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Using Nanotechnology in Food Packaging

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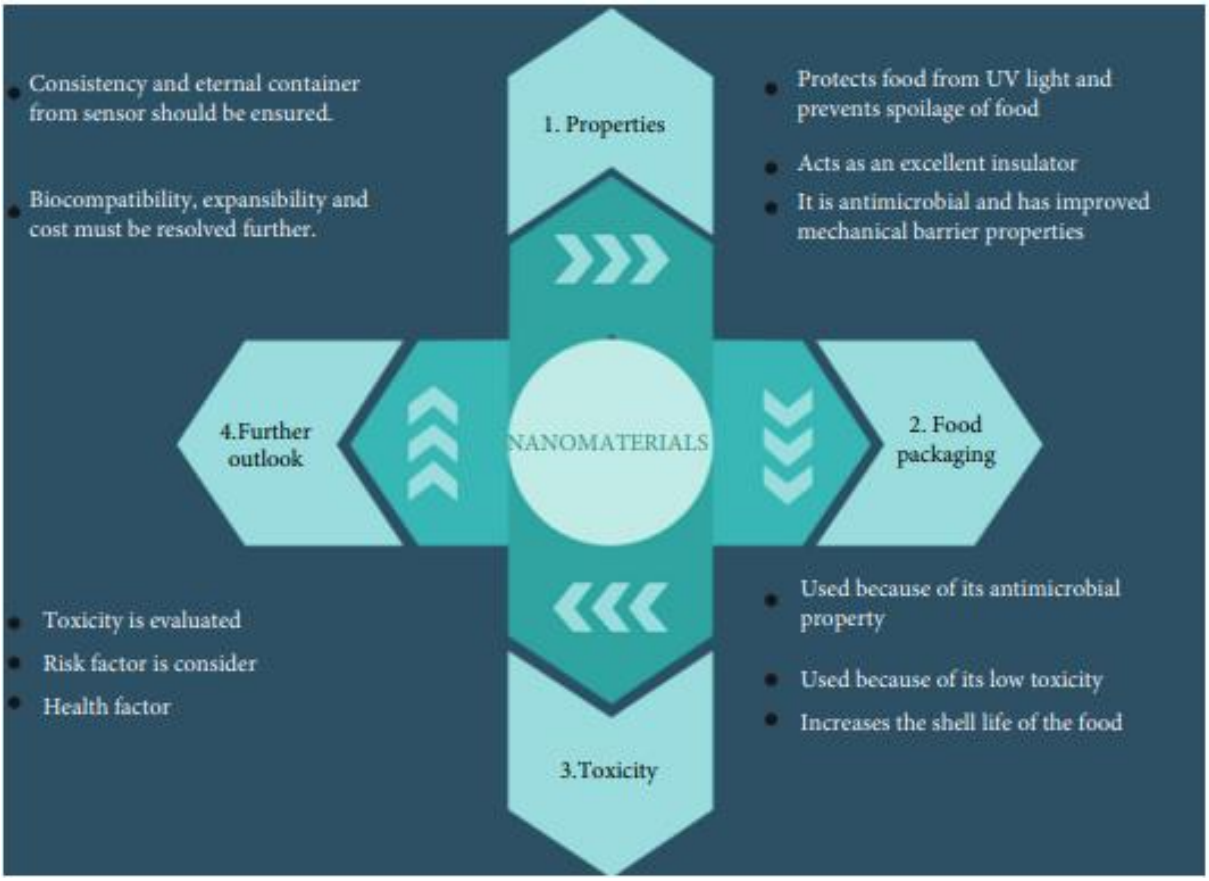
Abstract:
Nanotechnology is one of the emerging technologies that is used in various fields. This technique promises significant changes in the industry and health by improving the quality level. Today, one of the industries that plays a major role in the health of society is the packaging industry, and in a short period of time, it has made significant progress with the use of nanotechnology. In this article, the relationship between nanotechnology and packaging is explained with the help of data obtained from reliable scientific databases such as Science Direct, PubMed, and ResearchGate. The findings showed that nanotechnology can be used to improve health, gain wealth, improve the quality level of products, and according to all the mentioned cases, for a better life. However, food nanopackaging is still a relatively unknown field of nanoscience and food science that requires more extensive research.

