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Nanotechniques Used In Food Industries: A Mini Review

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Abstract

Nanotechnology is enabling the reassembling and self-assembling of the nanoparticles. Applications of nano-techniques have become an important part of food processing and manufacturing industries. In food processing, nano-technology revolutionizes the conventional concepts and stimulates the innovative ideas such as encapsulation of the functional food additive for proper targeting, nano biopolymers, nanoemulsion, nanocapsule from alpha-lactalbumin and different types of fortification in the food products to improve the nutritional values of the final food products. Application of different techniques in food packaging material can overcome many challenges in food sectors. Smart packaging, active packaging, antimicrobial packaging, and barrier applications broader the concepts of food safety by keeping the food safe for longer period of time and by ensuring the quality of the food perfect. Smart packaging also helps the consumer to choose the suitable product. Nano-sensors are used to express the products characteristics or to control the microbial load in the food product. Our findings from the literature review suggest that nanotechnology has important implications in food science and has potential to bring further improvement in food processing and packaging in particular. This review summarizes the recent developments in nanotechnology with special reference to its applicability to food processing and packaging.

Keywords: Nanotechnology; Food processing; Food packaging; Food industry

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Introduction

Foods are consisted of essential constituents including minerals, vitamins, proteins, carbohydrates, fibers, and lipids. The purity and persistence of these constitutes are prerequisites for healthy society to access the nutritional food to fulfill their food preferences. Expectedly 30 to 40% productivity requires to increase in agriculture products to feed the 9 billion population of world by 2050, which can be achieved by lessening the food wastes and demands and enhancing the food quality [1]. Variety of agriculture practices including biological, physical and chemical are conducted in the field to control plants insect pests and diseases. These means of controlling harmful impacts of diseases and insect pests before or after harvesting of crops, accumulate the contaminants in the raw food and reduce its quality for nutritional demands and international trade [2]. So, food processing is necessary to decontaminate and add values to raw foods before their commercialization and consumption. The food processing means the conversion of the raw material into the food products which have more shelf life and are more acceptable by consumer, by adopting the advance technologies and techniques instead of cooking, frying, filtering, and drying processes [3].

In the last decade, nanotechnology as an emerging technology has been adopted in most of the developed countries to alter the nano-constituents of food particles in food sciences [4]. The term nanotechnology, can be explained as ‘a technology executed on the scale of less than 100 nanometers, to take control on individual nanoparticles’. The prefix use “Nano” before the word technology explains a lot. “Nano” is a word of Greek language, which means “dwarf” or small, which refer to the size of a substance having magnitude of 10^{-9}, or in other words we can say that billionth part of something. Nano-science enables to play with the assembling of the atoms, molecules and particles (e.g. the small structural composition of chemical compound in chemistry and the small organelles even at molecular level of the cell of either plants or animals) [5].

Nanotechnology and nano-science are mostly applied in various fields to bring something innovative. Application of nano-technique in communication, electronics, energy production, pharmaceutical products manufacturing or in the food processing and packaging has revolutionized the conventional concepts. Using the concept of nanotechnology, food could be made by rearranging or reshaping the molecules and atoms in near future. Using nano-devices, it is easy now to rearrange the sequence of DNA of the crops, in order to get effective output / yield. The use of nanotechnology in agriculture was first introduced by United States Department of Agriculture (USDA) in 2003. We can make crops better and resistant against insect's attack and other plants diseases, which ultimately reduce the cost of production and improve the production rate which leads to the surplus of food material. Nano-technology will play an important role in the field of food technology in future, nanoparticles will be used inside the food materials during the processing for higher quality and texture. However, the nanoparticles are also used outside the products by coating the nanoparticles on packaging material which may play a role in food safety [6].

Application of nanoparticles in the following three ways could be very important; i) in food processing for improving food texture, quality, flavor and viscosity, ii) in food packaging as pathogen or abuse sensors, anti-counterfeiting devices and impermeable films, and iii) in nutrients supplements as higher bioavailability and stability of nutraceuticals [7]. This nano-technique can be divided as nano-inside which is application of technique at food additives and nano-outside which is its application as food packaging [8]. Nanotechnology has very wide application in food, related to its processing, packaging and more importantly food safety. Some applications of nano-based materials in food industries are provided in **Table 1**.

