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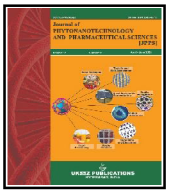

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Nanotechnology in food processing industries

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Abstract

Nanotechnology is rapidly advancing in the food industry to produce better food with improved quality, colour, texture, flavour and functionality. Nanoparticles, in the form of nanoencapsulation and nanoemulsion, can be used as colour and flavour enhancers, preservative agents and carriers for supplements. Nanobased food packaging provides better packaging materials with better mechanical strength, good barrier properties and antibacterial films, thus detecting pathogens. The application of nanotechnology in agriculture has the potential to increase crop yield while decreasing losses. Aquaculture applications for nanotechnology include disease detection in wastewater and water purification using nanomaterials such as graphene. As nanoproducts use grows, environmental and human health problems arise because of nanomaterials' unique physiochemical properties. Regulations are required to control the production, processing, use and disposal of nanomaterials. Biosynthesis of nanoparticles has now become an emerging issue for the design and development of nanomaterials for sustainable growth of the environment.

1. Introduction

All scientific fields, chemistry, biology, physics, material science and engineering, can benefit from the study and the usage of very small objects, which is nanoscience and nanotechnology.When compared to larger particles of the same composition, nanoparticles often exhibit higher level of chemical, biological and catalytic action. They are used in food as packaging materials, preservatives, flavoring agents, antimicrobial agent, sensors and other additives. Various novel food is being created due to versatile application of nanotechnology in the food industry. Bioactive components, nutraceuticals, pharma foods and functional foods are some recent examples (Chen *et al.*, 2006). The food business uses nanoparticles of titanium dioxide, silver, zinc, zinc oxide, silicon dioxide, platinum and gold extensively in a variety of forms. Nanotechnology is defined by the Nanotechnology Initiative as "the research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1-100 nanometres range, creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size and ability to control or manipulate on the atomic scale" (Chau, 2015).

Long before the term "nanotechnology" was coined, physicist Richard Feynman gave a lecture titled "There's Plenty of Room at the Bottom" at an American Physical Society meeting at the California Institute of Technology (Cal. Tech.) on December 29, 1959. In his lecture, Feynman laid out a method through which researchers will be able to control and manipulate specific atoms and molecules. Professor Norio Taniguchi introduced the term "nanotechnology" more than ten years later while researching ultraprecision machining. Modern nanotechnology did not start until 1981, with the invention of the scanning tunneling microscope, which could "see" individual atoms. The visibility and manipulation of specific atoms and molecules are key components of nanoscience and nanotechnology (Bugusu *et al.*, 2009).

Assessment of the research and development outputs that are connected to the activity level has mostly been the extent of the evaluation of nanotechnology programs. The food system, including agriculture, food production, processing, packaging, transportation, biodiversity of nutrients, *etc.*, is being significantly impacted by the rapidly evolving field of nanotechnology (Shrivastava and Dash, 2009). The commercial use of nanomaterials has a significant impact on the food sector. The dangers associated with nanoparticles will grow as we are exposed to them more. The advancement and transformation in the sector of active and smart, nanofertilizer, nanopesticides and nanosensors can be possible with application of nanotechnology (Figure 1). For enhancing the quality of food, consumer safety, crop development and environmental monitoring, numerous new nanomaterials have been produced (Cho *et al.*, 2008). Focus should be on the possible use of biologically generated and biologically inspired nanomaterial for sustainable development (Chau *et al.*, 2007).

To encourage the active development and implementation of nanotechnology, fundamental questions about high-performance, low-hazardous nanomaterials must be answered. Regulations are essential for controlling the production, processing, use and disposal of nanomaterials. To increase the public acceptability of the revolutionary nanoenabled food and agriculture products, further work needs to be done.

