

## Safety of Nanotechnology in Food Industries

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### Abstract:

The arrival of nanotechnology in various industries has been so rapid and widespread because of its wide-ranging applications in our daily lives. Nutrition and food service is one of the biggest industries to be affected by nanotechnology in all areas, changing even the nature of food itself. Whether it's farming, food packaging, or the prevention of microbial contamination the major food industries have seen dramatic changes because of nanotechnology. Different nanomaterials such as nanopowders, nanotubes, nano-fibers, quantum dots, and metal and metal-oxide nanoparticles are globally produced in large quantities due to their broad applicability in food-related industries. Because of the unique properties of nanostructures and nanomaterials – such as a large surface area, high activity, and small size, there is some concern about the potential for harmful adverse effects of used nanomaterials on health or the environment. However, because of tremendous advances in different industries, this concern may be unnecessary. This paper presents some uses of nanomaterials in food and related industries and their possible side-effects. This review covers the various aspects of nanomaterials and their impact on human exposure, safety, and environmental concerns.

**Keywords:** food-processing industry, food safety, nanotechnology

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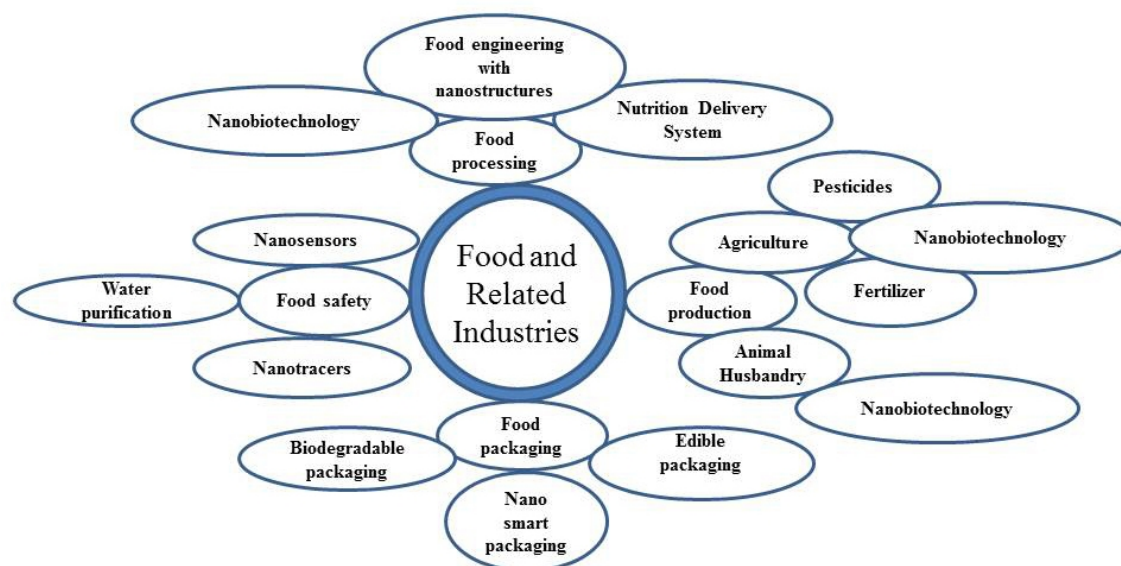
## 1. Introduction

Nanotechnology refers to materials, structures, and engineering systems in sizes ranging from 1-100 nm (1). New tools and techniques allow researchers to create extremely fine structures at atomic or molecular levels. These methods have rapidly developed in many different areas of science and technology and have created new multidisciplinary fields like nanobiotechnology, nanochemistry, nano information technology, etc. (2). New nanomaterials make them more suitable for different applications in different industries. However, these materials may create threats of environment pollution or even harmful effects on human health (3-5). Our knowledge regarding the safety of used nanomaterials in food and nutrition industries is low. Also, note that some nanomaterials enter the human body. A report by the British Royal Society notes that we may face a

nanotoxicity crisis in the future. This report calls for avoiding nanotechnology in products until there is a comprehensive understanding of the environmental and health risks of exposure to nanoparticles (6).

The main concern regarding human exposure to nanoparticles is that there are different entry routes such as digestion, inhalation, or skin absorption. After absorption, nanoparticles may enter the bloodstream and settle in different tissues such as the brain or trigger immune responses (4, 7). These particles behave similarly to asbestos (8). Some authors have studied genetic alteration as a potential consequence of nanoparticles in food or nanoengineering of food (9). Some social and non-government organizations like Action Group on Erosion, Technology and Concentration (ETC Group) have called for a moratorium on the release of nanotechnology products until their safety has been demonstrated (10). Despite all of these debates, nanotechnology has already entered into food packaging, agriculture technologies, and food processing, as well as the nature of food, so the public is seeking safety assurances from governments and food producers (11).

Nanoparticles possess unique properties, so the marketing of nanoproducts is expanding. For example, in 2006, USD 20 billion in food industry products was devoted to nanotechnology (10), in agriculture and food processing. Proponents emphasize that this can improve the quality, nutritional value, safety, and quantity of food to meet the needs of a growing population (12, 13). Here, we describe some nanotechnology applications in food and related industries and possible side-effects in humans and the environment.



