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Review on Nanotechnology and Its Applications in Veterinary Medicine

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Abstract

Nanotechnology is defined as the science and engineering involved in the design, synthesis, characterization and application of materials and devices whose smallest functional organization is at least one dimension on the nanometer scale (one-billionth of a meter). Nanotechnology is a research and technology development at atomic, molecular and macromolecular level on the scale ranging 1 - 100 nanometers. It is a newly innovated integrated science area capable of providing basic insights of phenomena of materials at nanoscale and enables creation and application of structures, devices and systems possessing novel properties unlike their bulk counterparts. Nanotechnology has also opened new applications in molecular biology, biotechnology and almost all disciplines producing new nanoscale tools beneficial of living organisms. The field has applications in disease diagnosis, treatment, drug delivery, animal nutrition, animal breeding, food production and processing companies and industries, reproduction and animal products. Representative nanomaterials presented in this review included metallic nanoparticles, quantum dots, carbon nanotubes, magnetic nanoparticles, fullerenes, liposomes and dendrimers. Though amid major innovations applied in variety of streams, yet in the early stages of its development and associated with negative environmental and public health issues. Nanotechnology is less awared publicly and poorly or none applied particularly in developing world including Ethiopia. Moreover, negative consequences are not uncommon and hence researchers and scientists are expected to indicate vividly the risks associated with nanotechnology.

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Introduction

Nanotechnology is an emerging scientific and technological area amid the 21st century leading innovations. It deals with investigation and potential uses of matter at the nanoscale level (Toumey, 2014). The field of nanotechnology is a research and development concerned with understanding, visualizing, measuring and manipulating matters at atomic, molecular and supramolecular levels ranging from 1 to 100 nanometers at which the physical, chemical and biological properties of materials differ fundamentally from their bulk counterparts (Patil *et al*., 2004). The concept is described by national nanotechnology Initiative (NNI) as―Research and technology development at the atomic, molecular or macromolecular scale leading to the controlled creation and use of structures, devices and systems having 1-100 nanometers size (nM) (McNeil, 2005). It can be defined as the science and engineering involved in the design, synthesis, characterization and application of materials and devices whose smallest functional organization is at least one dimension is on the nanometer scale (one-billionth of a meter) (Emerich and Thanosa, 2003).

Nanotechnology has been applied in improving diagnosis and treatment delivery systems, provision of new tools for molecular and cellular breeding, animal history, animal nutrition from uptake to utilization, modification of animal waste, pathogen detection (Scott, 2007), conversion of agricultural and food wastes to energy and byproducts through enzymatic nanobioprocessing, development in reproductive sciences, breeding managements, disease prevention and treatment in animals and public health (Patil *et al*., 2004), imaging of organs, tissues and deep molecular targets and provision of drugs at controlled release (Tiwari *et al*., 2011).

It is also being used in meat production, milk production and changing structure and enhancing quality and texture of food stuffs, in processing, transportation, storage, traceability, safety and security of food (Otles and Yalcin, 2008). Further advances are being made in nanobiochip materials, nanoscale biomimetic materials, nanomotors, nanocomposite materials, interface biomaterials and nanobiosensors (Tiwari *et al*., 2011). Despite its applications, nanotechnology is publicly or intellectually less awared and poorly or none applied particularly in the developing world. Therefore, the objectives of this review paper were to provide basic highlights on nanoparticles and indicate their potential applications in veterinary medicine discipline.

Nanomaterials

Carbon Nanotubes (CNTs)

Carbon nanotubes are long and miniature thin cylindrical carbon structure that has hexagonal graphite molecules attached at the edge with unique size, shape and physical properties. Carbon nanotubes are characterized by unique architecture formed by rolling of single walled carbon nanotubes or multi walled carbon nanotubes of graphite layers with enormous surface area and excellent electronic and thermal conductivity (Beg *et al*., 2011). Biocompatibility of nanotubes may be improved by chemical modification of their surface (Shin *et al*., 2011). 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 acting as potent and selective antibacterial agents in both cell cultures and mice studies (Fernandez-lopez *et al*., 2001). It can be made more soluble by incorporation of carboxylic or ammonium groups to their structure and can be used for the transport of peptides, and other drug molecules. Entry into the cell may be mediated by endocytosis or insertion through the cell membrane (Reilly *et al*., 2007).

