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Review Article

Current key Role of Nanotechnology in Food System

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ABSTRACT

Numerous areas of food science have undergone radical change as a result of the quick development of nanotechnology, particularly those that deal with food processing, packing, storage, transportation, functionality, and other safety-related issues. The food industry has used a wide variety of nanostructured materials (NSMs), from inorganic metal, metal oxides, and their nanocomposites to nano-organic materials incorporating bioactive chemicals. Despite the enormous advantages that nanotechnology offers, there are growing worries about its application since the buildup of NSMs in the environment and human bodies can pose a number of health and safety risks. As a result, when producing, processing, thoughtfully and actively packing, and consuming food products that have undergone Nano processing, regulatory laws as well as safety and health considerations must be taken into account. This review seeks to offer a fundamental comprehension. Addressing the uses of nanotechnology in the food processing and packaging sectors, and to determine the potential benefits and dangers of using NSMs in the future.

INTRODUCTION

Nanotechnology refers to the application of nanomaterials with nanoscale structures ranging from 1 to 100 nm and incorporates a number of fields, including physics, chemistry, biotechnology, and engineering. Materials take on distinctive features at these nanoscales that weren't there in the materials' original form. Nano-scientists from all over the world are working to understand these distinctive qualities in order to create new, better products using environmentally friendly methods. For their structural components, clusters, molecules, or crystallites, nanomaterials or nanostructure materials exhibit various dimensions, including zero dimensions (nanoparticles, nanoclusters, and quantum dots), one dimension (nanorods and nanotubes), two dimensions (nano-thin films), and three dimensions (nanomaterials) in the range of 1e100 nm. Blending nanostructures with other polymers, biomolecules, and nanostructures existing in aggregate form can, comparatively, result in a material with higher particle size (>100 nm), which can contribute to the creation of nanocomposite [1]. The unique physio-chemical properties of these nanomaterials with large surface volume ratios include solubility, toxicity, strength, magnetism, diffusivity, optics, colour, and thermodynamics. Due to their exceptional capacity to increase solubility and bioavailability as well as to safeguard bioactive components during processing and storage, these nanomaterials are finding increasing use in a variety of fields, including agriculture, medicine, clothing, cosmetics, food, and public health.

METHOD

Utilizing of Nanomaterials in Food Sectors

Nanomaterials are frequently employed in healthcare, crop protection, water treatment, food safety, and food preservation because of their superior physiochemical properties and antimicrobial potential. As a new packaging material, encapsulated food component, and nanosensor, nanostructured materials (NSMs) are also being used in the food business [2]. This review primarily focuses on the application of nanotechnology, particularly nanoparticles and constructed nanostructures, in the food industry. Numerous applications for food-related nanotechnology exist. These applications involve adding a certain kind of nanomaterial to a particular food item in order to give it the necessary qualities. Nanotechnology has also played a significant role in worldwide research and development for industrial-scale production of agricultural goods, processed foods, and beverages, as well as for food packaging. Numerous studies have shown that these nanomaterials can successfully increase food safety by increasing the effectiveness of food packaging, shelf life, and nutritional value as additions without altering the flavour and physical properties of food products. Despite their enormous potential to create novel products and production methods for the food industry, nanotechnologies are encountering challenges [3]. A significant problem is developing effective formulations that are safe for human consumption while using cost-efficient processing techniques to produce edible and non-toxic nano-delivery systems.

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As a result of the increased use of these NSMs, there have been growing concerns about the creation of biocompatible, secure, and non-toxic nanostructures from ingredients of the highest quality using straightforward, environmentally friendly, and economically advantageous methods, such as the layer-by-layer method.

Several advice on the potential risks to human health posed by the use of nanostructure materials in food have been released by regulatory authorities based in the United States, including the Directorate of European Health and Consumer Protection, FDA, and EPA. Nanotoxicology, a subfield of toxicology and an interdisciplinary field focused on the various toxicological characteristics of nanomaterials, is the tool that nanoscientists use to assess these possible threats. One important mechanism thought to be responsible for subsequent oxidative stress in humans is nanotoxicity, which is mediated by the production of reactive oxygen species (ROS). Additionally, there is a great deal of interest in employing nanomaterials in many different disciplines, despite some safety issues. As a result, there is an urgent need to address these problems in order to increase our understanding of the biocompatibility, safety, and toxicity of the usage of nanomaterials and nanostructures in the food industry. Although green-synthesized NSMs have been used in the food industry in a variety of ways thanks to nanotechnology, their use has occasionally been contentious because NSMs are scientifically ambiguous and can have long-term negative effects on human health and the environment (Figure 1) [4]. In this regard, it is only via in-depth study of the physiochemical and biological properties of NSMs that the complexity and constraints in the field of nanotechnology at terms of toxicity and accumulation (in appropriate dosages) may be addressed. This review has been designed as a "snapshot" to address the current status of the techniques and implementations of nanotechnology in food preservation, safety, and security criteria and to identify the underlying issues. This review was motivated by the effects of nanomaterials on the food industry [5].

