Food preservation methods and use of nanomaterials as a preservative

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Abstract

Food products may become spoiled as a result of microbiological, enzymatic, or chemical activities from the food itself as well as the surroundings. Meanwhile, the recent increase in global population necessitates the storage and transportation of food products from one location to another. Food products will begin to degrade, lose their shape, and lose nutritional content during delivery. Nowadays, a variety of methods for food preservation are used all over the world. Food deterioration can be prevented by the use of food preservation techniques such as conventional and advanced methods, food preservatives, and nanomaterials, which are also advantageous for maintaining the nutritional profiles of foods. Individual methods emphasis one or more of the primary causes of food waste, such as microbial growth, enzymatic activity, chemical reaction, and physical damage. As a result, the preservation procedures greatly influence the required process conditions. Heat transfer, moisture removal, and the avoidance of enzymatic and chemical reactions are a few examples techniques based on basic physical phenomena that are used to accomplish many sorts of preservation strategies. In this review, a variety of typical food preservation methods have been covered.

Introduction

A basic definition of food processing is the preservation of food by the use of methods to a form that is consumable. It is crucial to remember that the food quality and flavor should not be compromised and should be preserved using whatever methods are used (1). Processed meals now contain micronutrients, a feature that has been shown to satisfy many consumers, as the development of healthy foods is now a crucial consideration in addition to the preservation of fresh foods (2). Agricultural produce is handled and treated during the food preservation process in order to minimize loss and maximize shelf life. Additionally, preservation slows or prevents the growth of microorganisms that cause food to lose its nutritional content, quality, and palatability (3). Since ancient times, it has been difficult to preserve agricultural goods because microbial deterioration and pest contamination result in significant food losses during preservation, transit, and marketing. Fruits and vegetables are among the most perishable food products, with postharvest losses that can range from 35% to 40% and depend on the crop (4). Food's primary and most important ingredient is water. Dried food products' flavor, texture, microbiological development, and fat oxidation are all impacted (5). Dehydration is the oldest and most widely used food processing method for improving food stability by lowering water activity and microbial deterioration of the foods. It also minimizes the produce's physicochemical changes (6). According to the method used to remove the water, dehydration can be divided into three categories: mechanical dewatering, thermal drying, and osmotic drying (7). Even if numerous preservation techniques have been developed thus far for fruits and vegetables preservation, the bulk of them are successful for processed food products, there is still a potential for more efficient, state-of-the-art, and environmental friendly approaches (6). But there are a number of cutting-edge methods being utilized to preserve agricultural products, including high-pressure processing, irradiation, and plasma technology (8). A chemical technique of preservation was also investigated as an option, but using too many chemicals while processing and storing agricultural products could cause a number of consumer health issues, which could reduce customer acceptance and export (9).

Nanotechnology is a remarkable advancement that has the potential to significantly increase sustainability. It integrates several branches of applied science, including as physics, biology, food technology, environmental engineering, medicine, and materials processing. Nanotechnology, put simply, is the use of any substance or nanoparticle with one or more dimensions of the order of 100 nm or less (10). The technology is favored because it has a variety of characteristics, including gradual release action, target specificity, precise action on active areas, and high surface area (11). Nanotechnology's success can be attributed to its promising outcomes, lack of pollutant emission, energy efficiency, and little space needs. In addition to these success elements, nanotechnology has demonstrated a wide range of applications for risk assessment in the domains of agriculture, food, and the environment (12). Nanotechnology is thought to hold great promise for future economic growth, as well as for preserving the nutritional value and plant growth of food commodities. Food processing, agriculture, and packaging are the three main areas where the technology could advance (13). Nanomaterials are widely utilized against numerous pathogenic bacteria and in healthcare, crop protection, water treatment, food safety, and food preservation due to their outstanding physiochemical nature and antimicrobial capability (14). Additionally, the food sector is using nanostructured materials (NSMs) as a new type of packaging material, a nanosensor, and an encapsulated food ingredient (15). A vast range of food-related applications exist for nanotechnology. These applications involve the incorporation of a certain kind of nanomaterial into a particular food product in order to give that food product the desired qualities (16). This review paper's objective is to concentrate on two key areas: (a) food preservation techniques to preserve or ensure food quality and the use of food preservatives; (b) the application of nanomaterials to food preservation.