Keywords: Nanotechnology, Food packaging, Sensors, Nanocomposites, Nanoparticles

INTRODUCTION

Sufficient and appropriate food supply has become one of the most basic concerns. In order to solve it, various efforts are made in different fields, such as increasing the amount of production, increasing the interest at the time of consumption, improving the methods of storage and storage, and developing methods of preserving it against harmful factors such as fungi and bacteria. It is done with it. In order to preserve food against fungi and bacteria and ultimately preserve it for a long time, the packaging is of particular importance (Khalid and Arif, 2022; Manzoor et al., 2023). Along with other new technologies that are used in the food classification industry, nanotechnology has found itself as one of the most common new technologies in the fields of different places in the food industry. This technology is an emerging technique that manipulates atoms and molecules in 1 to 100 nanometers and creates some unique and different chemical properties and behavioral characteristics so that different applications can be made from these materials. Creates in the field. Creates different (Primožič et al., 2021). Nano is a word originally from Greek and means dwarf and short and refers to a size equal to one billionth of a meter (eighty thousand times smaller than the diameter of a human hair) (Chadha et al., 2022). Advances in nanotechnology improve the quality of various products in issues such as safety, quality control, etc., or the creation of new materials. From the beginning, the role of nanotechnology in the industry has been to increase the capabilities of packaging materials, which include increasing the mechanical properties of resistance to impact and wear and preventing the entry and exit of gases inside the packaging materials. classified and mentioned... This technology increases the quality of products from color, taste, texture stability, aroma, freshness, and longevity (Primožič et al., 2021).

Key functions of packaging systems, i.e., container of the product, preservation and protection of the product quality, presentation and identification of the product as sales element, facilitation for transportation and distribution of the product, and information of the product to the consumers



OVERVIEW OF NANOMATERIALS IN FOOD PACKAGING

In current packaging, the use of glass, metal cans, and materials made from plastic compounds is common. The use of glass and metal cans due to reasons such as high weight, increased transportation costs, low resistance, less uniformity of dimensions compared to other containers, serious risks due to the presence of pieces or fragments of glass or metal, the possibility of corrosion by packaging materials (in relation to metals), opening the door and tampering with it, low safety and some other reasons have gradually been replaced by various types of plastic packaging made of polyethylene terephthalate, polyvinyl chloride, polyvinylidene chloride, acrylonitrile and polystyrene (Liu et al., 2022; Zhuo et al., 2023). But plastic containers themselves have many problems, including environmental pollution, the inability to reuse, and the migration of dangerous and carcinogenic pollutants such as catalyst residues, organic peroxides, metal salts, and monomers that are used in the formulation of plastic materials. have been used in food packaging (Agarwal et al., 2023). It seems that according to the issues raised, the use of nanotechnology in the packaging industry can solve these problems. The concept of nanotechnology was proposed in 1959 by Richard Feynman, a quantum theorist and Nobel Prize winner, at the annual meeting of the American Physical Society (Adassooriya et al., 2023). Nanotechnology or microparticles is a modern technology that is widely used for the production of new materials at the nanoscale due to its rapid growth (Malik et al., 2023). This technology is the science of very small materials with dimensions less than 100 nanometers that cannot be seen with the naked eye. In this technology, according to the size of the particles, physical and chemical properties change, which creates a wide range of applications. Nanotechnology has various applications in different fields, including food, medicine, biomedicine, medicine, biotechnology, textile, electronics, computer, cosmetics, paint, environment, lubrication, etc. (Malik et al., 2023). Their use in the packaging industry will be discussed further.

FOOD PACKING

Packaging means making or providing a container or protection that preserves the product's internal health during the period of time after harvesting, production, transportation, storage, and distribution until final consumption and is safe from possible physical or chemical hazards. In addition, the packaging should be cheap and light. The purpose of food packaging is to preserve the product, prevent bacterial spoilage, increase shelf life, and prevent damage during transportation and storage. Food packaging plays an important role in the safety and quality of food and can control the transfer of moisture and gases; As a result, it significantly reduces food waste. Common materials used in food packaging are metal, glass, and paper. During the last decade, the use of polymers and plastics has replaced other types of food packaging due to their low price, plasticity, and diversity in physical properties. has created in the food industry. But their main problem is the possibility of permeability of gases and other small molecules. On the other hand, these materials are produced from fossil fuels that are non-degradable and cause environmental pollution and serious problems for the environment. To increase the quality of food and design packaging materials to complement the needs of the food packaging industry, many efforts have been made to replace new biodegradable packaging made from renewable resources; It has been done. Packaging based on nanotechnology, which is used for this purpose, has created a great transformation in this industry. By choosing the right materials and technology in the packaging, the quality and freshness of the products can be maintained until the required time. Packaging using nanotechnology can be divided into three categories: smart packaging, active packaging, and improved packaging (Chadha et al., 2022; Chausali et al., 2022).

