The future of food preservation: Nanotechnology

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ABSTRACT

Nanotechnology has been used to treat illnesses for a long time. It has been successfully employed as a means of drug discovery. However, it's used in food preservation is yet to become commonplace. Through this review paper, the authors wish to throw light on the application of nanoparticles in the preservation of food, to improve food color, texture as well as flavor. We also explore the use of nanotechnology in the encapsulation of the foodstuffs as a means of preservation. The article includes details about the usage of nanoparticles in the nutraceutical industry as well as its usefulness as a nanosensor. The purpose of the paper is to make use of nanotechnology in the food industry a well-known application of nanoparticles. It will be useful for professionals working in the food industry or entrepreneurs who wish to venture into the field of food preservation. Scientists may use the information and data provided in the paper to further their research.

Keywords— Nanotechnology, Food, Preservation, Ingredients, Biosensors

1. INTRODUCTION

Food preservation is one of the few activities that have been carried out with a scientific temper by people around the world since ages. The term defines the science and collection of techniques used to ensure that food does not get spoilt due to actions from chemical and biological agents. The techniques used in this regard are varied, both in terms of their principles and their applications.

There are many existing techniques in food preservation science that are used commonly for the preservation of foods, especially in the case of perishable foods like milk. Some of them are quite traditional in nature which has given rise to many other food products like aged butter, cheese, wine, etc. With the passage of time, modern techniques for the proper preservation and aging of these products have been devised. This has also resulted in further increasing the shelf life of the food products. However, with the rise in genetic mutations in a number of micro-organisms that cause food spoilage, as well as a continuous change in the physical conditions in the environment, a clear influence in the discovery and formulation of new technologies towards the science of food preservation can be observed. One of the major fields that have contributed to the same is the field of nanotechnology. When combined with the basic science of biology and engineering keeping the basic principles in mind, this application-oriented branch of engineering has been instrumental in devising new and simpler applications and techniques for food preservation.

Nanotechnology encompasses a wide area of food processing which includes food packaging. In food processing, the nanostructures are being used as food additives, carriers for delivery of nutrients, anticaking agents, antimicrobial agents, for improving mechanical strength and durability of the packaging material, etc. whereas food Nanosensing can be applied to achieve better food quality and safety evaluation.

2. LATEST STRATEGIES IN FOOD PRESERVATION USING NANOTECHNOLOGY

Honestly speaking all recognized applications of nanotechnology in food and meals packaging is currently available throughout the UK, mainly inside the United States of America, Australia, New Zealand, South Korea, Taiwan, China, and Israel. A chief consciousness of contemporary nanotechnology programs in meals is the development of nanostructured (or nanotextured) food elements and transport systems for vitamins and dietary supplements. For this, a spread of techniques is being utilized, inclusive of nano-emulsions, surfactant micelles, emulsion bilayers, and reverse micelles. The nanostructured meal's ingredients are being advanced with the claims that they offer advanced flavor, texture, and consistency. An example of this would be low-fats
Nanostructured mayonnaise, spreads and ice creams declared to be as “creamy” as their full fats alternatives and, hence, offer a healthier option to the client.

Another significant territory of current nanotechnology application is nanoencapsulation of nourishment fixings and added substances. The utilization of microencapsulated sustenance added substances is in vogue today. For instance, microencapsulation has been utilized to veil the taste and scent of fish oil added to bread for medical advantages (for example “Tip Top-up” brand bread from George Weston Foods, Australia [Internet]). An assortment of other microencapsulated sustenance fixings and added substances are accessible for use in the scope of nourishment items, and an ongoing pattern in the health food zone is microencapsulation of live probiotic microorganisms to advance solid gut work. In this unique circumstance, the nano-embodiment of sustenance fixings and added substances show up a legitimate expansion of the innovation into an effectively existing application region to give defensive obstructions, flavor and taste veiling, controlled discharge, and better dispersibility for water-insoluble nourishment fixings and added substances.

2.1 Food ingredients for enhancing color, texture, and flavor

The sustenance business is starting to utilize nanotechnology to create fixings on the nanoscale to improve shading, surface, and nourishment. The nanoparticles TiO$_2$ and SiO$_2$ and amorphous silica are used as food additives. TiO$_2$ is used as a coloring agent in the powdered sugar coating on doughnuts.

Nanocarriers are being used for delivery systems to carry food additives in food products without disturbing their basic morphology. Nanotechnology is being used in emulsions, the formation of biopolymer networks as well as in colloids.

Nanocapsulation covers scents or tastes. It also helps shield the foodstuff from dampness, warmth, or other atmospheric agents amid handling, stockpiling, and use.

The utilization of Nanomembranes to deliver lipid-dissolvable bioactive mixes is also becoming prevalent.

2.2 Food production and packaging

Nanomaterials used for food packaging provide many benefits such as improved mechanical barriers, increased shelf life and potentially enhanced bioavailability of nutrients. A number of nanocomposites, polymers containing nanoparticles, are being used by the food industry for food packaging and as food contact materials. The use of ZnO, MgO and amorphous silica in food and in food containers nanoparticles for food packaging has been reported.

