NEW ERA AGRICULTURE
MAGAZINE

Implications of Nanotechnology for Food Security, Postharvest loss reduction and Food Processing

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Abstract: -

Due to low agricultural production, resource degradation, substantial post-farm losses, little to no value addition, and rapid population expansion, ensuring food security in underdeveloped nations is extremely difficult. In an effort to close the gap between supply and demand for food, researchers are working to implement newer technology. One of the most promising technologies is nanotechnology, which has the potential to increase agricultural output through the use of effective pesticides and herbicides, nano fertilizers, soil feature modulation, wastewater management, and disease detection. With increased food production with superior market value, greater safety, enhanced nutritional and sensory qualities, and improved antimicrobial protection, it is equally advantageous for industrial food processing. By using nanoparticles to extend the shelf life, nanotechnology can help lower post-farming losses. To address the safety and health concerns related to the technology, more research is necessary.

Introduction

The issue of providing food security for a world population that is growing at an accelerated rate is the most pressing global concern. According to predictions, the world's population will reach 9 billion people by 2050, increasing food consumption from 59% to 98%. Even though the world's population is growing, especially in developing nations, the use of bioresources for energy production, chemical manufacturing, high post-farm loss, low value addition, ineffective distribution and

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marketing systems, and other factors have disrupted the world's food supply. Farmers everywhere will concentrate on utilizing cutting-edge inventions and technologies to increase agricultural yields through intensive and comprehensive farming. Precision farming and stimulants with nanomodifications are two further ways that the current efforts are being strengthened. Basic aspects of food security that could be enhanced by developments in nanotechnology research include agricultural efficiency, soil improvement, safe water usage, food distribution in stores, and food quality. For the country to maintain sustainable living standards and enhance food security, newer technologies that will boost productivity and decrease food waste is essential. Nanotechnology can offer a way to produce foods of exceptional quality in a much more manageable form while also increasing the bioavailability of nutrients. Increasing the use of nanotechnology for crop and food processing is the subject of numerous research studies. A rapidly growing area of nanotechnology research is the increase in publications, patents, and intellectual property in nano-agriculture-based foods with new research trends in food processing, nutraceutical distribution, packaging, quality control, and serviceable food.

The use of nanoparticles in food biotechnology, science, food processing, food packaging, functional food development, food safety, pathogen detection in food, and extended shelf life of food and food products has become increasingly necessary due to applications based on nanotechnology. Nanomaterials are excellent at improving food security and fostering the growth of the food production sector. Additional areas of use for aiding in food processing include the deposition of food manufacturing equipment (by biofilm coating), nanofabricated filters, sieves, and membranes, as well as nanocomposite-based and nanosized adsorbents and catalytic agents. According to Sozer and Kokini (2009), the use of nanomaterials in food packaging is intended to reduce waste production and the inconvenience experienced during material packing. It can also assist reduce the use of valuable raw components. Generally speaking, the most promising prospects for the creation of novel and enhanced products are made possible by nanotechnology. However, several scientific communities doubt the public's concern about the health dangers linked with nanotechnology products, which calls for more research. The purpose of this review paper is to outline the principles of nanotechnology, its applications in postharvest, food research, packaging, food process technology, and agriculture, as well as how it can help with efforts to ensure food security and the difficulties associated with implementing it in the food and agriculture system. Studies released between 2016 and 2021 were included in this study. Other publications were added outside of the allotted time frame, though, depending on the quantity of citations and the significance of the studies. Using various keyword or search string combinations, the search process was carried out in the "Web of Science" database. The terms nanotechnology, nanoscience, nanoparticles, nanopesticides, nanoherbicides, nanofertilizers, gene sequencing or nanocoding, nanosensors, nanoformulations, nanocoatings, nanoemulsions, nanocomposites, nanostructured materials, delivery, formulation, packaging, nanotubes, and nanotoxicity are among the keywords.

Nanotechnology's contribution to food security

Due to factors including growing climate change, land scarcity, population growth, industrialization, low productivity, and significant postharvest losses, the globe faces countless and hitherto unheard-of difficulties. Global food insecurity is the result of this. Moderate to severe food insecurity affects about 2 billion people worldwide (FAO, 2019). They are more vulnerable to hunger and ill health since they do not have regular access to food. New perspectives on food insecurity and its effects are necessary in light of this radically altered environment (FAO, 2019). Researchers from all around the world have proposed a number of strategies to increase crop productivity, reduce postharvest waste, and ensure sustainability in order to meet the world's food needs. Modern technology is required to provide a healthy food supply and safeguard the health and welfare of people everywhere. According to Singh et al. (2021), recent studies have demonstrated the potential of nanotechnology to improve the agriculture sector by increasing the efficiency of agricultural inputs and offering solutions to agricultural issues in order to increase food productivity and security. The following section covered the role of nanotechnology in food processing, postharvest loss reduction, and agriculture in ensuring food security.