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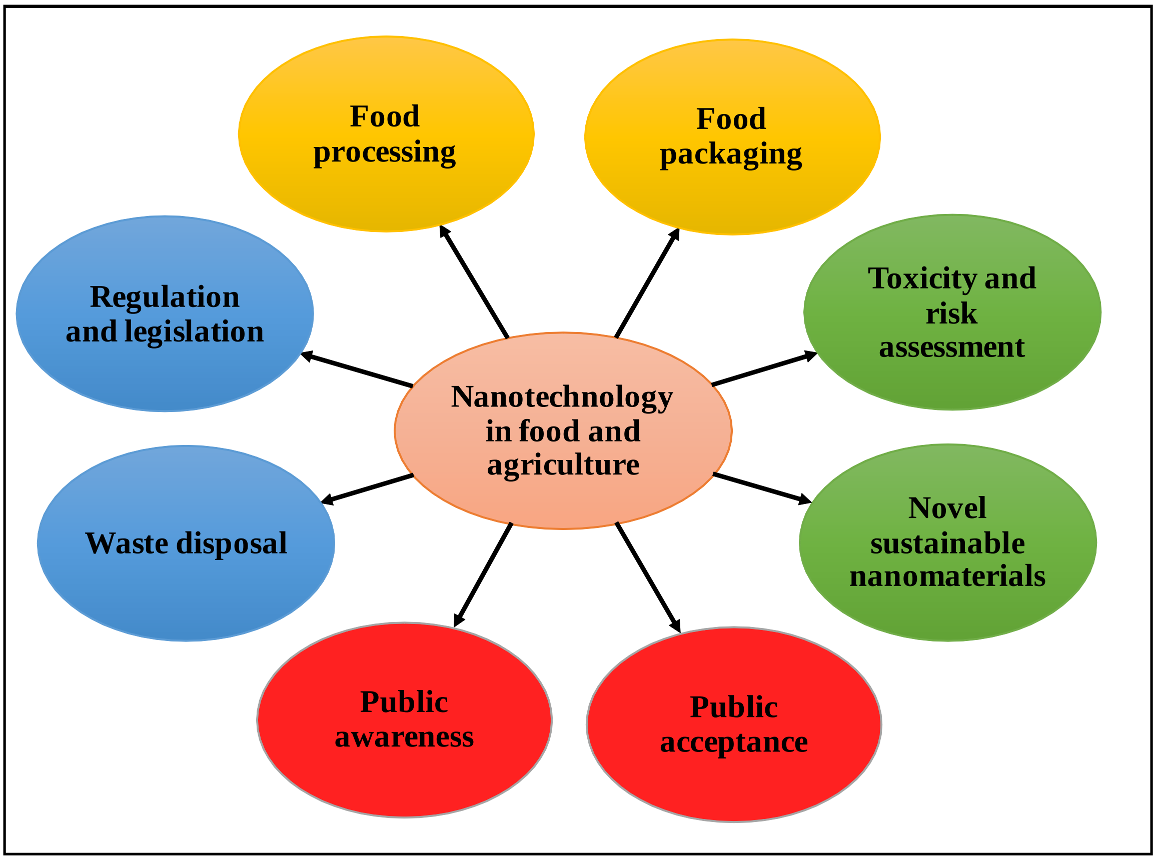

Figure 1: Agriculture use of nanotechnology in a wide range.

2. Status of food and agricultural nanotechnology

In the field of nanotechnology, materials with at least one dimension between 1 and 100 nm are called nanomaterials. Various inorganic, organic and mixed particles are used as nanoparticles in the food industry. Silver nanoparticles are used as antibacterials and gold nanoparticles are used as sensors and detectors while titanium dioxide is used as disinfectants and flavor enhancers. Natural products (NPs) are typically used in the food industry as ingredients or supplements as well as delivery system (Huang *et al.*, 2010).

2.1 Food nanotechnology

Products such as food additives, food preservatives and food packaging material are just a few examples of where food nanotechnology has applications. Acceptance of this innovative technology has enhanced the handling and storing methods of food that guarantee food safety. It has also been found that several conventional materials that are utilized as packaging or additives partially exist at the nanoscale. For instance, food-grade TiO_2 NPs up to roughly 40% in the nanoscale range have recently been found in food packages (Graveland-Bikkerand and de Kruif, 2006). Even though ambient exposure to nanoparticles like TiO_2 NPs is normally rated as moderately harmful, prolonged exposure to such nanomaterials may have negative effects. In addition, the usage of advanced food nanotechnology and the presence of nanoscale substances have drawn public attention to the possible risks (Morris, 2008). The European Commission (EC) and U.S. Food and Drug Administration are the main organizations that are responsible for food nanotechnology policy and regulation (Tiede *et al.*, 2008).

2.1.1 Food processing

Nanoparticles can be used as color and flavor enhancers, preservative agents and carriers for supplements in the form of nanoencapsulation and nanoemulsion. As additives and supplements, developed nanoparticles have significant benefits for food processing. The U.S. FDA also approves the use of inorganic oxide compounds as anti-caking agents, flavor carriers and food color additives, including SiO_2, MgO, and TiO_2. Foods like gum, white sauces, cake icing, candies, and puddings typically contain TiO_2 (Sekhon, 2010). USFDA had mentioned copper oxide, iron oxide and zinc oxide as generally recognized as safe GRAS.

