Nanotechnology in Livestock Production: A Review

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ABSTRACT

Nanotechnology , a technology that involves reduction of materials and structures into miniature/minute sizes that perform their functions accurately and better than the bulk size, has its usage in every aspect of life but the use in agriculture remain unharnessed especially in Africa and other developing countries. The areas of use of nanotechnology in the field of livestock production is reviewed in this paper alongside with the challenges and prospects with a view of motivating animal scientists , livestock farmers and other practitioners to adopt the technology in improving livestock productivity, animal health care management and husbandry practices that improve yield and efficiency,

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INTRODUCTION

The word "Nano" is from the Latin word "Nanus" meaning dwarf and thus nanotechnology is defined as the technology of materials and structures where size is measured in nanometers with application in diverse areas as physics, chemistry and biology (Buzea *et al*., 2007). Wang *et al*., (2007) defined nanotechnology as manipulation of (designing, synthesis) particle with dimension less than a micron to that of individual atom. Nanotechnology is therefore an aspect of science that studies, designs, creates, synthesizes, manipulates and also applies functional materials, devices and systems through control of matter at nanometer scale (1-100nm: one nanometer is equal to 1 x 10^{-9}, one billionth of a meter (i.e., at atomic molecular and supramolecular (NSTC, 2004) and the exploitation of novel phenomena and properties of matter and structure at that level. Nanoparticles present a higher surface volume with decreasing size of the particle; they also exhibit unique chemical, physical, photo-electrochemical and electronic properties when compared to their respective bulk materials.

History of Nanotechnology

The term nanotechnology was first used by the late Norio Taniguchi in 1974, while the concept was developed Nobel Laureate and physicist Richard P. Feynman in south California in 1952 (Kakade, 2003), but it was popularized by Eric Drexler in 1980s. Mannino and Scapicchio (2007) defined nanotechnology as a study of phenomena and manipulations in atomic, molecular and macromolecular scales where properties differ from those on a larger scale. Nanotechnology is a technology that deals with experimenting and manipulating with particles, called nano-particles that are demonstrated in the scale of nanometers (Chaudhary *et al*., 2005). Food and Drug Administration (FDA) in 2006 defined nanomaterials as particles smaller than micrometric scales, which exhibit specific properties. Thus, by exploitation of the concept of nanotechnology, miniature sized structures, materials, devises. Mannino and Scapicchio (2007) stated United States Department of Agriculture (USDA) was the first to discuss nanotechnology in Agriculture and Food industry in their action plan published in September, 2003. Joseph and Morrison (2006). According to Scott and Chen (2002) nanotechnology is useful in applied science and engineering of agriculture, animal and food systems. Kalil *et al*., (2023) noted that four generations of nanomaterials have emerged: active and passive nano assemblies, general nanosystems and small-scale molecular nanosystems. The first generation include passive nanostructures that maintain steady structures and functions during their use like dispersed and contact nanostructures like aerosols, colloids, those with products incorporating nanostructures in coatings, nanoparticle reinforced composites. Second generations makes use of active nanostructures that provide for specificity of target cell or organs,e.g. Bioactive structures that target drugs. Third generation include 3D networking, robotics, while the fourth generations which is molecular include molecular devices by design, atomic designs and other emerging functions.

APPLICATIONS OF NANOTECHNOLOGY TO LIVESTOCK PRODUCTION

Improvement of Livestock Growth/Reproduction Performance and Immunity by Use of Nanoparticles

Nanoparticles are of four different types: metals, polymers, natural compounds and nanostructured materials. Metal nanoparticles are powdery form of the solid minerals, after the large pieces have been ground to nano-versions, thus changing its physical properties (Praharee 2021). According to him, polymer nanoparticles are polymers that have been synthesized or fragmented into nanometers long, while nano particles made of natural compounds are materials that come from nature with limited manipulations such as natural polymers and proteins. Nonstructured materials are synthesized nanoparticles that originate from many sources including natural compounds such as lipid and protein- based nanoparticles. Nanoparticles in feed and water administered to livestock have yielded remarkable positive results. Wang and Xu cited in (Praharee 2021) reported that 200µg in the feed of pigs produced pigs that are 14.06% leaner at slaughter, increased skeletal muscle mass and improved pork quality. Praharee (2021) also reported that nano Chromium when added to poultry feed positively improved the breast and thigh muscles and at the same time lowered cholesterol, but raised average daily gain feed efficiency. Other nanoparticles have been reported to have many nutritional and health benefits especially nano zinc. Swain *et al*., (2016) reported on the growth promoting, antibacterial, immuno-modulatory and many more effects of nano zinc on animals. Lane and Andre (2012) similarly reported that feeding nano Zn to larger livestock and poultry produced encouraging results in terms of growth, immunity and reproduction. Nano-Selenium is another very important nano mineral with tremendous positive impact on semen quality . Shi *et al*., (2010) reported that nano selenium enhanced testis selenium content of goats, improved testicular and semen GSH-Px activity, protected the membranes system integrity and tight arrangement of mid-piece of the mitochondria.

