Nanotechnology in Food: Applications and Safety Considerations

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Understanding and manipulating matter at dimensions between 1 and 100 nm, where special phenomena allow for fresh applications, is referred to as nanotechnology. It is also known as the study of atomic and molecular scale manipulation of matter. Its scale varies from 1 to 100 nm, extending its potential from mechanics to medicine and enabling the development of new tools and methods. A nanoparticle is a tiny item that functions as a single entity for various purposes based on its properties. They are categorised based on their traits, dimensions, and structures. It deals with objects that can manipulate individual atoms and nanoscale building blocks, as well as materials having nanoscale structures.

Nanotechnology harnesses the characteristics of nanoparticles in multiple domains across a wide range of sectors. In the fields of engineering, energy, and medicine, there have been significant advances in nanotechnology. Food and farming systems could be revamped by nanotechnology. The features of the food at the nanoscale level can impact new goods and ingredients' molecular production as well as its efficacy, bioavailability, nutritional value, and safety. One of humanity's greatest problems — the food crisis, is being addressed with the use of nanotechnology. An array of products has been discovered recently, including nanoparticulate delivery systems that serve a variety of processes, including transporting functional compounds to the site of action, and nano encapsulated food ingredients.

The United States Department of Agriculture (USDA) roadmap, which was issued in 2003, was the first to explore the use of nanotechnology in the agriculture and allied sectors.

Government-funded programmes and research centres have been developed in nations including Brazil, India, the Philippines, Chile, Mexico, and South Africa, with many developing nations emerging as leaders in the field of nanotechnology. Nanotechnology is one such field where nations work together as well as compete with each other to attain the zenith of the field.

The safety of nanomaterials in food and food-related items will determine how well-liked they are by the general public. As a result, a unified international regulatory framework is required for nanotechnology in food.

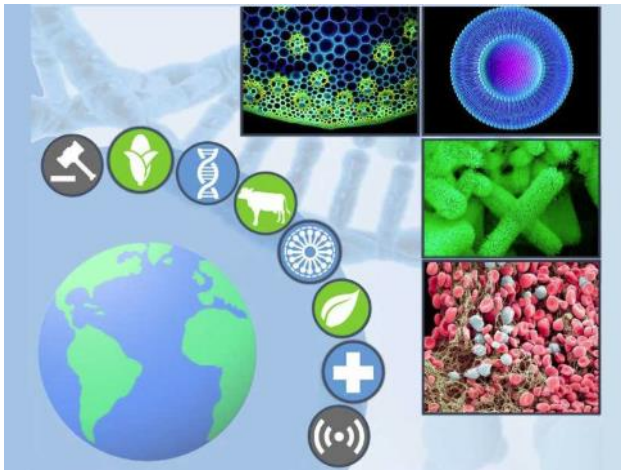

Fig 1: convergence of nanotechnology with food and agriculture
Image source: https://iupac.org/wp-content/uploads/2019/12/GRC-Nano_200621.png

Application of nanotechnology in food sector

Food packaging

Certain foods are highly perishable as they contain high amounts of moisture and make it unacceptable for its consumption by the consumers during prolonged storage. Packaging plays a crucial function in protecting these foods from the environment, keeping them contained, extending the shelf life of food, increasing food safety and maintaining its nutritional value. The use of nanotechnology in food packaging is expanding substantially globally. Initially the nanocomposite was created by combining an organic and an inorganic element in order to generate a material with greater durability. Nanotechnology can enhance the quality and safety of foods through packaging in a number of ways, including the enhancement of vapour and gas barrier attributes by the integration of nanofillers, antibacterial properties of nanocomposite films, and smart packaging based on nanosensors. An instance for this is a packing material composed of calcium carbonate and potato starch. The use of starch nanoparticles, also referred to as starch nanocrystals, as nanofillers in composite materials has been found to improve the strength, flexibility, biodegradability, water impermeability, heat, and barrier properties of the materials.

Dietary supplements

For increased absorption and bioavailability of nutrients and health supplements nanomaterials are used as components. The essential vitamins, flavors, minerals, antioxidants are encapsulated using nanotechnology that helps curb various deficiency symptoms and disorders. There is no denying the significance of a balanced diet that contains the essential nutrients in adequate amounts for the well-being of humans as well as animals. For these uses, biodegradable natural or semisynthetic nanocarriers such as "polymeric matrices, micelles, liposomes, nanoemulsions, solid lipid NPs, nanostructured lipid carriers", or appropriate inorganic matrices are particularly advantageous, ensuring not only improved stability but also frequently controlled release of nutrients.

Food processing

Farm to Fork. This is the common phrase that is used to describe food processing in recent times. It refers to various techniques and methodologies that are incorporated to transform a raw agricultural produce into a palatable food product. The method is used to enhance the taste, shelf life, texture of foods without leaching of its nutrients.

The basic idea behind adopting nanotechnology in food processing is emphasizing interactive foods and food preservation. In order to prepare and preserve beverages, meat, cheese, and other foods, nano-encapsulated active substances, including vitamins and fatty acids, are now commercially available. Many foods now employ nanoparticles to enhance their flow characteristics and stability upon processing. For instance, aluminosilicate compounds are frequently utilised as anticaking agents in granular or powdered processed foods. Milk protein self-assembled stiff hollow nanotubes that are a few micrometres long have the potential to be exploited as innovative ingredients for controlled release, viscosification, gelation, and nanoencapsulation processes.

