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Applications of nanotechnology in veterinary therapeutics

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Abstract

In the recent years, the application of nanotechnology in human and veterinary medicine has shown a great progress. Nanotechnology holds a major promise for animal health, veterinary medicine and other areas of animal production. Application of nanotechnology in medicine involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells such as cancer cells. There are varieties of nanomaterials that are probed nowadays for their probable use in diverse applications such as nanoshells (to destroy cancer cells using IR radiations), aluminosilicate nanoparticles (to reduce bleeding), carbon nanotubes (sensors and drug delivery), gold nanoparticles (diagnosis and labeling agents), nanocrystalline silver (antimicrobial agent), nanorobots (individual cell repair) and iron oxide nanoparticles (improved MRI imaging). In the upcoming years, nanotechnology research will reform the science and technology of the animal health and will help to boost up the livestock production. Veterinary nanotechnology has the potential to improve diagnosis, treatment and also to provide new tools for molecular and cellular breeding.

Keywords: nanoparticles, nanoshells, nanorobots

1. Introduction

Nanotechnology is a new discipline of science that has led to novel and innovative approaches in many areas of medicine. The National Science and Technology Council of United States of America (2004) defined nanotechnology as “research and development (R & D) aimed at understanding and working with seeing, measuring and manipulating matter at the atomic, molecular and supramolecular levels. This correlates to length scales of roughly 1 to 100 nanometers. The term nanotechnology refers to the ability to measure, manipulate and organize matter at the nanoscale level. The scale classically refers to matter in the size range of 1–100 nm, but it is often extended to include materials below 1 μm in size ^[5]. Key global challenges associated with animal production include environmental sustainability, human health, and disease control and food security.

Nanotechnology holds a major promise for animal health, veterinary medicine and other areas of animal production. Welfare of animals, animal safety derived products; risks to the environment, human health and industry consolidation are amongst the main concerns that are likely to extend from biotechnology to nanotechnology. Nanotechnology has a tremendous potential to revolutionize agriculture and livestock sector. It can provide new tools for molecular and cellular biology, biotechnology, veterinary physiology, animal genetics, reproduction etc. which will allow researchers to handle biological materials such as DNA, proteins or cells in minute quantities usually nano-liters or pico-liters. One particular application of nanotechnology in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Researchers across the world are also developing nanoparticles to defeat viruses. The nanoparticle does not actually destroy virus molecules but delivers an enzyme that prevents the reproduction of virus molecules in the patient's bloodstream. There are efforts underway to develop oral administration of several different drugs using a variety of nanoparticles ^[9].

Nanorobots are other promising area in healthcare that could actually be programmed to repair specific diseased cells, functioning in a similar way to antibodies in our natural healing processes. There are varieties of nanomaterials that are probed nowadays for their probable use in diverse applications e.g. buckyballs (trapping free radicals generated during allergic reactions), nanoshells (to destroy cancer cells using IR radiations), aluminosilicate

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nanoparticles (to reduce bleeding), carbon nanotubes (sensors and drug delivery), gold nanoparticles (diagnosis, labeling agents), nanocrystalline silver (antimicrobial agent), nanorobots (individual cell repair), iron oxide nanoparticles (improved MRI imaging) [7]. Nanotechnology tools like microfluidics, nanomaterials, bioanalytical nanosensors, etc. has the potential to solve many more puzzles related to animal health, production, reproduction and prevention and treatment of diseases. It is reasonable to presume that in the upcoming years nanotechnology research will reform the science and technology of the animal health and will help to boost up the 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. Nanotechnology is currently employed in the treatment of African animal trypanosomiasis [21]. Foot-and-mouth disease virus (FMDV) is a major threat because of failure to establish effective control on the disease [13]. Investigated the possibilities of using inert nano-beads that targets antigen and stimulates dendritic cells (DCs) to induce immune responses against FMDV-specific synthetic peptides in sheep, while single peptides induced responses in most sheep, multiple combinations could effectively induce CMI and HI [25]. Nanotechnology can be viewed as a series of technologies that are used individually or in combination to make products and applications and to better understand science [33].