Liposomes

Liposomes are small artificial vesicles of spherical shape composed of single or multiple concentric lipid bilayers surrounding a hollow core ranging from 50-500 nm. Liposomes play a key role in diagnosis as they can be used as carriers for radioisotopes and contrast agents. Drugs or other molecules can be loaded for delivery to tumors or other disease target sites (Mcmillan *et al*., 2011) since pharmacological agents can easily be placed inside them (Feneque, 2003). By directly fusing with bacterial membranes, drugs loaded on liposomes can be released to the cell membranes or the interior of the bacteria (Silva *et al*., 2011). Similarly, imaging agents can be loaded into either the bilayer or interior of liposomes, making them effective carriers for intensification of contrast in magnetic resonance imaging and computed tomography (Zheng *et al*., 2006) and blood pool or perfusion and lymphatic imaging for contrast enhancement (Suga *et al*., 2001).

Quantum dots

Quantum dots are nanometer scale crystals developed in the mid-1980s for optoelectronic applications (Bentolila and Weiss, 2003) being composed of hundreds or thousands of atoms of an inorganic semiconductor material with optical properties. Quantum dots offer construction of versatile nanoparticles that can be utilized for carrying out both imaging and treatment agents (Misra *et al*., 2010). They are used in diagnosis and therapy of biomedical purposes particularly in cancer imaging, tumor staging and planning of therapy (Cuenca *et al*., 2006). They are preferred over radioactive tags or fluorospheres like fluorescin or cyanine dyes in terms of longevity due to their stability and resistance to photobleaching (Cuenca *et al*., 2006).

Dendrimers

Dendrimers are nanomolecules with regular branching structures where the number of branching determines the size of the dendrimer (Freitas, 2005). They are used in gene therapy replacing conventional viral vectors and their major stress in the treatment of cancer as they accumulate at the site of tumors, enter the cells by endocytosis and the DNA gets transported into nucleus for transcription of the applied gene (Huang *et al*., 2007). Research indicates as dendrimers could be potential drug carriers for treatment of diseases with sustained release along and reduced side effects (Sobik *et al*., 2011). The presence of several surface functional groups enabled a simultaneous interaction with a number of receptors enhancing its biological activity. The drug may be encapsulated in the internal structure of dendrimers or chemically attached or physically adsorbed on dendrimers surface (Menjoge *et al*., 2010).

Magnetic nanoparticles

Magnetic nanoparticles are class of nanoparticles comprised of pure magnetic metals often iron, nickel, cobalt or magnetic oxides coated with a chemical component (dextran) to which specific antibodies will adhere. Some magnetic nanoparticles like iron oxide nanoparticles have been used in perfusion imaging for *in vivo* characterization of tumors (Strijkers *et al*., 2005). Magnetic nanoparticles are finding increasing applications in the areas of diagnostic and therapeutic because of the advantageous properties associated with the lesser dipole dipole interactions, lower sedimentation rates, facilitation in tissue diffusion and high magnetization so as to be controlled by external magnetic fields and to reach the targeted pathologic tissue and their small size that make them available for circulation through the capillary systems of organs and tissues (Sobik *et al*., 2011). Magnetic nanoparticles have been widely used in the early diagnosis of diseases like cancer. Magnetic nanoparticles show effective results in animal body as they can easily move in liquid medium and thus can be excited magnetically or detected inside nonmagnetic tissue (Zhao *et al*., 2011).

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 nanoparticle. Polymeric nanoparticles exist in a variety of forms utilizing both natural and synthetic polymers. Polymer delivery characteristics, surface properties, morphology and composition can be readily engineered and optimized to achieve the desired drug loading, biocompatibility, targeting, degradation and controlled release of kinetics (Yang, 2000). Polymeric nanoparticles are usually coated with nonionic surfactants in order to reduce immunological interactions as well as intermolecular interactions between the surface chemical groups of polymeric nanoparticles (Torchilin, 2008).

Nanoshells

Nanoshells are concentric particles in which one material is coated with a thin layer of another material by various synthesis methods. Nanoshells are currently being used in cancer chemotherapy and still more applications are conceived in the treatment of diseases. Gold nanoshells destroy cancer completely and they can also be used to immobilize cells or viruses, to trap and embed small and macromolecules on surfaces (Kumar, 2007).