Smart Packaging:

Smart packaging includes labels that indicate the health and freshness of the product over time and also includes sensors. This system includes labels on goods or products that are identified by a radio device. Using this system, it is possible to remotely monitor the safety and quality of the closed product or the closed environment. This type of packaging informs the consumer of the product's condition in terms of food conditions and its environment to identify chemicals, pathogens, and toxins in food. This type of packaging with specialized nano-sensors and nano-devices gives environmental factors on food and also gives the efficiency of information transfer about color, quality, new products, etc. in time. From smart packaging food, absorbable food can be used in which it can be absorbed in the packaging and thus the growth of microbes and the taste and quality of the food. You can use it by using mineral-based chemicals. Carbon dioxide can form microbes in meat products such as red meat, meat, and cheese. Absorbent materials used in smart packaging include ethylene gas and antimicrobial materials. From nanotechnology in the manufacture of smart packaging to increase product life, it is possible to produce polymers with long-lasting characteristics against gas penetration and reinforcement, create functional coatings, etc. (Enescu et al., 2019).

An example of smart packaging with temperature-time indicators: temperature-time indicators to provide information about whether a threshold temperature has been exceeded over time and/or to estimate the minimum time a product will be above a threshold temperature (time) is placed, it is appropriate (Enescu et al., 2019).

Active Packaging:

In this method, active substances that are directly and indirectly in contact with food have the ability to change the composition of food or the atmosphere around it. This packaging changes the conditions of the package in a way that increases safety, increases the shelf life of food,

strengthens mechanical and thermal properties, maintains quality, and reduces costs. Antimicrobial packaging is a type of active packaging in which the shelf life of the product is increased with the help of antimicrobial agents that are used in the preparation of the packaging material to prevent the growth and reduction of microorganisms. In this packaging, the use of nanomaterials such as; silver copper oxide, silver oxide, titanium oxide, magnesium oxide, and carbon nanotubes that show antimicrobial properties in direct contact with food or its environment; is common in the meantime, the use of silver nanoparticles in food packaging as an antibacterial agent has grown significantly. Active packaging is developed mostly for antimicrobial applications. It has created many hopes for improving food quality safety and shelf life of food products (Chadha et al., 2022).

An example of active pads; Food pads are absorbents that completely cover the package on all four sides, no chemicals are released from them, and the fibers in the absorbent materials never come into contact with food, which increases the product's lifespan (Enescu et al., 2019)

Improved Packaging:

Despite the many advances in nutrition science, there are dangers with microorganisms such as mold, bacteria, and the existence of viruses that threaten human health. Since they directly consume antimicrobial substances in food, they can be useful for food consumption. Antimicrobial packaging is very important. One of these packaging is improved packaging, which includes polymer compounds along with the weight of nanoparticles and nanocomposites, which are used in products such as carbonated beverage bottles, films, and edible oils. One of the most important features of this classification is its prevention of gas entry, temperature regulation, food resistance, etc. The use of nanocomposite materials in the food industry is approved by the FDA (Akhila and Badwaik, 2022; Babu, 2022).

Application of Nanotechnology in Food Packaging

Scientists have identified the potential of using nanotechnology in almost all sectors of the food industry. Two of the most important areas are improved food processing, food quality, and food packaging. Among these two, nanotechnology is the most used in food packaging; Because they are not added directly to food, and the natural structure of the food is preserved in these conditions. The use of nanotechnology in food packaging will protect food against pathogenic

agents and harmful gases. Nanosensors are used in contamination detection and evaluation of packaged materials, as well as food protection against ultraviolet rays. This technology improves food packaging and its capabilities, and it can be used to detect bacteria in food packaging, which creates a better taste and quality of food, increases safety, and prevents penetration. gas and moisture, increasing shelf life and preventing food spoilage (Singh and Nanda, 2022).

as additives that have been used functionally in the food packaging industry; It is possible to use all kinds of nanomaterials; including silver nanoparticles, titanium nitride, zinc oxide, and nano-clay (Awuchi, and Dendegh, 2022).