Functional food is currently one of the most important foods all over the world and nano-techniques are very useful in production of these types of food products. Many food industries develop nano-based emulsion type products such as ice-cream, which are lower in fat content but their fat related structure and texture is not altered by applying nano-techniques. These evidences show that nanotechnology has already stepped-in food market [9] and has greater potential to be an important tool for food sciences. In this review, our main focus is on the nano-techniques which are used in the food packaging and processing to make food better for consumption.

Nanotechnology In Food Processing

Basic nano-structures are combined to make life (i.e., DNA, cell membrane, hormones, and enzymes). Although these are nonliving nano-particles, they combine and work together to make the life possible. Similarly, food contains very small constituents, for example carbohydrates, protein, lipids, minerals, and amino acids [4]. The food processing means the conversion of the raw material into the food products which are more acceptable or desirable by consumers and have more extended shelf life. Different type of nano-techniques used in the processing of the raw material (e.g., nanocapsule, nanoemulsion, and nano-sized self-assembled structure of food molecules etc.) are very helpful [10] **(Figure 1)**. Nano-techniques applied in food processing are further detailed below.

Functional foods and nano-techniques

Different types of food additives are used in the functional food products, for performing a specific function (i.e., to preserve food or to improve the nutritional value of the food). Most commonly food additives used are antimicrobial agents, antioxidants, flavoring agents, anti-browning, anti-caking and nutrients. These additives have their own specific properties (physical or chemical) according to their chemistry. These additives are not used in their purest condition. A specific delivery system (nano-dispersion and nanocapsule) combined with the additives makes their use effective and valuable.

The first function of delivery system, which is used to deliver

Table 1 Application of nano-based materials in food industries (modified from [44]).

Nano content	Type of product	Product name and manufacturer	Purpose
300 nm particles of iron (SunActive Fe)	Nutritional drink	Oat Chocolate Nutritional Drink Mix, Toddler Health	Nano-sized iron particles have increased reactivity and bioavailability
50-150 nm starch nano-spheres	Food packaging	Adhesive for McDonald's burger containers, Eco synthetix	These nanoparticles have 400 times the surface area of natural starch particles. When used as an adhesive they require less water and thus less time and energy to dry.
Molecular cages 1-5 nm diameter made from silica-mineral hydride complex	Nutritional supplement	Nanoceuticals 'mycrohydrin' powder, RBC Life-sciences	Nano-sized mycrohydrin has increased potency and bioavailability. Exposure to moisture releases H-ions and acts as a powerful antioxidant
Nanoparticles of silica in a polymer-based nano-composite	Food packaging	Durethan ® KU 2-2601 plastic wrapping, Bayer	Nanoparticles of silica in the plastic prevent the penetration of oxygen and gas of the wrapping, extending the product's shelf life.
Nanoparticles of silver	Food contact material (cooking equipment)	Nano silver cutting board, A-Do Global	Nano-sized silver particles have increased antibacterial properties
Nanoparticles of silver	Food contact material (crockery)	Nano silver baby mug, Baby Dream	Nano-sized silver particles have increased antibacterial properties

