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A Review on Nanotechnology and Its Applications in Food Sector

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ABSTRACT: Nanoscience and nanotechnology are new frontiers of this century. Their applications to the agriculture and food sector are relatively recent compared with their use in drug delivery and pharmaceuticals. Smart delivery of nutrients, bio separation of proteins, rapid sampling of biological and chemical contaminants and nanoencapsulation of nutraceuticals are some of the emerging topics of nanotechnology for food and agriculture. Advances in technologies, such as DNA microarrays, microelectromechanical systems and microfluidics, will enable the realization of the potential of nanotechnology for food applications. In this review, we intended to summarize the applications of nanotechnology relevant to food and nutraceuticals together with identifying the outstanding challenges. Nanotechnology may be used in food applications in two ways: from the bottom up or from the top down. Physical preparation of the food ingredients, such as grinding and milling, is used to accomplish the top-down method.

KEYWORDS: Agriculture, Food Sector, Nano Technology, Nanoparticles, Polymers.

1. INTRODUCTION

Computer technology, communication, energy generation, medical, and the food sector are just a few of the areas where nanoscience and nanotechnology have already been used. Nanoscale devices, such as proteins, DNA, membranes, and other natural biomolecules, are often produced in order to mimic nanodevices found in nature. In today's environment, food materials are often seen as not just a source of nutrition, but also as having the potential to improve consumer health. The majority of nanoparticles utilized in the past belonged to the colloids category (i.e. emulsions, micelles, mono- and bi-layers). Michael Faraday created one of the earliest colloidal gold dispersions in the mid-eighteenth century. The particles were drawn together by Van der Waals interactions, which ensured colloidal stability.

Adsorption of polymers and surfactants on the surface of colloidal particles achieves steric stability. Coating nanoparticles with chemicals that can establish chemical bonds may help to stabilize them even more. Dry-milling technology, for example, may be used to produce fine wheat flour with a high water-binding capability. Green tea powder has been enhanced using this technique to increase antioxidant activity. The high ratio of nutrient digestion or absorption resulted in a rise in the activity of an oxygen-eliminating enzyme when the powder size of green tea was decreased to 1000 nm by dry milling. Self-assembly or self-organization, on the other hand, are biological principles that have inspired bottom-up food nanotechnology. Self-assembly structures that produce stable entities include the structuring of casein micelles or starch, as well as the folding of globular proteins and protein aggregates. Setting a balance between various non-covalent forces may lead to self-organization on the nano meter scale[1].

1.1.Food packaging & nanotechnology:

Food packaging using nanoparticles Bio nanocomposites are nanostructured hybrid materials that have better mechanical, thermal, and gas barrier characteristics. The use of bio nanocomposites in food packaging not only preserves the food and extends its shelf life, but it may also be considered a more ecologically responsible option since it eliminates the need for plastic packaging (Figure 1). The majority of conventional packaging materials are composed of nondegradable materials, which contribute to environmental contamination while also requiring fossil fuels to manufacture. However, existing biodegradable films have weak barrier and mechanical characteristics, which must be greatly improved before they can be used to replace conventional plastics. As a result, you will be assisting in the management of the world's garbage issue. The inclusion of inorganic particles, including such clay, into the biopolymeric matrix may improve the biodegradability of a packaging material, and surfactants employed to modify layered silicate can also be regulated. Inorganic particles also allow for the introduction of various functions, which may aid in the delivery of delicate micronutrients inside edible capsules[2].

