* 2022). To facilitate the delivery from mother to child, some isoforms of casein arrange themselves around various nutrients, protein and calcium. The inclusion of selected hydrophobic nutrients has been achieved through manipulation of these micelles (Hill and Li, 2017). Human volunteers were administered vitamin D encapsulated in casein nanoparticles, which increased *in-vivo* bioavailability of vitamin D because casein particles are proteolytically cleaved in the stomach, liberating the encapsulated vitamins (Hill and Li, 2017; Kareem *et al.,* 2022). A similar approach might be considered to assist manufacturers in assisting newborns through weaning, which is a delicate phase for children because their immune and digestive systems which are still evolving. Weaned animal must adjust to a diet contain complex carbohydrate and diminished immunological support in the absence of mother's milk. This is a critical stage not just for animal welfare, whereas also for productivity, as weaned animals that sustained growth rates throughout the process of weaning are heavier and healthier when slaughtered. The advantages of nutritional based supplements may also help weaning poultry and other domestic animals gain weight. By boosting nutrient cargo bioavailability, nanoparticles designed for delivery of nutrients could make this supplementation easier and boost animal growth rates (Hill and Li, 2017).

The livestock requires a carrier nanoparticle that can be taken orally. Each portion of the gastrointestinal tract has its own microenvironment, complete with enzymes and a certain pH level (Kareem *et al.,* 2022). The nanoparticles must be capable of overcoming these barriers in order to distribute their nutritional distribution to the right location, which is the small-intestine (Hill and Li, 2017). The canola protein cruciferin nanoparticle revealed that hydrophobic chemicals and nanoparticles encapsulate and shield hydrophilic molecules from gastric secretion. The nutrients being synthesized by nanoparticles and enter the intestinal epithelial cells. The nanoparticle does not reside in the intestine since it degrades based on the type of nanoparticle and the cellular absorption (Kareem *et al.,* 2022). The pancreatin enzyme digests the cruciferin nanoparticles in the small intestine, however indigestible nanoparticle carriers may be eliminated normally. Before going to advertise, a detailed investigation of nanoparticle action is required to check for potency and any undesirable biological effects, such as cytotoxicity (Hill and Li, 2017).

Although delivery of nutrient at the nanoscale could be natural or artificial, nanoparticles can actually strengthen bioactive substances and aid in uptake by cells uptake (Hill and Li, 2017). Nanoparticles are bioactive molecules that can be directly added to the body and counteract utilizing nanotechnological ways. They also have a high bioavailability in the intestinal mucosa due to their small size. Calcium citrate and Calcium carbonate were employed in the nanoscale to investigate bioavailability differences in lab animals by measuring bone density. Calcium nano compound-administered mice had more bone dinner than the conventional calcium-administered mice and control mice (Kareem *et al.,* 2022). It would be interesting to see if providing calcium in nanoform could help in production of animals like turkeys develop their bones, as body bulk is disproportionately chosen for over strength of legs, making it harder to support themselves in turkeys (Hill and Li, 2017).

Biocides: Nanoparticles act as a substitute for antibiotics, preventing microorganisms from entering the animal's body. Antibiotic resistance develops as a result of the uncontrolled use of antibiotics. Prophylactic antibiotic use in agriculture is a means of preventing the rising problem. Because of the increase in animal production, it is necessary to limit and utilize less antibiotics in order to recognize alternative molecules(Yang *et al.,* 2016).Bacterial growth is inhibited by positively charged nanoparticles. The positive charge on elements of nanoparticles on bacterial membranes causes leakage and bacterial lysis. Silver nanoparticles were reported to inhibit hemorrhagic development in intestine inflammation induced by E. coli and yeast isolated from bovine mastitis, according to Kim *et al.*In dentistry, silver is utilized to prevent dental irritation(Xu *et al.,* 2015). Qi *et al* investigated the effect of chitosan on bacterial infections and discovered that the bacteria's MIC was less than 0.25 g/ml. According to Colles *et al.*, antibacterial nanoparticles have a considerable effect on possible infections (Kareem *et al.,* 2022). Despite the fact that current biosecurity procedures can prevent pathogen entrance, the personnel, air, water and feed can still serve as entry routes. The utilization of antibacterial nanoparticles on these sites may build additional barriers to entrance for possible infections (Hill and Li, 2017).