ii. Nanoparticle as Biocides

Hill and Li (2017) discussed extensively the biocidal properties of nanoparticles and stated that. nano-particles present a feasible alternative to antibiotics. Drug resistance due to continuous use of antibiotics has remained a big challenge in the livestock industries worldwide, thus the emergence of legislations to control for prophylactic antibiotics use in agriculture. Limiting antibiotic use necessitates the search for alternatives, however, metal nano-particles with net positive charges according to Gahlawat *et al.,* (2019) are drawn to negatively charged bacterial membranes resulting in leakage and bacterial lysis. Kim *et al.,* (2007) cited in Hill and Li (2017) reported that silver nanoparticles can inhibit the growth of hemorrhagic enteritis-inciting E. coli. Gonzales-Eguia *et al*., (2009) demonstrated that nano form of copper could improve piglet through augmentation of lipase and phospholipase A activity in the small intestine compared to a basal diet supplemented with copper sulphate.

iii. Nano Meat Production

Nanotechnology is a promising technology that has applications in almost all fields. The technology has opened the path to an unexplored science for studying individual nanoparticles and their unique application to poultry and meat industry ranging from meat design, meat safety, overcoming food allergies, eliminating pesticide use and residues, meat packaging, restoring meat damage and sensory evaluation to processes such as filtration, separation, encapsulation. Nano-technology can make poultry and meat products cost-effective with the natural properties (Singh *et al.*, 2011). Production may be carried out by self- replicating nano-devices using small assent of material, energy, low capacity, less labour and land. Thus, production is more efficient (Rajkumar *et al.*, 2006). For quality meat products development, nanotechnology based diagnostic techniques may replace ultrasound-like existing technique, besides is naturally composed of nano-fibres. It is the nano-fibres that undergo changes during cooking or processing leading to changes in taste, texture and flavour. Singh and Neelam (2011) noted that differentiation in quality of products can be made using nanotechnology- based techniques. Many of the molecular structure that affect the meat quality are in the nanometer range, so information on the source can play a significant role in poultry meat design. Mastering the characteristic of meat components and the knowledge of nanotechnology approach to manipulating of individual atoms and placing them where they are needed are the two basic requirements for producing meat of desired flavor, texture and taste (Chaudhary *et al.* 2005).

Recently, nanotechnology is being utilized in the development of vegetarian meat as well as cultured meat. The power of nanotechnology here lies on the fact that everything is made of basic atoms, but simply arranged in different ways, thus rearranging the atoms at the nano- levels will give desired molecules. This is the basis for laboratory meat synthesis referred to as cultured meat. Moraru *et al.* (2003) predicted the creation of unlimited amount of meat by synthesis at atomic level which eradicates animal protein deficiencies and hunger. Cultured meat will reduce level of animal production drastically while fulfilling all the nutritional and hedonic requirement of meat eaters. Marquez (2004) stated that the more futuristic applications of nanotechnology lie in the production of 'interactive' poultry meat that change colour, flavour or nutrrients depending on the consumer's taste or health.

iv. Nanotechnology Based Meat Packaging

In many developed countries, there has been increasing competition between suppliers and government regulations regarding meat packaging materials. Generally, the consumers demand to have their meat fresh for longer period or safe meat products prepared with environmentally friendly packaging materials. Andersen (2007) noted that nanotechnology innovations has produced films that enhance products and packaging performance and at the same time addressed worldwide concerns with packaging waste. Nanotechnology provides food scientists with a quantity of ways to make novel laminate films suitable for use in the food industry. A nanolaminate consists of two or more layers of material with nanometer size that are physically or chemically bonded to each other. Nanolaminates can provide food scientists some advantages for the preparation of edible coatings. Edible coatings according to Morillon *et al*., (2002) and Cagri *et al.*, (2004), these coatings or films could serve, lipid and gas barriers. Edible coatings can also be made to improve textural properties of food or serve as carriers of functional agents such as colours, flavours, antioxidants, nutrients and antimicrobials.

