**Nanoparticles: Structure, Classification, Synthesis and their use in the field of Veterinary medicine**

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**ABSTRACT**

The distinctively small materials known as nanoparticles (NPs) are found on a nanometer size that varies from 1 to 100 nm. These NPs can take many different shapes. They can be divided into many classes according to their origin, characteristics, form, and size, such as Organic, Inorganic, and Carbon-based NPs. It is possible to create nanomaterials with exceptional magnetic, electrical, optical, mechanical, and catalytic capabilities that differ significantly from those of their bulk counterparts. The use of nanotechnology in veterinary and human medicine has advanced significantly in recent years. For veterinary care, animal production, and other fields, nanotechnology holds great potential. A brief overview of nanomaterials and how they have been used to progress the development of nanotechnology is covered in this review. In particular, many top-down and bottom-up techniques to nanomaterial production are reviewed. This chapter also emphasizes the use of nanoparticles in veterinary medicine.

**INTRODUCTION**

Nanomaterials have become a fascinating class of materials that are highly sought after for a variety of uses. Understanding the size of a nanometer may be done by comparing A nanometer is equal to five silicon atoms or ten hydrogen atoms lined up. If a material's size or one of its dimensions is between 1 and 100 nm, it is referred to as a nanomaterial. It is difficult to pinpoint the precise timeline of human use of nanoscale items. The use of nanomaterials, however, has a long history, and humans have inadvertently employed them for a variety of purposes for a very long time. Humans first used asbestos nanofibers to strengthen ceramic mixes about 4500 years ago (Heiligtag and Niederberger, 2013).

Richard Adolf Zsigmondy originally used the word "nanometer" in 1914. The term "nanotechnology" was first used in a speech given in 1959 at the annual meeting of the American Physical Society by the American scientist and Nobel Prize winner Richard Feynman. This is regarded as the first scholarly presentation on nanotechnology (Santamaria A.,2012). Although nanotechnology was simply a topic of conversation prior to the 1980s, the idea was planted in researchers' imaginations with possibilities for future advancement. The term nanoparticle or tiny particle is any kind of substance particle with a dimension of between one and 100 nanometers (nm). Mostly due to their relatively small size and enormous surface area, nanoparticles frequently display specific size-dependent characteristics. When a particle's size approaches the nano-scale and its characteristic length scale approaches or is less than the wavelength determined by de Broglie or the wavelength of light, the regular boundary circumstances of the crystal particle are abolished (Guo *et al*., 2013).

In comparison to micromaterials or bulky substances, nanomaterials exhibit different surface effects, primarily for three reasons: (a) scattered nanomaterials possess a huge surface area and a large number of particles per mass unit; (b) the proportion of particles at the surface is increased; and (c) the atoms that are located at the exterior in nanomaterials have a smaller amount direct neighbors (Roduner E., 2006). The chemical and physical characteristics of nanomaterials differ from those of their larger-dimension counterparts as a result of each of these distinctions.

There have been a number of projects in recent years to develop green technology that makes nanoparticles out of natural resources rather than risky chemicals. In "green synthesis," NPs are produced using biological processes because they are "eco-friendly," "clean," "safe," "cost-effective," "uncomplicated," and "highly productive."(Altammar KA , 2023). There are different nanomaterial varieties that can be created from diverse raw materials, such as nanorods, spherical, nanotubes, nanosheets, nanofibers, core-shell, and mesoporous, and their newly developed and have multiple uses in biological imaging, biological sensing, delivery of drugs, tissue engineering, and antibacterial activities, agro-foods, too. Nanomaterials can be employed as membranes, films, additives, moisturizers, and formulation modifiers depending on their architecture (e.g., size, aspect ratio, geometry, porosity). The testing of effective nanomaterial dosages requires strict regulation because toxicological assessment varies on sizes and morphologies. (Harish *et. al*, 2022)

**STRUCTURE OF NANOPARTICLES**

The chemical makeup of the material, the quantity of elements in the particle, and the type of chemical interaction between the atoms all have a role in determining the physical makeup of a nanoparticle made of that substance. Nanoparticles can create a pseudoclose packing that is not described by any of the of the crystallographic structure groups, can be amorphous, or may possess a regular crystalline structure. There are certain amounts of the atoms in the particle's structure that correspond to the best stable configurations in each one of the structural states of the nanoparticle (Shevchenko *et. al.,*2002). The structure of nanoparticles (NPs) is complicated. There are between two and three layers in them. The first layer is a surface layer that has been functionalized by various tiny molecules, metal ions, surfactants, or polymers The core material is the central section of NPs. The second layer is the shell layer that can be purposefully added and is chemically different from the core. and the third layer is the thirds layer is the core material which is the central portion of NPs (Shin *et. al*., 2016; Ealia S. A. M. & Saravanakumar M. P, 2019). The key factors used to categorize nanoparticles (NPs) are their structure, size, physical characteristics, and chemical composition.They are primarily divided into three categories: organic, inorganic, and carbon-based NPs.