Types of Nanoparticles

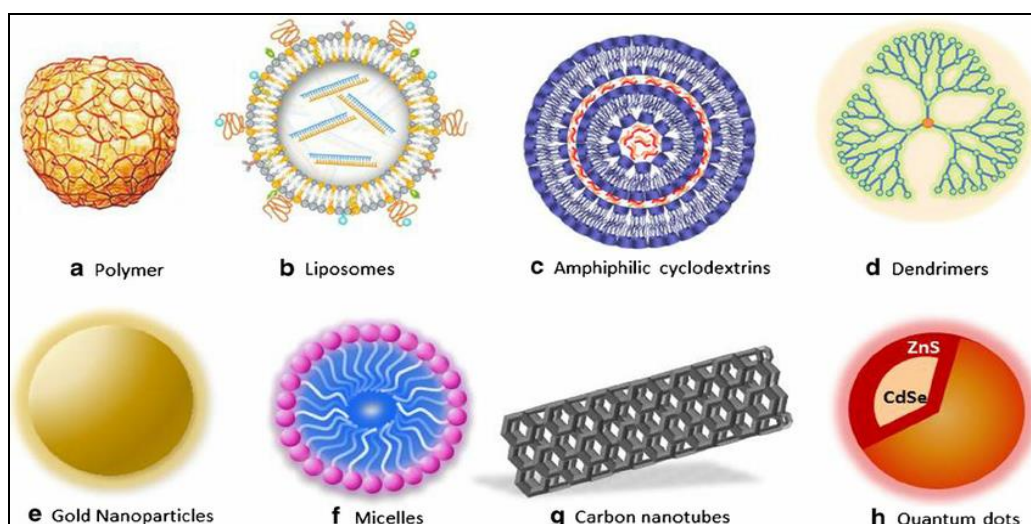


Plate 1: Types of Nanoparticles

Polymeric nanoparticles

Polymeric nanoparticles are prepared by combining the active molecule with a polymer. The active components are entrapped or adsorbed to the surface of the polymer nanoparticles. Polymeric nanoparticles exist in a variety of forms utilising both natural and synthetic polymers. Polymer delivery characteristics, surface properties, morphology and composition can be readily engineered and optimised to achieve the desired drug loading, biocompatibility, targeting, degradation and controlled release kinetic [38].

Liposomes

Liposomes are vesicles in which an aqueous core is encapsulated within one or more phospholipid bilayers. Liposomes are highly flexible delivery system able to carry both hydrophobic and hydrophilic substances. They can be conjugated to antibodies or ligands and engineered to optimise their suitability for an intended use. Liposomes are suitable for topical, intravenous and intra muscular administration but because they are susceptible to degradation in the gastrointestinal tract they are rarely suitable for oral use. They have been investigated for targeted drug, imaging agent, vaccine and gene delivery with promising results. Apart from being used for targeted drug delivery, liposomes are also used in cancer therapy. Similarly immunoliposomes are liposomes conjugated with an antibody directed towards the tumour antigen. Increased liposome production for commercial applications has resulted in the availability of liposomes that have a reasonable shelf life and are an

affordable and practical option for use in veterinary medicine [3].

Fullerenes

Fullerenes are pure carbon molecules composed of at least 60 atoms of carbon. Because a fullerene takes a shape similar to a soccer ball or a geodesic dome, it is sometimes referred as a buckyball after the inventor of the geodesic dome, Buckminster Fuller, for whom the fullerene is named. They are inert, nontoxic and because of their size, they can interact easily with cells, proteins and viruses. In addition, they are hollow inside so it is very easy to put pharmacological agents inside them. Besides delivering medicine more efficiently to the inside of cells, buckyballs may have a promising future in the area of diagnostic imaging [10].

Nanotubes

Nanotubes are a sequence of nanoscale C60 atoms arranged in a long thin cylindrical structure. They are related to two other carbon crystal forms, graphite and diamonds. They are often described as looking like rolls of graphite chicken wire, but as member of the fullerene family they are essentially buckyballs expanded into cylinders. Nanotubes are also called buckytubes in some references books. Scientists also have begun to look into the potential applications of nanotubes as pharmacological agents. The antibacterial properties of nanotubes are being extensively studied. The nanotubes insert themselves readily into bacterial cell membranes and act as potent and selective antibacterial agents, both in cell cultures

and in studies on mice ^[11].

Nanoshells

Nanoshells are concentric sphere nanoparticles consisting of a dielectric core and a metal shell, mostly of gold. In simple words they can be described as spherical glass particles with an outer shell of gold. Nanoshells are layered colloids that consist of a core of non-conducting material covered by a thin metallic shell. They are considered a very special kind of nanoparticle because they combine infrared optical activity with the uniquely biocompatible properties of gold colloid. By varying the thickness of the metal shell researchers can precisely tune the colour of light to which the nanoshells respond. This property of nanoshells makes them potential candidates to be used in expeditious diagnostic assays and non invasive detection of tumours ^[1].