Methodology

A preservation-related review paper has been developed by philanthropist researchers' works and their renowned articles. To collect the research work, authors have searched for three-dimensional papers on Food preservation, role of preservatives and aid of nanomaterials in preservation. The information outlined in this review has been accumulated from over eighty works. All the works were extensively reviewed by the authors as group work and they decided to write up such a paper. This review paper tried to establish the benefits of methods used in food preservation among the people worldwide.

Food preservation methods

We are trying to preserve foods since ancient times. When the food is being preserved, actually microorganisms' growth rate is being reduced (17). The aims of preservation of food are to maintain its texture, taste, quality, flavor; to reduce food waste; to increase food availability; to transport food before it spoils (18). There are many conventional as well as modern technologies to preserve food. As the time passed conventional methods have been revolutionized to provide benefit to food industries. Some of the examples of food preservation methods are as follows (Figure no 1).

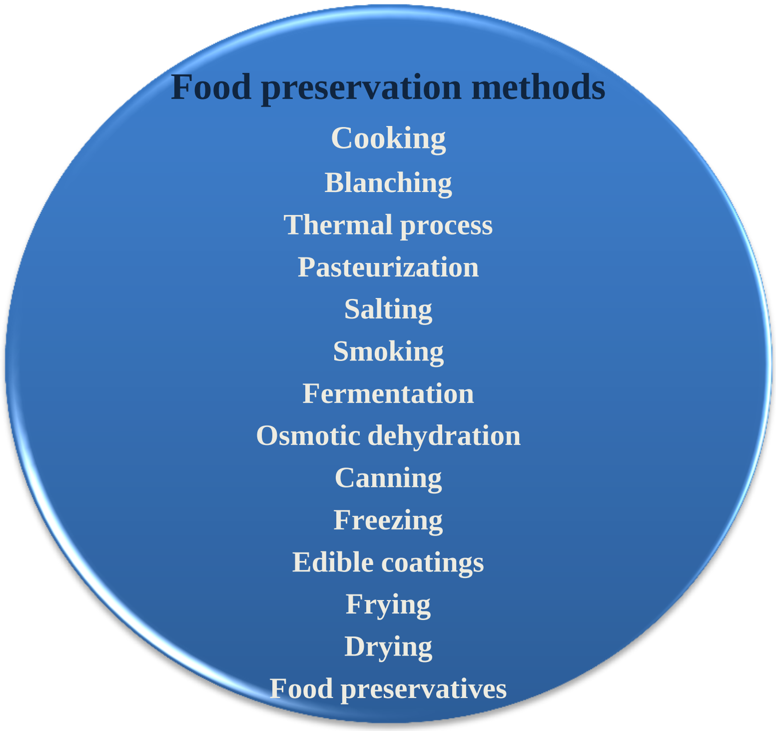

Figure:1 Food preservative methods

Cooking

As spices and herbs are commonly used to flavor and aromatize meat products, they are now increasingly acknowledged as one of the factors that increase food safety and maintain its quality (19). In addition, cooking enhances the flavor of the food. For instance, raw flour or sour apples have an unpleasant flavor, but when they are turned into bread or stewed with sugar, their flavors are substantially improved (20). The attraction of food might be proportionately increased by cooking. Depending on the methods used to heat the food, there are several ways to complete the cooking process (21). No known human foragers have been found to live without cooking, and those who adopt a "raw-foodist" lifestyle report feeling sluggish and having trouble becoming pregnant. This implies that humans may be forced to cook. Calculations implying that a diet of raw food could not provide enough calories for a typical hunter-gatherer lifestyle support the hypothesis that cooking is required. For example, most raw meat appears to be too rough to allow for easy chewing, and many plant foods are too fiber-rich when in raw form (22).