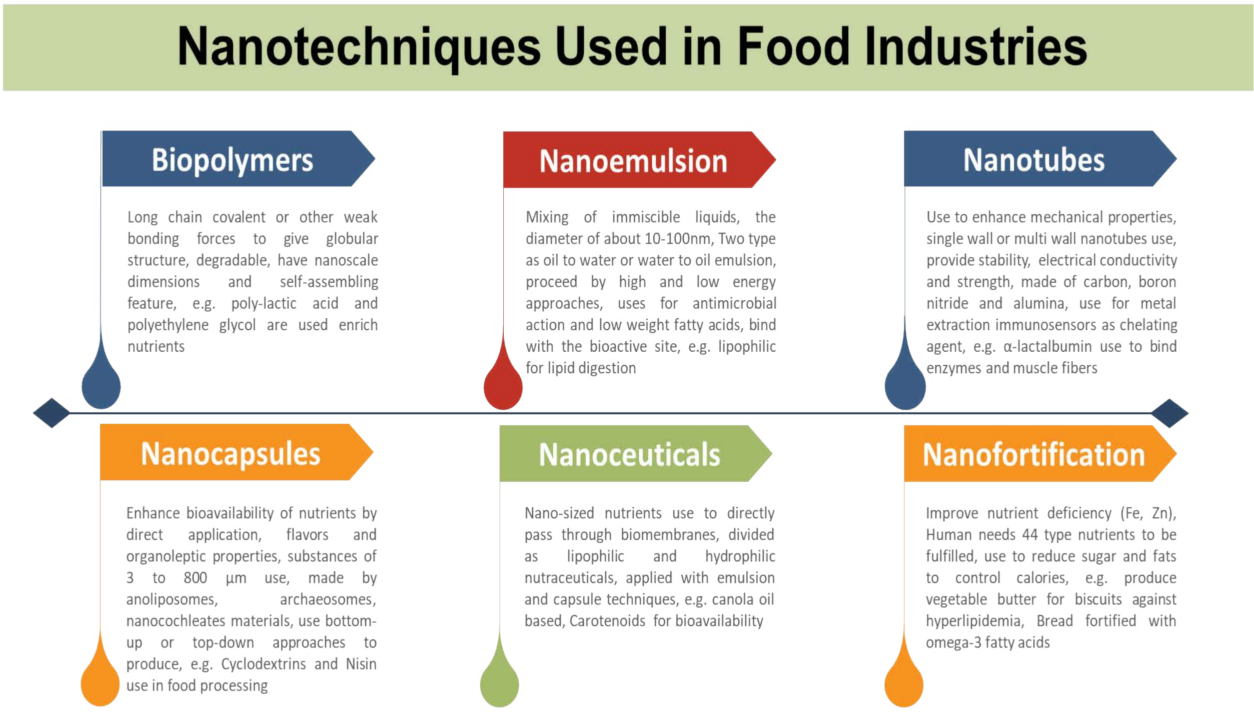

Figure 1 Nanotechniques used in food industries.

the functional ingredients to their proper target site, is to act like a vehicle for transporting the material. The second function performed by the delivery mechanism is to protect the functional ingredients from the degradation (deterioration and oxidation of ingredients by some specific enzymes). The delivery mechanism protects the ingredients from such impairments. Third function performed by the delivery system is to release the functional ingredient in the specific and optimal environmental conditions (i.e., pH, ionic strength, and temperature). The delivery system must be compatible with the conditions and the final attributes of the products. The efficiency of the delivery mechanism can be affected by the properties and characteristics of the delivery system. Each delivery system has its own benefits of encapsulation, protection and proper delivery of the functional ingredient [11].

Nanotechnology and biopolymers

Biopolymers are the long chain of covalently bounded monomeric units, have the better binding ability for the specific ions. All of the biochemical materials, performing functions in living organisms e.g. proteins, carbohydrates, enzymes etc. are in the form of polymers to perform better in their specific environment. For example, hemoglobin in the blood has globular structure to bind oxygen. If it is not consisted of polymeric structure, its binding ability for the oxygen will not work properly. In the food science, they are used to bind specific nutrients to enhance availability and stability inside the food. They are degradable and obtain from the living sources such as microorganisms, plant oils, fats, resins and proteins [12,13]. In the nanotechnology, the proteins and polysaccharides like molecules are used as biopolymers. They have nanoscale dimensions and self-assembling features in aqueous media by forming polymer to polymer or polymer to solute attraction. In addition, they have the ability to change their physical binding by changing the factors in the food (i.e., temperature, pH and addition of salts). The weak intermolecular forces i.e., H-bonding, electrostatic forces in selected biopolymers make their fibers, aggregates or complex structures like food gel or dispersions [14]. Some nano-particles are used to provide the different types of nutrients to food products which are deficient of these nutrients. For example, poly-lactic acid, which is a known biodegradable nano-particle, is used for the enrichment of iron, calcium, and vitamin in food products. The required material is encapsulated in the poly-lactic acid (PLA) that takes the nutrients to the target sites. Studies showed that the PLA required some additional compounds such as polyethylene glycol to perform its function effectively [6,15].

Nanoemulsion

Emulsion is the mixture of two immiscible liquid. Nanoemulsion can be created by droplets of the oil range from 10 to 100 nm **(Figure 2)**. The nano-sized oil droplets are dispersed in the solvent to produce two types of emulsions, oil-in-water and water-in-oil. Oil droplets are surrounded by the surfactant and form a nano-layer which produces nanoemulsion. The nanoemulsion can be created by any suitable methods that break the drops of oil into the nano-size particles by giving a shock or any other treatment. Two most common approaches used to produce nanoemulsion include, a high energy approach and a low energy approach. In the