Engineered water nanostructures created as vaporizers are efficient at killing foodborne pathogens, for example, Escherichia coli, Listeria, and Salmonella on steel nourishment generation surfaces.

Nanopolymers are replacing conventional materials in food packaging. Nanotechnology is helping in increasing the shelf-life of different kinds of food materials and also bringing down the extent of wastage of food due to microbial infestation.

2.2.1 Packaging categorized in the following criteria

- **Improved packaging**: Nanoparticles blended with polymer chain can improve the gas boundary properties, temperature, and moistness opposition of bundling. The use of nanocomposite in contact with food has been approved by the United States Food and Drug Administration.
- **Active packaging**: Several nanomaterials like Nano-copper oxide, nanosilver, Nano titanium dioxide, Nano magnesium oxide, and carbon nanotubes can provide antimicrobial properties. By and by, the utilization of silver nanoparticles as antibacterial operators in food packaging is expanding.
- **Intelligent/smart packaging**: Designed for sensing biochemical and microbial changes in the food.

Specific pathogen developing in the food or specific gases from food spoiling can be detected. Currently, Nestle, British Airways and Monoprix Supermarket are using chemical sensors, which detect the color change.

2.3 Nutrients and dietary supplements

Bioactive mixes, for example, lipids, proteins, sugars, and nutrients are sensitive to high acidic condition and compound action of the stomach and duodenum. Encapsulation of these bioactive compounds enables them to resist such adverse conditions, enhance absorption and bioavailability, and also allows them to assimilate readily in food products.

2.4 Food nanosensors

Nanomaterials are being used as sensors to detect contamination and thus, regulate the food environment. They can screen the freshness of the food during transport and capacity. They can distinguish a supplement insufficiency and convey this information to plants and manufacturers when required. Commercial use of Nanosensors has been reported to check storage conditions and can also be used during food transport in refrigerated trucks for temperature control.

Therefore, nanomaterials can be used as Nanosensors and Nano tracers with almost unlimited potential by the food industry. Nanosensors can be used to detect the presence of contaminants, mycotoxins, and microorganisms in food. For instance, the quartz precious stone microbalance (QCM) - based electric nose can distinguish the connection between different odorants and synthetics that have been covered on the gem surface of the QCM.
Carbon nanotubes (CNTs) are available as either single wall nanotube (SWNT) or multiwalled nanotubes (MWNT). SWNT is generally one atom thick, whereas, MWNT comprises of several concentric tubes with very high aspect ratios and elastic modulus. It was reported that CNTs infused with polyethylene films used for the packaging of Mazafati dates, prevented fungal invasion for up to 90 days. Single-walled carbon nanotubes with cobalt meso-aryl porphyrin complexes have also been explored for the development of a chemiresistive detector, which detects amines generated during spoilage of meat. Nonetheless, regardless of having wide application, concerns related to their handling and scattering properties restrict their use in nanocomposites.

Chitosan, a heteropolysaccharide is known for its biocompatibility, biodegradable property, and metal complexation. The polycationic nature of chitosan is responsible for its anti-microbial properties. Studies have shown that the blend of chitin hairs with soy-protein detach (SP) thermoplastics in a general sense improved the bendable characteristics of the network and their hyphobocity. It was therefore proposed that hydroxypropyl methylcellulose (HPMC) can be used as a potential material for palatable packaging films. The film demonstrated antibacterial development against E. coli, S. aureus, and B. subtilis. Packaging and coatings made from chitosan improved physicochemical and microbiological nature of fresh-cut vegetables and natural items. Chitosan/silver, chitosan/gold, and chitosan/cinnamaldehyde nanocomposite films have exhibited antimicrobial action against E. coli, S. aureus, P. aeruginosa, Aspergillus niger, and Candida albicans.

### 4. Societal Impact of Nanotechnology on Food Preservation

Antimicrobial Nanotechnology is expected to have a great impact on industrial production. The application of nanotechnology and nanoparticles in food are emerging rapidly, covering all areas of the food chain, from agricultural applications to food processing and enhancing bioavailability of nutrients.