Nanotechnology to control plant diseases

Globally, plant diseases and pests cause between 20 and 40 percent of crop losses annually. The use of pesticides, including insecticides, fungicides, and herbicides, is a major component of pest management in contemporary farming techniques. It is essential to produce high-performing, reasonably priced pesticides that are less damaging to the environment. New ideas like nanotechnology can benefit pesticides by decreasing toxicity, extending shelf life, and making poorly water-soluble pesticides more soluble, all of which could benefit the environment. There have been several reports on the importance of agricultural nanotechnology, mostly for disease management and safety. Conventional herbicides and pesticides based on nanotechnology help to ensure that plants receive a steady and gradual supply of agricultural chemicals and nutrients in a regulated quantity. According to Khota et al. (2012), nanoparticles may also play a significant influence in the management of host infections and insect pests. For the manufacture of nano-insecticides, various polysaccharides have been taken into consideration, including chitosan, alginates, starch, and polyesters. Generally speaking, there are two ways that nanoparticles can be used to protect plants: (a) they can protect crops directly, or (b) they can act as carriers for already-approved pesticides and be sprayed. However, little is known about the application of nanomaterials in food production and plant protection.

Using nanotechnology to enhance fertilizer distribution and soil quality

One of the most important technologies for increasing crop productivity is nanotechnology for crop management. Nowadays, agricultural research uses nanomaterials and nanostructures including carbon nanotubes, nanofibers, and quantum dots as biosensors to assess soil quality and fertilizer distribution. Nanoparticles are meant to decrease the number of chemicals that are disseminated, lessen the loss of nutrients during fertilization, and improve the yield and quality of the right nutrients. Vermiculite, nanoclay, and zeolite development and application could enhance crop yield and fertilizer effectiveness for ecological agriculture in coarse-textured soils. In ecological agriculture systems, amending sandy loam soils with inorganic amendments decreases NH_4–N passage and increases N fertilizer output. Based on its chemical makeup and the shape of its nanoparticles, nanoclay is divided into several modules, including montmorillonite, bentonite, kaolinite, hectorite, and halloysite.

Postharvest loss reduction

The post-harvest stage and processing point account for more than 40% of food losses in developing countries, whereas the trade and customer stages account for more than 40% of food losses in developed countries (cereals, roots and tubers, pulses and oil crops, vegetables and fruit, fish meat, and dairy). Unpreserved, freshly harvested, high-moisture yields may rapidly decline due to microbial attack. Nanotechnology is one of the most recent and sophisticated technologies that can aid in reducing post-harvest losses. By creating functional packing elements with the fewest amounts of bioactive constituents, enhanced gas and mechanical characteristics, and a lessened impact on the sensing qualities of fruits and vegetables, nanotechnology application can reduce post-harvest losses. Edible coatings are applied on food as a liquid, usually by dipping the item into a material that provides a solution and is produced by the structural medium (a mixture of protein, lipid, carbohydrate, or another substance). By preventing dehydration, reversing respiration, enhancing textural characteristics, assisting in the preservation of volatile fragrance molecules, and reducing microbial growth, they prevent untreated foods from getting worse. In addition to imparting flavors, colors, enzymes, antioxidants, and browning-resistant compounds, edible nanocoatings applied to various foodstuffs act as a barrier against gas and moisture exchange and may extend the shelf life of synthetic meals. According to Sekhon (2010), the method makes it possible to create nanoscale coatings with a thickness of up to five nanometers. For horticultural products, thin films and edible coatings are frequently used. The fencing effect versus gas flow, structural barriers to water migration, microbes, sensory suitability, mechanical properties (elasticity, tension), photosensitive properties (brilliance and opacity), cost, availability, and functional qualities are some of the factors that determine its use.

Food processing

The largest food corporations in the world are looking for different ways to alter the nutritional qualities, value, safety, and competency of food. For the food industry to improve quality, market price, and production, newer technologies are needed. According to Rashidi and Khosravi-Darani (2011), there are numerous applications of nanotechnology in the food production and processing industry, such as nanobased food additives, nanoencapsulation, nanosensors, nanoparticle-based smart distribution systems, nano-packing, medications, and healthcare. It can also be used to create encapsulations, biopolymer matrices, emulsions, simple solutions, and related colloids that provide efficient delivery methods. Nanotechnology-based industrial food processing is becoming more popular, especially for flavor encapsulation or odor enhancement, texture modification or value enhancement, and novel gelation or viscosity-increasing agents. Food nanotechnology focuses on creating nanometer-scale structures with unique properties that can be applied to a variety of applications, including delivery systems, food interaction surfaces with unique surface characteristics, food characterization tools, microfluidic instruments, sensor technology, and nanocomposite coatings, among many more.