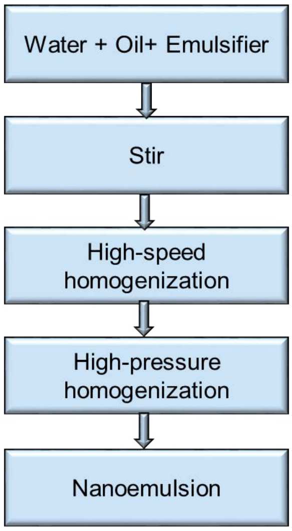

Figure 2 General process to prepare kinetically stable nanoemulsion.

high energy approach, high pressure and ultrasound techniques can be used to produce nanoemulsion through cavitation. It minimizes the size of droplet and provides the dissipative forces. In this method microfluidization, sonication and high-pressure homogenization are included. In the low energy approaches include emulsion inversion point (EIP) method, phase inversion composition (PIC) method, spontaneous emulsification (SE) method, and phase inversion temperature (PIT) emulsions are formed by spontaneously mixing of ingredients and droplets size can be reduced by changing the compositional and environmental factors [16,17]. Several nano-based emulsions have been practiced by food industries. For example, Nestle performs nanoemulsion to produce low fat ice cream products and to maintain the fatty structures same as previous products [18].

Nanoemulsion is also used as surfactants to decontaminate the food by binding the microbial populations from the solutions and reducing their activities. The oil droplets having diameters of 200 to 600 nm are important to hinder their activities. These droplets spread over the surface by using high stress mechanical extrusions which have ability to fuse or destabilize the bacterial, viral or lipids envelopes, disrupt the pathogens. For example, clinical pathogens such as *Bacillus cereus*, *Streptococcus pneumoniae*, and *Haemophilus influenzae* and food borne pathogens such as *Listeria monocytogenes*, and *Staphylococcus aureus* have been documented to remove through nanoemulsion method [19]. Nanoemuslion technique is also effective to kill the *Escherichia coli* from food within 5 mints by reducing only 1-log in essential oils and amplifying the antimicrobial activity of oils [20]. These droplets also have ability to bind with active components of biological membrane and have low turbidity and kinetic stability. For example, the bioavailability of lipophilic compounds such as carotenoids in the gastrointestinal track has been increased through nanoemulsion which produce in the lipid digestion process.

Importantly, the carotenoids especially β-carotenoids have potential to fight against cancer and ability to improve age and cardiovascular related diseases. The bioactive component of these lipophilic compounds are homogenized in oil phase with water-soluble emulsifier to enhance its bio-accessibility [21,22]. Several others lipophilic compounds such as flavonoids, omega-3 fatty acids, phytosterols, tocopherols and polyphenols are used to fortify foods [23].

Nano-tubes

Nanotubes are the nanometer-scale wire-like structure which have ability to enhance the mechanical properties of materials by its tensile strength and elastic properties [24]. The available nanotubes are boron nitride nanotubes, carbon based nanotubes (CNT), alumina nanotubes, and rutile nanotubes. CNT is the most frequently used nanotubes which is hollow cylindrical lattice of carbon molecules, having diameter of few nanometers and length of several millimeters. They are present in two main types which are multi-walled nanotubes (MWNTs) and single-walled nanotubes (SWNTs) [25]. CNTs have the extraordinary physical, chemical and mechanical properties and its small addition improves significant performance of materials. Its polymers are used for multiple aspects including stiffness, tensile strength, thermal and chemical stability, toughness and electrical conductivity [26]. Concentric and graphitic carbon layer of CNT can be synthesized by catalytic combustion, carbon arcs, ion bombardment, catalytic combustion, laser vaporization, and chemical vapor deposition [27].

Solid phase extraction (SPE) is a recent technique for the removal of heavy metals from foods samples. For SPE of metals, CNTs are used which have the properties of wide pH and surface area range, easily and repeatedly use and fast in quantitative adsorption. The CNTs are prepared by coating with ligands which have chelating properties. The TAR [4-(2-thiazolylazo) resorcinol] has been used as chelating agent on the surface of CNTs to effectively remove Pb, Cd, Zn and Ni from the food samples [28]. These CNTs can also be used as polymer coating in food processing units [26].