**Figure 1.** Nanotechnology matrix in food industries

## 2. Discussion

### 2.1. Nanotechnology and food production

Increasing crop yields is a primary goal of farmers in undeveloped countries. Nanotechnologies may improve the effectiveness of pesticides (14) and fertilizer (15, 16) to boost crop yields. Also nutrition delivery or genetic manipulation of the nanostructure of plants and animals may also be possible to further improve farming yields. The emergence of nanotechnology in animal husbandry has been reported in undeveloped countries (17). While new nanomaterials may help farmers reach these goals, they can also potentially create adverse effects in the environment and on human health (18).

### 2.2. Food processing

Today, people are seeking more nutritional supplements. This is because many nutrients in food are destroyed in the digestive tract, which is actually a sophisticated organ. From the oral cavity to the colon, each part presents a complete different environment. In other words, there are a number of factors affecting the absorption of food in the body for infants, children, the elderly, and those who suffering from gastrointestinal diseases.

Some nutrition has been ruined in the digestive tract. A system or nanocarrier that delivers nutrition to specific places is called a “nutrition delivery system”. The Chitosan nanocarrier is one of these systems (19). Extracting nutrition from raw materials is an important part of the food industry. With rapid spreading technology, conventional methods for processing food are being replaced by new techniques. Undoubtedly, nanotechnology will play a major role in this improvement. In food processing, such techniques may improve food processing yields and decrease waste or spoilage of nutrition (20). To prevent adverse effects on consumer health, nutrition delivery systems must be made with biodegradable materials.

### **2.3. Food packaging and safety**

Non-biodegradable materials such as plastics have been used in conventional food packaging. Recently, degradables, biodegradables (21), and smart packaging (containing sensors and nanocomposites), or even edible packaging (using lipids, proteins, polysaccharides, etc. have been present in food packaging (22). Biodegradable and edible packagings have faced major problems, including poor mechanical properties, low degradation temperatures, humidity, and gas permeability that prevent expansion (21). The unique properties of many nanomaterials can address these kinds of problems. Nanocomposites that contain different nanostructures such as inorganic phase and biodegradable polymers, have been considered. Nanoclays are being developed and refined (23).

For hygienic reasons, food packaging must be made with inert materials, but active and smart materials have also been marketed recently. Enzymes, antibacterials, and absorbent materials not only increase shelf life and improve storage conditions but also make food distribution much easier. Manganese oxide, zinc oxide, and silver nanoparticles are examples of these active particles in anti-microbial properties for packaging (24). Gold nanostructures, quantum dots (QD), carbon nanotubes, and other active nanostructures have been or can be used as sensors of microbes or other tests for food safety (25-27).

### **2.4. Water purification**

A lack of clean drinking water is a common problem in developing countries. Water purification challenges have attracted the attention of many scientists who use nanomembrane technologies that use materials such as carbon nanotubes (28). This nanomaterial is already considered a high risk material for human health and the environment (29). Also, the use of nanostructures for removing microorganisms or toxins from water has been common (30). The introduction of nanotechnology in this field is not quite safe, and some challenges and risks must be considered. For example, broad use of some nanostructures, likes fullerene and carbon nanostructures, has faced challenges from environmental activists who claim particles in the water after purification pose special risks to the environment and human health (30).

### **2.5. Toxicity measurement of nanoparticles used in food industry**

Nanomaterials have unique properties such as high surface area, that make them more chemically active than bulk material so they could participate in most of biological reaction that may had harmful effect on human health or environment. Nanostructures in nutrition or related industries must not create any direct or indirect damage to human health. Some features of nanoparticles are more important in unintentional side effects observed.

#### **2.5.1. Size**

Size is an important characteristic for the irreplaceable properties of nanoparticles. Size determines the surface area of nanoparticles. The effect of surface area on the respiratory response has been shown (31). It has been reported that the size of particles is an important factor in observed dermal-cell cytotoxicity *in vitro* (32). Absorbed nanoparticles in different absorption route could trigger an immune system response (33). The small size of these particles allows them to pass through different biological barriers and settle in tissues like the central nervous system (34). The size of the nanoparticles in different route of exposure should be considered in assessing the safety of nanomaterials that are to be used in food and food-related industries.

#### **2.5.2. Chemical composition**

During the production of nanoparticles, many reagents are used that could be toxic. Some may remain in the final product and result in exposure to toxins that are unrelated to the nanomaterials themselves. For instance, some observed toxic effects of carbon nanotubes and semiconductor nanoparticles are related to residual reagents during synthesis. The remaining reagents and impurities may hinder our understanding of possible side-effects of carbon nanotubes. Iron ions and impurities can accelerate the oxidative stress in cells (35). Crystallinity is another important aspect of chemical composition. Titanium oxide has three different levels of crystallinity that each has different cytotoxic effects (36).