Blanching

Prior to freezing, canning, or drying, fruits or vegetables are boiled to inactivate enzymes, change texture, maintain color, flavor, and nutritional content, and release trapped air. This process is known as blanching. The most popular heating methods for blanching in industry are hot water and steam, however, microwave and hot gas blanching have also been investigated. To enhance product quality, boost yield, and make it easier to process products with various thermal properties and geometries, several hot water and steam blanchers have been developed (21). The purpose of blanching as a vegetable preparation for canning is to remove tissue gases, shrink the material to allow for proper fills, and heat the material before filling to ensure that a vacuum is created during heat processing and boiling. Blanching is required as part of the freeze preservation procedure to deactivate the tissues' enzymes and shrink the material in order to save packaging space (23). Many fruits and vegetables must be thermally blanched before being processed. It not only influences other product quality characteristics but also the inactivation of polyphenol oxidase (PPO) and peroxidase (POD). Blanching serves a number of goals, such as deactivating enzymes, speeding up the drying process and improving product quality, eliminating hazardous pesticide residues, evacuating air from plant tissues, and reducing microbial load (24)

Thermal or heating processing

Thermal processing is that process which is mostly used to preserve fruits. It is a technology which is used to increase the shelf life of fruits and vegetables (25). It happens by decreasing the microbial growth and activity of natural enzymes (26). This method has been widely used for the preparation of canned foods and bottled fruits and vegetables (25). Canned foods are prepared under commercial sterilization therefore can be used upto 2 years or more. Thermal processing involves the heating of unsterilized food in containers as used in canning or the food can also be heated before packaging. This method is also used in pasteurization of milk (26).

Pasteurization

Pasteurization is a process that involves heating food—more specifically, liquids—to a specific temperature in order to inhibit microbial development. In emerging nations, milk and fruit juices are typically pasteurized (21). The process of pasteurization includes heating of food products. The type of food and the pathogen that needs to be destroyed determine the temperature and duration of heating. The heating procedure destroys potentially hazardous microorganisms (pathogens) and enzyme activity that could otherwise degrade food or change its sensory properties over time. Consequently, this procedure can increase the food's shelf life by a few days or weeks. (27). The practice of heating liquids is relatively new, at least in terms of the documentation. In 1782, the Swedish researcher Scheele utilized heat to preserve vinegar. Before giving milk to newborns, William Dewees, a professor of obstetrics at the University of Pennsylvania, advised heating it to just below boiling point and then cooling it. Even at the beginning of the 19th century, people knew that heating milk had health benefits. Without a doubt, housewives had turned to boiling or preparing milk from forages, as similar customs still persist in places where pasteurized milk is not readily available (28).

Salting

Salting is the most popular technique used in food preservation worldwide. In this process salts are used to cure meat products and other food commodities. Salt cured meat is the famous processed product which is available in almost all of the developing countries due to its low cost and easy processing (29). Large quantity of vegetables is also preserved in this way. Preserved cabbages are available on large scale and can be easily purchased through stores. By using salting process we can stop the activity of microorganisms present in food commodity because of the hypertonic nature of salt. After adding salt to product, activity of large number of bacteria and fungi stops and they cannot survive in food product at the end they will die through salting process. Through salting method osmosis process is generated in foods, by which all the living cells become inactivate and die (30). Salting techniques are most commonly used for fish and meat. In salting process fish and meat are arranged in such a way that salt enters into the flesh easily and moisture could leave the meat or fish product. Meat or fish is rubbed on dry salt in dry salting process whereas in wet salting process meat or fish is rubbed on dry salt and packed in brine solution (21).

Smoking

Smoking is the technique in which food is cooked on a smoke produced by burning of wood. It also enhances the flavor of food. This is the oldest method of preservation for meat and fish. Most commonly used in almost all of the developing countries. Large number of people uses this technique by cooking meat easily on smoke to enhance flavor and increase shelf life of meat (31). Major advantages of smoking process are flavor enhancement, antioxidation and preservation of meat. Smoking is a an antimicrobial process in which most of bacteria are killed. Heat involves in smoking process also helps in cooking foods. Smoked products have long shelf lives but smoking is insufficient for curing meat products because smoke does not completely penetrate into foods therefore products are prepared by combined effects of bacteria destruction, drying and cooling (32).