CLASSIFICATION OF NANOPARTICLES

Classification of nanoparticles are tabulated below:

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| Basis of classification | Types | Examples and properties | References |
| On the basis of their dimensionalities | Four types (Zero-dimensional (0 D), One-dimensional (1 D), Two-dimensional (2 D) and Three-dimensional (3 D)) | O D Nano: Ex: quantum dots  1 D Nano: Ex: nanofibers  2 D Nano: Ex: nanofilms  3 D Nano: Ex: nanotubes | Joudeh and  Linke (2022) |
| On the basis of their composition | proteins, carbohydrates, lipids, polymers, other organic compounds | Dendrimers, liposomes, micelles and D ferritin | Pan and  Zhong (2016) |
| On the basis of carbon atoms | fullerenes, carbon black NPs, and carbon quantum dots | A symmetrical closed-cage structure (fullerenes), grape-like aggregates (carbon black NPs), discrete, quasi-spherical carbon (carbon quantum dots) | Ealia and  Saravanakumar (2017) |
| On the basis of carbon or organic materials | Metal, ceramic, and semiconductor | Metal types are made of metal precursors, Ceramic types are made of carbonates, carbides, phosphates, and oxides of metals and metalloids whereas semiconductor types are made of semiconductor materials | Joudeh and  Linke (2022) |

PROPERTIES OF NANOPARTICLES

Physicochemical properties of Nanoparticles includes Electronic and optical properties which states the interdependence between NPs' optical and electrical characteristics is stronger. As an example, noble metal nanoparticles (NPs) have size-dependent optical characteristics and a significant UV-visible attenuation band that is absent from the bulk metal's spectrum (Ibrahim *et. al.*, 2019). The localized surface plasma resonance (LSPR) is the excitation band that is produced when the absorbed photon wavelength is identical with the cumulative excitation of the conduction electrons. It is well known that the size, shape, and interparticle spacing of the NPs, as well as their own dielectric characteristics and those of their immediate environment, which includes the substrate, solvents, and adsorbates, all affect wavelength at the peak of the LSPR spectrum (Eustis and El-Sayed, 2006). Surface area and particle size are key factors in how materials interact with biological systems. According to appearances, as materials get smaller, their surface area grows exponentially faster than their volume, increasing their reactivity toward one another and their surrounding environment. It should be noted that the system's reaction, distribution, and elimination of the materials are determined by the size of the particles and surface area (Powers *et. al*., 2007). Surface area is a crucial component in presenting hazardous symptoms (lung as well as additional epithelial-induced inflammatory reactions) in rodents, according to various investigations using different classes of nanoparticles (Holgate, 2010). Additionally, the size of nanoparticles affects their oral toxicity. In general, when size decreases, the oral toxicity rises. One study found that the oral cytotoxicity of copper nanoparticles rose with decreasing size. Even at higher dosages, larger particles were not dangerous, however smaller particles were marginally toxic (Chen et. al., 2006). .

Other property is magnetic properties of Nanoparticles. To study this researchers from a diverse variety of fields, including heterogeneous and homogeneous catalysis, biomedicine, magnetic fluids, data storage, magnetic resonance imaging (MRI), and environmental remediation, such as water purification, are found very interested. According to the literature, NPs function at their peak between 10 and 20 nm in size (Reiss and Hütten, 2005). The magnetic property of NPs is caused by the unequal electrical dispersion. These features are also influenced by the synthetic methodology, and they can be prepared using a variety of synthetic techniques, including solvothermal synthesis (Qi et al., 2016), micro-emulsion, co-precipitation, flame spray synthesis and thermal decomposition (Wu et al., 2008). Superparamagnetic nanoparticles are particularly intriguing because, while they display significant magnetic interactions in the presence of an external magnetic field, these interactions vanish when the outside magnetic field is removed. Due to the fact that magnetic namoparticles can be stabilized in solutions and do not exhibit magnetic interactions when the external magnetic field is turned off, this property enables the design of ferrofluids and permits in vivo performance in the form of cell marking, drug systems guided by a magnetic field, image contrast agents and heat generators in hyperthermia treatments (Flores-Rojas *et. al*., 2022)