Additionally, CNTs are used to remove toxins from the food such as antibodies produced by *Staphylococcal enterotoxins* (SEs). The toxins produced by groups of SEs cause food borne diseases and have severe gastrointestinal symptoms including nausea, vomiting, anorexia, and diarrhea. The CNTs are prepared with coating of specific antibody adsorbents and then spread over the surface of food. The wide surface area of CNTs binds the toxins produced by harmful microbes, which can be detected by immunosensors [25]. They are also used in microfluidic devices to detect the water soluble vanilla flavors, antioxidants, vitamins, and isoflavones [29]. Studies showed that the milk protein such as hydrolyzed α-lactalbumin make nanotubes by assembling their structural formation **(Figure 3)**. The α-lactalbumin is the milk protein and highly enriched in human milk. It plays crucial roles to synthetize lactose and tryptophan contents. It has ability for self-assembling and makes long micrometers nanotubes [30]. This activity can be performed with other protein too,

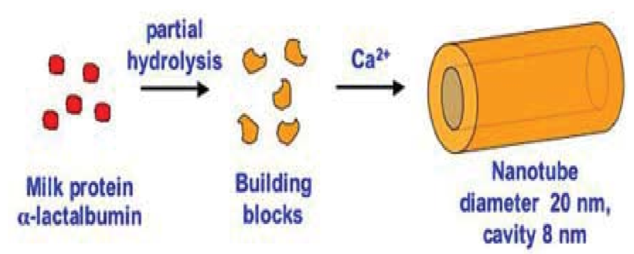

Figure 3 Formation of nanotubes in milk by alpha-lactalbumin [31].

but in appropriate and suitable conditions. This α-lactalbumin nanotube technique is applicable to bind the enzymes or to build the muscle fibers [31].

Nanocapsule

Number of technique are developed using nanotechnology to provide the nutrients to its proper target site. Encapsulation of the nutrients and delivery of the proper targeted tissue, enhance the flavoring characteristics and stimulate the organoleptic properties of the food product. In the nano-capsulation technique, tiny substances are encapsulated in food at nanoscale range [32]. These micro substances are in capsules form having diameter of 3 to 800µm [33]. These capsules are in vesicular forms, formed by the process of encapsulation in which small core, bioactive materials are packed within the cavity. The walls of cavity are formed with biopolymer materials. This technique is used to prevent the direct application of bioactive substance including antioxidants, polyphenols, micronutrients, nutraceuticals, and enzymes in adverse environment. These nanocapsule materials have potential to slow and control release near to target point and enhance bioavailability [34].

Nanocapsules are applied as carriers in the food systems and are formed by using biodegradable materials such as gelatin, anoliposomes, α-lactalbumin, archaeosomes, and nanocochleates, albumin, collagen, alginate, and chitosan. Different techniques have been adopted to form these nanocarriers such as nanoprecipitation, emulsification, emulsification-solvent evaporation, inclusion complexation, coacervation, spray and freeze drying. These techniques are used on the bases of two approaches as top-down or bottom-up approaches. In top-down approach, the precious tools are used to reduce the size of nanomaterials and shaping their structure according to the development but in bottom-up approach, self-assembling and self-organizing materials are used and their mechanisms are changed by altering pH, temperature, concentration, and ionic strengths [35].

The nanocapsules have wide range application in cosmetic and dermatology. In food these nanocarriers are used as flavoring agent, stabilizing agents, and controlling food pathogens. Food flavors are mostly volatile in nature and their aromatic compounds are changed with changing in oxidation and chemical interactions and heating. Encapsulation prevents the volatilization of the aromatic compounds and entraps their flavors. Cyclodextrins are the sugar compounds which provide inner and outer hydrophobic and hydrophilic surfaces to fit the nanomaterial in suitable dimensions [36]. Nisin are bacteriocins which have the heat stable peptide structure. It disrupts the membrane function of food pathogens and reduce microbial activities. In nano-capsulation this nisin like materials are encapsulate with macromolecules as proteins to pose the antimicrobial activities [37].

Casein is the principle protein present in the milk. Casein micelles play a vital role as natural nano-capsular vesicle for nutraceutical. These casein micelles are important because they are biological active and have good digestibility. Casein micelles are very stable during most of the process and never lose their structure [38]. This approach is generally adopted to provide the nutrients and their bioavailability at proper action site. For example, casein micelles are responsible for delivery of nutrients such as calcium phosphate and protein [39].