Fermentation

One of the earliest methods of food preservation is fermentation. It has changed, improved, and varied throughout time. Today, this technology is used to create a wide range of food products in homes, small-scale food businesses, and major corporations. Additionally, fermentation is a cost-effective method of food preservation that is significant economically for underdeveloped nations (33). In food processing technique known as fermentation, carbohydrates are transformed into alcohol or organic acids utilizing yeasts or bacteria under anaerobic conditions (34). During this stage, both the naturally occurring sugar found in raw meals and the added sugars are transformed into acid. All of the other qualities, including flavor and texture, are created by the action of lactic acid bacteria. Products can be stored in this way all year round (35). Fermented foods are incredibly popular all around the world as tasty, healthy, and nourishing parts of our diets. They use a wide range of components and production methods to create them on a massive scale. The consumer's safety is still of the highest concern, whether they are using high-tech items created from genetically modified organisms or conventional home-cooked foods (36). Although mycotoxins in fermented cereal meals and outbreaks of disease brought on by pathogens in soft cheeses and fermented meats have gravely harmed the reputation of fermented foods as being safe, this reputation has previously been shared by the general public. Additionally, consumers have expressed safety concerns regarding modern genetic engineering and biotechnology techniques, which present significant prospects for the manufacture of fermented foods (37).

Osmotic dehydration

Osmotic dehydration is now more widely recognized as an effective method for preserving fruits and vegetables. The few examples of foods that are typically maintained through osmotic dehydration in developing nations are bananas, pineapple, mango, and leafy greens. Fresh features of fruits and vegetables, including color, flavor, and nutritional components, are efficiently preserved during osmotic dehydration (38). Fruits and vegetables are osmotically dehydrated by soaking them, whole or in fragments, in a hypertonic solution (sugar or salt) while simultaneously allowing solutes from the osmotic solution to diffuse back into the tissues (39). Osmotic dehydration is suggested as a processing technique to produce food items of higher quality. The source material's structural, nutritional, sensory, and other useful features can be changed through partial dehydration. However, due to a lack of knowledge of the connected counter current flow phenomenon, the food industry's use of osmotic dehydration of foods has not been as widespread as expected (40). Osmosis is a physical phenomenon that has been thoroughly investigated in a number of scientific and engineering fields. Fruits and vegetables can benefit from osmotic dehydration in many different ways. As a result, it can be utilized to reduce post-harvest losses. Being a relatively easy process, it enables you to process fruits and vegetables while maintaining the original fruit's color, aroma, texture, and nutritional profile. It has no negative effects on the human body because no preservative was employed. This procedure could be utilized on a small scale to build home-based businesses and industries (41).

Canning

Providing meals in cans that are both highly nutritive and microbiologically safe is the basic aim of the canning industry. Nicolas Apert wrote the first description of food preservation in hermetically sealed containers in 1810 (42). Food packed in metal containers is usually sterilised commercially using saturated steam. Steam condenses on the containers' surfaces during the heating process, producing high values of surface thermal conductivity. As a result, the heating medium quickly transfers heat through the container wall to the food's exterior layer. Foods processed with water as the heating medium are typically stored in glass containers (43). Although many people contributed to the early growth of the canning industry, Nicolas Appert, a Frenchman, is usually recognised as the canning art's original inventor and as the source of the industry's fundamental techniques (44). First, the raw materials must be properly prepared because some foods, like fish, contain harmful microorganisms like Clostridium botulinum. All foods must not be cooked uniformly during the canning process (45).

Freezing

Food deterioration is determined by physical and biochemical mechanisms, which slows down by freezing foods but does not completely stop. When handled and prepared appropriately, frozen meals are frequently regarded as having better sensory and nutritional properties than foods stored in other ways. These characteristics depend on the ability to carefully regulate the freezing process, prepare the product before freezing, and store it after freezing (46). New technologies are energy-efficient and enhance the quality of frozen and thawed products. Pulsed electric field pre-treatment, ultra-low temperature, ultra-rapid freezing, ultra-high pressure, and ultrasound are some of the unique technologies used in freezing. Ultra-high pressure, ultrasound, high voltage electrostatic field (HVEF), and radio frequency are some of the unique technologies used in the thawing process. Small ice crystals are formed and distributed uniformly throughout frozen items when the temperature is extremely low and the freezing process is relatively fast. Non-thermal technologies that reduce the time needed to freeze and enhance product quality include ultra-high pressure and ultrasonic assisted freezing (47). Food items' quality is preserved through freezing over a long duration of time. In comparison to canning and dehydration, freezing is typically regarded as the best method of long-term food preservation (48).

