



Food Nanotechnology: A Primer

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Abstract Nanotechnology involves the manipulation of matter at the molecular scale. It is already impacting several aspects of food science, as it is applied in the agricultural production, food processing, safety, food packaging, and preservation. It has emerged as a technological advancement to radically develop and transform the food industry. As with innovation, the pace of social understanding food nanotechnology lags behind technological progress. This paper provides a primer on the applications, benefits, and challenges of nanotechnology in the food industry.

Keywords food nanotechnology, nanofoods, nanomaterials

1. Introduction

Food is any substance which has nutritional value. It is a complex biological system that is governed by principles in biology and biochemistry. The basic components of foods such as vitamins, antioxidants, flavorings, and preservatives come in various molecular and physical forms [1]. Many foods contain nanoscale components.

Nanotechnology is a newly emerging multidisciplinary field integrating several disciplines such as engineering, physics, chemistry, and biotechnology. It refers to the controlling and manipulating materials at the nano (one nanometer is one billionth of a meter) scale. It is the science of the very small things. It helps us understand nature well in the nanometer scale. It enables development of novel materials (nanomaterials) with a wide range of potential applications in a variety of consumer, medical, commercial, and industrial products. Nanomaterials are designed to have at least one dimension (length, width, height) in range from 1 to 100nm. For humans, cell membranes, hormones, and DNA are typical examples of structures that measure in the nanometer range. Some industries such as microelectronics, aerospace, and pharmaceuticals have already begun manufacturing commercial products of nanoscale size [2].

Nanotechnology is penetrating every life aspect including the food sector. Food nanotechnology is the application of nanotechnology in the food industry. Technology has attracted the attention of many scientists, academics, and economists. Some proponents of nanotechnology claim that the technology will enable the making of high-quality products at a very low cost and at a very fast pace. A significant number of companies have been using nanotechnology in the development of their products

What is Nanotechnology?

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as *nanotechnology*, the materials or objects themselves are called *nanomaterials*, and the study and discovery of these materials is known as *nanoscience*. Nanotechnology can



work from the top down (by reducing the size of the smallest structures to the nanoscale) or the bottom up (by manipulating individual atoms and molecules into nanostructures) [3].

Richard Feynman, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. Nanotechnology is a multi-disciplinary field that includes biology, chemistry, physics, material science, and engineering. It is the science of small things—at the atomic level or nanoscale level. It is revolutionizing many fields including the military, mechanical industry, electronics, biotechnology, medicine, energy, communication, solar, optics, agriculture, and food [4,5]. Nanotechnology is regarded as a transformative technology, which can stimulate scientific innovation and greatly benefit the society. Research on nanotechnology has skyrocketed over the last decade, leading to numerous applications in virtually every segment of the economy. All potential applications of nanotechnology significantly affect our lives, our health, our convenience, and our environment [6].

Nanotechnology in Food

As the world population continues to increase, new means of food production are constantly being investigated. The food industry is the largest manufacturing sector in the world. One of the latest food technologies to emerge is food nanotechnology. Manipulating food at nano scale could help to develop lower-fat foods that still taste great.

Food nanotechnology was first addressed by a United States Department of Agriculture (USDA) roadmap published in September 2003. It is one type of food technology that has been recently introduced. Nanotechnology application in the food industry is growing rapidly and has revolutionized food engineering, processing, and packaging techniques. It can improve crop productivity and reduce pesticide use. Food becomes nanofood when nanotechnology tools are used during farming, production, processing, or packaging of the food. Common nanotechnology-based products include candies, baby bottles, and plastic storage containers.

Applications

Nanotechnology is invading the food industry and having an impact on several aspects of food science, from how food is grown to how it is packaged. Figure 1 shows some applications of nanotechnology in the agriculture, feed, and food sector [7]. The most studied applications of nanotechnology in food production (also called nano-food or food nanotechnologies) currently focus on the agricultural production, food processing, safety, food packaging, food detection, food storage, and food detection [8].