Synthetic Nanostructures in Food System

The food system naturally contains a variety of nano-sized components, including lipids and carbohydrates that can self-assemble into higher order structures. These substances can be utilised to create nanoemulsions, nano-encapsulates, and food-grade polymers because they are distinct from artificially created nanomaterials and nanostructures. Nanostructures are produced through food processing, manufacturing, or thermal treatments, including coagulation, emulsification, and homogenization, which are not related to contemporary nanotechnology [6]. Food proteins, which also include polysaccharides and lipids, are globular particles with a size range of 10 to several hundred nanometers. Nanostructures in two and three dimensions. Small, three-dimensional crystalline structures barely tens of nanometers thick melt when maize starch is boiled to create a custard-like meal. Nanostructures, such as milk proteins and casein, are present in fresh milk and milk-based products by nature. About 100 nm-sized fat globules are created during the homogenization of milk. In the food industry for functional and nutraceutical products, nanotechnology is crucial [7]. It is possible to increase the bioavailability and solubility of colouring agents and nutritional elements like minerals and vitamins by encapsulating them in NSMs. This allows for regulated release and the protection of biologically active compounds and micronutrients throughout processing. Currently, nanoemulsions and nanocapsules, some of which are made of carbon-based, environmentally benign nanomaterials, are the most useful NSMs.

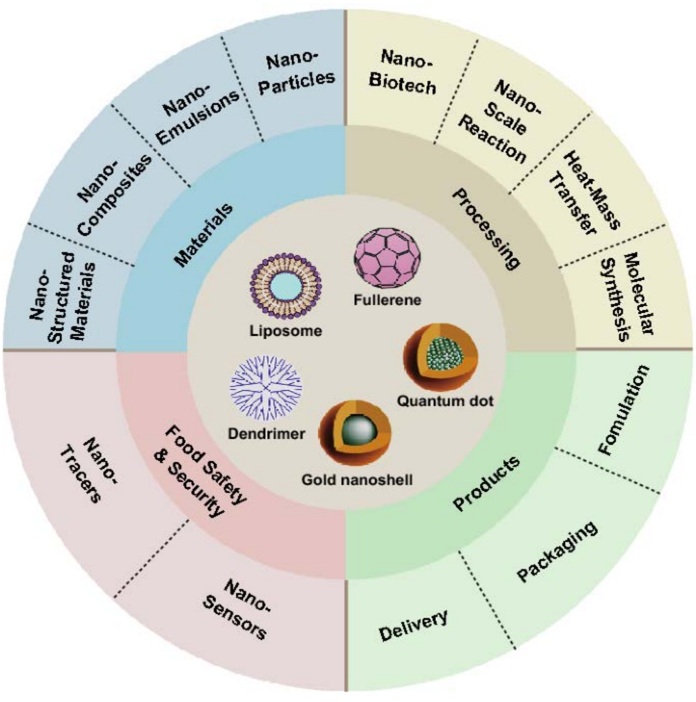

Figure 1: Role of Nanotechnology in Food System.