Solid lipid nanoparticles (SLNs)

SLN are composed of lipids that are solid at room temperature stabilised by surfactant and suspended in an aqueous solution. The pharmaceutical agent is dissolved or dispersed within the lipid. SLNs exhibit several advantages over polymeric nanoparticles. For example, they have comparatively higher drug entrapment efficiency and can be administered by multiple routes (orally, topically and Intravenous). Hydrophobic drugs are stable in their lipid matrix. They have minimal toxicity and do not require the use of organic solvents in their production^[19]. Additionally SLNs can be used in production of controlled release formulations lasting up to several weeks. They have the capability of adhering to mucosal surfaces, thus promoting the absorption of orally administered drugs. The speciality of SLN is that they can deliver drugs across blood brain barrier so can have numerous implications in drug delivery to the brain ^[27].

Micelles

Polymeric micelles are nanostructures formed by the self-assembly of amphiphiles in water. Polymeric micelles are characterised by a hydrophobic core stabilised by a hydrophilic shell. Due to their hydrophilic shell they are highly water soluble. Micelles have long circulation time. Hydrophobic substances are stored in the micelle core, where they are solubilised and protected from enzymatic degradation. Micelles are divided into four classes, based on the constituents of their hydrophilic shell: (1) phospholipid micelles, whose shell is comprised of phospholipids; (2) pluronic micelles, where the shell is a block copolymer comprised of hydrophilic polyethylene oxide and hydrophobic polypropylene oxide blocks; (3) poly (L-amino acid) micelle (4) polyester micelles with a shell composed of biocompatible polymers. Micelles have low toxicity and are versatile system for effective delivery of therapeutic agent, with many micelle formulations currently being studied in clinical trials ^[20].

Dendrimers

These are usually regularly-branched three- dimensional structures with a tree like form and a molecule as the central core. Branch lengths have steric limitations and dendrimer forms are sphere-shaped, with low molecular size but high molecular weight. Dendrimers have a lot to offer to the field of Veterinary Medicine. These structures are used to transport drugs in two ways: (a) by attaching drug molecules to functional groups on the dendrimer surface (b) by enclosing the drugs in the dendritic channels within the sphere. The well-defined structure, size, surface functionalization

capability and stability of these nanoparticles make them a promising vehicle system for various agents (e.g., genes and anticancer drugs) by complexation or encapsulation ^[2]. One such example is the formation of dendrimers with polymers such as polyamidoamine (PAMAM), which confer stability, availability and tolerability. Researchers envision that dendrimers may execute a five step task when dealing with the treatment of tumors: (i) dendrimers may be able to find tumors cells through the body by looking for tumor receptors, (ii) bind and pass through cell membranes, (iii) perform a chemical analysis inside the cells to inform veterinarians what type of tumors is present in the animal's body, (iv) release chemotherapy or radioactive agents inside the tumor cells and (v) confirm via chemical analysis that the procedure killed the cells ^[11].

Metallic nanomaterials

Various metals have been used to prepare nanoparticles. Gold, silver and copper are most commonly used ^[24]. Metal nanoparticles are mostly used in bio-sensing, bio-imaging and cancer chemotherapy above all they are also used for targeted drug delivery by conjugating with various functional groups ^[13] and yielding a stable nanoparticle synthesis with a range of sizes (1-150 nm).

Magnetic nanoparticles

Magnetic nanoparticles are basically composed of iron oxide. They have been studied for use as biosensors for imaging and for drug delivery. Apart from performing targeted drug delivery magnetic nanoparticles can be directed from bloodstream to disease sites by application of a high gradient magnetic field over that tissue. Despite having many characteristics that make them excellent agents for drug delivery and imaging concerns over toxicity and the accumulation of metal-based particles haunts clinical application at the present scenario ^[23].

Ceramic nanomaterials

Ceramic nanoparticles are made up of materials such as silica, alumina and titania. They have several advantages over polymeric nanoparticle systems as they are easy to prepare and can be designed to a desired shape, size and porosity. They are biocompatible with large surface to volume ratios have and are extremely inert. They provide protection to the adsorbed particles they carry against denaturation induced by extreme pH and temperature ^[35].

Quantum dots

Quantum dots are semi-conductor nanoparticles that measure approximately 2-10 nm and fluoresce when stimulated by light. They are comprised of an inorganic core, an inorganic shell and an aqueous coating to which bio-molecules can be conjugated. The size of the core determines the colour of light emitted. Quantum dots offer the advantage that varying the size of the crystal can cause a varying degree of colours to fluoresce. The smaller the quantum dots, the brighter the colour. They stay lit for much longer periods of time than dyes often for hours or days. Similar to fluorescence, they allow us to tag different biological components like proteins or DNA strands with specific colours. Some scientists envision the possibility of injecting quantum dots into animal bodies. Once injected into the body they may detect cells that are not working normally. In veterinary profession quantum dots could be used in a blood sample to quickly screen for certain proteins that may indicate a higher propensity for

certain diseases. Apart from the above uses quantum dots can be prospectively used as a probe and in immune assays ^[25].