Food storage

Nanomaterials' antibacterial qualities make it possible for them to keep food fresh during storage and transportation. Nano sensors are now employed to detect the quality deterioration during the storage of food products. Pathogenic bacteria, toxins that contaminate food, adulterants, fertilisers, pesticides, taste, and odour in stored products can be detected using the nanosensors.

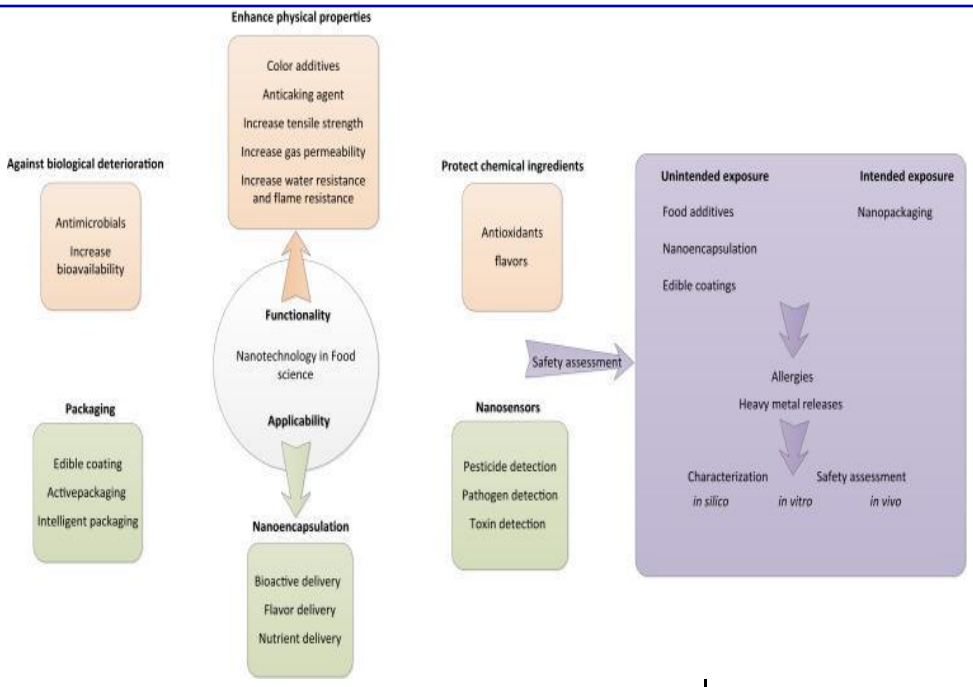

Fig 2: Diagram showing the functionality, applicability, and safety assessments of nanotechnology in food

Safety and efficacy of nanotechnology

It becomes inevitable that, whether intentionally or otherwise, human exposure to nanomaterials will rise in various ways. However, a few studies have investigated food samples used as food additives/ingredients and food packaging to examine the possible toxicity of the presence of nanomaterials in foods. The bioavailability, biodistribution, pathways, and ultimate toxicity of nanomaterials are all unidentified. They may bioaccumulate in numerous human organs after being absorbed in the digestive system, which could have negative effects. Additionally, nanoencapsulation permits oral ingestion of nanomaterials for direct contact with people.

The two major concerns of nanotechnology are allergy and heavy metal release, which cause adverse effects of nanomaterial exposure. Thorough characterization and assessment in silico, in vitro, and in vivo are required for the safe use of nanotechnology to the food companies. A study on TiO2 in sugar-coated chewing gum indicated that over 93% of the TiO2 in gum is of nanosize, drawing attention to the growing usage of nanomaterial substances in meals as flavour or colour enhancers

A report on the safety of food and animal feed using nanoscience and nanotechnology was issued in March 2009 by the scientific committee of the European Food Safety Agency. In May 2011, a document offering practical advice to regulators on how to assess applications from industry to use engineered nanomaterials in food additives, enzymes, flavorings, food contact materials, novel foods, food supplements, feed additives, and pesticides was released. This guidance document described how to assess potential risks associated with certain food-related uses of nanotechnology. Until the safety of nanotechnology products has been shown, certain social and non-governmental organisations, such as Action Group on Erosion, Technology, and Concentration (ETC Group), have advocated for a moratorium on their release.

Conclusion

The advancements in food processing nanotechnology are more concerned with the texture of food components, encapsulating food additives, creating novel tastes and sensations, managing the release of flavours, and enhancing the bioavailability of nutritional components. Due to the dependence of many foods' distinctive features on components with a size of a few nanometers, nanotechnology is a natural component of food processing and conventional foods. The safety of nanomaterials in

food and food-related commodities will determine the level of acceptance by the general public. It is essential to have a unified international regulatory framework for food-related nanotechnology. Due to the special characteristics of nanomaterials, the food industry as well as related industries including agriculture, packaging, and food processing have seen significant changes.

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