Fullerenes

Fullerenes, a carbon allotrope, also called as ―bucky balls‖ are proven for drug transport of antiviral drugs (Thakral *et al*., 2006). Fullerenes are antibiotics and anti-cancer agents and used as free radical scavengers due to presence of high number of conjugated double bonds in the core structure (Marzo *et al*., 2007). Fullerenes have the potential to stimulate host immune response and production of fullerene specific antibodies. Animal studies with C60 fullerene conjugated with thyroglobulin have produced a C60 specific immunological response which can be detected by ELISA with IgG specific antibodies (Chen *et al*., 2006).

Applications of nanotechnology

Application in drug delivery systems

Nanotechnology allows the development of better drug efficacy results by loading drugs into nanoparticles through physical encapsulation, adsorption or chemical conjugation. The pharmacokinetics and therapeutic index of the drugs can be significantly improved in contrast to the free drug counterparts. Drug-loaded nanoparticles can enter host cells through endocytosis and then release drug payloads to treat microbe-induced intracellular infections (Zhang *et al*., 2010). Nanoparticle based drug delivery provides many advantages in drug efficiency and pharmacological characteristics including improving pharmacokinetics, reducing unwanted side effects, and improving delivery to disease sites has been demonstrated for a number of nanodrug delivery systems (Mcmillan *et al*., 2011) and produce low or none residues in animal products resulting in no withdrawal time needed (Zhag *et al*., 2008). Furthermore, nanoparticles improve the solubility of poorly water-soluble drugs, increase drug half-life by reducing immunogenicity, increase specificity towards the target cell or tissue, improve bioavailability, sustained release of drugs to the tissues and cells of the interest, diminish drug metabolism and enable a more controllable release of therapeutic compounds and delivery of combination therapy (Sanvicens *and* Marco 2008; Peer *et al*., 2007).

Nanoparticles in veterinary medicine

The field of veterinary science stands to gain with nanotechnology diagnostic tools (nanoprobes) that can be used in vitro and on living animals, targeted delivery of medications, therapeutic nanomaterials, vaccine antigen vectors, in vivo imagery, or traceability of products of animal origin. An important increase of scientific researches for nanostructured products development in the last years has been verified in veterinary medicine, especially using antimicrobial actives (Mcmillan *et al*., 2011). Conventional synthetic and natural antimicrobial substances are being tested, and have shown excellent results against multi-resistant microorganisms and bacteria strains that are normally hard to eliminate by using the conventional treatment, like *Brucella abortus*, *Mycobacterium bovis*, *Staphylococcus aureus*, *Salmonella*, *Ehrlichia*, *Anaplasma*; *Rhodococcus equi*, etc. (Mcmillan *et al*., 2011).

Veterinary diagnostic applications

Nanoparticles have been used within the body, within the cells for diagnosing and treatment of diseases. Unique size dependent properties of nanoparticles have numerous diagnostic applications such as diagnostic biosensors and imaging nanoprobes for magnetic resonance imaging contrast agents (Prabaharan *et al*., 2010). Nanotechnology has the potential to provide cheaper, fast and precise diagnostic tools. Nowadays, nanomaterials are playing a key role in imaging and monitoring and hence earlier detection of disease (Tripp *et al*., 2007). Better diagnosis has a positive effect in the cost of animal health care. Bionanomaterial based research has emerged as a new exciting field of DNA, RNA and peptides and are considered as important bionanomaterials for the fundamental development in life sciences. The nanomaterials such as quantum dots, nanoshells and carbon nanotubes can be synthesized and functionalized which may be coupled with the imaging sources and accompany the molecule with ultrasound, magnetic resonance, X-rays techniques to diagnose the targeted organ effectively (Loukanov *et al*., 2012).

Application in disease treatment

The effective delivery of conventional 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. These drawbacks would be solved by nanomedicine which has potential to solve unique biological challenges. Therapeutic and diagnostic agents are at the forefront projects of nanomedicine and research is focused on rational delivery and targeting of pharmaceuticals in animals (Zhag *et al*., 2008). Nanopharmaceuticals are the most promising and productive area of nanotechnology application in animal treatment for broad range of biological targets owing to their small size, higher mobility, diffusion and degradation characteristics of the encapsulated material and carry drugs to the targeted site (Si *et al*., 2007).