Nanoemulsion

Nanoemulsions are dispersions of oil and water where the dispersed droplets are stabilised with a surface film composed of surfactant and co-surfactant. Its mode of action is not chemical but a physical one. When the oil nanodrops contact the membranes of bacteria or enveloped viruses the drops surface tension forces a merger with the membrane blowing it apart and killing the pathogen. A characteristic feature of the nanoemulsion is that they don't affect cell structures of higher organisms, which make it ideal to use in animals and humans. If nanoemulsion research continues showing promising results in the near future we may see bactericidal and veridical products that can be used topically in animals and humans. The advantages of nanoemulsions include simplicity, inexpensiveness, stability, versatility and the ability to solubilise lipophilic substances and to protect them from degradation. Promising results have been achieved for use of nanoemulsion in veterinary medicine and use as potential drug delivery agent ^[36, 18].

Nanobubbles

Therapeutic drugs can be incorporated into nanoscaled bubble like structures called as nanobubbles. These nanobubbles remain stable at room temperature and coalesce to form microbubbles at physiological temperature. These have the advantages of targeting the tumour tissue and delivering the drug selectively under the influence of ultrasound exposure. The delivery of doxorubicin has been studied by use of nanobubbles. This method needs further exploration for its utility in treatment of various malignancies. Liposomal nanobubbles and microbubbles are also being investigated for their role as effective non viral vectors for gene therapy ^[31].

Respirocytes

Respirocytes are nanodevices which can function as red blood cells but with greater efficacy. These have higher capacity to deliver 236 times more oxygen per unit volume than natural red blood cells. These devices have sensors on the surface to detect changes in the will thus regulate the intake and output of the oxygen and carbon dioxide molecules.

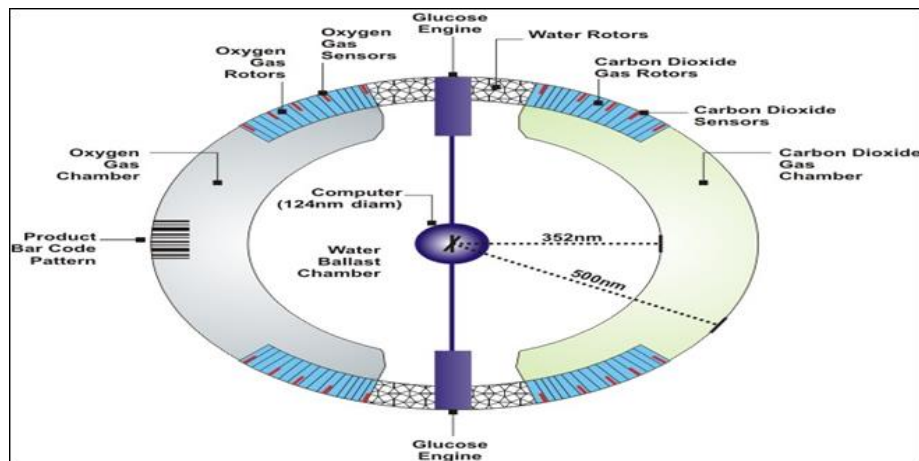


Plate 2: Respirocytes

Microbivores

Microbivores are hypothetical white blood cells in the blood stream designed to trap circulating microbes. They are expected to have greater efficacy than cellular blood cells in phagocytosis. The microbivores surface has processes which can extend in length and secure the microbe which gets in contact with it. The microbe will gradually be directed to ingestion port for enzymatic degradation. The end products are released as amino acids, fatty acids, nucleotides and sugars. Application of the microbivores in human and animal circulation could theoretically clear the blood stream in septicaemia at a much greater rate than the natural defence mechanism with antibiotics ^[18].