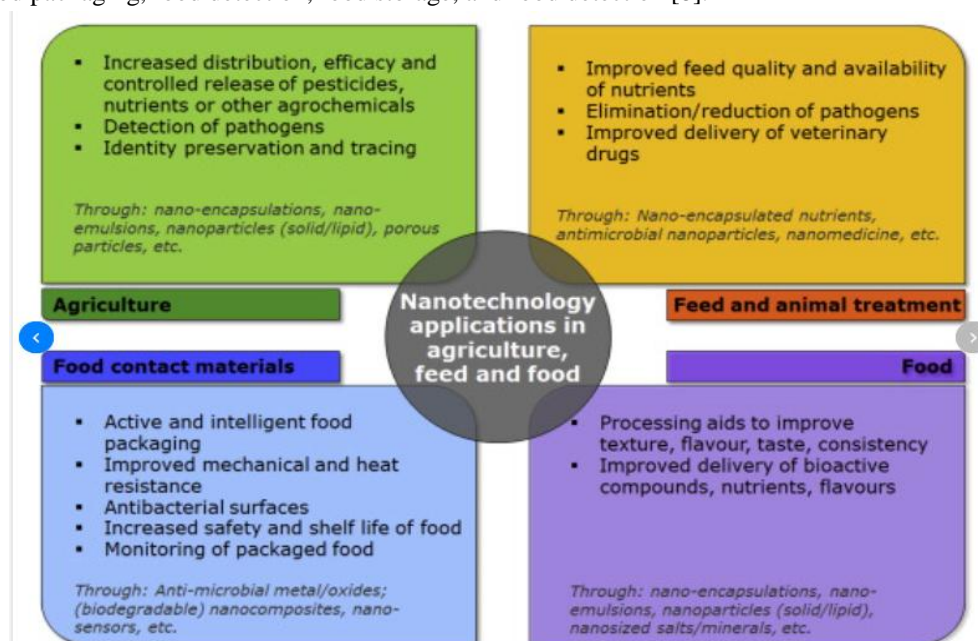


Figure 1: Applications of nanotechnology in the agriculture, feed, and food sector [7].



- **Agriculture:** Nanotechnology has been developed and integrated into agriculture and food. It can transform conventional agricultural systems and make them smart. It has been applied in food machinery mainly are food machinery lubricants and nano magnetic refrigeration. Use of nanotechnologies is also being explored for use with livestock, animal breeding and genetics, and identity preservation and tracking. Nanotechnology has also been proposed for water treatment and bioremediation of irrigation water [9]. It has been used to alter the genetic structures of crop plants.
- **Food Processing:** Food processing involves the conversion of raw ingredients into ready-to-eat food. Nano food processing can change the color, flavor, or sensory characteristics. Nanomaterials can be used in food processing as additives, which are expected to modify food's texture and taste. Some foods with nano additives have been commercialized. Common examples of nano additives include minerals, antimicrobials, vitamins, and antioxidants [10].
- **Food Packaging:** Food packaging has a great significance in preserving the food to make it marketable. Nanotechnology is creating a revolution in food packaging due to the integration of nanocomposites and nanosensors for leakage proof, gases free, and pathogen less food packaging. Typically, packaging would provide protection from moisture, bacteria, and pathogens. Oxygen is mainly responsible for food deterioration due to oxidation. Nano food packaging (or smart labels) materials may extend food life, improve food safety, detect bacteria in packaging, produce stronger flavors, and alert consumers of food spoilage [11]. Active packaging is an intelligent or smart system that involves interactions between package and food. Smart packaging responds to environmental conditions, repairs, or alerts a consumer to contamination.
- **Food Safety:** Food safety is a growing health issue of global importance. The main objective of food safety is to ensure that food will not cause any harm. The development of some food technologies has made modern food businesses more vulnerable to safety incidents. Nanotechnology is being utilized to improve the quality and safety of food. Human exposure to nanomaterials will continue to grow. The direct or indirect impact of nanomaterials on human health is still controversial. Public acceptance of food and food products containing nanomaterials depends on their perceived safety. Nanotechnology offers some potential benefits for the quality and safety of foods [12].
- **Food Detection: Nano sensors have been created for food detection.** Nanomaterials such as magnetic nanoparticles, quantum dots, carbon nanotubes, magnetic nanoparticles, and nanowires are used as sensors to detect microbial and other food contaminants. They are used for the detection of antibiotics in chicken, in food production, and at packaging plants. They can monitor the condition of food during transport and storage [13]. The use of nanomaterials in sensing and detection is providing alternative methods to conventional techniques for detecting chemical and biological contaminants in food products.

Nanotechnology will find applications in food innovation and genetically modified foods in the near future. It is expected to influence numerous areas of the food industry in ways that will benefit the consumers.

Benefits and Challenges

The benefits of applying nanotechnology in the food industry are many and are expected to grow with time. They have been driving the development of new materials for different areas of the food sector. Nanotechnology in the food industry offers many potential benefits for consumers and manufacturers, with many applications yet to be realized. It can contribute to improve quality and safety of packaged foods. The use of nanotechnology in food gives producers the power to control how food looks, tastes, and lasts. It is expected to bring other benefits including new tastes, textures, less use of fat, nutritional value, modifying color, improved packaging, enhancement of shelf life, improved food storage, tracking, tracing, and security of food products [14].