2.1.2 Food packaging

Primary packaging materials are in prolonged contact with the food product while they are being produced, delivered and stored. Primary packaging material are in contact with the food product through their entire shelf -life. The food industry has been researching and creating nanotechnology as a cutting-edge replacement for food packaging. Such packaging materials made specifically for the food, offer various advantages over typical packaging materials (Hu and Fu, 2003). Nanoclay is one of many novel nanomaterials that have been studied and utilized extensively as food packaging materials due to its barrier, cooling and low-cost properties (Rao, 2009; Ray *et al.*, 2006).

Ideal packaging material must have proper gas and moisture barrier properties along with good strength and be biodegradable. Nano-based "active" and "smart" food packaging provides better packaging materials with better mechanical strength, good barrier properties and antibacterial films, thus detecting pathogens and alerting consumers to food safety (Dingman, 2008; Brody *et al.*, 2008). Nanosensing offers several advantages over traditional packaging methods. It is also possible to enhance food packaging by using nanocomposites as active materials in coatings and packaging (Garland, 2004; Sorrentino *et al.*, 2007). Bacteriocins, organic acids and essential oils have antibacterial properties and their polymers are used as effective packaging materials components (Figure 2) (Hu and Fu, 2003). These chemicals are not appropriate for many food processing processes since they need high temperatures and pressures as they are sensitive to these physical conditions. Strong antibacterial activity at low concentrations and better stability under harsh conditions can both be obtained by employing inorganic nanoparticles. The truth is that antibacterial packaging is a type of active packaging that comes into touch with food or internal headspace and inhibits or postpones the growth of any germs that may be present on the food surface. There have been numerous reports of the antibacterial capabilities of nanoparticles, including silver, copper, chitosan and metal oxide nanoparticles like titanium oxide and zinc oxide (Asadi and Mousavi, 2006).

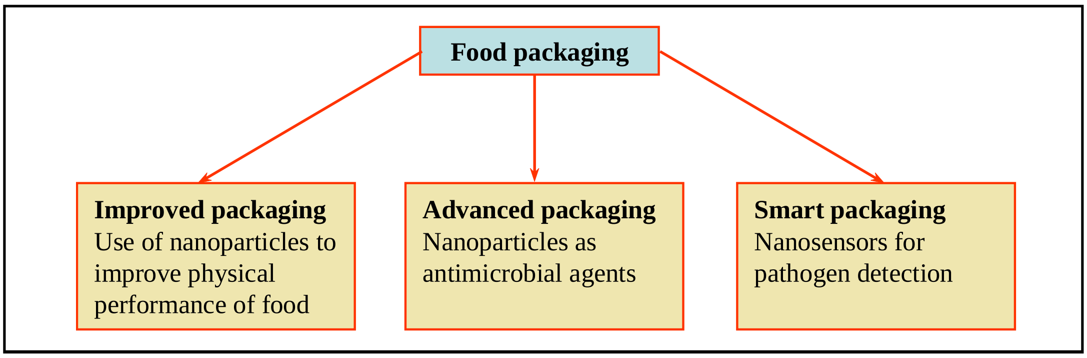

Figure 2: Use of nanotechnology in food packaging.

The ability of edible coverings with embedded nanomaterials to preserve and store food has also been demonstrated. Fresh food-coated fruits and vegetables continue to be edible while being stored and transported. Continuous respiration even after harvesting causes great losses as well as decreased nutritional and aesthetic value of the goods as transportation and storage times grow (Brody, 2006; 2008). The extension of the shelf-life of fresh food products depends on the prevention of such nutrition and weight loss. These two factors are the primary ones: temperature and relative humidity. Together, they have an impact on both the items' microbiological processes and the respiration of fresh food.To enhance mechanical and sensory properties, serve as a gas and moisture barrier, prevent microbiological decomposition and extend the shelf-life of fresh food products, an edible coating of natural extracts is being used (Arora and Padua, 2009).

Edible coatings are made using apple pectin, lemongrass and quinoa. Some nanoedible coatings are used in pesticides, pharma and toxin detection. ZnO quantum dots (QD) can be used to detect a variety of pesticides, including aldrin, atrazine, glyphosate and tetradifon. This is because substances like chlor, with strong leaving groups, easily interact with QD and have a high binding affinity of 107 M1. ZnO QD may also photocatalyze pesticides during the contact (Zhang *et al.*, 2007).