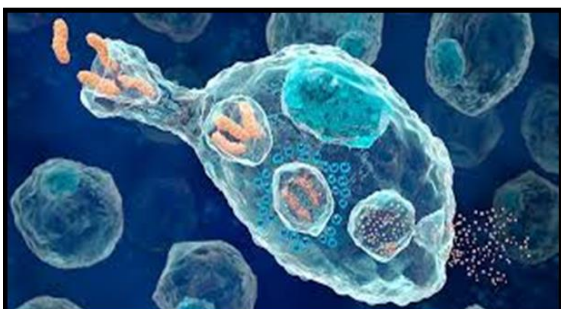


Plate 3: Microbivores

Mechanism of Action of Nanoparticles

The behaviour of nanoparticles is a function of their size, shape and surface reactivity with the surrounding tissue. The smaller a particle, the greater its surface area to volume ratio and the higher its chemical reactivity and biological activity. The greater chemical reactivity of nano materials results in increased production of reactive oxygen species (ROS) ^[16]. ROS production has been found in a diverse range of nanomaterials including carbon nanotubes and nanoparticle metal oxides. ROS and free radical production is one of the primary mechanisms which may result in oxidative stress, inflammation and consequent damage to proteins, membranes and DNA. Nanosized particles of various chemistries have been shown to create reactive oxygen species (ROS). ROS production has been found in Nps as diverse as C60 fullerenes, SWNTs, quantumdots, and UFPs, especially under concomitant exposure to light, UV, or transition metals ^[9]. It has been demonstrated that NSPs of various sizes and various chemical compositions preferentially mobilize to mitochondria. Because mitochondria are redox active organelles, there is a likelihood of altering ROS production and thereby overloading or interfering with antioxidant defences. Some of the antioxidant defence systems that occur in animals, and possible areas where NSPs may create oxyradicals. The exact mechanism by which each of these

diverse NPs causes ROS is not yet fully understood, but suggested mechanisms include:

- a) Photo excitation of fullerenes and SWNTs, causing intersystem crossing to create freeelectrons
- b) Metabolism of NPs to create redox activeintermediates,

- especially if metabolism is viacytochrome P450s
- c) Inflammation responses in vivo that may causeoxyradical release by macrophages. Othermechanisms will likely emerge as studies on NPtoxicity continue.

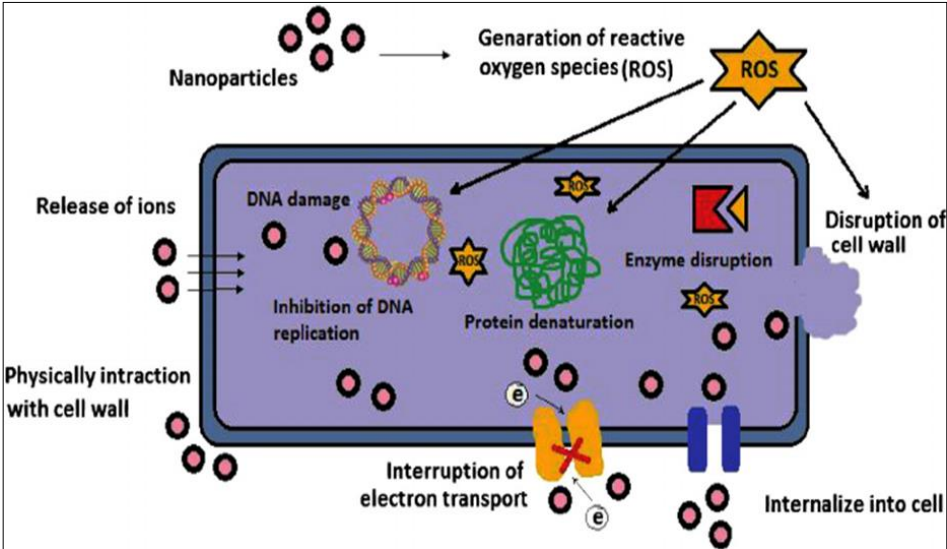


Plate 4: Mechanism of Action of Nanoparticles

Table 1: Applications of Nanotechnology in Veterinary Science

S.No	Nanocarriers	Medical/Veterinary Applications	Animal species under trial/evaluated/approved
1.	Magnetic nanoparticles	MRI contrast, drug delivery	Cats ^[35]
2.	Gold nanoparticles	<i>In-vitro</i> diagnosis.	-
3.	Quantum dot	Fluorescent contrast, <i>in-vitro</i> diagnostics.	-
4.	Dentrimers	Microbicide and vaccine delive.	Pigs ^[35]
5.	Micelle	Therapeutics	Sheep, birds, horse ^[35]
6.	Liposomes	Therapeutics	Cattle, dogs, horse, Cats, birds, sheep ^[35] .
7.	Nanoemulsion	Drug delivery and therapeutics	Dogs, Cats ^[35]
8.	Nanosphere	Vaccine delivery	Horse ^[35]