While the potential benefits of food nanotechnology are exciting, its potential risks are not well understood as with all innovations. The benefits and risks of nanotechnology applications in food-related products are shown in Figure 2 [15]. Food nanotechnology faces challenges with entering the consumer market due to perceived public perceptions and concerns. Food neophobia is the reluctance to try new foods and new technologies used



in food production and processing. This may be due culture, consumer personality traits, and uncertainty about potential health effects of the new food [16]. Communication of new development in food technologies and the media can shape public opinion and affect public support for legislation and policy [17]. It is of serious public concern that most nano-products are entering the market without following proper testing and labeling standards. There appears to be no limit to what food technologists can do to our food and nanotechnology will give them new tools to go to new extremes. Debate over the regulation of nanotechnology focuses on the technical evidence of safety of nanotechnology-based products. Manufacturers have been asked to provide proof that nanotechnology foods are safe. Thus, an international regulatory framework for nanotechnology in food is important. Such regulatory compliance is needed before nanotechnology gains wide-spread acceptance in the industry.

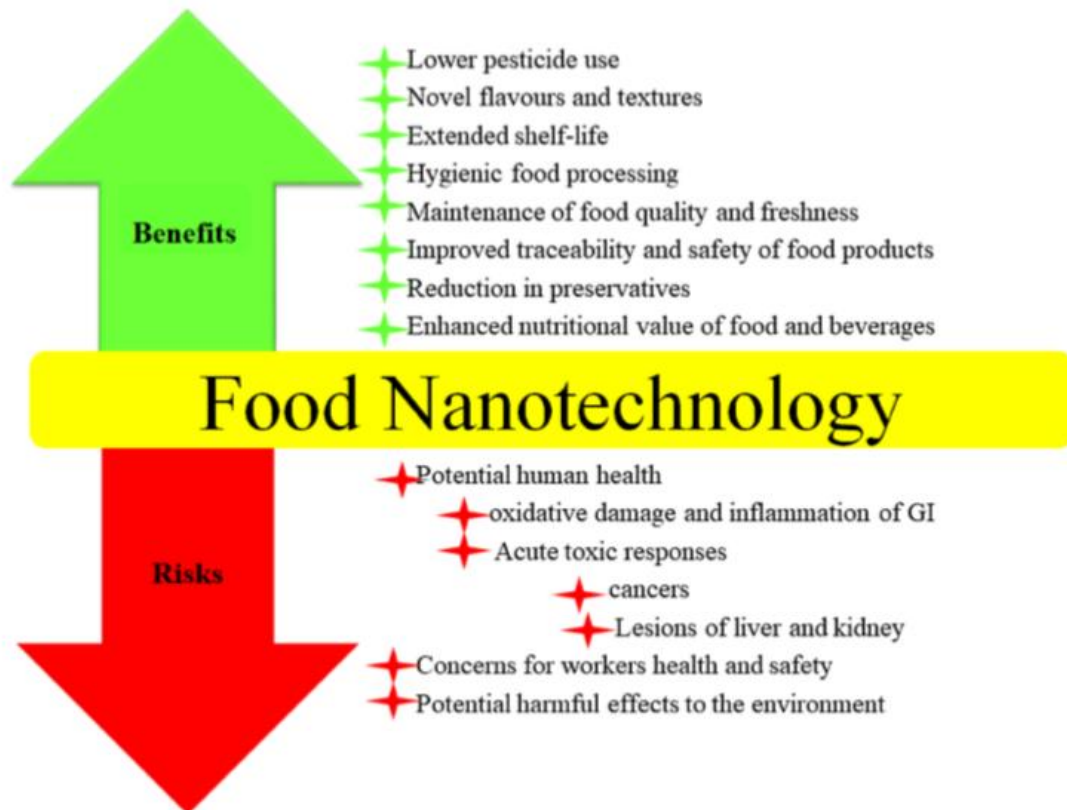


Figure 2: The benefits and risks of nanotechnology applications in food-related products [15]

Food companies are not allowed to use new nanotechnologies in their products without regulatory approval. All nanotechnology-based products fall under the same regulations as conventional food. No specific regulations on nanotechnology applications have been yet established possibly because nanotechnologies pose enormous regulatory hurdles. Nations all over the world are addressing and regulating the use of nanotechnologies. These challenges must be addressed before any routine application of nanotechnology in food could be imagined.

Conclusion

Nanotechnology focuses on the creation, fabrication, and manipulation of biological and nonbiological materials at dimensions of roughly 1 to 100 nanometers. It involves controlling and manipulating structures at the nano-scale to create new and unique materials and products. It is an exciting and rapidly emerging field. It is expected to be the key technology of the 21st century. It has become one of the most promising technologies that will revolutionize the food industry.

In spite of media's scrutiny of nanotechnology, knowledge about nanotechnology, its commercialization, and its food application among American laypeople remains low. Some are pessimistic about nanofood. Government



agencies, organizations, academia, industry, and consumers will need to work together to overcome the challenges faced by nanotechnology-based products and increase their acceptance. More information about food nanotechnology can be obtained from the books in [18-23] and also from the following journals: IEEE Transactions on Nanotechnology, Food Nanotechnology, and Journal of Food Chemistry & Nanotechnology.

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