2.2 Agriculture nanotechnology

For increasing food production and improving nutritional value, quality and safety, nanotechnology is employed in agriculture. The most important methods for boosting agricultural output involve using fertilizers, insecticides, herbicides and plant growth regulators effectively. Insecticides, pesticides, herbicides and all other hormones used in agriculture need to be regulated, if they contain nanocarriers. Currently, nanocapsules for atrazine herbicide delivery have been developed and increase herbicidal activity. Similarly, nanocarriers like silica nanoparticles and polymeric nanoparticles have been developed to apply pesticides in a controlled manner. These nanocarriers are being used for transportation and delaying the release of species. This is called "precision farming," which increases production without adversely harming the quality of the soil. Nanoencapsulation allows us to use less herbicide without losing any effectiveness, which is good for the environment (Augustin and Hemar, 2009). In addition to nanocarriers, plant cultivars that are resistant to insects have been developed *via* nanoparticle-mediated gene or DNA transfer.

Some nanomaterials can function as pesticides on their own with increased toxicity and sensitivity. Due to their inherent toxicity, metal oxides like CuO, TiO_2 and ZnO are being extensively researched for their ability to shield plants from pathogen infestations. We use ZnO NPs as an illustration. *F. culmorum*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Fusarium graminearum*, *Aspergillus niger* and *F. oxiporium* have all been shown to be effectively inhibited by ZnO NPs, which also exhibit potent antifungal and antibacterial properties.

Low nutrient absorption efficiency and large losses severely compromise the effectiveness of conventional mineral fertilisers. The creation of nanofertilizers offers a cutting-edge remedy for such financial losses. Nanofertilizers can increase nutrient uptake by crops and soil microbes while decreasing nutrient loss. Most commercially available nanofertilizers are composed of micronutrients at the nanoscale (*e.g.*, Mn, Cu, Fe, Zn, Mo, N, B). It is claimed that using extra nanomaterials in place of conventional agricultural fertilisers, such as carbon nano-onions and chitosan nanoparticles, could enhance crop growth and quality (Rhim *et al.*, 2006). Due to various favourable characteristics of nanosensors are used pesticide and pollutants detections.

In situ and real-time monitoring systems, when used in conjunction with the right application of nanofertilizer, nanopesticide and nanoherbicide, assist in the remediation of potential crop losses and improve crop output. Another study showed how disease detection in wastewater and water purification may be achieved using nanomaterials like graphene, indicating potential applications in aquaculture (Das *et al.*, 2009).

3. Risk and toxicity

3.1 Interaction

Attention has been drawn to the growing use of nanotechnology in the food and agricultural industries during the past ten years. Nanotechnology is either added or accidently moved into numerous food and agricultural products. As the use of nano-products grows, problems with the environment and human health arise because of the unique physiochemical properties of nanomaterials. The direct cause of the environmental health problems is the interaction between nanomaterials in nanofertilizers, nanopesticides, nanoherbicides, immobilised nanosensors. The physiochemical characteristics of a nanomaterial have a significant impact on its behaviour and fate in an environment (Groves, 2008).

Additionally, the capacity to anticipate the behaviour and fate of nanomaterials is limited by the complexity of environmental variables. Due to the complex connections between nanomaterials, biology and the environment, it is difficult to monitor and trace nanomaterials. There is a need to promote the interactions that took place between the nanomaterials and biotic and abiotic components of the environment to determine the environmental nanotoxicity. In artificial saliva, samples do not change throughout the first phase of digestion. In stomach fluid, aluminium NPs start to partially dissolve and release aluminium ions. During the digestive process, notably in the stomach, particle aggregation may take place. Agglomerates often break down into primary particles in intestinal fluid. In addition, free ions are used to create new nanoparticulate formations. Silver NPs are subjected to the same procedure. Any media can contain silver colloids, which are complex combinations with specific species adsorbed on the surface. $Ag+$ ions are released as a result, acting as both toxicants and antimicrobials against bacteria that are resistant to common antibiotics (Vartiainen *et al.*, 2005). Gold nanoparticles releases Au I and III ions, which can affect subsequent interactions (Sondi and Salopek-Sondi, 2004).

3.2 Mechanism of nanotoxicology

When exposed to nanoparticles food additives and other functional components in agricultural and food products, there are significant implications for human health. The health of people could be harmed by the direct ingestion of nanoparticles utilised as food additives, functional ingredients, or nutritional components. Unwanted effects like allergy and effects from metal ions release are also possible when exposed to food nanoproducts. Furthermore, over time and at larger concentrations, the deposition of nanomaterials in food and then in human body may cause severe problems. Reactive oxygen species (ROS) are one of the main causes of cellular damage and death. Extreme DNA damage, damage to autophagy neurons and probably human mutagenesis, carcinogenesis and aging-related disorders can all result from excessive ROS generation.

