Nano Technology in Animal Feed: Benefits and Applications

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Abstract

The term nano originates from the Latin word nanus, signifying dwarf. Nanotechnology is the examination of phenomena and the manipulation of materials at the nanoscale, where properties diverge from those at larger scales. Manipulating matter at the nanoscale enhances the functionality of feed molecules, hence benefiting animal productivity. Nanotechnologies possess the capacity to enhance nutritional assessment, function as innovative vehicles for nutrient delivery, and serve as a means to further elucidate nutrient metabolism and physiology. Minerals in nanoparticle form, as feed additives, can penetrate the intestinal tract and enter body cells more rapidly than conventional minerals with bigger particle sizes, hence enhancing bioavailability. The introduction of nanonutrients presents issues such as altered metabolism, toxicity, and the environmental impact of nanoscale materials relative to microscale materials; consequently, the economic, social, ethical, and legal ramifications of nanotechnology must also be addressed. Consequently, nanotechnology can enhance nutrient bioavailability, production performance, and immunological status in cattle through its application in animal feeding.

Keywords: Nano, Feed, livestock, nutrient.

Introduction

Nanotechnology involves the creation and application of materials, mechanisms, or systems at the nanoscale scale. Nanomaterials are defined as substances with particle sizes under ۱۰۰ nm, exhibiting unique properties relative to their macroscale equivalents, mostly attributed to their elevated surface-to-volume ratios(۱). The foundational notions of nanotechnology were initially articulated in ۱۹۵۹ by eminent physicist Richard Feynman during his lecture "There's Plenty of Room at the Bottom," wherein he elucidated the potential for synthesis by direct atomic manipulation (Feynman, ۱۹۵۹). The phrase "nano-technology" was initially coined by Norio Taniguchi in ۱۹۷٤, however it remained largely obscure. K. Eric Drexler, drawing inspiration from Feynman's concepts, independently coined the term "nanotechnology" in his book Engines of Creation: The Coming Era of Nanotechnology, which introduced the notion of a nanoscale "assembler" capable of constructing replicas of itself and other objects of arbitrary complexity with atomic precision. In ۱۹۸٦, Drexler co-founded The Foresight Institute to enhance public knowledge and comprehension of nanotechnology principles and their ramifications. The emergence of nanotechnology as a discipline in the ۱۹۸۰s resulted from the convergence of Drexler's theoretical and public endeavors, which established and disseminated a conceptual framework for nanotechnology, alongside prominent experimental advancements that garnered significant attention towards the potential for atomic manipulation of matter.

Division of Nanomaterials

Nanoparticles can be categorized into inorganic, organic, emulsions, dispersions, and nano clays according to their chemical properties. Nanoparticles can be classified into inorganic, organic, emulsions, dispersions, and nano clays according to their chemical properties. Inorganic nanoparticles are synthesized inorganic substances at the nanoscale, and certain feed additives, such as titanium dioxide, which serves as a feed colorant, are already authorized for use in feed, functioning as a UV protection barrier in feed packaging when utilized as nanoparticles. The predominant application is the utilization of silver nanoparticles as antimicrobials. Nanosilver applications encompass refrigerator panels, storage containers, packing lines, and other surfaces that interact with feed during production. Feed storage containers are manufactured with silver nanoparticles integrated into the plastic, effectively eliminating microorganisms from previously stored feed and reducing health hazards. Inorganic nanomaterials utilized in feed, feed additives, food packaging, or storage comprise nano-clay platelets for feed packaging, minerals such as silicon dioxide, calcium, and magnesium, as well as silver nanoparticles for water purification, antimicrobial packaging, or feed storage.

Organic nanoparticles are expected to boost the nutritional value of feed systems by improving or modifying feed functioning. Organic nanoparticles, often known as nanocapsules, have been engineered to administer vitamins or other nutrients in feed without altering the taste or appearance. These nanoparticles encapsulate nutrients and transport them through the gastrointestinal tract (GIT) into the circulation, enhancing their bioavailability. Additionally, certain categories of nanomaterials are deemed pertinent for uses in feed. Organic nanomaterials comprise proteins, lipids, and saccharides. Nutraceuticals comprising plant-derived feed additives are also classified as organic nanomaterials utilized in animal feed. Nanoparticles previously documented in food and feed applications encompass those designed for encapsulation systems, such as micelles and liposomes, for the delivery of food and feed components, as well as those specifically developed for food and feed packaging, including biosensors, identification markers, shelf-life prolongers, and antimicrobials.