### 2.5.3. Surface structure

There are many factors in the surfaces of nanostructures that could affect their cytotoxicity. Hydrophobicity, charge, roughness, and, most importantly, surface chemistry are factors that could change the toxicological effects of absorbed nanoparticles in the human body (37). The coating of nanoparticles with hydrophilic polymer-like polyethylene glycol (PEG) decreases the toxic effects of bare particles (38). Evidence indicates that positively charged nanoparticles are more toxic than negative or neutral nanoparticles (39). Different types of coatings or functionalization groups on the surface of nanoparticles are referred to as surface chemistry. Surface chemistry is one of most important factors affecting the interaction of nanoparticles and biological systems (40).

### 2.5.4. Solubility

Solubility is also important in the toxicity of nanoparticles. For instance soluble (hydrophilic) titanium oxide nanoparticles are more toxic than insoluble titanium oxide nanoparticles (41). Some soluble nickel compounds are recognized as carcinogenic agents (42). A detailed report on the solubility of the oxide nanoparticle's toxicity has been published (43). Thus, understanding the toxicity and biological activity of nanoparticles requires an understanding of these factors and many others that must be considered in applying nanotechnology in food and related industries. In other words, all factors regarding the toxicity and environmental activity of nanoparticles should be investigated. Nanoparticle uptake routes and pathways are also important and must be considered in nanosafety investigations (44)

A properly calibrated exposure level for nanoparticles is also important to determine the type and severity of injuries they can cause in different cells and tissues. The three main routes of nanoparticle exposure are dermal, respiratory, and digestive routes (45). Nanoparticles in food and related products could penetrate the human body through each route. During the production of nanoparticles used in food and related industries, some nanoparticles disperse in the air. Therefore, respiratory tract uptake of nanoparticles should be considered to protect workers' health (39). Nanoparticles used in packaging and in pesticides and fertilizers may also enter the respiratory systems of workers. The digestive path is obviously the main route of uptake for nanoparticles (10). Some nanoparticles that enter in respiratory tract subsequently enter the digestive system through mucociliary clearance (46). From production of nanoparticles through application and consumption of them in food, agriculture, and other related industries, skin is the main route of contact between human and nanomaterials (47).

## 2.6. Nutrition industry's approach to nanotechnology

In food industries, the main priority is quality and safety of food, so health risk assessments in this area are essential. Since nanoparticles have entered food and related industries, toxicology research of nanoparticles is essential. Researchers in this area should pay special attention to the gastrointestinal absorption and possible side-effects of nanoparticles. Nanoparticles can have serious effects on health when they accumulate in high concentrations in tissues, eventually leading to tissue dysfunction or damage. With the increasing use of nanomaterials, concerns are also growing between experts but with increasing information of nanomaterials toxicity, public have not participate in this issue. Perhaps the main reason for contradictory information on the toxicity of nanoparticles is in terms of characterization and tests (48). Therefore it is necessary to establish standard protocols for risk assessment. Moreover, the difference between humans and laboratory animals prevents extrapolation of the results (49).

A complete understanding of the risks of nanomaterials in food industry requires improvements in at least three domains. First, methods must be developed because of the unique properties of nanomaterials. Conventional methods cannot be used in their case. Conventional methods like 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) or calcein AM (CAM) have not been useful for evaluation of toxicity in some nanostructures like single-wall carbon nanotubes (SWCNT), QD, fullerene, etc. It has been shown that SWCNT could interact with markers of this test (50). It has been suggested that, in the case of nanomaterials, several methods for cytotoxic evaluations may be needed (50). Following the fate of nanoparticles in humans or laboratory animals requires a precise characterization technique. Recently, specific analysis methods have been introduced to nanotoxicity evaluations (51).

Another area related to the use of nanoparticles in food and related industries is the absence of regular and systematic classification of used nanomaterials. The method of preparation and synthesis of nanoparticles in food products must also be classified and published. The absence of such classifications creates consumer reluctance to use nanoproducts. In another scope, researchers must develop proper *in vitro* and *in vivo* models for toxicity assessment of used nanoparticles in food and related industries. It has been shown that *in vitro* models are not proper for pulmonary toxicity estimates of nanostructures (52).

### 3. Conclusion

Food and related industries such as agriculture, packaging, and food processing have seen huge changes because of the unique properties of nanomaterials. But these unique properties may occasionally lead to ambiguous and sometimes dangerous side-effects to ecosystems and even in people. The main role of nanotoxicology is to provide clear guidelines and roadmaps for reducing risks in the optimal use of nanomaterials. Exposures routes in industrial workers and consumers of food products that contain nanomaterials must be studied carefully. With a precise understanding of the properties of nanomaterials such as size, dose, surface chemistry, and structures, we will have useful and safe food products. To make full use of nanotechnology in the food and related industries, we must have a thorough understanding of nanomaterials.

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### Conflict of Interest:

There is no conflict of interest to be declared.

### Authors' contributions:

All of authors contributed to this project and article equally. All authors read and approved the final manuscript.

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