Food fortification and nanotechnology

Recently, fortification becomes a mandatory method to successfully improve the inadequate nutrients concentration, associated deficiencies, and nutrients short falls in staple food for improving the human health [40]. In fortification, the specific nutrient or non-nutrient concentrations are increased in edible portion to enhance nutrient intakes and to improve public health. Human requires 44 types of nutrients in adequate quantity which are fulfilled by adopting various industrial and agricultural practices. Three main staple foods i.e., wheat, rice and maize are primarily focused crops to feed the poor population of the world but advancement in green technology reduce the quality of food in respect to nutrients. Fortification is the main technique of green biotechnology to enhance the bioavailability of essential nutrients and provide suitable strategy with no extra cost or investment in nutrients maintenance [41].

Nonratification method has been used to overcome the Fe, Zn, vitamins, and proteins deficiencies. Because approximately 1.2 billion people of the world are suffering from Fe deficiency and to overcome this problem hybrid material are prepared by fixing the Fe nanoparticles with fibers of edible portion [42]. Many food industries are trying to increase the nutritional value of food product by fortification of nutrients. Encapsulation methods, boosting the flavoring properties of the product and reducing the fat level and improve the mouth feel of the product, are now done by the nano-modification in the food products. Nano-techniques are used in the processing of the junk food item, for lowering the fat and sugar content in the junk food or made such modification in the junk food which reduce the absorption of the fat and sugar contents in the body. So, the body will not absorb or consume too much calories from food and eventually no or less harmful effects on health. Food can be fortified by the fibers and vitamin. Reduction in fat and sugar contents will reduce the consumption of calories, which can help to those who want to reduce their body weight [43,44].

Nano-ceuticals

Nano-ceuticals are nanosized nutrients, have ability of uniform absorption and directly pass through membranes. They are actually bioactive ingredients and slowly release at target site, mostly applied to cure diseases. They are used as bioactive compounds in nanoemulsion technique and are classified into two classes as lipophilic and hydrophilic nutraceuticals on the basis of their dissolution rate. Lipophilic nutraceuticals are insoluble in water but soluble in lipids. Hydrophilic nutraceuticals are soluble in water, so their dissolution rate is higher than lipophilic but are less permeable. They are alternatively used in nanocapsules to prepare external wall and as nanocarriers in nanoemulsion techniques [35,45].

Nanoceuticals are one of the recently emerging trends becoming very popular in many type of supplements. Nanoparticles are added for better availability of the nutrients [45].

There are few example products related to the nanoceuticals:

1. Carotenoids nanoparticles, which are dispersed in water and added to the juice product to improve their bioavailability.
2. Canola oil based nano sized micelles are considered to provide the nutrients to the body such as vitamins and minerals.
3. Chinese nano-tea (nano-based supplement) which stimulates or improves the selenium uptake [8].

Nanotechnology In Food Packaging

Food packaging is one of the most important factor which influence the quality of the food product for a longer period of time and has a very wide commercial application in the food industries [46]. Many different techniques are used to developed innovative packaging materials for food products. Waxy nano-coating, antimicrobial property, mechanical barrier and carbon tubes and films are used commonly to produce nano-based food packaging for food items.

The primary purpose of the packaging is to provide the protection against hazards associated with food safety (i.e., physical, chemical and biological hazards) and to improve or enhance the shelf life of the food inside the packaging materials. Now, food industries are investing more than past few decades in packaging of food. Statistical analysis shows nano-based nano-packaging produced over $860 million in sales throughout the globe in 2006. However, it was estimated to be a $30 billion market within the next 10 years [47]. Different types of innovative packaging based on nanotechnology are explained below.

Smart packaging

Smart packaging is the type of packaging used to indicate the internal condition of the product such as the shelf life of the product. Nano-sensors are placed on the packaging material of the food product. The sensors sense the conditions and properties of the product and express the results in the form of different types of signals. The sensor expresses the condition of the barrier and properties of the materials (permeability of gasses i.e., oxygen). It also detects the microbial load in the food product and explains about the shelf life of the product. Nano-sensors are good for the consumer for judging the properties of the product and satisfied their needs [48].

Active packaging

There are several active packaging systems which are commercially available **(Table 2)** [48]. In active packaging a unique system is used to modify the environmental or surrounding conditions for extending shelf life and improving food safety. For example, a very common type of activity is performed to control the oxidation of food products by creating the oxygen free storage condition. Synthetic antioxidant is widely used in food manufacturing processes (e.g. BHT and BHA common example of antioxidants) [49].

Antimicrobial packaging

The food manufactures have been facing a number of challenges related to the food safety. Food safety means food will not cause

Table 2 Currently available active packaging systems (modified from [48]).

