Nanotechnology and animal health

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Abstract

Nanotechnology, although still in the early stages of its development, is beginning to equip scientists, engineers and biologists to work at the cellular and molecular levels for significant benefits in healthcare and animal medicine. It is reasonable to presume over the next couple of decades that nanobiotechnology industries and unique developments will be revolutionising animal health and medicine.

Keywords: Nanotechnology, Nutrition, Health, Medicine.Nanobiotechnology.

Introduction

Nanotechnology is an exciting and rapidly emerging technology allowing us to work at the molecular level, often atom by atom, to create and manipulate tools, materials and functional structures that have nanometer dimensions. Nature has been performing 'nanotechnological feats' for millions of years. Through the arrangement of atoms and molecules, biological systems combine wet chemistry and electro-chemistry in a single living system.

Due to the small size of engineered nanomaterials (ENMs), unique properties may arise. One important consequence of nanoscaling of materials is increased surface area, which can affect reactivity with other materials and may result in increased ability of ENMs to translocate across biological membranes.

'Nano' usually refers to a size scale between 1 nanometre (nm) and 100 nm. For comparison, the wavelength of visible light is between 400 nm and 700 nm. A living cell has dimensions of microns (thousands of nanometres) (Table-1).

Table-1. Comparison of scales of nanotechnology in the biological world

Biological structures	Size in nanometers
Leukocyctes	10,000
Bacteria	1,000-10,000
Virus	75-100
Protein	5-50
Deoxyribonucleic acid (width)	~ 2
Atom	-0.1

Buckminster fullerene C60, also known as the buckyball, is the simplest of the carbon structures. known as fullerenes. Members of the fullerenes family are a major subject of research falling under the nanobiotechnology umbrella.

Application to animal health

Animal health is an increasingly important issue, both for animal agriculture and pet owners. Many reviews have suggested that nanotechnology has the potential to significantly affect the way veterinarians practice veterinary medicine (Feneque, 2003). Food security and safety and an increasingly aged pet population, along with heightened costs for medication and veterinary care create a need for new solutions. Nanotechnology has the potential to provide these solutions, since the possible applications of the technology in medical and veterinary applications are almost mind-boggling. Although much research and major company developments are necessary before nanotechnology is commonplace, in veterinary medicine, there are numerous glimpses of the future in applications for drug delivery, disease diagnosis and treatment, breeding and identity preservation (IP). Some exciting applications are discussed below.

Smart' drug delivery

Today, antibiotics, probiotics and pharmaceuticals are delivered to animals primarily through feed or injection systems. Nanoscale devices are envisioned that will have the capability to detect and treat an infection, nutrient deficiency, or other health problem, long before symptoms are evident at the macro-scale. This type of treatment could be targeted to the affected area.'Smart' delivery systems can have multifunctional

characteristics to avoid biological barriers to successful targeting and they may also be: time-controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed.

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 (potentially using buckeyballs, nanotubes and dendrimers, etc.) for biological and bioactive systems (drugs, nutrients, probiotics, pharmaceuticals, nutraceuticals and implantable cell bioreactors) for targeted site delivery capability.
– develop integrated sensing, monitoring and controlling capabilities, including the ability to be self-regulating.
– develop large animal health monitoring and therapeutic intervention.
– develop small animal health monitoring and therapeutic intervention.
– develop nucleic acid (e.g. DNA) delivery systems through a bottom-up approach using DNA molecules to build nanowires and nanotubes for assisted reproduction, animal vaccines and animal control agents.

Disease diagnosis and treatment

Imagine the possibility of injecting nanoparticles into an animal and then a week or so later being able to run a light over the animal's body to activate cancer-killing agents to destroy the tumour. Researchers at Rice University (Hirsch L.R et al., 2003) have been doing just this by using nanoshells 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.

Identity preservation

An 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. Looking at the number of shipments of livestock and other agricultural products are moved all over the world monitoring critical control points of the production, shipment and storage processes have become the order of the day.

Quality assurance of the safety and security of agricultural products could be significantly improved through IP at the nanoscale. Nanoscale IP has the potential to continuously track and record the history of a particular agricultural product. The keys are biodegradable sensors for temperature and other stored data containing the history of stored food for both physical and biological parameters. 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. The major issue exists with regard to biodegradable nanoparticles in the commodity.

Animal breeding

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 (O'Connell M.J et al., 2002) 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.

Ethical issues

Nanotechnology is a part of the future of animal health. Clearly, this technology has a high potential to benefit animal agriculture and food systems. However, as with any new technology, we have an ethical responsibility to apply it wisely and to recognise that there are potential unforeseen risks that may come with the tremendous positive potential.

Nanotechnology applications for the food sector have raised a number of safety, environmental, ethical, policy and regulatory issues. The main concerns stem from the lack of knowledge about the potential effects and impacts of nano-sized materials on human health and the environment.

The special characteristics and properties of (Engineered Nanomaterials) ENMs, such as the small size, surface reactivity and translocation across biological membranes, are issues that may need special considerations as well as interactions of ENMs with the surrounding matrix and unexpected effects resulting from this. The need for proper identification of any particulate matter (including physicochemical characterization) used in the food and feed sector is particularly emphasised. Detailed knowledge of a set of representative ENMs with respect to physico-

chemical and toxicological properties is essential for future development of predictive models.

References

1. Feneque J. (2003). Brief introduction to the veterinary applications of nanotechnology. Nanotechnology now. Website: www.nanotech-now.com/Jose-Feneque/ Veterinary- Applications-Nanotechnology.htm (accessed on 3 June 2005).
2. Hirsch L.R., Stafford R.J., Bankson J.A., Sershen S.R., Rivera B., Price R.E., Hazle J.D., Halas N.J. & West J.L. (2003). Nanoshell-mediated near-infrared thermal therapy of tumors under magnetic resonance guidance. *Proc. natl. Acad. Sci. USA*, 100 (23), 13549-13554.
3. Iezzi E.B. (2002). Take three buckeyballs before meals. Spacedaily. www.spacedaily.com/news/carbon-02e.html (accessed on 3 June 2005).
4. O'Connell M.J., Bachilo S.M., Huffaman C.B., Moore V.C., Strano M.S., Haroz E.H., Rialon K.L., Boul P.J., Noon W.H., Kittrell C., Ma J., Hauge R.H., Weisman R.B. & Smalley R.E. (2002). Band gap fluorescence from individual singlewalled carbon nanotubes. *Science*, 297 (5581), 593-596.
5. The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety. *The EFSA Journal* (2009) 958, 1-39.
6. http://en.wikipedia.org/wiki/Nanotechnologies.

Glossary

Nanocarrier: A nanoscale structure whose purpose is to carry a second substance (e.g. a vitamin.)

Nanoparticle: A discrete entity, which has all three dimensions in the order of 100 nm or less.

Buckeyballs: A buckeyball (also known as a fullerene) is a novel collection of carbon atoms in a spheroid shape in which each carbon atom is bonded to three of its neighbours.

Nanotube: A discrete hollow entity which has two dimensions of the order of 100 nm or less and one long dimension.

Dendrimers: Dendrimers (polymers) are a new class of three dimensional, man-made molecules produced by an unusual synthetic nanofabrication route that incorporates repetitive branching sequences to create a unique novel architecture.

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