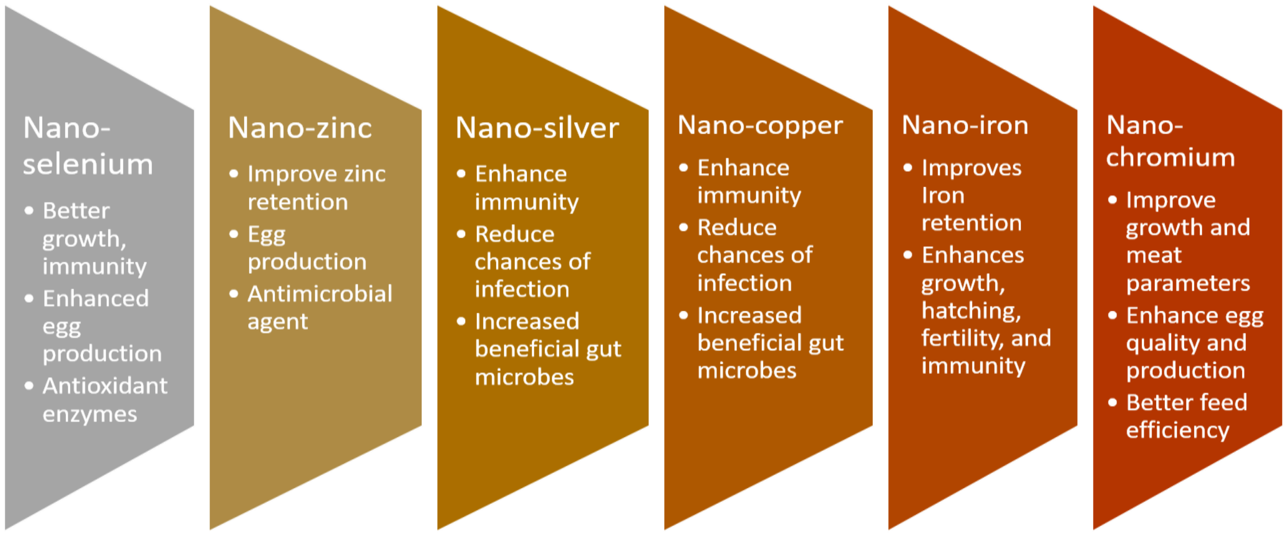


Figure 5- Application of Nano minerals in poultry

Copper is commonly added to diets in order to boost growth and performance (Kareem *et al.*, 2022).Although copper is given to orally in animals through their feed, it faces the same issues as nutritional delivery. Copper nanoparticles have been shown to pass through intestinal mucosa more easily than microforms, facilitating absorption. Gonzales-Eguia revealed that by boosting lipase and phospholipase, nanoform copper might increase digestion of fat and energy in piglet. When compared to a $CuSO_4$-supplemented diet, an activity in the small intestine, weight gain, metabolic rates, and immunological capabilities all were increased in these piglets on a daily basis. However, hematology did not differ between experimental groups, nano-copper's effect analysis on the animals immune system revealed considerably higher concentration of serum superoxide dismutase and total globulin. These findings imply that by adding antimicrobial metal supplements in nanoform to feed, the nutritious content of the feed can be improved. These findings imply that the nutritious content of the feed can be improved by adding metal supplement of antimicrobe in nanoform. Whereas, further research is needed before it can be determined whether nano-antimicrobials can totally replace antibiotics in feed (Hill and Li, 2017, Zhang *et al*., 2008).

Antibiotic-resistant microorganisms can be found almost anywhere, and antibiotics have no effect on them. Antibiotic nanoparticles have a substantial influence on resistant bacteria and reduce the amount of antibiotics necessary for therapy. In *Staphylococcus aureus*, penicillin nanoparticles are effective on the β-lactam ring by interacting withβ-lactamase. Penicillin nanoparticles were studied, and it was discovered that they could suppress MRSA. When antibiotic nanoparticles were employed systemically or topically in mice, there was no evidence of harm. The bacterial growth of tetracycline-resistant Escherichia coli is reduced when tetracycline-chitosan nanoparticles are used (Kareem *et al.*, 2022).

While bacterial pathogens are predominantly Gram negative, nanoparticles manufactured from natural or organic materials that can target specific Gram -ve bacteria are the most desirable for feed. It is essential to keep an eye on the materials fed to animals as food because toxins can build up in their bodies, posing a risk to consumers and potentially dampening public support for nanotechnology addition in animal production. This emphasizes the benefits of only using nanoparticles (biocompatible) in feed (Hill and Li, 2017). Nanotechnology applications are vital in preventing and killing all diseases that exist in food, hence it is used by scientific civilization. The use of nanoparticles in the feed not only kills pathogens, but the hydrogels can also limit pathogen proliferation. The hydrogels used to prevent germ attachment on surfaces can also bond with viruses.

Toxicity was shown to be dependent on the type of polycation and the molar mass of the polymer when using cationic polymers. When mice were given unquaternized PDMAEMA, it caused hemolysis, hence, only unquaternized PDMAEMA can only be used as a biocide for exterior usage (Kareem *et al.,* 2022). Spreading biocidal hydrogels and nano-solutions across thresholds, pens, and feed containers is another application that need further research (Hill and Li, 2017).

Meat and egg quality: The use of nanoparticles to improve the quality of meat and eggs has also been researched. For example, Wang and Xu(Hill and Li, 2017) found that finishing pigs headed for market were 14.06 percent thinner at slaughter when administered chromium nanoparticles (200 g/kg) in feed compared to control pigs that were fed a corn-soybean meal diet. Pigs were offered supplement of chitosan nanoparticle that are enriched with chromium, which resulted in an increase in skeletal muscle mass and increased pork quality (Hill and Li, 2017). In addition, the chromium level was found to be higher in tissues such as the longissimus muscle. Copper and silver nanoparticles were discovered in the blood-brain barrier (Kareem *et al.*, 2022).

Incorporating nanomaterials into livestock water or feed can improve the quality of the production cycle and final product. In chickens, nanoparticle of chromium added in feed that are not only increased the average daily gain and feed efficiency of broilers in the experimental group fed 500 g/kg Cr3+ but also significantly lowered the cholesterol. The significances of these findings are including lower feed consumption by broilers to get the market age, production cycle become shorter, and improve the quality of meat. In contrast, no significant effect were perduced on egg production or body weight when layer fed the diet containing chromium nanoparticles. Yet, Sirirat (Hill and Li, 2017) explore the shell and yolk of eggs and found greater calcium and chromium levels which indicate their positive effect the quality of egg (Hill and Li, 2017). However, Chauke N, Siebrits (Kareem *et al.*, 2022) reported that employing chromium nanoparticles does not increase egg quality. In the treated experimental subjects, nanoparticles accumulate in the liver (Kareem *et al.*, 2022).

Regardless the size of particle, the supplementation of vitamins in livestock is totally depend on market demand as it is beneficial for producers. If eggs and meat from animals administered supplements of nanoparticle are enhanced or indistinguishable from the unique product, people are much more likely to accept them. whereas, it is critical to recognize the role of nanoparticle as additive in a natural system as well as the by-products of tha particular system before using it in animal production to verify that it is safe for consumption (Hill and Li, 2017).

