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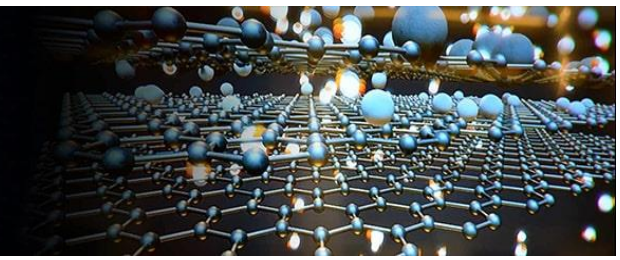

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Nanoparticles in packaging films: Processing technologies and future trends

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Abstract
Nowadays, food packaging has become very demanding and with the help of nanoparticles it has become easier to upgrade the qualities that aid in extending the lifespan of packaged goods. Nanoparticles are useful for use in the creation of nano composites because of their antibacterial activity, oxygen scavenging capacity, and UV impermeability. Meat, seafood, milk, fruits, vegetables, and other food items all expire quickly. Nanotechnology has a stronger influence and is used by several food sectors to extend the shelf life of such food goods. It helps make materials more resistant to heat, pressure, and gases while also making them more biodegradable and nontoxic. Zinc oxide, silicate, kaolinite, silver NPs, and titanium dioxide are a few of the significant nanomaterials utilised in food packaging. These films-coated materials function as a barrier against gases such as carbon dioxide and oxygen, as well as favourable chemicals. Basically, the use of nanotechnology is to prevent the food products from mechanical damage as well as some derogative changes such as physical, chemical or microbiological changes. This review paper discusses packaging films and emphasises the major division of the most prevalent polysaccharides for use in the food industry. We also talked about the processing methods used to create food packaging films with nano-integration. Recent developments in the use of various forms of nanotechnology during food preservation are highlighted in the debate. Finally, potential developments in nanotechnology for applications in the food industry were described.

Keywords: Nanoparticles, oxygen scavenging, UV impermeability

1. Introduction
Spoilage of food products may occur rapidly and hence it becomes unacceptable to consumers. In order to prevent spoilage as well as to maintain quality and shelf life of certain food items has become a major concern to the progressing world globally. To compensate the ongoing problems in food industry, nanotechnology has a greater impact on it (Dey *et al*., 2022) [5]. This technology prevents spoilage, maintains quality and increase shelf life which in turn becomes acceptable to consumers. Mechanical components and physical characteristics of food packaging can be modified by nano materials which improves their strength, barrier, flexibility, durability, and reusing characteristics (Bumbudsanpharoke *et al*., 2015) [3].

The light permeability and mechanical barrier characteristics are improved by incorporating certain metal oxides in polymers (Garcia *et al*., 2018) [7]. Nani packaging improved power distribution and granularity with improved efficiency. It enables power conversion, power sources, and energy harvesting using batteries, generators, supercapacitors, capacitors and inductors. The advantages of Particles of small size are improving soluble in water to increase absorption. Additionally, it lengthens the barrier period for delivering medication to a specific location inside the human body. In food industry the application of nanotechnology was utilised to find microorganisms in the container or producing flavour and colour quality and safety. Many food products are eaten safely for generations which are containing nanoscale components. Fabrication, characterisation and manipulation of nano-range (<100 nm) molecules are the key features of nanotechnology. For more effective food packaging, amplification of advanced augmented polymers will be much more beneficial. Besides this, beverage industries also rely on nanomaterials application (Cushen *et al*., 2012) [4].

Protein nanoparticles effectively improve the barrier and strength. One of the potential nanoparticles which is nontoxic, Ecofriendly and having antimicrobial properties is Chitosan (Medina *et al*., 2019) [10]. It is found in exoskeleton of arthropods, the cell wall of fungi, and

crustaceans, is a type of polysaccharide derived from chitin. This review discusses about the nanotechnology in packaging films, about the processing technologies and its future trends. The materials used in packaging has been described briefly which will be beneficial in the upcoming future. It shows how nanotechnology has wider impact on today's lifestyle and how food industries are getting benefitted from it. There are different manufacturing techniques which are being used in food industry. Therefore, nanotechnology is making our life easier as well as comfortable.