Application for in vivo treatment

Nanostructured *streptomycin* and *doxycyclin*e were tested against *Brucella melitensis strains* and the efficacy results of nanoparticles were better than the conventional antimicrobials (Seleem *et al*., 2009). This specific pathogen usually stays inside animal‘s macrophages and its pharmacological control is very hard. Technically, both antibiotics were encapsulated in anfihilicpolymers allowing the nanoparticles to reach the interior of murine macrophages. When tested *in vivo* (in infected marines), the nanostructured formulation determined reduction of the number of colony-forming units and also with a better efficacy compared to the conventional formulation. *Escherichia coli* and *Salmonella typhi* bacteria are two common pollutants developing resistance to the most used bactericide. New biocide materials are being tested. Thus, gold nanoparticles are proposed to inhibit the growth of these two microorganisms. Gold nanoparticles dispersed on zeolites eliminate *Escherichia coli* and *Salmonella typhi* colonies at short time (Lima *et al*., 2013).

Similarly, antimicrobial effects of silver ion or salts are well known and the silver nanoparticles show efficient antimicrobial property compared to other salts. The Ag nanostructures are most effective on *E. coli*, *S. aureus*, *Klebsiella* and *Pseudomonas*. These nanoparticles preferably attack the respiratory chain and cell division, finally leading to cell death. Ag nanoparticles can be used as effective growth inhibitors in various microorganisms making them applicable to diverse medical devices and antimicrobial control systems. The scanning transmission electron microscopy confirms the presence of silver in the cell membrane and inside bacteria (Rajasokkapan, 2013). Furthermore, the antimicrobial activity and bactericide effect of propolis against a wide range of bacteria, fungi, yeasts and viruses have been investigated since the late 1940s and it showed variable activity against different microorganisms. The alcoholic extracts of propolis inhibited the growth of various bacteria including strains of *Streptococci* and *Bacillus*. The inhibition of bacterial RNA polymerase by the components of propolis is probably due to the loss of their ability to bind to DNA (Hepazi, 2013).

Application in vaccination

Vaccination is one of the important methods of prevention of disease in advance by developing antibody against the particular pathogen. Nanoparticles are also used as vaccine carriers and adjuvants. Synthetic oligodeoxynucleotides and antigens in biodegradable nanospheres are used for immunization. Better immune responses seem to be obtained with biodegradable nanosphere vaccines produced by conventional methods. These new perspectives for vaccines development are contributing with better efficacy and safety results both in pets and livestock animals (Akagi *et al*., 2012).

Liposomal vaccines can be made by associating microbes, soluble antigens and cytokine with liposomes. Liposomes as vaccine adjuvant have been firmly established as immunoadjuvants (enhancers of the immunological response) potentiating both cell mediated and humoral immunity. Liposomal immune adjuvants act by slowly releasing encapsulated antigen on intramuscular injection and also by passively accumulating within regional lymph nodes (Gregoriadis, 1995).

Adjuvants are agents added to a vaccine to augment immune responses toward antigens. A number of studies describe the use of nanoparticles as adjuvant. Immunization of animals with both complete antigens and haptens (small molecules that can elicit an immune response only when attached to a large carrier such as a nanoparticle or a protein) conjugated to the surface of colloidal gold particles generated higher levels of specific antibodies than immunization of the same antigens with classical adjuvants. Furthermore, the amount of antigen required to achieve a high antibody response was an order of magnitude lower than for immunization with Freund‘s adjuvant (Andreev, 2000).

Application in animal breeding

Nanotechnology has begun to blossom in the field of reproduction and fertility (Verma *et al*., 2012; Chen *et al.,* 2011). Nanotechnology-based investigations related to animal reproduction characterize the nanoscale features of gamete cells using atomic force microscopy and related scanning probe microscopy techniques (Carvalho *et al*., 2013). Management of breeding is an expensive and time-consuming problem for canine, 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 actual breeding (O‘Connell *et al*., 2002). 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 (Weibel *et al*., 2014).

Application in meat production industry

Nanotechnology studies individual nanoparticles and their unique application for meat industry ranging from meat design, achieving food security, meat safety, overcoming food allergies, eliminating pesticide use, meat packaging, restoring meat damage and sensory evaluation to processes such as filtration, separation, encapsulation etc., (Mallika *et al*., 2005). One of the more futuristic applications of nanotechnology lies in the production of ―interactive‖ poultry meat that change color, flavor or nutrients depending on diner‘s taste or health (Marquez, 2004). There are many methods to improve livestock meat products by nanotechnology.