Machanical property of nanoparticles leads Researchers to search for new applications in a variety of significant domains, including tribology, surface engineering, nanofabrication, and nanomanufacturing, because to the unique mechanical properties of NPs. To determine the precise mechanical makeup of NPs, one can examine a variety of mechanical metrics including hardness, elastic modulus,  stress and strain, adhesion, and friction. In addition to these factors, surface coating, coagulation, and lubrication also influence how mechanically strong NPs are (Guo et al., 2014). The volume, surface, and quantum impact of nanoparticles provide nanomaterials exceptional mechanical qualities. When nanoparticles are incorporated to a typical material, the nanoparticles can refine the grain to some extent, creating an intragranular pattern or an intergranular framework, which will improve the boundary of the grain and improve the mechanical characteristics of the material (Zou *et. al*.,2006).

Thermal property is other important property of nanoparticles. Metal Nanoparticles are known to have thermal conductivities that are higher than fluids in solid form. For instance, copper has a thermal conductivity that is approximately 3000 times larger than motor oil and 700 times bigger than water at ambient temperature. Thermal conductivity of even oxides, like alumina, is greater as that of water. As a result, it is anticipated that the fluids containing solid particles in suspension will exhibit significantly improved thermal conductivities in comparison to those of traditional heat transfer fluids. Dispersing solid particles with nanometric scales into liquids like water, ethylene glycol, or oils results in nanofluids (Ibrahim *et. al.*, 2019).

SYNTHESIS OF NANOPARTICLES

To create nanoparticles (NPs) with regulated form, size, dimensions, and structure, a variety of techniques have been used. Top-down and Bottom-up approaches are the two main methods for the synthesis of NPs (Arole & Munde, 2014; Hasan, S., 2015). The bulk material is broken down into nanosized particles using a top-down technique. This approach is detrimental. Top-down methods are easier and rely on either the removal, division, or reduction of bulk production processes to create the desired structure with the right characteristics. Some of the most popular techniques for creating nanoparticles include manual milling, nanolithography, laser ablation, sputtering, and thermal breakdown. Mechanical milling is a high-energy impact procedure that commonly involves balls inside of containers and can be done in a variety of mills, including shaker and planetary mills (Gorrasi and Sorrentino, 2015). A useful method for producing resources at a nanoscale from large quantities of material is mechanical milling. According to Baig et al. (2021), laser ablation is an eco-friendly method for creating noble metal nanoparticles. Metal nanoparticles and other types of nanomaterials can be produced using this technique. Sputtering is an appealing technique since it is less expensive than electron-beam lithography and produces nanomaterials with a comparable composition to the target material and fewer impurities (Baig et al., 2021). In other method because it creates plasma through the electrical blast of a metallic wire, the electron explosion method can create nanoparticles from a Pt mixture without the addition of a substance that reduces them (Joh et al., 2013).

An alternate strategy uses a build-up procedure called the bottom-up or constructive method, in which nanoparticles are created from clusters, which are created from atoms. Typically, this strategy uses techniques for sedimentation and reduction. This strategy is thought to be more inexpensive because there may be less trash produced as a result. Sol-gel, spinning, green synthesis, chemical vapour deposition, pyrolysis, and biosynthesis are some examples of this technique that are most frequently utilized. The sol-gel method, a wet-chemical technique, is frequently used to make nanomaterials (Das and Srivasatava, 2016; Baig et al., 2021). In solution, metal alkoxides or metal precursors undergo condensation, hydrolysis, and thermal breakdown. A stable solution, or sol, is the end outcome. The gel becomes more viscous as a result of condensation or hydrolysis. By varying the precursor concentration, temperature, and pH levels, the particle size can be observed. The process of removing the solvent, allowing Ostwald ripening to take place, and changing the phase during the mature stage—all of which are necessary for the formation of solid mass—may take a few days. Utilizing bioactive substances, such as plant matter, microorganisms, and other biowastes like waste from vegetables, peelings of fruits waste, eggshell, and agricultural waste, different metal nanoparticles can be created.The creation of "green" or "biological" nanoparticles using algae and other organisms is known (Kumari et al., 2021). Nanoparticles are produced by microbes using metal capturing, enzymatic reduction, and capping. Metal ions are primarily retained on the outermost layer or inside of microbial cells before being transformed by enzymes into nanoparticles. It is quick, easy, and affordable to synthesize metallic nanoparticles using microorganisms, particularly marine bacteria (Patil and Kim, 2018).