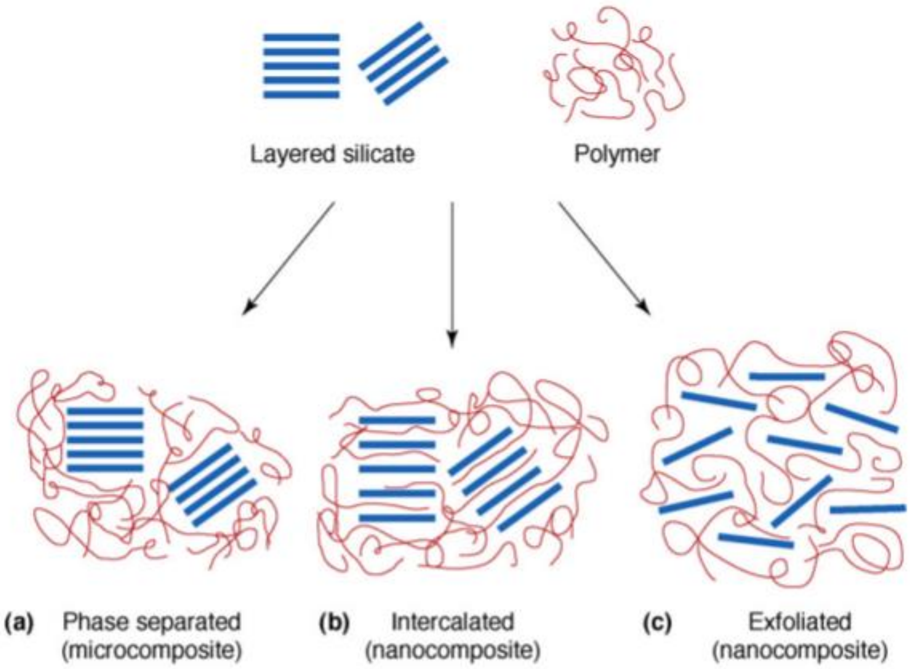

Figure 1: Different kinds of composites that may result from the interaction of layered silicates and polymers are shown. (a) Composite with phases separated (microcomposite). Intercalated composite (b) (nanocomposite). c) A composite that has been exfoliated (nanocomposite). With permission from, this image has been reproduced[3]**.**

New uses for zein are anticipated to emerge as a result of nanotechnology developments in specialized foods and the biodegradable plastics sector. After treatment with formaldehyde, zein may create a meshwork consisting of tubular structures that are microbiologically resistant and inert. Zein nanobeads or nanoparticles, on the other hand, may be utilized as edible carriers for taste compounds or nutraceuticals, as well as to enhance the strength of plastic and bioactive food packaging. In terms of mechanical and tensile characteristics, controlling the homogeneity and organization of zein films at the nanoscale is critical. In order to regulate the surface morphology, researchers experimented with various solvents and discovered that films made with acetic acids were smoother or structurally more homogeneous than films made with ethanol.

Nanoscale fillers are often formed up of nanofibers, nano whiskers, or nanotubes, although solidlayered silicate structures may also be used. Only solid-layered inorganic clays have been

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utilized in the packaging sector so far because they are inexpensive and simple to use. The initial use was a nylon–clay combination. Another kind of double hydroxide is layered double hydroxides (LDHs). Nanoparticles that may be utilized as polymer nanofillers matrixes they have the ability to create positively charged structures. Inside a three-dimensional network of linked silicate layers, this may explain why the mechanical characteristics have improved of the finished product As a result, LDHs may be useful. In applications, traditional supporting matrices are being phased out.

1.2.Biopolymers from nature:

Other significant natural polymers that may benefit from nanotechnology improvements include starch and its derivatives. Following extrusion, starch is usually transformed into a thermoplastic polymer with low mechanical resistance and poor oxygen and moisture resistance. Park et al. created thermoplastic starch (TPS) nano clay hybrids and studied their characteristics. They discovered that as compared to a native TPS matrix, the strong connection between the TPS and the nano clay enhanced tensile strength and reduced water vapor permeability. Polylactic acid (PLA), polyhydroxy butyrate (PHB), and polycaprolactone are examples of bio polyesters, which are biodegradable polymers made from biological monomers (PCL). Bio polyesters may be produced into films or melded into objects and are biodegradable and biocompatible[4].

1.3.Nanoparticles' advantages in food packaging applications include:

Bioactive packaging materials must be able to maintain the optimal condition of bioactive components including prebiotics, probiotics, encapsulated vitamins, and bioavailable flavonoids until they are released in a controlled way into the food product. Bioactive-packaging materials may aid in the management of food oxidation and the prevention of off-flavors and unpleasant food textures. Bioactive chemicals contained in the packaging itself are a potential option since they would allow for controlled release of the active components. Carrageenan, chitosan, gelatin, polylactic acid, polyglycolic acid, and alginate are just a few of the already-approved food additives that may be utilized for nanoencapsulation[5].