Type	Trade name	Principle	Manufacturer
Antimicrobial packing	Agion®	Silver based	Life Materials Technology Limited, USA
Antimicrobial packing	Biomaster®	Silver based	Addmaster Limited, USA
Ethylene scavenger	Evert-Fresh	Activated zeolites	Evert-Fresh Corporation, USA
Ethylene scavenger	Neupalon	Activated carbon	Sekisui Jushi Ltd., Japan
Ethylene scavenger	Peakfresh	Activated clay	Peakfresh Products Ltd., Australia
Heat Resistance	PLA	Lactic acid based	NatureWorks LLC, USA
Heat Resistance	POSS®	Silicon based	Hybrid Plastics Inc, USA
Interleavers	SANICO®	Antifungal coating	Laboratories STANDA, France
Moisture absorber	Dri-Loc®	Absorbent pad	Sealed Air Corporation, USA
Moisture absorber	Tenderpac®	Dual compartment system	SEALPAC, Germany
Oxygen scavenger	Ageless	Iron based	Mitsubishi Gas Chemical Co. Ltd., Japan
Oxygen scavenger	Bioka	Enzyme based	Bioka Ltd., Finland
Oxygen scavenger	Freshilizer	Iron based	Toppan Printing Co. Ltd., Japan
Oxygen scavenger	Freshmax, Freshpax, Fresh Pack	Iron based	Multisorb Technologies, USA
Oxygen scavenger	Oxyguard	Iron based	Toyo Seikan Kaisha Ltd., Japan
Oxygen scavenger	Zero2	Photosensitive dye	Food Science Australia, Australia

any harm to human health when it is consumed according to its intended use. Many microbial agents (i.e., bacteria) can cause food spoiling when they have perfect conditions to reproduce. Nano-technology has helped in many ways to keep the microbial agents in food at acceptable level [18,48]. In the antimicrobial packaging, the antimicrobial agents are used in order to control the food spoiling microbes in food items. Various forms of silver nano-particles are used in large amounts and have the capability to control a large range of microbes. *E. coli* is commonly found in contaminated water and can contaminate the product in which water (containing *E. coli*) is used as ingredient. *E. coli* can be controlled by the application of the titanium dioxide coating on the packaging material [10].

Barrier protection

The barrier protection is done by modifying the packaging material of the products. Food spoilage can be delayed or reduced by inhibiting the gasses exchange through the packaging material and making the material more permeable to the gasses in the surrounding of the packed products. The nano-clays, which are composite material, have very complex metallic ores. This material is a good type of barrier against the gasses. Many polymers based clays are also prepared from nylon, polyethylene (PET) and poly-methane, and are used for the poly-matrix in the packaging of food materials. Many other types of materials are also used for barrier in packaging such as silicon dioxide and aluminum based clays [50].

Biodegradable packaging

Biodegradable packaging is a need of present as well as future. Because, non-biodegradable packaging has a major issue of disposal. In fact, industries have to spend huge amount of their earnings on the disposal of such non-biodegradable materials. These non-biodegradable materials accumulate in the soil and cause environmental pollution, toxicity, and global warming. Therefore, biodegradable type of packaging materials is introduced and considered the most suitable packaging material due to their renewable nature [51,52]. Biodegradable packaging can be synthesized using the material having degradable properties. For example, protein, carbohydrates, and nano-oxide metal particles can be used for biodegradable packaging along with the nano-clays [53].

Conclusions and Future Prospects

Nanotechnology and its outstanding techniques are the future of food processing industry. In food processing, nano-techniques bring many unique ideas such as encapsulation mechanism and fortifications of healthy nutrients, which made the food better for consumption. The packaging of the food product is also very emerging technology related to the nano-technological concept. Different types of packaging based on nanotechnology have important implications in food industries and resolve many challenges of food industries such as replacement of non-degradable packaging material with bio-degradable packaging material. Additionally, through advances in smart packaging, antigen-specific markers will assist to find and isolate the microbe responsible for food spoilage. Nanotechnology through betterment in food packaging can also address the food shortage crises by assuring safe food supply to the food affected regions. Advancements in nanotechnology will further contribute in detection of toxic chemicals (e.g., pesticides and other toxins) in food tracking-tracing-monitoring chain. Food manufactures should adopt these nano-techniques in food production, processing and packaging for further improving the quality of the end product. However, before applying any new nanosystem in food industry one should keep in mind that the new applied nanosystem must be eco-friendly and provide no or minimum toxic impact to the consumers of the product.

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