2. Packaging films

The chemical vapor deposition (CVD) method is used to create powerful thin nanofilms (Medina *et al*., 2021) [16]. A volatile initial is applied to material, acting on its outer layer to generate the required films, typically removes volatile byproducts with flow via reaction chambers. When bigger particles break down, tiny nanoscale are created. There are also two approaches for the synthesis of nanomaterials. They are top-down and bottom-up approaches (Arole *et al*., 2014) [1]. In top- down approaches the bulk materials are mechanically machined and converted in to fine particles in nano dimension, whereas, in bottom -up approaches fine particles are assembled to build the nano materials too self-assembly or coprecipitation method. Films are packaged with regulated transport of carbon dioxide and oxygen Produced plasticise poly vinylidene chloride, which is suitable for gassing cheese (Mullan *et al*., 2011) [11]. It contains 8-10 wt % plasticiser these are chosen from the azelaic acid polymer hydrolysis products and 1, 3-butanediol, Ethylene glycol and polymeric adipic acid plasticizer, epoxidized soyabean oil. It improves warmth instability and lessen iron plates' adhesion while 2 wt % of epoxidized soyabean oil is added as plasticiser. Packaging films can be classified into five various (Suresh *et al*., 2021) [15] category like linear low-density polyethylene (LLDPE), low density polyethylene (LDPE), bi-axially- oriented polyethylene (BOPE), bi-axially oriented polypropylene polymer (BOPP), bi-axially-oriented polyethylene terephthalate (BOPET).

3. Processing technologies of nano integrated packaging films

3.1 Solvent Casting

Solvent Casting, also known as solution mixing, is a process in which the nanoparticles in a polymer are vigorously stirred or ultrasonicated before casting into a mold and then the solvent is evaporated. Both organic solvents and water can be used to prepare nanocomposites with either thermoplastic or thermostats. The organic solvents are removed after casting to have environmental implications. A film is formed by evaporation using a solvent in which copolymer and drugs get dissolved (Felton *et al*., 2013) [6]. After that, hot water or a buffering agent is added, and the polymer film is agitated to break down it. Solubilization, casting liquid flooding onto a predetermined Mold and burning can be the steps used involving casting solvent procedures. In the first step, biopolymer material is solubilised in a suitable solvent. The solvent should be edible and non-toxic. The solvents which are used generally includes water and ethyl alcohol. Then the solution is poured. In case of drying, the solvent is evaporated to form a gel like structure.

3.2 Extrusion

The method of extrusion is used for creating metal, when a metal or work item is pushed by a die that minimizes its area of distribution or take on a particular shape (Felton *et al*., 2013) [6]. This process is extensively used in pipes and steel rods manufacturing. Compression force is applied during the extrusion step of the product item. In the packaging production process, plastic extrusion consists of guiding thermoplastic material under pressure through a die with a hole that is generally complex in shape (Riley *et al*., 2012) [14]. The resulting cross section of the material is the same shape as the hole. Nylon is made by joining extensive chains of ethanol and propylene, they act as fundamental building blocks that may be shaped into a multitude of forms to make the thin film web required in flexible packaging, the polymers are melted down and squeezed through a very narrow slot via a technique called blown film extrusion. The resultant web is perfect for inexpensive packaging that is flexible since it stays to very effectively unless a great lot of force is applied.

4. Application in food preservation

Nanoparticles have become increasingly demanding in food industry and serves different purposes including food packaging, processing of food, safety of food, shelf life of food items, functional food development, detection of microbial contamination and so on (Bumbudsanpharoke *et al*., 2015) [3]. These nanoparticles are potential and they provide safety and assurance to the consumers based on any contamination, spoilage, etc. Ut has become one of the most attractive as well as efficient technology in food sector. Food manufacturing uses food nanostructured particles parts and food nano sensing to assess its use. Food additives, intelligent nutrition delivery, anti-caking agents, and flickers that improve the elasticity and longevity of the packaging materials are all covered by food nanostructured substances. According to one each other, nano sensing aids to enhanced assessments of food safety and quality (Mustafa *et al*., 2020) [12]. It is now necessary to use nanostructured food components to enhance consistency, taste, and texture. Besides increasing shelf life, this technology prevents wastage of food too. Nano sensors are utilized for tracking temperature, time, and oxygen indications in addition to using for identifying illnesses caused by food rotting, and the incorporation of poisons, nutrients, chemicals that are and undesirable tastes or smells. They also transform physical amounts into easily observable signals. It is very essential in food quality and food safety.