Nanocomposites:

Reinforced polymers using nanoparticles are called nanocomposites, whose use has been developed in the food packaging industry. Compared to pure polymers, polymer nanocomposites have more strength, high resistance to ignition, better thermal properties, low melting point and gas transfer temperature, and suitable resistance to moisture conditions. In most cases, 5-weight clay nanoparticles have been used in the structure of nanocomposites. These nanocomposites are based on layered silicates of clay, for example, montmorillonite. The use of nano-clay in the design of nanocomposites leads to the creation of features such as high mechanical strength, and low weight, improving the properties of preventing the passage of liquids and gases, preventing the penetration of oxygen and moisture in food, and thus preventing food spoilage. be. A number of biopolymers including polyamide, nylon, polyolefin, polystyrene, epoxy polyurethane resins, and polyethylene terephthalate have been used in the design of nanocomposites based on nano clay. It is also possible to produce nanocomposites with thermoset and thermoplastic polymers, polyethylene, polypropylene, and poly methyl methacrylate. Research groups have started and studied the identification and preparation of biodegradable polymer nanocomposites such as starch and its derivatives, polylactic acid, poly hydroxybutyrate, etc. for a wide range of applications. The use of biocompatible nanocomposites in food packaging, in addition to preserving food, and increasing the useful life of food products, has solved biological problems and reduced the need to use plastics; It has improved mechanical, abrasion, and thermal properties, which is an important feature in packaging materials. Today, the use of biodegradable films of pure natural polymers in packaging is limited due to poor mechanical properties and poor performance in the entry and exit of gases. However, nanocomposites as a supplement in the formulation of packaging films have increased the hope of expanding the use of natural films. Polymer nanocomposites or bio-nano-composites are hybrid nanostructured materials with improved mechanical, thermal, and gas properties that cause less environmental pollution due to the reduction in the use of plastics in food packaging. These materials have more potential and stability in active food packaging industries to maintain antimicrobial activity and reduce the transfer of metal ion derivatives to packaged food (Perera et al., 2022).

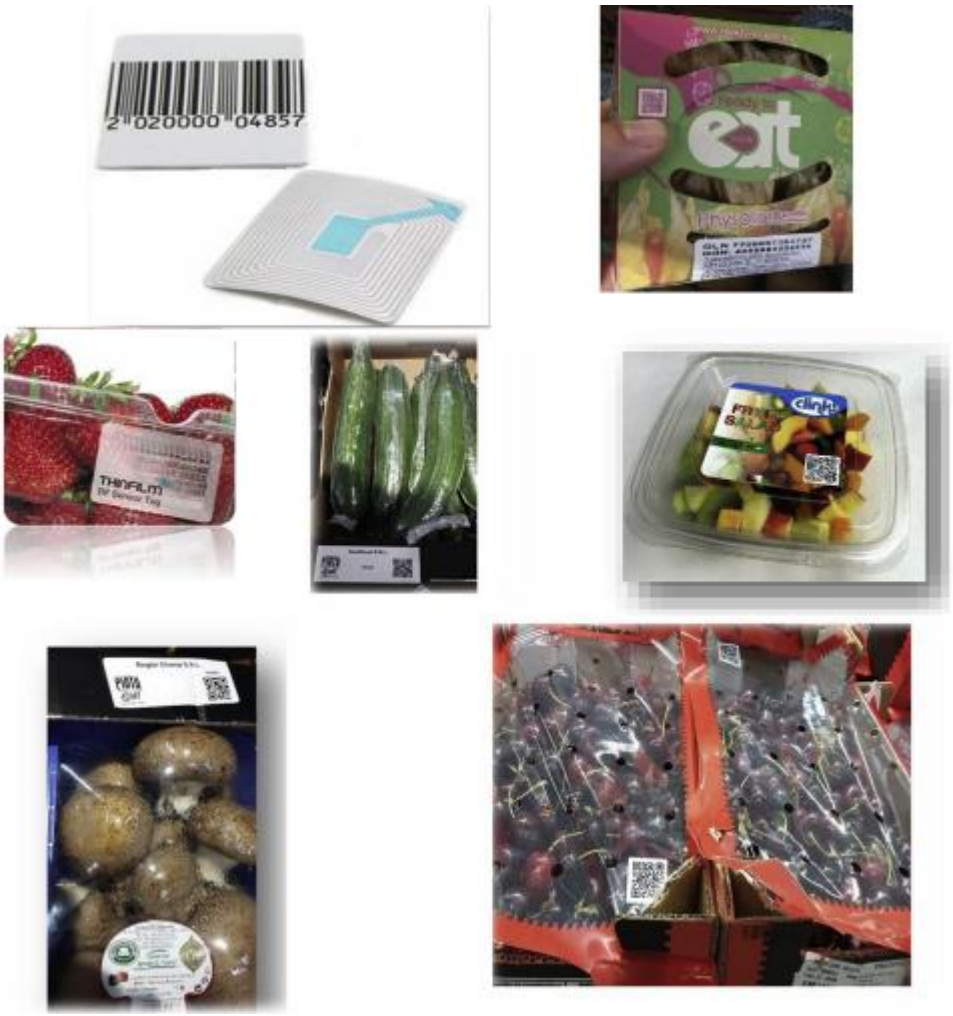
Coatings:

Nano coats were used several decades ago, and now they are generally used. Coatings are layers, a waxy coating that is of considerable interest and is used as coating products such as cheese and apples. The main role of nano-coatings is to protect food and also beautify packaging surfaces. Nano-coated foods have been used in a variety of foods such as meat, vegetables, fruits, cheese, candy, chocolate, fried potatoes, and bakery products. In general, nanocoatings are mostly used to prevent the passage of gases. Nanocoatings are antibacterial coatings without chemical germicides and are stable against chemicals, alkalis, and resistance. Nanocoatings are a fine layer that has an organic or inorganic origin, and their work is from penetration and migration, in the

packaging industry, these factors create quantitative and qualitative characteristics of food products. Nano-coatings made from materials such as titanium dioxide are used for photocatalytic disinfection. It acts as a chemical protective layer and plays the role of surface modifier (Mahmud et al., 2022).

Sensors:

In technology, the biosensor is an important option in the agriculture and food industry to ensure the quality and safety of food with cost-effective and fast methods, control products and processes, and detect packaged gases in order to ensure the integrity of the packaging. Different types of nanomaterials are used in the manufacture of biosensors, of which gold nanomaterials are one, these materials create other materials such as suitable, low, quick response, precision, and particles. The purpose of closing these materials in food packaging systems is to identify nanoparticles released in classified food in a short period of time, among their other uses, they can help to improve and detect pharmaceutical compounds, drugs, and substances. Sami pointed out. These materials can monitor the quality and freshness of food during storage and its sanitary conditions. Nano sensors react to environmental factors such as temperature, humidity, the effect of microbial factors and pathogens and provide useful information to suppliers and consumers in the conditions of storage of materials in terms of temperature, expiration date, etc.



An example of smart packaging with a sensor tag (advanced data carrier, capable of storing data up to 1 MB; this data includes traceability, inventory management, and improving quality and safety.) (Enescu et al., 2019)

Nanomaterials:
Many nanomaterials are used on an industrial scale in various food products, including nano clays, silver nanoparticles, as well as zinc oxide, silicon dioxide, and titanium dioxide... Silver, titanium dioxide, and zinc oxide are among the most important metal materials, and metal oxides that are used in packaging.

Dititanium Oxide Nanoparticles:
Titanium dioxide in a small size of about 1000 nm or less is used to improve food consumption and is antimicrobial in packaging materials and storage containers. Among the characteristics specified in the structuring, we can mention the increase in mechanical strength and help in the packaging process. This material protects plastics from UV rays. Rather, it causes the production of active oxygen (oxygen in the presence of ultraviolet rays and thus causes the analysis of pathogenic microorganisms.

Dicar titanium oxide nanoparticles are among the best semiconducting nanoparticles that have properties such as hydrophilicity, photocatalysis, ultraviolet light absorption, and antibacterial to prevent the growth of various microorganisms, gram-negative and gram-positive bacteria, and fungi as additives and antimicrobials. are. It is used for food and storage containers in the structure of polymer nanocomposites used in packaging. For packaging films coated by titanium dioxide to reduce Escherichia coliform on food surfaces.