### Table 1: Different Nano techniques to encapsulate and delivery of functional ingredients.

<table>
<thead>
<tr>
<th>Nano technique</th>
<th>Characteristic feature</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edible coating</td>
<td>To preserve the quality of fresh food during extended storage</td>
<td>The gelatin-based edible coating containing cellulose nanocrystal</td>
</tr>
<tr>
<td>Chitosan/nanosilica</td>
<td>Chitosan film with nano-SiO₂</td>
<td>Alginate/lysozyme nanolaminate coating</td>
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<tr>
<td>Hydrogels</td>
<td>Can be easily placed into capsules, protects drugs from the</td>
<td>Protein hydrogels</td>
</tr>
<tr>
<td></td>
<td>extreme environment, and to deliver them in response to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>environmental stimuli such as pH and temperature</td>
<td></td>
</tr>
<tr>
<td>Polymeric micelles</td>
<td>Solubilize water-insoluble compounds in the hydrophobic</td>
<td>PEO-b-PCL [poly (ethylene glycol) block poly(caprolactone)] polymeric</td>
</tr>
<tr>
<td></td>
<td>interior, high solubility, low toxicity</td>
<td>micelles                    Methoxy poly (ethylene glycol) palmitate polymeric micelles</td>
</tr>
<tr>
<td>Liposomes</td>
<td>Greater stability to droplet aggregation and gravitational</td>
<td>β-Carotene-based Nanoemulsion</td>
</tr>
<tr>
<td></td>
<td>separation; Higher optical clarity; and, Increased oral</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bioavailability</td>
<td></td>
</tr>
<tr>
<td>Liposomes</td>
<td>Since liposome surrounds an aqueous solution inside a</td>
<td>Cationic lipid incorporated liposomes modified with an acid-labile polymer</td>
</tr>
<tr>
<td></td>
<td>hydrophobic membrane, it can be used delivery vehicles for</td>
<td>hyperbranched poly(glycidol) (HPG)</td>
</tr>
<tr>
<td></td>
<td>hydrophobic molecules (contained within the bilayer) or hydrophilic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>molecules (contained in the aqueous interior)</td>
<td></td>
</tr>
<tr>
<td>Inorganic NPs</td>
<td>They display good encapsulation capability and their rigid</td>
<td>Mesoporous silica nanoparticles</td>
</tr>
<tr>
<td></td>
<td>surfaces allow controlled functionalization</td>
<td></td>
</tr>
</tbody>
</table>

3. Examples of Currently Used Nanoparticles

One of the most used nano-materials used for preservation of food-materials is clay and silicates. Clay and silicates, inerferable from their accessibility, minimal effort, and moderately basic processability have pulled in the attention of specialists as potential nanoparticles. The layered silicates, around 1 nm thick to a couple of microns long are generally utilized in nanocomposites in their two-dimensional structure. The blend of silicates and polymers confer fantastic obstruction properties. This mix upgrades the diffusive way for an invasive particle. The intercalated nanocomposites pertain to a multilayered structure with exchanging polymer/inorganic layers lying separated by a couple of nanometers. Such structures result through the infiltration of polymers chains into the interlayer district of mud lead.

Montmorillonite (MMT) [Mx (Al4-xMgx) Si8O20(OH) 4] is the most widely recognized dirt filler. It has an octahedral sheet of Al (OH) 3 between silica tetrahedral bi-layers connected together by feeble electrostatic powers. The unevenness between the surface negative charges is repaid by the nearness of interchangeable cations, Na+ and Ca2+.

Cellulose is the building material of long fibrous cells and is a strong natural polymer. It is ubiquitous, cost-effective, environmentally friendly and easy to recycle. Cellulose is also explored as supporting material for many nanomaterials. Application of cellulose leads to an increase in surface area of the nanoparticles associated with their enhanced activity. These features make cellulose nanofibers a very attractive class of nanomaterials. Cellulose-based nano fortifications improve the quality and modulus of polymers. Cellulose nanofibers and starch frameworks have improved thermo-mechanical attributes, alongside decreased water affectability and flawless biodegradability as compared to other conventional nanomaterials. Cellulose nano fortifications likewise improved the dampness boundary properties of polymer films.

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However, Nanomaterials (e.g., carbon nanotube, silver, silica, titanium dioxide, and zinc oxide) exhibit properties not found at the macro-scale and might result in unpredictable safety problems and risks. For example, aluminium oxide is being used in dentistry. It can spontaneously explode at the nanoscale and is being tested as potential rocket fuel. Though not necessary, the reduced size might adversely affect the biological system. Little has been explored to determine the toxicity of nanomaterials, and many plausible mechanisms of their interaction with the biological system are only speculative. Long-term exposure to an environment containing carbon nanoparticles would cause pulmonary inflammation and their diffusion from the lung to the surrounding blood vessel system would result in further vascular disease occurring in the body. In addition to causing oxidative stress and inflammation, it is important to consider that some of the nanomaterials may also result in other forms of injury, such as protein denaturation, membrane damage, DNA damage, immune reactivity and the formation of foreign body granulomas.

5. CONCLUSION

Despite the fact that the down to earth use of nanotechnology in food is as of yet a far-off dream, it is normal this could permit a progressively effective and reasonable nourishment creation procedure to be created where fewer crude materials are expended and nourishment of higher nourishing quality is gotten. Nano-items are going to the market without guideline and societal discussion. Concerns are raised as no legislature has built up an administrative system that addresses the nanoscale particles. The US Food and Drug Administration (FDA) does not have rules regulating the use of nano fabricating forms all things considered; be that as it may, a few guidelines are forced on certain items available for utilization. In addition, the merger of nanotech and biotech has uncertain consequences on the health of humans and animals, biodiversity and the earth. In this manner, much more research is required to create vigorous and dependable hazard appraisal conventions for nanomaterials to be utilized in food items/ventures.

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7. REFERENCES