Nanostructures enhances the bioavailability of ingredients like vitamins, carotenoids, flavouring agents, prebiotics, omega fatty acids, antimicrobial, antioxidant, protein and peptides and other preservatives by incorporating by incorporating in the delivery system rather than direct administration in their pure form (Mantovan *et al*., 2022) [9]. Nani encapsulation and nanoemulsion can be performed for the absorption of functional food ingredients. Numerous kinds of products utilizing nanocluster technologies have been introduced to the consumers, increasing the particle's surface to volume ratio. For instance, the cocoa-flavoured micro silica in Slim Shake Chocolate enhances the absorption of taste receptors to augment the chocolate Flavors. The release of active substances into the targeted intestinal area is controlled via nanoencapsulation, which also extends the retention period. Nanotechnology can be

used to solubilize lipophilic substances, such as carotene and phytosterol anti-oxidants, in water.

5. Future trends

Nanotechnology will play a major role in 3D and 4D printing of living tissue and smart materials. Besides providing enormous benefits, nanotoxicity has also become a major concern in the sector regarding sustainability and waste reduction. The most future view of nanotechnology involves the potential creation of new weapons of destructiveness made available from nanotechnologies, as well as the utilization of nano as diagnostic and therapeutic reasons inside the body and bloodstream (Baswaraj *et al*., 2012) [2]. In the future, nanotechnology might help us making electrical lines, solar cells and biofuels more efficient and nuclear reactor safer. Alongwith with these, nanotechnology may lead to huge advances in health care by improving different methods for detecting and treating fatal diseases like cancer. The method of encasing tiny food parts, nutrients like taste and colour, and vitamins and minerals including carbohydrates and antioxidants, which may be added to make food functional, into a food item is known as the nanoencapsulation (Rashidinejad *et al*., 2020) [13]. The purpose of this is to transport and dispose insoluble water substances, providing protective barrier and masks unusual tastes and odour. Nanotechnology helps to combat different food related disorders like diabetes and obesity by ensuring environmentally friendly food production.

Some of the traditional packaging methods which are used in food industries include plastic, glass, metals, woods and its derivatives that is sensitive materials and readily breakable. In addition, the density of steel is greater than that of other materials. Even it is quite expensive process on the basis of manufacturing and production cost. To solve this issues, nanotechnology provides all the benefits and assurance to the food sectors as well as health concern consumers. In the near upcoming future, nanotechnology will be leading and efficient in the food industries and other sectors too, as far as reliability, convenience and betterment of healthy lifestyle concerned (Ingale *et al*., 2018) [8].

6. Conclusion

During a packaging business, food-grade packaging is frequently used as a substitute for traditional powered by petroleum packaging substances. The packaging of edibles was developed in response to the demand from consumers for food that is viable, devoid of chemical additives, and favourable to the ecology. Food-grade ingredients and additions have been used throughout every one of edible packaging components. In food packaging, novel substances having enhanced properties have been researched. Dietary supplements are having a longer lifespan when they are made with the right biopolymer mixture substances and naturally active ingredients. Although it is unlikely to totally replace traditional packaging, food containers that are edible can be utilized as the main kind. The dietary the product's nutritional value is extended by oxygen, water vapor, an aroma barrier, lowering food weight loss, and the addition of antibacterial and antioxidant chemicals. Scientists recently studied the benefit of nanotechnology in edible food packaging. Nanomaterials improve the ability to dissolve of any biological agents that make up bio polymers and inhibit its biological breakdown. The efficacy and longevity of food-grade packaging were enhanced by the use of nano encapsulated bioactive ingredients. Packaging that is edible is still relatively new. The physical characteristics, costly manufacturing, and barriers restriction prevent application at the company level. To further increase durability and lower manufacturing costs, further research must be conducted before edible packaging becomes a business item.

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