1.4.Nano sensors are tiny sensors that are used to detect:

Food preservation, in addition to food packaging, is very important in the food business. Food spoilage may be detected using so-called nano sensors, which are made up of hundreds of nanoparticles that glow in various colors when they come into contact with microorganisms in food. The many kinds of nano sensors available and their prospective uses in the food industry are outlined. Given the critical role of time in food microbiology, the primary goal of nano sensors is to decrease pathogen detection time from days to hours or even minutes. These nano sensors may be embedded directly into packing materials, acting as a "electronic tongue" or "nose" that detects compounds emitted during food deterioration. Other kinds of nano sensors are based on microfluidics devices and may be used to identify infections quickly and accurately in real time. Microfluidic sensors have a number of advantages, including their small size or ability to detect substances of interest quickly in just microliters of sample volume, which has led to extensive use in medical, biological, and chemical investigation[6].

1.5.The public's opinion:

Another significant issue that will influence the use of nanotechnology methods in the food sector is public perception of nanotechnology, as shown in the case of genetically modified (GM) foods. Consumers cannot immediately evaluate the advantages of a product produced from nanotechnology, similarly to GM foods, and any benefits must be communicated to the consumer. However, it is probable that certain nanotechnology-engineered goods will be more widely accepted than others. A recent study to assess consumer perceptions of several food materials, such antimicrobial food packaging, a nanocoating that protects vegetables from humidity or oxygen, a bread with omega-3 fatty acid nano capules, and a juice with vitamin A encapsulated in starch. Nanotechnology-derived packaging was regarded as being more helpful than nanotechnology-engineered meals, according to the findings of a survey of 153 individuals. These findings also backed up the theory that nanotechnology within a meal is less acceptable than nanotechnology on the exterior (i.e. in the food packaging)[7].

1.6.In agri-food production, nanobiotechnology is being used.

Food, agricultural, and energy uses are all possible with nanobiotechnology. Nano sensors/nano biosensors and bacteria identification are two of the most frequent applications of nanobiotechnology in food standards monitoring in the food processing sectors. The nano sensors may be used to detect the presence of insects or fungus in stored grain bulk in storage rooms with pinpoint accuracy. Researchers proposed nanobiotechnology usage models, either as a stand-alone technology or as a supplement to current technologies. The researchers were able to change the colors of rice from purple to green in 2004. Golden rice has been genetically modified via cellular "injection" with carbon nanofibers carrying foreign DNA. Industry now has unprecedented capabilities to manipulate genes and even create new creatures thanks to nanobiotechnology. This is owing to the fact that it allows foreign DNA and chemicals to be carried by nanoparticles, nanofibers, and nano capsules. Synthetic biology may also be used to create new plant types. Researchers recently made a breakthrough in this field by fully replacing the genetic material of one bacteria with that of another, thus changing it from one species to another. Nanotechnology has the ability to boost agricultural production by improving plant and animal genetics and delivering genes and medication molecules to particular locations in plants and animals at the cellular level.

Lopes et al. studied about Nanotechnology is a new branch of study that has found widespread use in a variety of scientific and technical fields. The agro-food industry is no exception, with applications in a variety of sectors of significant interest to both consumers and producers. The main ideas linked to nanostructures and nano-based instruments utilized in the food industry, as well as their applications in agro-food items, are discussed in this study. Food safety through nanosensors for disease detection, smart packaging, including food product valorisation via nanoencapsulation or nanodelivery of food components (e.g. flavors) are all significant fields of nanotechnology. Consumers' concerns about food stability and safety are also taken into account[8].

In recent years, there has been a significant increase in worldwide interest in Nisin and other related natural food preservatives, according to Khan et al. The use of nanotechnology to control and modify nisin for improved capabilities in the food and nutrition industry is rapidly growing. Food science uses of nanotechnology include nanoparticle delivery methods, packaging, food security, including safety. Nevertheless, there have been many concerns about nisin's usage in the food industry, including uncontrolled interactions with different food components, degradation, and electrostatic repulsion. These problems may restrict its use. To improve the usefulness of nisin in the food business, a range of nanoparticle systems including such nano emulsions, polymeric nanoparticles, nanofibers, and combinations of nisin with other technologies are used. This study focuses on current advancements and fresh views in the field of nisin usage in the food business. Relevance to Industry The present state of nanotechnology in the food sector is highlighted in this study. The problems surrounding the food industry's usage of nisin are discussed. Nisin has shown to be more effective when used in conjunction with other existing technologies to improve food safety[9].