3.3 Data analysis

Due to toxic effects, it is imperative to create, handle and use nanoparticles in food and agricultural products safely, which makes a full and accurate assessment of nanotoxicology crucial. Furthermore, present toxicological approaches rarely provide information that can aid chemists in creating sustainable designs for widespread application. Although, work on damage at the cell level *in vitro* and *in vivo* has made tremendous strides, there is currently inadequate toxicological data to draw any conclusions regarding the patterns of human exposure to nanomaterials and their detrimental consequences on health. *In vitro* and *in vivo* studies were expensive and produce fewer data since they focuses on a narrow range, such as ROS, DNA damage, immune responses and many more. Research on toxicity is important to move toward the collection of data utilising cell line models, such as *Escherichia coli* and the human A549 lung adenocarcinoma cell line. The machine learning approach needs to be changed to simultaneously study the expanding data.

4. Frontier topics

Although, several research indicates that nanomaterials in food and agricultural goods have low harmful impact, prolonged exposure may change the toxicity. Given the lack of knowledge on the bioavailability, biodistribution and eventually acute and chronic toxicity upon exposure to nanomaterials, it is preferable to take measures. TiO_2's (Maneerat *et al.*, 2006) safety as a food additive has recently been reevaluated at the legislative level, with France setting the global trend.Traditional nanomaterials' possible dangers are a subject of continuous discussion and ongoing research and more information on risk assessment is needed (Grobe *et al.*, 2008). Additionally, several methods have been employed to improve target selection and performance dependability while reducing the toxicity of engineered nanomaterials. For instance, it has been demonstrated that carefully adjusting functional properties and morphological parameters (like shape and size) management are effective ways to improve the sustainability and reduce the toxicity of nanomaterials (Weiss *et al.*, 2006).

4.1 Biosynthesized nanomaterials

Biosynthesis of nanoparticles has now become an emerging issue for design and development of nanomaterials for sustainable growth of environment. Bacteria, fungi, yeast, actinomycetes, enzymes and plant parts like leaves, fruits, roots, and their extracts have the potential for the production of nanomaterials (Figure 3). Numerous investigations have identified three key benefits, including:

i. Biological system can operate as a capping, stabilizing and reducing agent in the manufacturing host, allowing for the employment of fewer hazardous compounds in the engineering processes.

ii. Ambient temperature, pressure and neutral pH are frequently included in biosynthesis, which can reduce the need for energy resources.

iii. Materials are biocompatible and low-toxic as a result of the biosynthesis process' surface functionalization.