Edible coatings

The biggest problem a food producer faces is the quality of food goods diminishing during storage, which ultimately increases waste. By preventing microbiological spoilage and offering moisture and gas barrier qualities, edible packaging is recognised as a potential substitute for preserving food quality and extending shelf life. Technology and advancements in edible packaging have showed promise in extending the shelf life of food stuffs (49). Hydrocolloids, or water-soluble gums, are utilised in a variety of products as thickeners, stabilizer, coating agents, texture modifiers, packing films, and emulsifiers. The main purposes of edible coatings are to improve the appearance of food products and increase the fruit's shelf life. Natural gums like alginate, chitosan, xanthan, tragacanth, mesquite, gellan, psyllium, guar, basil seed and arabic gums have the potential to be used in the formulation of edible coatings and to improve their qualities, according to a number of studies (50). In order to enhance the mechanical barrier, antioxidant, and antibacterial properties of polysaccharides edible coatings, plant extracts, essential oils, phenolic compounds, and vitamins can be added. Gums are superior to synthetic polymers in many ways since they have been recognized as GRAS by FAO and are safe for human consumption (51).

Frying

One of the popular and affordable methods of food preservation is frying (52). Foods, such as fruits and vegetables, have a longer shelf life when they are fried, and the flavors are also enhanced. On the other hand, using the wrong frying oil could be harmful to the health of the consumers (53). One of the most often used techniques for processing of food is deep-fat frying. Heat and mass are transferred simultaneously when being heated to a high temperature. Standard fried foods typically have a bright color, a crisp texture, and a wonderful flavor. In reality, fried meals are unhealthy because they are high in oil, calories, and acrylamide. Innovative frying technologies must be created in order to limit oil absorption during the frying process and produce healthier fried foods with less oil (54). Fried meals are the main option in our diets today and are favored by customers of all ages because of their distinctive organoleptic qualities, which include flavor, color, texture, and scent. A number of chemical and physical changes occur during the frying process, including the gelatinization of starches, denaturation of proteins, water evaporation, and the development of crispy fried crust. It can eliminate bacteria, deactivate enzymes, and lessen food's capacity to retain water (55).

Drying

One of the ancient, perhaps the oldest methods of food preservation is drying. As a result, it remains one of the most popular methods of food preservation, being used in underdeveloped nations all over the world (21). The oldest way of food preservation may be drying food. Numerous food products are now dried commercially using traditional drying techniques. There are benefits and drawbacks to various drying techniques. Valuable commodities have been preserved through both natural and artificial means. The main issue with drying using an artificial drier is that, despite taking less time than a natural technique, it uses a lot of energy. For a variety of food products, drying kinetics has been explored to anticipate drying time and variables (56). To address the demands of energy-efficient consumption and high-quality dehydrated products, numerous unique dryers have been developed. Innovative dryers eliminate or recycle waste heat during thermal drying to minimize energy use and environmental effect. Some energy-saving methods for modifying the drying process have been researched. When compared to a standard dryer, the use of a drying rate adjusted system, for instance, can increase energy resilience. Other examples are heat-integrated adsorption dryers (which use around 55% less energy than a typical dryer without an adsorption process), controllability and customization of conventional convective dryers, and chemical heat pump-assisted convective dryers (57).

Food Preservatives

Food additives are compounds, either natural or manufactured, that can be added in trace amounts to food to serve technological purposes, such as adding color or sweetness or extending shelf life (Figure no 1). Even though some of these chemicals are safe when used in low amounts (like the permitted limits), using others poses dangers to human health (58). Some food additives, including salt in meats like bacon or dried fish, sulphur dioxide in wine, or sugar in marmalade, have been used for food preservation for decades. Food additives can also be employed to give foods a particular functional quality (59). Additives are necessary to keep processed foods safe, in good shape, and fresh throughout their route from factories or industries to stores and warehouses, and then to consumers, who frequently seek for foods that are fresh, safe, nutritious, and healthy (58). Food additives are employed increasingly worldwide due to the rise in the consumption of processed foods since the 19th century. The use of food additives is regulated in numerous nations. From the 1870s to 1920s, boric acid was widely used as a food preservative, but it was restricted after World War I due to its toxicity, which was shown in both animal and human research. They were once again used during World War II due to a desperate need for readily available, inexpensive food additives, mostly preservatives, but were eventually forbidden in the 1950s (60).