Kalpana Sastry et al. investigated the use of nanoscience-based technologies in the food sector is quickly becoming a hotbed of innovative research and development. Several academic organizations, including private sector firms, have launched research programs to investigate the broad spectrum of nanotechnology's use in the food processing and manufacturing value chain. This article examines the present emphasis of research in this field and its possible consequences. A methodology to organize and map nanoresearch topics to the food processing industry was created using the established relational database architecture and R&D indicators such as literature or patent papers for assessing the potential of nanotechnology in the food sector. Food processing, packaging, nutraceuticals delivery, food safety, as well as functional foods are among the roughly five main areas of nanotechnology applications and functionalities presently under development in the food industry, according to the research[10].

2. DISCUSSION

Nanoscience and nanotechnology have already been applied in various fields, such as computer electronics, communication, energy production, medicine and the food industry. The nanoscale devices are often manufactured with the view to imitate the nanodevices found in nature and include proteins, DNA, membranes and other natural biomolecules. In today’s world, food materials are often considered not only a source of nutrients but also as having to contribute to the health of consumers. Nanoscience and nanotechnology are new frontiers of this century. Their applications to the agriculture and food sector are relatively recent compared with their use in drug delivery and pharmaceuticals. Smart delivery of nutrients, bio separation of proteins, rapid sampling of biological and chemical contaminants and nanoencapsulation of nutraceuticals are some of the emerging topics of nanotechnology for food and agriculture. The 2006 report of the Institute of Food Science and Technologists mentions that ‘size matters’ and recommends the use of nanoparticles in the food sector only after safety has been proven following vigorous testing. Special attention should also be given to consumer attitudes towards food nanotechnology. Taking lessons from the GM arguments across European countries, it is crucial to discuss the benefits and risks of this highly promising technology. Governments should consider appropriate labeling and should also set down regulations that will help to increase consumer acceptability

3. CONCLUSION

Computer electronics, communication, energy generation, medical, and the food sector are just a few of the areas where nanoscience and nanotechnology have already been used. Nanoscale devices, such as proteins, DNA, membranes, and other natural biomolecules, are often produced in order to mimic nanodevices found in nature. In today's environment, food materials are often seen as not just a source of nutrition, but also as having the potential to improve consumer health. Nanoscience and nanotechnology are the twenty-first century's new horizons. In contrast to their usage in medication delivery and pharmaceuticals, their uses in agriculture and food are relatively new. Some of the developing issues in nanotechnology for food and agriculture include smart nutrition delivery, bio separation of proteins, fast sampling of biological and chemical pollutants, and nanoencapsulation of nutraceuticals. The Institute of Food Science and Technologists said in 2006 that "size matters" and that nanoparticles should only be used in the food industry once their safety has been established via rigorous testing. Consumer perceptions regarding food nanotechnology should be given special consideration. It is critical to examine the advantages and dangers of this very promising technology, using lessons from the GM debates throughout Europe. Governments should think about proper labeling and enact laws that will assist to improve consumer acceptance.

4. CONCLUSION

For the food industry, nanotechnology is becoming more essential. In the fields of food industry and food safety, promising findings and applications are already being created. Nanomaterials in food packaging are anticipated to enhance the barrier characteristics of packaging materials, reducing the usage of precious raw materials and waste production. Edible nanolaminates may be used to protect food against moisture, lipids, gases, off-flavors, and smells in fresh fruits and vegetables, bread goods, and confectionery. Natural nanoscale biopolymers, including such polysaccharides, may be utilized to encapsulate vitamins, prebiotics, and probiotics, as well as to deliver medicines and nutraceutical. Among the most significant issues in the food industry is the time-consuming and arduous process of food quality-control analysis. Innovative equipment and methods are being developed to make food sample preparation as well as analysis more accurate and affordable. In this regard, food nanotechnology's creation of nano sensors to detect bacteria and pollutants is a particularly promising application. However, there are social or moral concerns to consider when utilizing nanotechnology in the food industry. Nanomaterials' potential hazards to public health and the environment are still unclear. The Department of Food Science and Technologists' 2006 study states that "size matters" and advises using nanoparticles in the food industry only when safety has been shown.

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