Milk: Mastitis is a common condition among dairy cows caused by a variety of provoking factors, many of which are bacterial, and which can necessitate the use of antibiotics to clear. Tilmicosin is an example of a mastitis medicine that might cause undesirable side effects if taken at higher dose. In context of this, Han (Hill and Li, 2017) used lipid nanoparticle (hydrogenated caster-oil) carriers to modulate the release of tilmicosin. The longer half-life of the medication, which was present in mouse blood serum for 5 hours without nanocarrier delivery and 8 days with nanocarrier delivery, was a source of worry for milk disposal times (Hill and Li, 2017; Kareem *et al*., 2022).In a *S. aureus*-induced murine mastitis model, however, a lower dosage (10 mg/kg versus 20 mg/kg) was required for resolution.

Producers could profit from careful modification of therapeutic nanocarriers to create a balance between dosage and half-life, reducing milk discard times and waste (Hill and Li, 2017).

The nanoparticle treatment has the advantage of reducing the amount of milk discarded. Nanotechnology aids in ensuring that milk quality is safe for human consumption. Han *et al*(Kareem *et al.,* 2022) developed a 40-minute colorimetric test for the presence of *S. aureus* in milk using nanoparticle antibodies as anti-*S. aureus*, gold nanoparticles, and magnetic nanoparticles. The carcinogenic aflatoxin M1 was employed by Wang *et al.* (Kareem *et al.,* 2022, Hill and Li, 2017) to diagnose the toxins in cow milk using comparable polyclonal antibodies and gold nanoparticle immunochromatography. Many studies are focused on removing hazardous components from cow milk; certain nanoparticles are present in the milk. Lee *et al.* (Kareem *et al*., 2022) used nanoparticle powdered oyster with milk to boost calcium levels from (100) to (120) mg/ml. Adding calcium from nanoscale oyster shell to milk provides numerous advantages (Kareem *et al.,* 2022).

Use of Nanotechnology in veterinary medicine: Disinfectant, vaccines manufacturing, cell engineering, diagnostic tools, and therapeutics are all available to veterinarians due to nanotechnology. Animal nutrition, animal reproduction and breeding, and animal production and health are all major fields where nano-applications are already practiced. The ability to transport medications directly to target cells allows for the use of very low doses, which reduces withdrawal time of drug, as well as the drug residues in farm animals.(El-Sayed and Kamel, 2020a).One of the inefficiencies of certain currently accessible drugs is poor distribution to the target site(Halwani, 2022). The overview of role of nanotechnology in veterinary medicine is shown in figure 8.

Nanotechnology's potential applications in animal production, reproduction and breeding: In the reproductive and reproduction fields, nanotechnology has begun to develop (Woldeamanuel *et al.,* 2021). Some of the drugs, vitamins, probiotics, and nutritional supplements, for example, may utilize nanoparticles to detect and remove infection-causing agents without undergoing surgery (Youssef *et al*., 2019a).

Overtime, the NPs are employed for the release of particular reproductive hormones. They protect the supplied hormones and vitamins against oxidation (e.g., vitamins and steroid hormones) or hydrolytic inactivation and destruction (e.g., gonadotropic hormones)(El-Sayed and Kamel, 2020a). The routine antibiotic usage in domestic production of animals can contribute to antibiotic residues that could affects the ultimate consumer, despite the fact that nanotechnology minimizes the number of medicines utilized due to nano size. Fattal *et al.* used nanoparticles load on ampicillin and validate it impact against *S. typhimurium* in mice and found that mice treat with ampicillin loaded nanoparticles had a higher ratio of survival than the control group. The difference is that previously 40 times less antibiotic was required to achieve the same effect with a greater delivery in tissues, therefore they tested the smaller amount of an antibiotic. Animal production will benefit from this technique if nano-fertilizers are used to provide vitamins to specific locations in the forages in the required amounts. This can be performed with the help of magnets, which are a great resource. Similarly, nanoparticles can be used with hydrogels or zeolites to improve water quality by absorbing harmful chemicals (Youssef *et al.*, 2019a).

Nanosensors are incredibly sensitive nanoscale devices that come with mobile probe biomolecules. The probes are typically employed for diagnostic purposes and are made of nanomaterials. They could be used to identify estrus, diagnose genital tract infections, metabolic and hormonal abnormalities, and even diagnose genital tract infections. In the same way, nanotubes can be utilized to detect estrus. When the cows come into estrus, the tubes are inserted beneath their skin and glow (El-Sayed and Kamel, 2020a).

Use of NPs in the poultry Nutrition: In this era, there has been a tremendous surge in interest in investigating the possible usage and usefulness of nanomaterials in animal production. The ability for these nanomaterials to be used as supplements, medicines, and probiotics in animal nutrition is being thoroughly researched (Hassan *et al.*, 2020). Feed additives such as trace minerals in the form of nanoparticles have recently been found to be efficient in meeting mineral requirements in cattle and poultry feed. These nano enhancers are intended to have higher bioavailability, lower dosing rate, and a steady interaction with other components. They can be utilized as a replacement for antibiotics as growth promoters, eliminating antibiotic residues in animal products, reducing environmental contamination, and producing pollution-free animal products due to their low dose consumption. Nano-additives can also be used in protein micelles or capsules, as well as other natural feed ingredients (Marappan *et al.*, 2017). Copper (Cu) NPs are the most investigated NPs in poultry field research, followed by zinc, zinc oxide, gold, silver, and selenium NPs, and then other NP formulations such as chitosan and chromium to a lesser extent (Abd El-Ghani *et al.*, 2021).