2. Nanotechnology in disease diagnosis

Biochips can be used for early disease detection in animals. A Biochip (or microarray) is a device typically made of hundreds or thousands of short strands of artificial DNA deposited precisely on a silicon circuit. Biochips can also be used to trace the source of food and feeds to detect the presence of animal products from different species as a means to locate the source of pathogens a response to public health threats such as avian flu and mad cow disease. In addition to DNA biochips, there are other variations that detect minute quantities of proteins and chemicals in a sample, making them useful for detecting bio warfare agents or disease ^[30]. Using biochips, biological samples such as blood, tissue and semen can be instantaneously analysed and manipulated. Bio analytical nanosensors are devices or systems that measure or detect a chemical with the use of a biological material or tissue. These will enable us with detection of very small amounts of a chemical contaminant, virus or bacteria in agriculture and livestock system. Nanoshells are a new type of optically tunable nanoparticle composed of a dielectric (for example, silica) core coated with an ultra-thin metallic (for example, gold) layer ^[14]. Nanoshells can be injected into the animal’s bloodstream with targeted agents applied to the nanoshells to seek out and attach to the surface receptors of cancer cells. Illumination of the body with infrared light raises the cell temperature to about 55°C, which ‘burns’ and kills the tumour. Others have been experimenting with ‘smart’ super paramagnetic

nanoparticles, which when injected in the bloodstream target tumour receptor cells. These nanoparticles are made from iron oxides that when subjected to a magnetic field enhances the ability of the nanoparticles to locate tumour cells. At the site of the tumour the nanoparticles emit an attached drug to kill the cancer cells. Other form of nanomaterial is Quantum dots which are nanometre-scale crystals that were originally developed for optoelectronic applications. Quantum dots may be injected into the bloodstream of animals and they may detect cells that are malfunctioning. Because quantum dots respond to light it may be possible to illuminate the body with light and stimulate the quantum dot to heat up sufficient to kill the cancerous cell. Nucleic acid engineering-based probes and methods offer powerful new ways to deliver therapeutic or preventative treatment for particular diseases. These various methods of nanotechnology can be a potential therapeutic aid in extenuating the health problems of the animals ^[12].

3. Diagnostic tools

Commonly available diagnostic tests that are usually sent to outside laboratories and can take from hours to days to provide the results may be considered obsolete sooner than expected. Nanotechnology can bring to our veterinary hospitals cheaper, faster and more precise diagnostic tools.

a) Quantum dot particles

Quantum dot particles are tiny crystals which are a ten-

millionth of an inch in size. These particles enable new approaches to genetic analysis, drug discovery and disease diagnostics. Today quantum dots are considered an important advancement in our understanding of how genes work. Scientists believe that in a couple of years these particles will be instrumental in allowing researchers to monitor reactions of cells to certain drugs or viruses. Some scientists envision the possibility of injecting quantum dots into animal bodies. Once injected into the body they may detect cells that are not working normally because they respond to light, it may be possible to affect the behavior of the dot once it is inside the cell. For example, they may be able to respond to a flash and heat up enough to destroy cancerous cells. Quantum dots offer many technical advantages over traditional fluorescent dyes, which are commonly used to detect and track biological molecules. They not only can stay for a prolonged period of time, they are also brighter and easier to visualize than organic dyes. They can be very helpful in visualizing cell pathways, which is essential for our understanding of how certain the drugs are going to behave in an animal's body. In addition to their usefulness in identifying and tracking molecules, they promise faster, more flexible and less costly tests for clinical analysis ^[07].

b) Immunoassay

Immunoassay technology capitalizes on the characteristic way that antibodies attach themselves to invading pathogens in the body. Antibodies recognize and bind to antigens with great specificity. One of the diagnostic applications of this behaviour is the conventional immunoassay. In a routine immunoassay test we expose a solution, such as blood plasma example, to a tray containing antibodies that bind with a specific antigen under investigation. When the antibodies bind to the antigen, the test changes colour. This system is used to identify and diagnose various conditions that afflict the animal population.

4. Nanotechnology for treatment

Veterinary health care is highly visible and growing concern for the pet owners and the government. Keeping in view the higher costs of medications and veterinary care, and increasing pet population the need for innovative solutions is urgent. The effective delivery of therapeutic molecules has been a major barrier to obtain targeted response against the disease agent. Many drugs are effective in treating diseases but most of them also have certain limitations with regard to toxicity, poor aqueous solubility and cell impermeability. Therapeutic and diagnostic agents are at the forefront projects of nanomedicine and research is focused on rational delivery and targeting of pharmaceuticals in animals. Nanopharmaceuticals, the most promising and productive area of nanotechnology application in animal treatment involves nanoparticles as these have relatively higher intracellular uptake compared to microparticles and hence they are available for broad range of biological targets owing to their small size and higher mobility. Various nanomaterials are used in the treatment of veterinary diseases like polymeric nanoparticles, carbon nanotubes, liposomes, dendrimers, nanoshells, nanopores, magnetic nanoparticles, etc. The main challenge is to design the various novel devices and technologies with the help of above discussed nanomaterials which will enable to guide the therapeutics to its correct location of action and will certify that pharmacological activity is maintained for an adequate duration.