Silver Nanoparticles:
One of the nanomaterials that are used in the food industry due to their antimicrobial properties is silver Nanocomposites, Silver is widely used as an antimicrobial agent in the food and beverage industry. This material prevents the growth of bacteria and Fungi in the packaging due to its permeable rather than non-consumable nature increases the shelf life of the product and does not change its appearance and properties. Due to their anti-bacterial and anti-odor properties, they are used in the packaging industry for sanitary materials. Because this substance has a catalytic property, it is used in the absorption and destruction of some materials in packaging, for example, ethylene, which is produced by the industries of fruits and vegetables, which makes them grow faster and reduces their shelf life. In the packaging of this type of food, silver nanoparticles are used in the packaging structure to absorb and analyze ethylene and thus increase their shelf life. These particles are mixed with nanomaterials to increase and improve the properties of packaging materials. In this process, silver nanoparticles release silver, which binds to cell walls, and ultimately leads to the inactivation of enzymes. Due to the lack of information about the materials of these nanoparticles on human health and their impact on the ecosystem, nanoparticles are not directly added to food and packaging. Another application of nanoparticles is to use them as nanocomposites. The physical and chemical properties of these materials are such that they exist and rotate on it. As a result, it causes oxidative stress. The packaging material has shown good antibacterial properties, for example, against samples such as *Escherichia*, *coliform*, and *Staphylococcus aureus*. One of the applications of silver nanoparticles is to use them in the form of silver zeolite. The antimicrobial activity of silver is due to the use of silver in the production of other types of chemicals that cause cell death.

Zinc Oxide Nanoparticles:

Nanoparticles of various metal oxides such as zinc oxide, magnesium oxide, and silver iron... Are used in packaging industries. Among these, one of the most widely used metal oxides is zinc oxide. This compound is white in color and has a vorticity structure and high mechanical stability. The range of applications of zinc oxide in nano fields is wide due to its piezoelectric, pyroelectric, and semiconductor properties. This compound has many applications in the medical field due to its biocompatibility, activity against ultraviolet rays, and good antibacterial properties (Ballesteros et al., 2022)

Nano Clays:

Nano Polymer becomes a two-phase system. These materials are composed of two organic and inorganic polymers that are formed from silicate layers. Due to their availability, low cost, and high acceptance, clay nanoparticles are used in polymers more than ineffective fillers such as clay, silicate, silica nanoparticles, etc., which results in lightness. The strength of resistance to heat and impermeability to gases can be mentioned. We can definitely say that clay nanoparticles are used in food packaging. The most important are composites. These nanocomposites are divided into two categories (1) internal nanocomposites and (2) multilayer structures of alternating polymers. They use bio-nano composites that are combined with non-mineral materials such as soil for food packaging. One of the main advantages of using these materials is their compatibility with the environment. Poly, amide, nylon, polyolefin, polystyrene, etc. can be mentioned among the biopolymers that are made on this basis. The combination of polymer and nano clay can be used in the packaging of various foods such as meat products, cheese, cereals, and juice. used (Schmitz et al., 2023).

Antimicrobial Properties:

The main application of nanotechnology in food packaging is its antimicrobial properties. The use of nanotechnology has provided many hopes for obtaining food with high safety capability, increasing storage time, and ultimately creating healthier food. The purpose of food packaging is to prevent microbial spoilage and the loss of nutrients and thus increase the storage time of food. One of the disadvantages of food is infectious diseases caused by contact with food, the primary source of which is milk. So; Eliminating bacteria in food packaging is one of the most important issues in the process of food production, processing, transportation, and storage. The use of nanomaterials has increased the useful life of food due to their antimicrobial properties (Suvarna et al., 2022).

CONCLUSION

Food packaging is one of the most important steps in food production, which is important for the shelf life of food. Meanwhile, the use of nanotechnology in food packaging has a special place and its value is increasing day by day. The important and fundamental principle of using this method is to maintain the safety of food, in this regard, important issues such as the type of packaging (e.g., Smart, active, and improved) and the number of antimicrobial properties of that type of nanoparticles suitable for achieving antimicrobial properties is considered. It is worth mentioning that in food packaging, these materials are used as disinfectants to increase resistance to light and heat and to prevent the attack of all kinds of microorganisms and pathogens. Finally, it is important to acknowledge that food packaging And paying attention to its quality along with paying attention to biocompatible materials is used as a determining priority and a determining role in increasing the quality of food, reducing the consumption of primary raw materials, reducing food consumption, maintaining individual and social health and vitality, and as a result,

resources For this purpose, for this purpose, for nanomaterials and their use in the food packaging industry, Melli Ayandag has found its place in this industry and with the increasing growth in the state of progress and development, it is needed and suggested. It is possible that different food industries, in addition to all their production activities, spend their capital and time on research to increase and improve the quality of the packaging of their products using different technologies, and in this way play their role in preserving national resources for future generations to do. Perform identification. Although nanotechnology has many collections, it still cannot be fully applied in relation to the non-influence of the materials used in it and their performance and human health and product safety. Because most of the review has been on it.

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