Nanoparticles containing Zinc: The addition of nano-Zn to the broiler diet increased their growth performance (Hassan *et al.*, 2020).Zinc is routinely added to chicken diets in the amounts of 0.12–0.18 g/kg for optimal growth, bone formation, feathering, and immunity. Zinc oxide (ZnO) and zinc sulphate (ZnSO4), both inorganic feed-grade Zn sources, are commercially utilised in chicken diets. ZnO, which is less bioavailable and reactive than Zn sulphate, is used for 80–90% of the supplemental Zn (Patra and Lalhriatpuii, 2020). Furthermore, various amounts of ZnO-nanoparticles were discovered to limit the growth of mycotoxic fungus as well as the production of the corresponding mycotoxins (AFs, OA and Fs). As a result, the approach can be used to treat feed to lower the risk of mycotoxicosis (Marappan *et al.*, 2017).

Supplementing broilers with nano-Zn has also been demonstrated to improve their performance in hot environments. Even in hot weather, studies shown that broilers' meat quality (thigh meat, pH, drip loss, and sensory evaluation) can be improved by nano-Zn (Hassan *et al.*, 2020). Zn depletion decreases eggshell quality because it is a cofactor of the carbonic anhydrase enzyme, which is required for carbonate ion production during eggshell development. As a result, Zn supplementation is likely to boost egg quality and productivity (Patra and Lalhriatpuii, 2020).

When administered in poultry diets, nano-zinc has demonstrated to have a greater bioavailability than inorganic zinc while having no influence on cumulative feed conversion ratio. In broiler chickens, use of Zn nano particles and Zn from organic source as alternative to inorganic Zn could increase production performance, weight of lymphoid organs, ND antibodies titer, and lipid profile, while having no effect on antioxidant capacity. In birds, gut health is critical for maintaining nutrition absorption and immunological function. Zinc has the potential to influence bird's intestinal health, but research on this important topic is lacking. In a recent study, broilers were given a combination of ZnO nanoparticles and a probiotic, such as *Bacillus coagulans*, showed significant improvements in production, morphology of intestine (villus length (VL) to Crypt depth (CD) ratio, VL, villus height (VH), and villus width (VW), and function of immune system. This demonstrates the ability of nano-Zn to regulate gut shape, but more research is needed to determine the influence of nano-Zn on gut microbiota in order to get insight into enhanced gut health and physiology (Hassan *et al.*, 2020).

Nanoparticles containing silver: Silver nanoparticles, for example, have antibacterial properties in the colon and can stimulate the immune system in animals (Patra and Lalhriatpuii, 2020). As an alternative to antibiotics, nanoparticles containing silver i.e., nano-Ag can be supplemented in poultry ration and found to be growth promoting due to antibacterial properties in poultry. Nano-Ag is utilized in animal nutrition to minimize nitrogen oxides and ammonia emissions because of its antibacterial characteristics (Hassan *et al.,* 2020). Silver NP diets containing 2 to 10 mg/kg of silver NP enhanced body weight gain and overall serum antioxidant status in birds. In broiler chickens, birds fed silver NP at a level of 4 mg/kg had the best development and feed efficiency compared to those fed at a high dose (10 mg/kg). Silver NP reduced E. coli levels in this investigation, but had no effect on Lactobacillus. Silver NP (3.5 nm) in drinking water (50 mg/L) was similarly found to reduce body weight growth, impair immunological processes, and have no antibacterial effects on various intestinal bacterial groups (Patra and Lalhriatpuii, 2020). The addition of 5 ppm nano-Ag hydrocolloid to the basal diet increased phagocytic activity, however lowering activity of blood antioxidative enzyme and haemoglobin content. Nano-Ag has been shown to have antagonistic effects on the mineral absorption in the birds' intestine. Ingestion of nano-Ag could accumulate of Ag inside the intestine that would be dose-dependent. Furthermore, while nano-Ag in intestine had no effect on Ca absorption, it did reduce K and Fe absorption. In quails, nano-Ag administration by drinking water had no negative effects on duodenal villi or gut microbiota, although it did increase lactic acid bacteria.

Many investigations have examined the impact of nano-Ag supplementation in ov on embryogenesis and chick metabolism (Zulfiqar *et al.*, 2020). The size and number of lymph follicles were reduced when broiler breeder eggs were injected with nano-Ag (10 ppm).Furthermore, injecting nano-Ag into eggs minimizes the embryo's requirement to consume fat from yolk as a source of energy. This guarantees that the residual fraction of yolk fat is available for chicks to use for fulfillment of their energy requirements even after hatching. In layers, nano-Ag inoculation in eggs could increase day old body weight and metabolic rate at hatching, but had little effect on broiler chicks. Although nano-Ag can be used in poultry in a variety of methods (intubation in crop, water, and diet), and the efficiency of its use may vary (Hassan *et al.,* 2020).

Nanoparticles containing selenium: Selenium (Se) is found in over 25 selenoproteins, which include a number of essential enzymes. For example, glutathione peroxidase (GPx) converts hydrogen and lipid hydroperoxide to harmless products, maintaining membrane integrity and protecting biomolecules like lipid, protein, and DNA from oxidative damage; thioredoxin reductase reduces nucleotides in DNA synthesis and aids in maintaining intracellular redox state; Thyroid hormone is activated by iodothyronine deiodinase, which converts inactive precursors into active hormone(Patra and Lalhriatpuii, 2020).

The antioxidant properties of selenium are well-known. Selenium is important for muscular development, thyroid metabolism, male reproduction, anti-oxidative mechanisms, and cancer prevention. Because of its smaller size and increased bioavailability, nano-Se has a increases the activity of Glutathione-S-transferase and Se retention (Hassan *et al.,* 2020).