5. Nanotechnology in drug delivery system

Smart drug delivery systems in animals would most likely contain small, sealed packages of the drug to be delivered. Smart drug deliveries allow judicious use of smaller quantities of antibiotics than would otherwise be possible. A molecular coded 'address label' in the package could allow the package to be delivered to the correct site in the body. Nano and microscale mechanical systems would serve as the 'carriers' in such a system. Smart delivery systems could also contain on-board chemical detection and decision-making capability for self regulated drug delivery or nutrient treatments as per need. This will aid livestock owners to minimize use of antibiotic and to reduce the expenditure on medication. Smart delivery systems can also have the capacity to monitor the effects of the delivery of pharmaceuticals, nutraceuticals, nutrients, food supplements, bioactive compounds, probiotics, chemicals and vaccines. Thus, in the future, further technological advances will make it possible to develop delivery systems more precisely with use of nanomaterials (are materials that provide the potential to manipulate structures or other particles at the nanoscale and to control and catalyze chemical reactions, e.g. buckeyballs, nanotubes, quantum dots and dendrimers etc.) for biological and bioactive organisms for targeted site, develop integrated sensing, monitoring and controlling capabilities, including the ability of self-regulation, develop large as well as small animal health monitoring and therapeutic intervention ^[34].

6. Nanotechnology in animal reproduction

Nanotechnology has begun to blossom in the field of reproduction and fertility. In this way, the aims of these nanotechnology-based investigations related to animal reproduction are characterize the nanoscale features of gamete cells using atomic force microscopy and related scanning probe microscopy techniques develop nano biosensors for detection of physiological or altered (pathogens and diseases) reproductive status develop chemical approaches for production of metal nanoparticles for used fertility control applications develop nanodevices for secure cryopreservation of gametes and embryos and develop sustained release systems of molecules, including hormones, vitamins, antibiotics, antioxidants, nucleic acids, among others ^[32]. The goal of all these innovative efforts is not just to be able to characterize and manipulate the matter on nanoscale, but also develop products and processes with economic, social and environmental value added with emphasis on the development of solutions to animal reproduction challenges ^[33].

a) Nanobiosensors for the detection of reproductive status

Nanobiosensors are very sensitive devices equipped with immobilized probe biomolecules and which are made up of nanomaterials, such as nanoparticles, nanotubes, nanowires, nanofibers and others. They are mainly applied in environmental monitoring and clinical diagnostics. The development validation of nanobiosensors for the detection of diseases, pathogens, oestrus, hormone levels and metabolites profile provide to such systems the status of an important and promising tool for reproductive management.

b) Nanosystems for cryopreservation of gametes and embryos

Cryopreservation of gonadal tissues, sperm, oocytes and embryos has brought about novel and exciting research field in animal reproduction. The use of biocompatible metal nanoparticles for cryopreservation of cells and tissues may

become the next step of cryopreservation technologies to achieve ultra-fast cooling rates and also allow rapid and homogeneous rewarming of the biological materials under near physiological conditions. However, there are an incipient number of studies carrying out the use of nanoparticles for cryopreservation of cells and tissues [34].

7. Nanotechnology in animal breeding

Management of breeding is an expensive and time-consuming problem for dairy and swine farmers. One solution that is currently being studied is a nanotube implanted under the skin to provide real time measurement of changes in the level of estradiol in the blood. The nanotubes are used as a means of tracking oestrus in animals because these tubes have the capacity to bind and detect the estradiol antibody at the time of oestrus by near infrared fluorescence. The signal from this sensor will be incorporated as a part of a central monitoring and control system to actuate breeding. Microfluidics is used today in animal science to significantly simplify traditional in vitro fertilisation procedures used in animal breeding. It is being used in livestock breeding to physically sort sperm and eggs. Microfluidic and nanofluidic are the systems which analyse by controlling the flow of liquids or gases through a series of tiny channels and valves, thereby sorting them, much as a computer circuit sorts data through wires and logic gates [30].

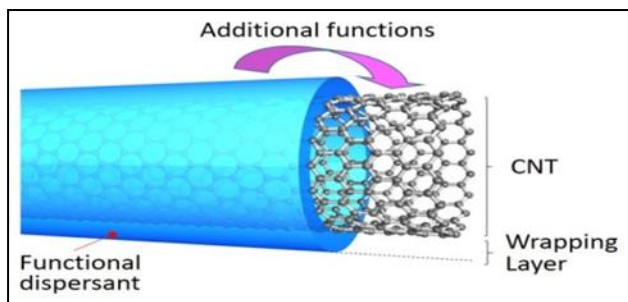


Plate 5: Nanotubes

8. Nanotechnology in Livestock Products

Nanotechnology is quite competent in new products and new processes development with the objective of enhancing the performance of the products, extending the product shelf life and freshness as well as in getting better the safety and quality of food. It can also reduce the time of production of eggs and meat. Thus, consumers can get faster eggs and meat. The quality of fermented livestock products are now well proven for health benefits which can easily be obtained by this vital technology.