Method of Impact of Nanoparticles

The modes of action of the nanoparticles are outlined below(۲):
Enhance the surface area for interaction with biological support.

- Extend the residence period of compounds in the gastrointestinal tract
- Mitigate the impact of intestinal clearance mechanisms Penetrate extensively into tissues via fine capillaries.
- Trans-epithelial fenestration (e.g. liver)
- Facilitate effective cellular uptake
- Optimize distribution of active substances to targeted areas within the body

The use of nanotechnology in Animal Feeding

Nanoparticles can infiltrate the gastrointestinal tract (GIT) through many routes, including direct ingestion from food and drink, administration of therapeutic nano-drugs (ingestion or swallowing pathway), and the respiratory tract (inhalation pathway) (۳). Nanoparticles diffuse more readily than solid particles and exhibit behavior akin to gas molecules in the atmosphere and large molecules in liquids, experiencing reduced sedimentation compared to larger particles. This may potentially affect the mobility of nanoparticles within tissue. A smaller particle diameter facilitates more rapid diffusion through gastrointestinal mucus, enabling quicker access to the intestinal lining cells, followed by absorption through the gastrointestinal barrier into the bloodstream. In a particle translocation experiment (Jani et al., ۱۹۹۰), female rats were administered polystyrene spheres (۵۰ nm-۳ µm) via gavage for ۱۰ days. The findings indicated that approximately ٣٤٪ and ٢٦٪ of nanoparticles (٥٠ and ١٠٠ nm, respectively) were absorbed, whereas particles exceeding ٣٠٠ nm were not detected in blood, heart, or lung tissue. Nanoparticles, based on their size, may either traverse the gastrointestinal tract without absorption into the body and are swiftly excreted(٤), or they may penetrate the gastrointestinal lining and enter the bloodstream, subsequently migrating to other organs. After absorption by the gastrointestinal tract, gold nanoparticles smaller than ٥٠ nm entered the bloodstream and disseminated throughout the body.

An further factor in the adsorption of biomolecules onto nanoparticle surfaces is its impact on the shape of proteins, including enzymes, as well as their function, stability, activity, and aggregation state, among other characteristics. Numerous instances demonstrate improved enzyme stability and functionality after adsorption onto nanoparticles; for instance, the longevity of the enzymes trypsin and peroxidase significantly increased from several hours to weeks when conjugated with magnetic iron nanoparticles (٥). The capacity to augment protein stability by interaction with nanomaterials may influence various biological processes, including digestion, metabolism, and nutrition absorption. Nanoparticle absorption typically transpires in the intestinal tract by passive diffusion across mucosal cells, active transport mechanisms, and intercellular pathways (٦); nanoparticles that are ingested will ultimately reach the intestinal tract. Particles smaller than ٣٠٠ nm enter the bloodstream, and those under ١٠٠ nm are absorbed by diverse tissues and organs(٣). Generally, smaller particles are absorbed in greater quantities and penetrate more deeply into the body. After absorption from the gastrointestinal tract, nanoparticles can migrate through the lymphatic system to the liver and spleen, as evidenced by studies on polystyrene nanoparticles measuring ١٠٠ nm or smaller(٧) Smaller particles that can be absorbed by the villus epithelium(٨) may directly enter the bloodstream and are mostly filtered by the liver and spleen. Organic nanoparticles, such as casein micelles, are expected to exhibit behavior akin to their micro or macro counterparts and can be anticipated to be easily absorbed and highly bioavailable. Insulin encapsulated in vitamin B١٢-dextran nanoparticles has demonstrated absorption from the gastrointestinal tract without degradation (٩). Latour and colleagues at Clemson University have recently created biofunctionalized nanoparticles (BN)(١٠). BN have garnered attention as a therapeutic option for gastrointestinal infections, functioning as pathogen-clearing agents before transportation and processing. Adhesins, or surface molecules on bacterial cells, enable adherence to the epithelial tissues of the intestinal wall by recognizing receptor sites on the epithelium. Furthermore, studies indicate that D-mannose impedes the adhesion of bacteria to intestinal cells in both animals and humans(١١). The adhesion of Campylobacter jejuni to epithelial cells is facilitated by mannose-specific, lectin-like adhesins on the bacterial surface that interact with mannose receptor sites. Consequently, the BN are postulated to be adhesion-specific to the enteropathogen C. jejuni(١٢). The BN have an affinity for the mannose receptor sites on the Campylobacter cell surface, potentially facilitating cell aggregation or adhesion between the bacteria and BN.