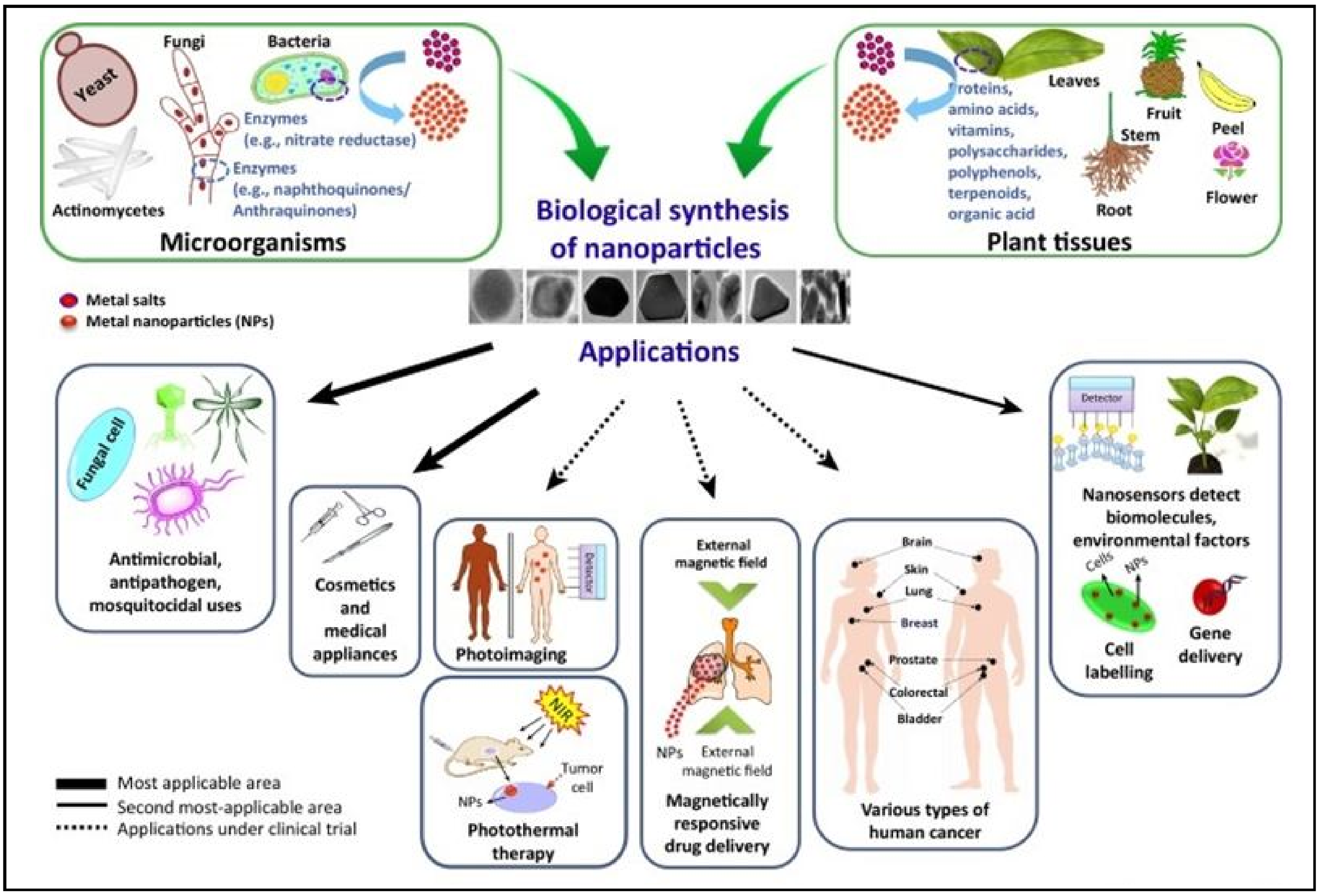

Figure 3: Biological synthesis of nanomaterials.

Nanotechnology application in food sector can be classified into two parts: Nanostructured ingredients and nanosensing.

I. Nanostructured ingredients

This includes a broad range of industries, including food packaging and food processing. Traditional encapsulation techniques are less effective at encapsulating and releasing substances than nanoparticles. In addition to protecting active ingredients from moisture, heat, chemical, or biological degradation during processing, storage and use, nanoencapsulations can also carry active ingredients and ensure their target delivery (Wang *et al.*, 2009). The use of nanotechnology in the food processing industry is depicted in Figure 4. Additionally, these delivery methods can enter tissues deeply due to their tiny size, enabling effective administration of active substances to specific body locations. For easy bioavailability and preservation of food components, several artificial and natural polymers have been developed. The use of nanotechnology in food processing can be assessed by improvement and effect on foods.

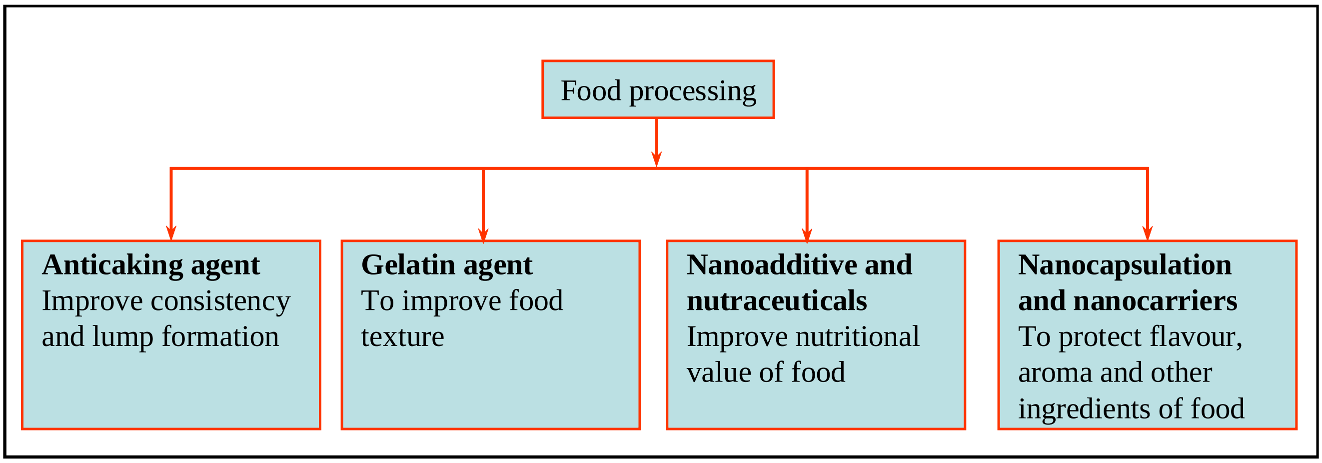

Figure 4: Major application of nanotechnology in food processing.