Nanocoatings as Intelligent Packaging for Surfaces

In food packaging, NSMs with biopolymers can either increase the functional qualities of active and intelligent packaging or enhance the property characteristics of neat polymers. The terms "improved," "active," and "intelligent" packaging describes the types of packaging materials that can be utilised for different applications. However, the European Union (EU) has placed formal prohibitions on the use of "active" and "intelligent" packaging materials in meals, with the exception of titanium nitride in plastic bottles [8]. Mill created a good photo-indicator intelligent ink based on nano-sized titanium dioxide (TiO2) or tin dioxide particles for the in-packaging detection of oxygen. This detector was gradually able to change the colour in response to minute changes in oxygen quantity. The packaging has changed recently. Due to their easy accessibility, low cost, simple processing capabilities, and excellent performance, the industry has concentrated on several forms of nanostructures and specific nanomaterials, including nano-clay particles. In addition, the development of carbon-based nanomaterials like graphene nanosheets and carbon nanotubes is encouraging. Due to its capacity to keep out oxygen and odours, flexible or static polymeric substrate-based films and bottles (made of various materials, including glass and plastic, etc.) are in high demand in the packaging and ageing of products. While aluminium foil and aluminum-metallization were once the preferred material and process, new materials are being utilised more frequently. Nanocoatings are a general term for thick, homogeneous layers (10–100 nm in thickness). A small number of researchers have recently created an intelligent type of nanocoating film that can detect contaminants during storage. The capacity to continuously and easily monitor the gas content, excess moisture, and oxygen content of a package's headspace has also proven to be very impressive. This has made it possible to assess the quality and safety of food long after the production process. Due to oxygen's capacity to foster a favourable environment for microbial development, its presence inside packaging might shorten food's shelf life. Utilizing a nanocomposite of in-situ crystalline silica, we generated biodegradable and inexpensive films utilising polyvinyl alcohol and chitosan [9]. The permeability of oxygen and moisture decreased by 25.6% and 10.2%, respectively, indicating that the films tripled the time cherries could be preserved compared to standard packaging. Using a combination of nanostructures of magnesium oxide (MgO) and polylactic acid biopolymer, produced a food packaging material and discovered that it was an efficient barrier against bacterial biofilms. Zero-valent iron particles were created to serve as oxygen scavengers in food packaging.

Nanoparticles for Preventing Heavy Metal Reduction

There is a significant risk of hazardous breakouts due to the release of heavy metals from nanomaterials. Long-term accu- mulation of the release of heavy metals in food products has negative effects. ZnO, Ag, and CuO are examples of metal and metal oxide-based nanomaterials that raise intracellular ROS levels and eventually lead to lipid peroxidation and DNA damage. Magnetite nanoparticles with silica modification and cationic surfactant coating serve as adsorbents for micro-extraction and are capable of detecting trace amounts of Cu, Ni, Co, Cd, Pb, and Mn in environmental samples. The cetylpyridinium bromide-synthesized silica-coated NPs can solubilize metal ions after becoming complexed with 8-hydroxyquinoline. Despite the enormous potential of various nanomaterials for the removal of pollutants, magnetite nanoparticles have emerged as the best-looking and reasonably priced substrates for recovering heavy metals from various sources. Using nanowires and nanonecklaces, chromium may be taken out of aqueous solutions. Aminated magnetic iron oxide nanoparticles, particularly Cu2, Ni2, Pb2, and Zn2, have recently been shown to have the capacity to serve as adsorbents to remove aqueous heavy metal ions. The study's findings showed that increasing the amount of amination had a beneficial impact on both the capacity and the initial pace at which heavy metal ions were absorbed. The solegel and calcination techniques used to create MgO nanoparticles demonstrated excellent promise against bacterial infections and the ability to remove heavy metal ions from contaminated water samples [10]. These results suggested that the high removal effectiveness, cheap cost, easy manufacturing, and environmentally favourable properties of nano-sized MgO particles may have potential for the treatment of bacterial and heavy metal contaminated wastewater.

CONCLUSION

Recently, iron oxide nanoparticles that were manufactured, reused, and recoverable were shown by Lingamdinne. to be capable of reducing heavy metals without losing stability. Additionally, various carbon nanoparticles with high fluorescence characteristics, such as carbon dots (C-dots) with particle sizes smaller than 10 nm and carbon nanoparticles (CNPs) with a size of about 10 nm or larger, have demonstrated a variety of biological properties over time, including low toxicity and good biocompatibility. Recently, carbon nanoparticles (66 nm) containing glycerol were made, described, and approved for the detection of heavy metal ions with a detection limit as low as 0.30 ppm by a thermal method in the presence of H3PO4. Bacterial meta-bolism at low concentrations (0.2 ppm) and so advised the use of an ideal concentration of nanosilver particles for different types of nanomaterials to stop the production of biofilms [11]. A biofilm is a dense mass of bacteria that adheres to numerous surfaces and forms a polymeric extracellular matrix that is very hard to penetrate. Van der Waals forces are used to bind free-floating microorganisms to the surface, which starts the creation of the biofilm and leads to issues including biocorrosion, biofouling, and accumulation in the food processing industries.

A number of Gram-positive bacteria, including Bacillus anthracis, are resistant to the antibacterial effects of glycerol monolaurate (GML), which the USFDA has approved as safe. Three separate MRSA and S. aureus strains' ability to build biofilms has been demonstrated to be inhibited by GML. In addition, biofilm growth is avoided by using antimicrobials inside the nano-fibers of filter membranes. Additionally, it was shown that nanosilver particles [12-13].

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Conflict of Interest

None

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