Conclusions

Nanotechnology can enhance nutrient absorption, productivity performance, and immunological status in cattle by its application in animal feeding. Nevertheless, more research remains necessary to validate the efficacy and, primarily, the safety of nanotechnology, ensuring it does not pose risks to cattle, the environment, or human beings.

References

١. Delshadi R, Bahrami A, Tafti AG, Barba FJ, Williams LL. Micro and nano-encapsulation of vegetable and essential oils to develop functional food products with improved nutritional profiles. Trends in Food Science & Technology. ٢٠٢٠;١٠٤:٧٢-٨٣.

٢. Chen H, Weiss J, Shahidi F. Nanotechnology in Nutraceuticals and Functional Foods. Food Technology. ٢٠٠٦;٠٣,٠٦:٣٠-٦.

٣. Hoet PHM, Brüske-Hohlfeld I, Salata OV. Nanoparticles – known and unknown health risks. Journal of Nanobiotechnology. ٢٠٠٤;٢(١):١٢.

٤. Oberdörster G, Oberdörster E, Oberdörster J. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. Environ Health Perspect. ٢٠٠٥;١١٣(٧):٨٢٣-٣٩.

٥. Sharma A, You Q, Antony J, Meyer D, Kornacki P, Paszczynski A. Dramatic Increase in Stability and Longevity of Enzymes Attached to Monodispersive Iron Nanoparticles. Magnetics, IEEE Transactions on. ٢٠٠٧;٤٣:٢٤١٨-٢٠.

٦. O'Hagan DT. The intestinal uptake of particles and the implications for drug and antigen delivery. J Anat. ١٩٩٦;١٨٩ (Pt ٣)(Pt ٣):٤٧٧-٨٢.

٧. Jani P, Halbert GW, Langridge J, Florence AT. Nanoparticle uptake by the rat gastrointestinal mucosa: quantitation and particle size dependency. J Pharm Pharmacol. ١٩٩٠;٤٢(١٢):٨٢١-٦.

٨. Hillery AM, Jani PU, Florence AT. Comparative, quantitative study of lymphoid and non-lymphoid uptake of ٦٠ nm polystyrene particles. J Drug Target. ١٩٩٤;٢(٢):١٥١-٦.

٩. Florence AT, Hussain N. Transcytosis of nanoparticle and dendrimer delivery systems: evolving vistas. Adv Drug Deliv Rev. ٢٠٠١;٥٠ Suppl ١:S٦٩-٨٩.

١٠. Taylor TM, Davidson PM, Bruce BD, Weiss J. Liposomal nanocapsules in food science and agriculture. Crit Rev Food Sci Nutr. ٢٠٠٥;٤٥(٧-٨):٥٨٧-٦٠٥.

١١. M G, Pearlin V B, Ramasamy Dk, Shanmathy M, Govindasamy P. Role of Nanoparticles in Animal and Poultry Nutrition: Modes of Action and Applications in Formulating Feed Additives and Food Processing. International Journal of Pharmacology. ٢٠١٧;١٣:٧٢٤-٣١.

١٢. Cinco M, Banfi EG, Ruaro E, Crevatin D, Crotti D. Evidence for l-fucose (٦-deoxy-l-galactopyranose)-mediated adherence of Campylobacter spp. to epithelial cells. Fems Microbiology Letters. ١٩٨٤;٢١:٣٤٧-٥١.