Encapsulation system at present including spray drying melts extrusion, coacervation, coating with fat and sprays chilling are commonly employed encapsulation techniques. The encapsulation system using nanotechnology has numerous benefits as detailed below (Raj Kumar *et al*., 2006).

Taste masking, head-triggered release consecutive delivery of multiple active ingredients, change in flavor character and long lasting organoleptic perception of nanotechnologies ranging from the actual to the speculative promise a variety of ways to create real meat without killing animals. On top of this, add the promise that genetic engineering could produce cells that have a variety of new qualities that would make meat even healthier and tastier: higher protein, lower fat, high omega 3 acid levels or other healthful concoctions (Kolata, 2006).

Some of the researchers in this field, for instance, are so committed to the development of cultured meat largely out organizations to pursue the technology. For example, New Harvest is a __non-profit research organization working to develop new meat substitutes, including cultured meat—meat produced in vitro, in a cell culture, rather than from an animal. Cultured meat has the potential to make eating animals unnecessary, even while satisfying all the nutritional and hedonic requirements of meat eaters. It also has the potential to greatly reduce animal suffering (Hopkins and Dacey, 2008).

Application in milk production industry

Nanotechnology is a new technological tool in modern raw milk production and pasteurization, recent and ongoing advances in biomedical technology will assist in advancing our understanding of disease prevention and health promotion, as well as medical diagnostics and therapeutics (Ross *et al*., 2004). Recent developments of nanotechnological tools begin to bring sophisticated Polymerase Chain Reaction (PCR) methods, cantilever systems, various microarray systems, new biosensors, etc. This substantiates an intensified research in new solid on-line/at line methods, which can measure critical points throughout the milk production chain (e.g., feed, cow, raw milk, milk tank, throughout the processing chain, during storage and distribution with regard to pathogens, indicator organisms of contamination, antibiotics, toxins, chemical contaminants, and allergens). These support the development of hazard analysis critical control points (HACCP)-based quality management systems. Development of mentioned HACCP-based quality management systems as well as shelf-life prediction systems also calls for development of sophisticated modeling of growth and decline of pathogens, spoilers and contaminants in the milk and dairy products (Andersen, 2007).

Liposomes micelles used to encapsulate both water and lipid soluble compounds. The dissolution of fat-soluble nutrients in water-based drinks is one of the key applications of liposomes. Examples of current research into the use of liposome technology in food are the encapsulation of enzymes, lactic acid bacteria extracts and/or antimicrobials for accelerated cheese ripening. Liposome technology can be used potentially to target specific sites within a food product for enzymatic degradation (Taylor *et al*., 2005).

Application in egg production industry

Poultry meat and eggs are often the source food borne pathogens, like salmonella. Early detection of food borne pathogenic bacteria is critical to prevent disease outbreaks and preserve public health. Now, a novel nanotechnology-based biosensor is showing great potential for food borne pathogenic bacteria detection with high accuracy (Park, 2008). Nanotechnology has to supply cholesterol free eggs, yolkless or reduced yolk eggs which can be the high value protein source, immune eggs which can supply the predetermined antibodies and therapeutic eggs with supply the predetermined physiological factors for treatment purposes. The tools and techniques currently with us will not give the solution for these challenges. They can only be meeting out by the emerging nanotechnology, which deals not merely at the molecular level but at the atomic level (Kannaki and Verma, 2006).

Challenge of nanotechnology

The concern over the possible adverse influences of nanomaterials on living systems has given rise to nanotoxicology (Dhawan *et al*., 2009). However, nanotoxicology has lagged far behind nanotechnology due to a number of experimental challenges and problems faced in designing studies involving toxicological assessment of nanomaterials. The health and safety concerns nanoparticles raised due to their unique physicochemical properties drew initial attention to their sustainability implications (Linkov *et al*. 2015). Physicochemical properties such as small size, specific surface area, structure, aspect ratio, morphology, solubility, chemical composition, reactivity, photochemistry, production of reactive species and surface properties (i.e. charge and coating) can be of prime importance (Yadav *et al*., 2014). In fact, the very similar properties that guide to the technical advantages of nanotechnology have also led to unique biological effects. For instance, size is the key feature determining the scope of uptake and toxicity of many nanomaterials, which have been shown to be size dependent (Oberdorster, 2010). It has been proved that engineered nanoparticles like quantum dots, single or multi-wall carbon nanotubes with nanoscale titania and surface coating have lethal effects on fibroblasts and epidermal keratinocytes and are competent of altering their gene or protein expression (Haliullin *et al*., 2015).