In chicken diets, inorganic sodium selenite and sodium selenate, as well as organic selenomethionine and Se-yeast, are often utilized as Se supplements. Organic forms of Se are usually better absorbed from the gastrointestinal tract than inorganic forms (especially selenite), with selenomethionine absorption exceeding 90% compared to roughly 60% for selenite (Patra and Lalhriatpuii, 2020). Supplementing broiler diets with nano-Se (0.2ppm, 0.3ppm, 0.4ppm, and 0.5ppm) increased growth, immunological function, and carcass features while having no effect on internal organs. In broilers, a combination of probiotic (*Aspergillus*) and Se nanoparticles has been demonstrated to increase growth, skeletal muscle fatty acid profile, and serum tocopherol concentration. Nano-Se supplementation in the meals of egg-laying birds has also been tested to see how they respond in terms of laying performance. Except for retention of Se in eggs, egg mass and egg weight, which were all improved by supplementation regardless of source, studies found no significant effect of diverse selenium sources (nano-se, Se yeast and Se methionine) on productivity and egg quality indicators (Hassan *et al.,* 2020).

As feed additives: Essential oils, flavouring agents, antioxidants, coenzyme Q10, vitamins, minerals, and phytochemicalsare carried by minute micelles (nanocapsules) with increased bioavailability.Nanoparticles of active compounds (such as polyphenols, minerals, and micronutrients) are enclosed to limit oxidative reactions and off-taste. Liposomal nanovesicles are used in the food business to encapsulate and release nutrients, enzymes, tastes, and antimicrobial agents.Similarly, proteins or other substances can encapsulate nano-additives. Micelles are microscopic oil spheres having a thin layer of bipolar molecules on one end that is soluble in fat and the other end that is soluble in water.They can be suspended in water or, in the case of nanocapsules carrying omega 3 fish oil with an unpleasant taste, they can be encapsulated in micelles and suspended in oil (Marappan *et al.*, 2017).

Dairy and pig farmers face a costly and time-consuming dilemma with breeding management. A nanotube placed beneath the skin is currently being studied to analysis the variation in estradiol levels in blood by the mean of real-time monitoring

(Woldeamanuel *et al.,* 2021). Estradiol sensors measure blood hormone levels and relay real-time results can be transferred from the cows to cow monitoring central computer. Nanocapsules containing bull sperm can be delivered to the ovum in order to fertilize cows. It is possible to sort sperm and oocytes using nanotechnology. Biochips are being developed to allow for the selection of a fetus's gender (foetus sexing)(El-Sayed and Kamel, 2020a).

Furthermore, devices of nanotechnology like as nano-sensors for bio-analysis, nanoparticles and microfluidic can help to answer even more mysteries in diseases treatment & prevention, animal reproduction, animals' growth and health. Nanofluidic and microfluidic techniques are new ways to improve *in-vitro* fertilization as well as embryos growth. Microfluidics have been found to be effective in protecting motile sperm deprived of centrifugation in recent studies (Woldeamanuel *et al.,* 2021).

Cryo-conservation of sperm/oocytes or embryos can also be done with nanosystems. "Cryoprotectant propylene glycol" (Microinjection) contained NPs having gold/metal which allows for freezing as ultra-fast and then rapid and homogenous gametes thawing using laser light. The entire procedure is carried out on a chip using the microfluidics technique.

Low dose of metallic (cadmium) NPs has been used because higher level could be toxic, and these NPs can potentially be utilized for animal sterilization as contraceptives. To exercise their impact, the metal NPs are guided to the animals' reproductive tracts. To avoid employing hazardous NPs, they could utilize antibodies conjugated or heat the gonads using an external magnetic field (El-Sayed and Kamel, 2020a).

Nanotechnology applications in animal disease diagnosis and therapy: Nanotechnology allows us to come up with new solutions to old veterinary problems. This seems to have limitless potential in the domains of veterinary care and animal welfare. NPs can be used to eradicate a variety of pathogens from animals, including those that cause recurring infections, intracellular pathogens, and blood parasites (Osama *et al*., 2020, CHAUDHRY *et al*., 2009).

Nanotechnology is expected to play a significant role in worldwide veterinary practice in the near future. The use of nanotechnology devices for animal disease detection or as animal models for human disease diagnostics is a significant success in the one health initiative (Num and Useh, 2013). In veterinary medicine, identifying an illness might take a couple of days or weeks, or just as months, especially in chronic cases with no symptoms. As a result, an infection might have developed by that passage of time, necessitating the eradication of the whole herd. The nanotechnology acts on the similar scale as a particles of disease causing or viruses, allowing it to be recognized and eradicated at an early stage. Nanotechnology can thus be an effective tool for sensitive clinical diagnostics(Woldeamanuel *et al.,* 2021).

According to recent reports, quantum dots (QD) could be utilized for in-vivo imaging within tiny animal models. Functionalized NPs coupled with monoclonal antibodies being utilized *in-vitro* and *in-vivo* for the detection syncytial virus of respiratory system. The study found that NPs could provide a sensitive, rapid and direct virus identification, provide linkage between current time-consuming virus detection techniques and the needs for more rapid and sensitive detection of viral agents (Num and Useh, 2013).

Nanotechnology offers novel methods to veterinary problems including infections of blood pathogens or intracellular pathogens, FMD, S. aureus (methicillin resistant), brucellosis, and tuberculosis. Trials are being undertaken to direct the given medicines toward mastitic udders Mastitis is still most likely one of the most significant issues in dairy cow production. Traditional antibiotics cannot be used to treat the infection since many microorganisms are resistant. As a result, researchers have been focused on determining new remedies, and metal nanoparticles have been discovered the most effective agents. Kaliska *et al.* analyzed the performance of silver-copper, copper, and silver NPs on various pathogenic species usually implicated in udder inflammation (e.g., E. coli and S. aureus). They discovered that commercial products NPs were of excellent quality and did not harm mammary gland tissue. Furthermore, the examined NPs reduced pathogen viability. Yuan and co-workers (2017) investigated the efficiency of biologically produced silver nanoparticles against two multidrug-resistant strains of S. aureus and P. aeruginosa isolated from milk sample of goat showing symptoms of mastitis. The Silver NPs MICs towards S. aureus and P. aeruginosa were estimated to be 2 and 1 g/mL, respectively (Osama *et al.,* 2020).