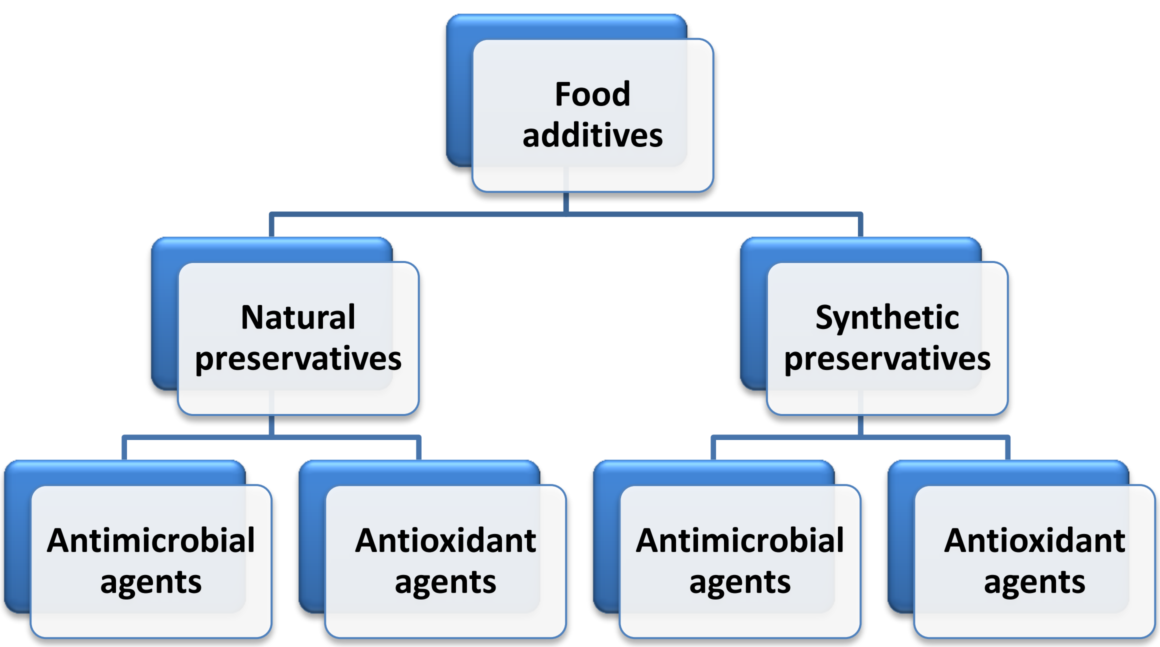

Figure 2 Food additives

Nanotechnology in food preservation

Nanotechnology creates and uses materials with novel qualities by working with atoms, molecules, or macromolecules that are between 1 and 100 nm in size. The developed nanomaterials had one or more outward dimensions or an internal structure on a size ranging from one to one hundred nanometers, which enabled the study and control of matter at the nanoscale. Due to their high surface to volume ratio and other unusual physio-chemical features, including as colour, solubility, strength, diffusivity, toxicity, magnetic, optical, and thermodynamic, it has been found that these materials are distinct from their macroscale counterparts (61). Better packaging materials with improved mechanical strength, barrier properties, antimicrobial films, and nanosensing for pathogen detection and alerting consumers to the safety status of food are just a few of the advantages that nano-based "smart" and "active" food packaging have over conventional packaging methods (62). In addition to delivering flavors, colors, antioxidants, enzymes, and anti-browning agents, edible nano-coatings on a variety of food components may operate as a barrier to moisture and gas exchange and extend the shelf life of produced meals even after the packaging has been opened (63). Using this method, it is possible to conserve bioactive substances including vitamins, antioxidants, proteins, and carbohydrates while producing functional foods with improved functionality and stability (64). The most prevalent category of contemporary nanotechnology applications for the food industry is materials used in food packaging (65). Using an interface agent, the emulsification technique enables the blending of two liquids that are often immiscible (surfactant). Through the formation of droplets (dispersed phase), which remain dispersed into a continuous phase, this method enables the incorporation of a lipid into an aqueous medium or vice versa (67). The solvent displacement technique is another name for nanoprecipitation. It is based on the spontaneous emulsification of the organic internal phase into the aqueous external phase, which contains the medication, dissolved polymer, and organic solvent. A polymer is precipitated from an organic solution using the nanoprecipitation process, and the organic solvent is diffused into the water (67). The bioactive component and the polymer were solubilized in a supercritical fluid and the solution was expanded through a nozzle in the supercritical antisolvent precipitation process. After that, the supercritical fluid evaporated during the spraying operation, resulting in the eventual precipitation of solute particles (68). As building blocks for nanostructures, many materials such as nanoliposomes, nanoemulsions, nanoparticles, and nanofibers can be used. Both inorganic and organic materials are used in the production of nanomaterials for food applications (64). Typically, lipid, protein, or carbohydrate-based nanocarrier systems are used. Due to the need for complex chemical or heat treatments, nanocapsules based on carbohydrates and proteins cannot be fully scaled up. However, lipid-based nanocarriers are more advantageous due to their higher encapsulation efficiency and lower toxicity, as well as the possibility of industrial production (69).