i. **Food additives:** These are used to boost the absorption of nutrients in already-existing foods. For example, Western Australian bakeries have been very successful in incorporating tuna oil (a source of omega 3 fatty acids) into nanocapsules into the best-selling "chip top" bread. Microcapsules are designed not to burst until they reach the stomach, avoiding the unpleasant taste of fish oil and providing a comfortable experience (Mozafari *et al*., 2006; 2008). Cell lines can be used to study carrier-size for intelligent nutrient delivery, which has a direct impact on the distribution of bioactive chemicals throughout the body. Only nanoparticles in the submicron range are efficiently absorbed here, whereas largermicro particles are not. An ideal delivery system have to deliver the active ingredients to the target site at required rate and at the correct time (Semo *et al*., 2007). The amount of active ingredient available, should not degrade to unacceptable level during the storage of the product. Encapsulation (Padua and Wang, 2009) is also an example of nanotechnology in large-scale use. Some more places to which it applies are biopolymer and emulsions, simple solutions and associative colloids that provide a suitable delivery system with all of the favourable properties (Rhim and Ng, 2007; Sletmoen *et al*., 2008).

ii. **Anticaking agents:** Anticaking agents, such as silicon dioxide nanoparticles, are used in some starchy foods to prevent the formation of clumps in flour and is often used in hamburger buns.

iii. **Antibacterial:** Nanomaterials as antibacterial complements to antibiotics have shown significant promise and great interest as they can bridge the gaps where medicines frequently fail.

For instance, enhancing mechanical strength, increasing volume, increasing surface area and quantum effect of the nanoparticles, filler nanomaterials have outstanding mechanical properties. Nanoparticles refine traditional materials to some extent when they are added, creating intra and inter-particle structures that enhance the mechanical properties of materials and improve grain boundaries (Sozer and Kokini, 2009). For instance, concrete's compressive, bending and split strength can all be increased by adding 3 wt per cent nano SiO_2. The tensile strength, break point elongation, and impact resistance of kenaf epoxy composites can be greatly increased by adding 3% nanooil palm filler for empty fruit strings.

iv. **Food texture, shape and appearance:** Numerous solutions for boosting food quality and flavour are made available by nanotechnology. Techniques like nanoencapsulation have been extensively employed to improve the taste, release and retention of flavors. Most unstable and reactive plant pigment anthocyanins, which have a variety of biological activities, can be enclosed in nanoparticles by encapsulation. Although, rutin is a widespread dietary flavonoid with significant pharmacological functions, its poor solubility prevents it from being used in the food business. Comparing ferritin-captured rutin to free rutin, encapsulation of ferritin nanocage increased solubility, heat stability and UV stability (Yang *et al.*, 2009). Nanoemulsions are widely used to deliver fat-soluble bioactive chemicals because they can be manufactured from natural food ingredients using straightforward manufacturing processes and may be customized to increase water dispersion and bioavailability (Scheffler *et al*., 2010; Wang *et al.*, 2008).

Nanoparticles provide a viable method of enhancing the bioavailability of dietary supplement ingredients. This results in increased medication bioavailability. Numerous metal oxides, including titanium dioxide and silicon dioxide (SiO_2), have historically been employed in cuisine as colorings and liquids (De Azeredo, 2009). As carriers for food and flavors, SiO_2 nanoparticles are among the most popular food nanomaterials.

v. **Nutritional value of foods:** The majority of bioactive substances, including carbohydrates, proteins, vitamins and lipids are sensitive to acidic conditions of the stomach and duodenum's enzymes (Shimoni, 2009). These bioactive compounds can endure such harsh circumstances by being encapsulated, but they can also easily enter into food products due to the low water solubility of these bioactive compounds, which can not be possible without encapsulation. To optimize the distribution of medications, vitamins, or delicate micronutrients in daily diets, tiny edible capsules based on nanoparticles are being developed. For efficient work of nutrients and antioxidants, numerous techniques like nanocomposite, nanoemulsification and nanostructuration have been used. It has been discovered that polymeric nanoparticles are suitable for encapsulation of bioactive components (such as flavonoids and vitamins) and delivering such substances to their intended functions.

vi. **Food shelf-life:** Nanomaterials increase the shelf-life by slowing down the processes of deterioration or stopping degradation till the product is delivered to the target. Nanoencapsulation of these bioactive components extends the shelf-life of functional foods.

Edible nanocoatings of different food components also work as an obstacle against oxygen and moisture and also act as a carrier for antioxidants, colour, flavour, enzymes and antibrowning agents. Coating help to preserve manufactured foods even after they have been opened in their packaging. Longevity can be increased (Weiss *et al.*, 2008). By changing the characteristics of the interfacial layers around functional components, it is frequently able to delay the chemical decomposition process.