The use of nanodrugs has several advantages over traditional drugs in various ways, one of which is their ability to make independent results. For example, linking gentamicin to a hydrogel via a peptide linker makes the gentamicin therapeutically ineffective unless the linker must be intact. The linker which are forming by peptide bond will only be degraded by *P. aeruginosa* as they are producing protease enzyme, for example *P. aeruginosa* presence is helpful for activation of gentamicin. NPs targeting bacterial toxins, which hinder the binding of pathogenic bacteria to being attached with intestinal wall and disturb microflora, (Zulfiqar *et al*., 2020), and receptors were also produced (El-Sayed and Kamel, 2020a, Khan *et al*., 2016).

Furthermore, nanotechnology is currently being used to treat trypanosomes. This was seen in the improved diminazene (DMZ) delivery to the action site.

Cationic nanoparticles with pores that were used boosted the possible of trypanosomes. Following nanoparticle treatment, medical data demonstrated a partial reduction in allergy symptoms (Youssef *et al.,* 2019a). Moreover, application of protein-cage nanoparticles on mice can helpful for protection against the lethal as well as sub-lethal dose of mouse pneumovirus , SARS-coronavirus or 2 different influenza virus, independent of any particular viral antigens. PCN treatment resulted in improved viral clearance, quicker production of antibodies that are viral-specific, and substantial reductions in lungs damage and morbidity, all of which contributed to increased survival. Clinical research usage of aerosol formulation of nontoxic-gelatin nanoparticles which are biocompatible and biodegradable for the treatment of recurrent airway blockage in equines. The regulatory anti-allergic and anti-inflammatory cytokine expression was markedly induced by 5 consecutive inhalations, which was particularly notable. Following nanoparticle treatment, a thorough evaluation of clinical indicators revealed a partial reduction of allergic illness. The researchers concluded that, despite being used for the 1^{st} time, during the treatment regimen in animals which are reared for food production that demonstrated the efficacy of colloidal immunotherapy by nanocarrier-mediated, with the possibility of future application to other species, including humans (Num and Useh, 2013).

Cancer is a prevalent disease that has been extensively studied. Although traditional chemotherapeutic agents are not specific to tumor cells, they have an impact on patients with a variety of adverse issues. Nanotechnology is a cutting-edge, intelligent technology can builds gadgets with the ability to deliver medications to various parts of the body. Submicron nanoparticles composed of various materials or devices are examples of such systems (Woldeamanuel *et al.,* 2021). Technology of nano-biotics and its application in the therapy of cancer is a new concept that is quickly gaining acceptance in diagnostics and therapeutics. Unique concept of nanotherapeutics, which involves nanoparticles containing therapeutic core which could be activated with the help of external energy source and have a control diameter of less than 70 nm. The nanoparticles are administered intravenously or intratumorally into the patient's tumor tissues and aggregate selectively in them after 20-48 hours. An outside energy field can be used for nanoparticle activation once they have been swallowed by the cancer cells, and a local chemical or physical action eliminates the tumour cell (Num and Useh, 2013).

Nanoparticles have a high surface-to-volume ratio, which allows diverse functional groups to adhere to the nanoparticle and hence bind to specific tumour cells. Because cancers lack an appropriate drainage network of lymphatic system, the nanoparticles' modest size of 10 to 100nm permits them to be accumulated preferentially at tumour locations. It is possible to create nanoparticles with capacity of multifunction including diagnose, envisage, and treat a tumour as part of a prospective cancer therapy (Woldeamanuel *et al.,* 2021). Liposomes are the most investigated nano-drug delivery methods in veterinary medicine, according to Zabielska-Koczyws and Lechowski. Because there is no cardiac toxicity associated with commercially available liposomal doxorubicin, it should be used instead of free doxorubicin in dogs with cardiac problems. The most promising nanomedicines for treating oral sarcoma, oral melanoma, and anal adenocarcinoma in dogs appear to be cisplatin-incorporated hyaluronic acid nanoparticles, cisplatin nanocrystals, and paclitaxel (Osama *et al.,* 2020).Other researchers analyzed the effects of paclitaxel (Tx)-loaded biodegradable nanoparticles (NPs) on tumour inhibition in a prostate cancer mouse model. They believed that NPs conjugated to the transferrin (Tf) ligand (NPs-Tf) would improve the therapeutic efficacy of the encapsulated medication.(Num and Useh, 2013)

Detecting cancer is critical for directional treatment regimens and determining the therapy efficacy. Traditional methods such as MRI and ultrasound have been enhanced by the nanoparticles usage for enhancing and comparing pictures, and new approaches including imaging for detection optical based cancers have been invented as a result. The treatment's efficiency is determined by the medication's ability to attack and kill tumor cells while leaving healthy cells unharmed. In a nutshell, one of the most important aspects of innovative anticancer drugs would be their high level of cancer cell selectivity. In current field, the fusion of nanotechnology and medicine offers a viable way to better cancer treatment (Woldeamanuel *et al.,* 2021).

The use of NPs in arrangement with nucleic acid or antibodies allows for the creation of diagnostic assays that are quick, sensitive, specific, and portable. Nano- and biochips have aided in the diagnosis of pathogens as well as the identification of genetic predisposition factors. The chip of nano array (high-density) can concurrently examine and detect hundreds different biomarkers for diseases, gene and antigen. Microarrays containing DNA and proteins have also been developed for determining medication efficacy and expression of genes. When LOC (Lab-on-a-Chip) era emerges, it became possible to determine smallest particle size and identify target proteins or DNA. NPS was also employed in a variety of diagnostic tools, as in Cat, during MRI it has been using as imaging agent. In the United States, gold nanoparticles have taken the place in dogs as treatment of cancer (prostatic) through surgical intervention. The therapeutic approach employed required thousands of times lower doses than chemotherapy and safe condition for healthy tissues (El-Sayed and Kamel, 2020a).