**APPLICATION OF NANOPARTICLE IN VETERINARY MEDICINE**

Although the use of nanoparticles in the field of veterinary medicine and livestock breeding is still relatively new, they have long been employed as therapeutic and diagnostic agents in human medicine. Due to growing concerns about microbial antibiotic resistance, the cattle industry has recently faced increased production pressures that rely on the use of drugs as growth promoters. Regulations and legislation are being amended to stop the use of in-feed antibiotics in the animal husbandry sector as a result of several nations reporting a rise in the incidence of bacteria that are resistant to antibiotics. This establishes the requirement for acceptable substitutes to be developed for incorporation in feed.

By utilizing the huge broad surface and tiny amount of nanoparticles, lab-on-a-chip technologies are improving healthcare diagnosis and food safety testing. Without the need for bulky benchtop instruments, these molecular technologies use fewer samples, have quicker run times, and simplify the user experience (Jain, 2005). To enhance profitability, livestock farmers need their livestock and flocks to quickly attain appropriate slaughter weights. Antibiotics are currently added to feed as a preventive measure to avoid disease and enhance growth, which shortens animal production cycles (Wang *et. al*., 2016). Use of nanoparticle in the different field of animal production are tabulated below:

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| **Field of application** | **Uses** | **Ref** |
| Veterinary medicine | The nano-applications are currently being applied in the fields of animal welfare, animal rearing, animal proliferation, and animal nourishment. The ability to deliver the treatment directly to the cells of interest allows for the use of extremely low dosages, gradually reducing medication buildup and withdrawal symptoms in farm animals. | Sayed and Kamel, 2018 |
| Animal production | Despite the fact that employing nanotechnology limits the types of antibiotics utilized due to their Nano size, regular usage of antibiotics in livestock farming can still leave a residue affecting the ultimate consumer.  To improve water quality by employing zeolites or hydrogels to absorb poisons, nanomaterials may be used in tandem with them. | Dong *et. al*., 2009  Lal, 2007 |
| Animal health | Nanoparticles can also aid in controlling feed infections and enhancing rumen fermentation. One of the more promising nanominerals, nanozinc oxide, is used to treat illnesses that impact livestock reproduction as well as conditions that affect growth rate and immunological response. | Yang and  Sun, 2006 |
| Animal nutrition | The prevalence of mycotoxicosis is a significant issue that affects both humans and animals. About 25% of the time, they can be found in animal feed. A potent nano antimycotoxin that successfully binds to aflatoxins and renders them inactive is thought to be made of nano silica particles and nano magnesium oxide. | Moghaddam *et. al*., 2010 |
| Animal breeding and reproduction | Nanotechnology can be used to address several reproductive issues, including retained placenta. Additionally, nanoparticles have a significant role in preserving and maintaining the release of reproductive hormones such steroid hormones and gonadotropic hormones. | Joanitti and  Silva, 2014 |
| Nanomeat production | Production of "interactive" poultry flesh that alters color, flavor, or nutrients according on the diner's preferences or health is one of the sci-fi uses for nanotechnology. The purpose of poultry meat design is to master over the distinctive features of meat its constituents in a creative way by manipulating atoms independently and placing them precisely where they are needed to generate the desired flavor and texture. Many of the molecular frameworks that determine these properties are in the nanometer category, and information on their origin can play a vital part in the design. | Muktar *et. al*;. 2015 |
| cryopreservation of gametes | In order to accomplish ultra-fast cooling speeds and also enable quick and homogenous warming up of biological materials under circumstances that are close to physiological, the use of biodegradable metal nanoparticles for cryogenic preservation of cells as well as tissues may become the next phase of cryopreservation technology. However, a small number of research are currently being conducted that employ nanoparticles to freeze tissues and cells. | Tomanek and  Enbody, 2000 |

CONCLUSION

Recent researchers around the world are engaged at the radioactive and molecular levels in order to research, handle, and implement nanometer-dimensional phenomena of the exciting and quickly developing field of nanotechnology. Nanoparticles has made new potential uses in molecular biology and biotechnology possible. By delivering in-depth information and revealing what is happening inside an organism's inner biology, nanotechnology has changed practically all of the veterinary medicine and animal science fields, particularly in wealthy nations. Quantum dots, nanoparticles with magnetic properties, polymeric nanoparticles nanopores, nanoshells, fullerenes, liposomes, and polymer-coated Nanocrystals, dendrimers are a few examples of the nanoparticles that are utilized for illness detection, therapy, medication administration, animal breeding, and reproduction. The creation of antibiotic nanoparticles is crucial and has a fantastic effect on treating bacterial illnesses anywhere they have a strong therapeutic effect without unfavorable side effects.Comparative to other sister disciplines, nanotechnology is regarded as one of the major advancements now employed in a variety of fields, but it is still in the early phases of application to veterinary science.

**Conflict of interest**

I have no apparent conflicts.

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