II. Nanosensing

Implemented to improve food quality and take evaluation of safety a further step. These are very useful and are used to determine the next existence: (a) Contamination, (b) Mycotoxins and (c) Microorganisms in food. Nanotechnology as a food sensor platform offers important advantages in contaminant detection, particularly in food quality and safety applications. Chemical sensors (chemical nanosensors) and biosensors (nanobiosensors) based nanomaterials can be used online for the advancement of current industrial processes and distribution lines. A portable, disposable snack that doubles as a contamination sensor. Pesticides, veterinary and human medications, microbial toxins, preservatives, pollutants from food processing and packaging and other residues are examples of contaminants.These surroundings can make it challenging to find food contamination. A novel technique that can be used to identify numerous food contaminants, mycotoxins and numerous food allergens are the use of nanosensors with new applications. Nanosensors can be integrated with wireless technology to send contamination alerts and test results to distant servers in real-time for quick verification and reporting, whether the servers are online or offline. This means that compared to equipment and conventional methods, nanosensors are more affordable, quick and sensitive. More applications for using nanosensors to detect food contamination may be provided by recent advancements in this field.

Nanomaterials when used as biosensors offer higher accuracy and some other benefits. Nanosensors and nanobiosensors detect the quality of plant and food products concerning their ingredients, infection and microbial quality and assure manufacturers, retailers and consumers about the safety (Chen *et al.*, 2006). The nanosensor and nanobiosensors act as an indicator for change in the environmental factors temperature, humidity, microbial contamination and deterioration of items. Numerous nanostructures have been studied for potential use in biosensors, including thin films, nanorods, nanoparticles and nanofibers (Wypych and Satyanarayana, 2005). Rapid and extremely sensitive detection devices for microbial compounds or cells have been made possible by thin film-based optical immunosensors. These immunosensors encapsulate particular antibodies, antigens, or protein molecules on thin nanofilms or sensor chips, which generate signals when target molecules are detected (Subramanian, 2006).

Due to their quick detection, ease of use and affordability, carbon nanotube-based biosensors have also attracted a lot of attention. They have also been effectively used to detect microbes, poisons and other degradation products in food and beverages (Kang *et al.*, 2007). Toxin antibodies coupled to these nanotubes modify their conductivity noticeably when they bind to aquatic toxins, making them useful for watery toxin detection. Additionally, food condition is monitored by an array of nanosensors used in electronic tongues and noses that emit signals in response to aromas or gases emitted by food. The interaction between different odorants and chemicals that have been coated on the crystal surface of the quartz crystal microbalance (QCM) can be detected by an electric nose that is based on the QCM.

Although, some negative results have been observed about food nanosensing, they facilitate research and development and encourage the food industry to evolve in a better way. But, if we see there are more positive results than negative and various regulating bodies are there for controlling the negative results.

5. Conclusion

With the help of nanotechnology, food can be enhanced in taste, nutrition as well as new product development, packaging, and storage. Some new applications are still in their infancy and, for the time being at least, the majority of them are concentrated on high-value goods. There are few successful uses of nanotechnology in food. Nanotechnology is also being used to improve flavour and texture, lowering the lipid profile and encapsulation of vitamins to prevent their deterioration throughout a product's shelf-life. Nanomaterials can also be employed to create packaging that preserves the freshness of the product for a longer period. Nanosensor-equipped smart food packaging may potentially inform customers of the state of the food it contains.

The development of food nanotechnology poses significant obstacles for both the government and businesses. The food sector must guarantee that consumers will accept and believe in nanofoods. Guidelines for the standards to be used in assessing food safety, food packaging and the supplemental use of nanomaterials with unique features should be developed by regulatory authorities like the FDA.

It is vital to remember that laboratory-produced nanofoods differ from regular nanofoods in that they come from a different sources. The advantages of naturally occurring nanosystems have not received enough scientific attention. Therefore, it is challenging to draw broad conclusions regarding whether nanotechnology is beneficial or harmful. Food packaging made using nanotechnology was deemed to be less problematic than food made with the technology. In addition, nanofoods are not identified as such on the packaging, making it difficult for customers to steer clear of them. Foods that have been nanomodified, should therefore undergo testing before being approved for sale. To evaluate the possible risk related to human exposure to nanoparticles, new methodologies and standardized test techniques to examine the impact of nanoparticles on living cells are urgently required. It is commonly anticipated that in the upcoming years, people would have more access to food products made possible by nanotechnology.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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