v. Nanotechnology Applications in Egg Production

The role of nanotecnology in designer egg production is now a well- known fact. Scientists are of the opinion that in the near future the share of designer eggs in the egg production will be more than 30% and similarly supply of cholesterol free eggs, yolkless or reduced egg yolk, immune boosting eggs (which enhance production of predetermined antibodies), increased albumen eggs will be in the market. These egg qualities according to Kannaki and Verma (2006) can only be met by the emerging nanotechnology.

Furthermore, through nanotechnology, there is possibility of advanced detection of sources of pathogens in eggs and poultry meat. Such early detection of food borne pathogenesis is critical in prevention of disease outbreak and safeguarding public health. Though numerous methods have evolved over the years for this purpose, however the biggest challenges remain the speed of detection and sensitivity. Presently, novel nanotechnology-based biosensor is showing great potential for food borne pathogenic bacteria detection with high precision.

vi. Nanotechnology Applications in Milk Production

Many research has been carried out on the improvement of composition and quality of milk by the use of nanominerals. Mohamed *et al.*, (2022) reported that Chitosan nanoparticles and Selenium nanoparticles showed high antimicrobial activity against milk microorganisms that deteriorate milk quality. Rajendran *et al*., (2013) reported on the effect of feeding of dairy cattle with nano ZnO and posited that nano ZnO fed to dairy cattle increased milk production, immunity and suppressed subclinical mastitis (reduction in SCC values). Cai *et al.*, (2021) also reported that nano Zn supplementation in dairy cattle feed improved Zn availability without impairing lactation performance, health status and mammary gland permeability.

vii. Nanotechnology Use in Controlling of Piglet Weaning Challenges

Diarrhoea is a common intestinal disease of piglet, often resulting in high morbidity and mortality of piglets (You *et al*., 2012). For long, microelements like Selenium and Zinc are the essential additives required in the treatment of such diseases in piglets (Bian *et a.l*, 2010). Zinc added in feed dietarily often occur in high dosage resulting in zinc toxicity in pigs, besides; a greater proportion of the Zinc is discharged via feaces resulting in environmental pollution. Kociova *et al* (2020) cited in Baholet *et al*., (2023) showed that there was increase in piglet weight in all supplementation with nano Zinc from 500mg/kg to 2000mg/kg of Zn in enhancing growth performance and preventing diarrhoea in piglets. Pan *et al*., (2005) earlier noted that nano Zn has unique advantage of being highly effective at dosages far lower than that of the quantity of Zn) it replaces.

CHALLENGES OF NANOTECHNOLOGY

The challenges of nanotechnology are categorized into four: philosophical, ethical and societal issues. Of all these, one major challenge of nanotechnology is that, a lot of prospective adopters of the technology are ignorant of the happenings in the nanoworld. People need to understand how atoms fix up to become large structures and materials except this knowledge is available, adoption of nanotechnology will be low. Bonsor and Strickland (2007) stated that the most immediate challenge of nanotechnology is that people need to learn more about the properties of materials at the nanoscale. This is because elements at nanoscale behave differently from their bulk size. According to them, there fears about nanoparticles being toxic .

Secondly, in the human health parlance , doctors are worried that nanoparticles are so small and capable of crossing the blood-brain barrier, a membrane that protects the brain from harmful chemical in the bloodstream. This is a serious issue that is also applicable to livestocks.

Another concern of scientists is ethical issues, nanotechnology appear to take away science from nature, if nanoparticles increases sperm motility, dairy production. Nanotechnology practices may appear pervasive against societal norms and cultural beliefs and in Africa this poses a major hindrance to adoption of innovations. However , serious extension services is required if this novel discovery is to be adopted by farmers; such extension services must use native language and easily comprehensible teaching aids to bring the teaching to the farmers level of understanding.

CONCLUSION

Nanotechnology is touching every facet of life, its application in the field of animal science provides an outlook of unimaginable possibilities. It is therefore imperative for animal scientists in Nigeria to begin to appreciate the outlook of its possibilities and harness the ones that can fit into our peculiarities and utilize it to move animal production forwards,

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