It is reported that the acute toxicity of copper particles (bulk) and nanocopper in mice and discovered that nanocopper was several folds lethal than bulk copper. Nanocopper was also reported to source pathological damage to kidney, liver and spleen (Chen *et al.*, 2006). The highest levels of acceptance and benefits for society can be achieved if technological development of nanotechnology is attached with the evaluation of societal, environmental and economic impacts posing the basis for complete sustainability evaluation of different nanoparticles with the same functionality (Iavicoli *et al*., 2014).

Potential setbacks of nanomaterials

Nanocarriers used for medical applications have to be biocompatible and nontoxic though their undesirable effects of nanoparticles strongly depend on their size, shape, amount, surface chemistry, the route of administration, reaction of the immune system and residence time in the bloodstream. Due to many factors affecting toxicity of nanoparticles, toxicological studies of each nanodrug delivery formulation are needed (Ai *et al*., 2011). For example, quantum dots may release potentially toxic cadmium and zinc ions into cells. However, because of their protective coating, quantum dots have minimal impact on cells. Additionally, studies using 2-nm core gold nanoparticles have shown that cationic particles are moderately toxic, whereas anionic particles are quite nontoxic (Goodman *et al*., 2004). Besides, the blood incompatibility of carbon nanotubes limits their use in the clinic. Many studies have shown that functionalization of carbon nanotubes can improve their water-solubility, proof of their biocompatibility and safety is currently insufficient (Li *et at*., 2016). Nanomaterials are likely to receive closer attention from regulatory bodies for toxicological potential in a number of different applications (Gaspar, 2007).

Future directional view of nanotechnology

In the past few years nanotechnology has grown by leaps and bounds, and this multidisciplinary scientific field is undergoing explosive development (Williams, 2004). It can prove to be a boon for animal health care, because nanoscience and nanotechnologies have a huge potential to bring benefits in areas as diverse as drug development, water decontamination, information and communication technologies, and the production of stronger, lighter materials. Animal health-care nanotechnology research can definitely result in immense health benefits. The genesis of nanotechnology can be traced to the promise of revolutionary advances across medicine, communications, genomics, and robotics. A complete list of the potential applications of nanotechnology is too vast and diverse to discuss in detail, but without doubt, one of the greatest values of nanotechnology will be in the development of new and effective medical treatments (Shaffer, 2005).

Nanotechnology is beginning to change the scale and methods of vascular imaging and drug delivery (Taton *et al*., 2001). Indeed, the NIH Roadmap's "Nanomedicine Initiatives" envisage that nanoscale technologies will begin yielding more medical benefits within the next 10 years. This includes the development of nanoscale laboratory-based diagnostic and drug discovery platform devices such as nanoscale cantilevers for chemical force microscopes, microchip devices, nanopore sequencing, etc. (La Van *et al*., 2002).

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. buckey balls, 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 (Tomanek and Enbody, 2010). It is considered as a potential technology to revolutionize veterinary medicine, animal health and other areas of animal production. By the use of emerging technology one can alter the form of production, processing, packaging and even mode of products ultimate use (Sekhon, 2012).

Conclusion and recommendations are as follows:

Nanotechnology has emerged as one of the most innovative technology with potentials to provide fast and precise drug delivery system, diagnostic nanomaterial tools and therapeutic nanoparticle and Nanomedicine (nanodrug), animal nutrition, meat and milk industry, breeding and reproductions and value addition to animals' product. Furthermore, the field is expected to it provide new products and new processes with the goal of enhancing the performance of the product, prolonging the product shelf life and freshness and improving the Safety and quality of animal origin food. Some of the nanoparticles or nanomaterials observed under this review included: carbon nanotubes, magnetic nanoparticles, nanoshells, fullerenes, polymeric nanoparticles, dendrimers, quantum dots and liposomes.

Based on the above conclusion the following recommendations are forwarded:

Continuous research and critical review need to be made on nanotechnology, particularly on nanobiotechnology in animal science and veterinary medicine to increase production of low fat and low cholesterol animal products

More advanced research should be conducted on nanoparticle, nanomaterial and nanomedicine to improve nanotechnology side effects

Risk or safety assessment should be done before field application and public awareness should be done. about the effect of nanoparticles

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