Nanotechnology implementation in pet animal care: Nanotechnology has also been linked to the development of novel items for pet animal care. Due to their various physicochemical qualities, they are utilized to improve surface refreshing and disinfectants. Silver nanoparticles, for instance, are used in topical shampoos (Osama *et al.,* 2020).

Nanoparticles as Nanovaccines and nanoadjuvants: In the development of veterinary vaccinations, nanoparticles are commonly employed (Osama *et al.,* 2020).

The nanovaccine is growing rapidly as a potential vaccine replacement. Nanovaccines are more potent than regular vaccines at stimulating both humoral and cell-mediated immune responses. They have the potential to use the immune system of body to fight pathogens and prevent the propagation of illnesses and disorders. The recent vaccination process has shifted away from killed and live organisms and toward synthetics and recombinants, which are far safer. Such novel vaccination candidates are frequently immunogenic and susceptible to degradation, necessitating the use of a designed adjuvant to improve immunogenicity (Woldeamanuel *et al.,* 2021).They increase peptide cross presentation and activate / modulate the antigen presenting cells. They can also be used as adjuvants to delay the release of antigens, increasing vaccine efficiency (Osama *et al.,* 2020).

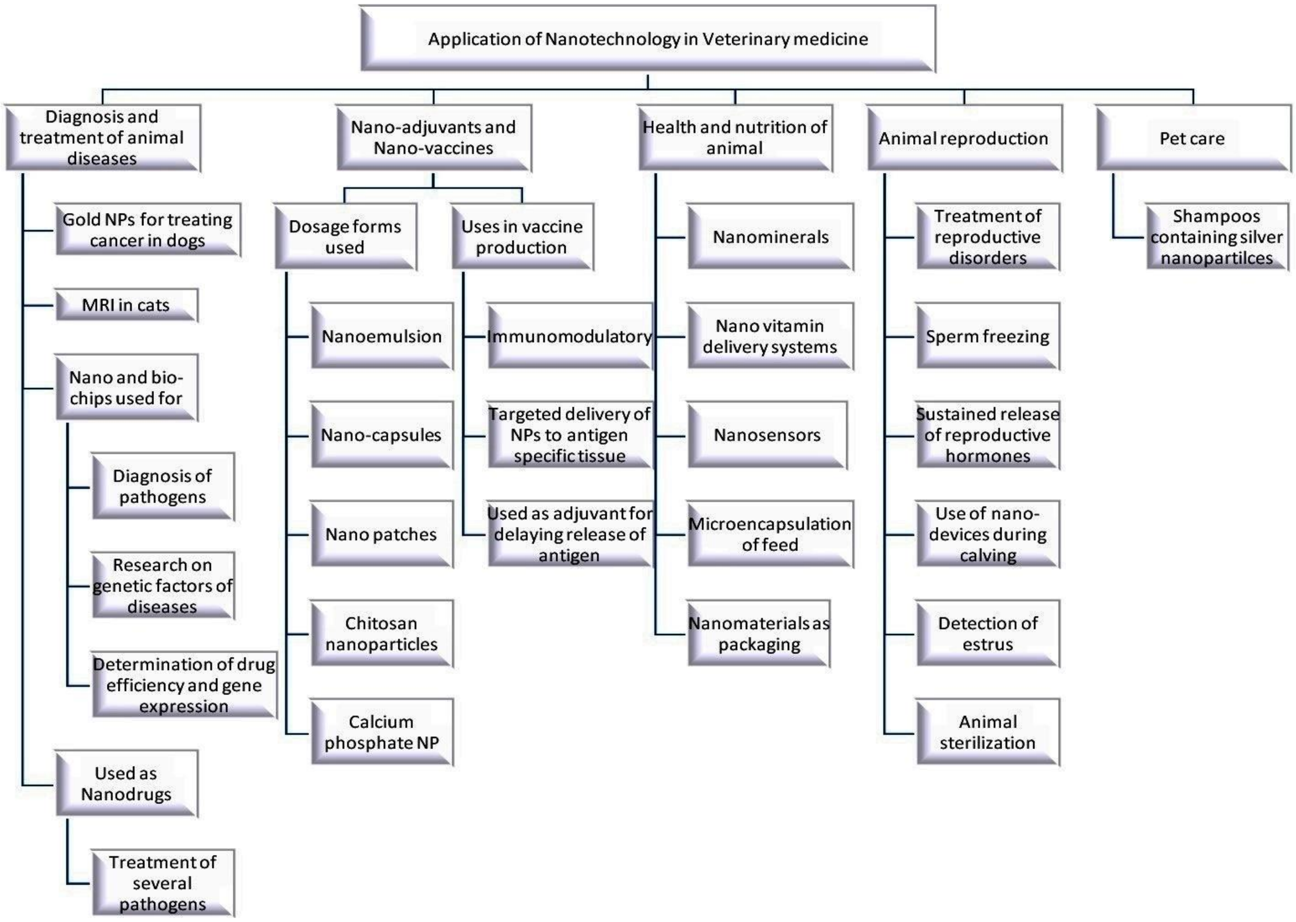
Although conventional adjuvants are inflexible, the emergence of nanotechnology has resulted in many of the new antigen-carrying techniques. Such nanoparticle-based adjuvants can be developed for lower dose rate and a more convenient mode of administration for the production a specific target immunological response, such as improving targeted mucosal immunity, which makes them ideal for veterinary practice, where higher animal numbers must be held at once, or somewhere traditional immunization methods are unfeasible due to complex system of management or a absence of accessibility (Woldeamanuel *et al.,* 2021). The lymph nodes can be targeted directly by NPs that are antigen-loaded, increasing vaccination efficacy.(El-Sayed and Kamel, 2020a)