Several guidelines on the potential dangers to human health linked with the use of nanostructure materials in food have been released by regulatory bodies throughout the United States, including the Directorate of European Health and Consumer Protection, FDA, and EPA (70). Nanotoxicology, a subfield of toxicology and an interdisciplinary field that examines various toxicity features of nanomaterials, is used by nanoscientists to assess these possible threats (71). One important mechanism thought to be responsible for subsequent human oxidative stress is nanotoxicity, which is mediated by the production of reactive oxygen species (ROS) (72). Additionally, there is a great deal of interest in employing nanomaterials in many different disciplines, despite some safety issues. As a result, there is an urgent need to address these problems in order to increase our understanding of the biocompatibility, safety, and toxicity of the usage of nanomaterials and nanostructures in the food industry (70).

Preservation techniques and recent preserved foods

By using variety of food processing techniques we can keep food quality at level required and maximize its nutritional value. Food preservation methods include growing, harvesting, processing, packaging, and distributing food (73). In the 20th century, a variety of techniques for food preservation were developed. There are many different types of these cutting-edge technologies, such as physical ones like high hydrostatic pressure and high-pressure homogenization, electromagnetic ones like pulsed electric fields, ohmic heating, microwaves, radio waves, and UV light, and others like membrane technology and compact phase CO2 (74). Because of the rise in consumer desire for easy-to-eat foods with excellent nutritional content, scent, and natural flavor, consumers now place a high value on how comparable minimally processed goods are to fresh foods (75). Some of the recently preserved foods and technologies used are given in Table no 1.

Table1. Recently Application food preservation techniques

Foods	*Preservation Techniques*	*References*
Fish	gelatin–chitosan films incorporated with essential oils	76
Fish	Chitosan coating incorporated with the lactoperoxidase system	77
Fruit salad	Nanocomposite based on (laser ablation synthesis in solution) LASiS-generated CuNPs as a preservation system	78
Fruit	Encapsulation of Thymol in Biodegradable Nanofiber via Coaxial Eletrospinning	79
Fruit and vegetable smoothie	Combinations of natural antimicrobials, nisin, natamycin, green tea extract (GTE) and citric acid	80
Fruit	Model and control of a refrigeration system (analysis in the refrigeration components and analysis in the conservation chamber)	81
Litchi fruit	Immersion freezing (IF) followed by microwave thawing	82
Fruit juice	Moderate intensity Pulsed Electric Fields (PEF)	83
Peach fruit	Chitosan-chlorogenic acid conjugate and its application as edible coating	84

Strawberry fruit	active packaging with encapsulated thyme essential oil in zein nanofiber film	85
Meat	Curdlan/polyvinyl alcohol/ thyme essential oil blending film	86
Meat	Almond gum oligosaccharide	87
Vegetables	*Cymbopogon citratus* (Essential Oil) as antimicrobial agent	88
Rice	chitosan-linalool composite nano-matrix as innovative controlled release delivery system	89

Conclusion

Due to the enormous volume of food that is wasted daily in an endeavour to extend shelf life and feed millions of people worldwide, food preservation has become increasingly crucial. The development of a sustainable food system still requires considerable steps despite the fact that numerous cutting-edge technologies have been created. It's critical to maintain a precise and suitable balance between technology in terms of design and cost effectiveness. Additional natural preservatives that are safe to consume and have outstanding antioxidant and antibacterial properties are being sought after through continuing study. Another emerging solution is the use of nanotechnology in food, which has been covered in this article. The research on diverse nanomaterials, their toxicity, their safety for consumers, and genetic factors is still the subject of debates and worries.

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