Nanofiltration, nanoscale enzyme-based reactors, nanoencapsulation for absorption and modification, heat and mass transfer, and nanofabrication are all multifunctional uses of nanotechnology in food processing. In the pharmaceutical industry, nanofiltration works better for pharmaceutical purification and is a necessary step for forgetting certain solutes. By extracting salt from lactose, it is also used to treat drinking water and dairy products to alter their quality. Package heat resistance was improved by heat and mass transfer nanofabrication. Nanoscale enzyme reactors are used in food treatment and processing techniques to change food mechanisms for improved flavor, nutritional value, and a variety of health benefits. When compared to macroscale supported products, the addition of nanomaterials leads to higher enzyme assisted systems (to improve activity, shelf life, and economy) because of their assistance in scattering through food media due to large surface-to-volume relations. According to research, peptide nanotubes produced better enzyme supports at higher temperatures (65 °C), with lipase activity in the nanotubes being 70% higher than that of free lipases. For example, nano-SiO_2 particles greatly hydrolyzed olive oil with enhanced stability, reusability, and adaptability. The process of nanoencapsulation is used to enhance food items. This method is typically used to enhance flavor, preserve food, and provide cooking balance. Nanocapsules in the form of nanoceramic pots can be used to alter absorption in order to reduce cooking time and the amount of spent oil; reduce trans fatty acids by substituting plant oil for hydrogenated one; and, finally, create safer nanofood by distributing nutrients in food in nanocapsules for improved absorption. In addition to exhibiting similarities with other ingredients in the system, nanoencapsulation conceals tastes and odors, controls interactions between food and active ingredients, regulates the release of dynamic agents, protects accessibility at a specific time with a defined rate, and protects them from moisture, chemicals, heat, or biological interference during storage, processing, and application. SiO_2 and TiO_2 are examples of metallic oxides that have been utilized as coloring or flow agents in food products. According to Dekkers et al. (2011), SiO_2 nanoparticles are used in food waste to transfer fragrances or odors.

Conclusion

Nanotechnology is a recently developed yet rapidly growing technology that has applications in many areas of human endeavors and offers advantages all around the world. Numerous research discoveries have demonstrated its intriguing characteristics, which include the improvement of numerous attributes by nanoparticles and nanostructures as a result of their small size, huge surface area, and highly catalytic nature. Achieving food security requires nanotechnology, particularly in the agricultural industry. Through efficient microbial, pest, and weed control with great economic value, security, and safety, it can increase agricultural productivity. Additionally, it is essential for food processing, food modification, stability, sensing, extended shelf life, reduced food loss, and safe food provision. Because nanotechnology improves stability, safety, and packaging materials, it also reduces post-harvest losses. Commonly employed in food processing, nanoparticles such as Ag, Au, Zn, TiO_2, ZnO, SiO_2, and MgO can also pose health problems because of their easy cell penetration, which can result in negative reactions in a variety of human, animal, and plant organs. Future studies could reduce the dangers associated with nanoparticles or nanocomposite materials by employing greener synthesis techniques and looking for simple, less expensive methods for breaking down and removing the current nanomaterial from attack locations.

References

1. Dekkers, S., Krystek, P., Peters, R.J., Lankveld, D.P., Bokkers, B.G., Van Hoeven- Arentzen, P.H., Bouwmeester, H., Oomen, A.G., 2011. Presence and risks of nanosilica in food products. Nanotoxicology 5, 393–405.
2. FAO, 2019. The State of Food and Agriculture 2019. Moving Forward on Food Loss and Waste Reduction. Rome.
3. Khota, L.R., Sankarana, S., Majaa, J.M., Ehsania, R., Schuster, E.W., 2012. Applications of nanomaterials in agricultural production and crop protection: a review. Crop Protect. 35, 64–70.
4. Rashidi, L., Khosravi-Darani, K., 2011. The applications of nanotechnology in food industry. Crit. Rev. Food Sci. Nutr. 51, 723–730.
5. Sekhon, B.S., 2010. Food nanotechnology–an overview. Nanotechnol. Sci. Appl. 3, 1–15.
6. Sozer, N., Kokini, J.L., 2009. Nanotechnology and its applications in the food sector. Trends Biotechnol. 27, 82–89.