The several forms of nano vaccinations used in veterinary medicine are explained through examples.

a. Influenza vaccine and vaccine which are spore-based formed by recombinant ***B. anthracis*** are two examples of nano emulsion vaccines (Youssef *et al.,* 2019a). Upon intranasal administration, mucosa immunity arises (El-Sayed and Kamel, 2020a).
b. They synthesize Immunoglobulin type-A and G after taking a vaccination loaded on PLGA nanoparticles orally. Vaccines for Bovine parainfluenza, B. pertussis, T. toxoid, and *H. pylori* are some of these vaccinations.
c. Leishmania recombinant SOD vaccine could illustrate chitosan nanoparticle-loaded vaccinations administered by subcutaneous injection. Furthermore, a chitosan-loaded tuberculosis vaccination is administered via the respiratory tract. Vaccines against Streptococci equi and Pneumococcal antigen A and are also placed on chitosan and administered intranasally. In fighting against the foot and mouth disease, a gold nanoparticle-based vaccination is being used.
d. Vaccines for the virus that causes African horse disease (empty capsid and center-like particles) (Youssef *et al.,* 2019a).

The host capacity to prevent or control the development of infections and/or pathological processes caused by infectious pathogens is known as disease resistance. The outcome of infection and disease pathogenesis is determined by interactions between the host immune system, invasive pathogens, and host genome. Frontline defense system of host counter to attacking pathogens is provided by innate immunity, and genes that trigger innate immune responses are thought to be promising candidates for disease resistance. Response of innate immunity characteristics are the initial choice to be included in the breeding plan for disease-resistant animals because they offer quick and non-specific resistance against a larger spectrum of pathogens (Islam *et al*., 2020). The host's immune system's diversity in response to infection is primarily responsible for the variety in genetic resistance to illness. Therefore, knowledge of both immunology and genetics might help to describe the illness phenotype. Immunogenomics is the use of genomic technology to the study of immunology. In order to find possible disease resistance candidate genes in cattle, immunogenomics includes integrated investigation of genomic and immunologic data on response showing by host towards infectious pathogens (Zulfiqar *et al*., 2020). The candidate gene's single nucleotide polymorphisms (SNPs), which are linked to host immunocompetence to infection, might thus be thought of as a maker of DNA for resistant against diseases.

Editing of genomic sequences is a bioengineering technique that entails addition, deletion, or alteration that includes a targeting mechanism for a particular DNA sequence in the genome as well as a sequence of DNA could cut by the nuclease enzyme (Petersen, 2017). The genome-editing system includes a mechanism that directs the enzyme for specific location on the genome as well as a nuclease enzyme for slicing DNA sequence. One of the enzymes to a specific place on the genome is the [CRISPR/Cas9] system known as "clustered regulatory interspaced short palindromic repeats (CRISPR)" / "CRISPR-associated protein 9 (Cas9).". One of the newest genome-editing techniques that has gained significant traction in recent years is the clustered regulatory interspaced short palindromic repeats (CRISPR)/CRISPR-associated protein 9.



CRISPR-Cas9 system for enhancement resistance of diseases

In prokaryotes, the CRISPR-Cas system uses a single defense mechanism that offers an efficient resistance against plasmids, bacteriophages, and transposons (Barrangou *et al*., 2007). The CRISPR loci are made up of spacers, which are regions of varied sequences, followed by numerous palindromic DNA repeats spaced regularly (CRISPR repeats) (Ahmed *et al*., 2018). Even in closely related bacteria, CRISPR loci encode a wide variety of spacer sequences, but a wide range of functions of CRISPR sequences have been discovered, including DNA repair, modulation of the expression of genes that are closely related, replicon partitioning, chromosomal rearrangement, and direct targeting of DNA binding proteins (Hale *et al*., 2009).

According to studies by Bikard (2012) and Hatoum-Aslan (2014), the CRISPR-Cas system can protect chromosomes from invasive genetic elements, preserving genomic homeostasis and acting as a barrier to the acquisition of exogenous elements that might be advantageous to the cell (Bikard *et al*., 2012, Hatoum-Aslan and Marraffini, 2014). The majority of the conjugative elements, phage, and plasmids that have been discovered carry specific helpful genes that are crucial for the bacterial adaptation. They positively contribute to provide evolutionary benefits, and support the maintenance of the fitness of the bacteria in a variety of environments, including those with virulence factors and antibiotic resistance. Recent research (Vercoe *et al*., 2013) has demonstrated that CRISPR targeting in bacterial chromosomal sequences affects pathogenicity islands.

Conclusions and future perspective: The current study sought to assist in concentrating on scientific methodologies and discovering prospective applications for the cutting-edge nanoparticles in the animal sector. In animals and veterinary sciences, a major research revolution is nanotechnology. Due to the unreasonably high cost or impossibility of using current equipment, these cutting-edge technologies have proven to be very helpful in supplying diagnostic information on animal health and productivity in developing nations. This assessment sought to highlight such applications and offer ideas for potential new uses. In the areas of food safety, illness detection, treatment, vaccine manufacturing, nutrition and medication delivery systems, reproductive biotechnology, and the poultry industry, nanotechnology is being utilized to replace antibiotics. The current types of nanoparticles might have their properties further honed for a wider variety of applications with ongoing research and development. In comparison to other scientific fields, its application to veterinary care and animal production is still in its infancy. The authors have discovered several applications for nanoparticles in the veterinary area that need further research to confirm their efficacy and determine their safety with regard to possible environmental risks.

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