a) Nanotechnology in meat and meat products

Applications of nanomaterial are currently used for meat and food generally, include the use of NPs and nanomaterials as food ingredients/additives which are placed directly into food, or as a part of food packaging. Microencapsulating process can improve dispersing ability of fat-soluble additives in food products, enhance taste and reduce the use of fat, salt, sugar and preservatives. Reducing the salt level is especially important and presents a great challenge for meat industry because in spite of advantages, use of salt has shortcomings since it is linked to hypertension and consequently increased risk of cardiovascular disease. One of the functions of nano-carrier systems is to protect nutrients and supplements from degradation during processing. For example, carriers enable nutritive substances to be resistant to proteases and other

denaturing compounds, improve their stability to pH value and temperature changes and increase their ability to be transferred across intestinal membranes into the blood and controlled release and better dispersion in aqueous systems for water-insoluble food ingredients and additive. Nanotechnology can be utilized to improve the stability of such micronutrients not only during processing but storage and distribution, as well [22].

b) Nanomeat production

Nanotechnology can make poultry and meat products cost-effective with the natural properties and the differentiation in qualities of products can easily be made by nanotechnology based cooling rates and also allow rapid and homogeneous techniques. One of the futuristic applications of nanotechnology lies in the production of "interactive" poultry meat that changes, color, flavor or nutrients depending on the diner's taste or health. Many of the molecular structures that determine these characteristics are in the nanometer range and information on the source can play an important role in the poultry meat design, the purpose is to master over the characteristic of meat the components in an intelligent manner by manipulating atoms individually and place them exactly where they are needed to produce the desired flavor and texture [26].

9. Nanotechnology in food safety

Identity preservation (IP) system is a system that creates increased value by providing consumers with information about the practices and activities used to produce an agricultural product. Today, through IP it is possible to provide stakeholders and consumers with access to information, records and supplier protocols regarding the farm of origin, environmental practices used in production, food safety and security, and information regarding animal welfare issues. Quality assurance of the safety and security of agricultural and animal products could be significantly improved through IP at the nanoscale. The future of the meat industry may well depend on an ability to track all stages in the life of the product, including the birth of the animal, its medical history, and its movements between the ranch, the slaughterhouse and the meat-packing plant, right through to the consumer's table [30].

10. Nanotechnology in sterilization of animals

Despite the advantages associated with the use of nanoparticulate systems in order to optimizing the reproductive performance, it is largely accepted that some nanoparticles (e.g. metal nanoparticles) can elicit toxic and deleterious side effects towards living organisms. However, this toxicity may also be used for reproduction technologies on the basis of contraceptive approaches. Since several metals, including cadmium, at low to moderate concentrations may lead to sterility in a dose-dependent fashion, the delivery of metals as NPs to reproductive organs remains as a wide field to be explored by researchers and can be actively driven to reproductive and related organs (e.g. pituitary) by targeting molecules (e.g. antibodies) or using some physical characteristic (e.g. magnetic field-based delivery of magnetic nanoparticles) and thus avoiding or at least minimizing the systemic toxicity [17].

11. Conclusion

In the recent years, nanotechnology has shown a great progress and great potential. The present review highlighted

how nanotechnology has influenced the healthcare of animals both in diagnosis and in treatment. Nanomaterials such as carbon nanotubes, quantum dots, liposomes, polymeric nanoparticles, magnetic nanoparticles, etc. are explored for their potential use in diagnosis and treatment of diseases. In the future, it can be conceived that bacterial infections can be eliminated in the patient within minutes, instead of using treatment with antibiotics over a period of weeks. With the advancement in technology, we can expect to generate capability to perform surgery at cellular level, thereby removing individual diseased cells and even repairing defective portions of the individual cells. Several nanotechnology based products are already in the market and many are under development or in experimental stages. The profession of Veterinary Medicine will be substantially different in 25 years from that of today. It can be hoped that nanotechnology, in addition to contributing to the creation of changes in veterinary profession, will also be one of the technologies that help practitioners stay abreast of and manage these developments. In order to appreciate the advantages of this technology, the veterinary profession needs to understand new technologies such as cloning and stem cell research through nanotechnology. Veterinary profession extensive research is still required to support the effectiveness and safety of nanotechnology, avoiding any harm to the environment or to human beings and animals health.

12. Acknowledgement

We declare that we have no conflicts of interest.

13. References

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