# Recent Advancement in Food Packaging Technology A Review

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**Abstract: Food packaging is defined as enclosing food to protect it from tampering or contamination from physical, chemical and biological sources with different kinds of packaging. Food packaging lies at the very heart of the modern food industry. This review covers only some of the aspects of food packaging related to food process engineering and technology. Food science is important to understand the deterioration kinetics of food and governs the food's shelf life. Food packing technology is a science based solution to address specific food packaging needs: examples are active and intelligent packaging, anti microbial packaging, water soluble packaging, micro packaging, edible packaging, self heating and self cooling packaging and chitosan based films**.

**Keywords: edible, self heating and self cooling, nano technology, chitosan.**

## I. INTRODUCTION:

The demand for exploring advanced and eco friendly sustainable packaging materials with superior physical, mechanical and barrier properties is increasing. Food packaging plays an important role protecting from chemical, physical, and biological hazards along the food chain. Packaging is essential to deal with the influences (odors, shocks, dust, temperature, light, humidity) that facing food. The development of petroleum-based polymers such as polypropylene, polyester and ethylene vinyl alcohol and others allowed the changing of metal, glass or cardboard packaging into plastic packaging. Nowadays, petroleum-based products are the most widely used materials in the food packaging industry because of its good properties at relative low price. Nevertheless, massive use of petroleum-based materials leads to a negative impact on the environment since they are not derived from sustainable sources, not recyclable, compostable or biodegradable. Food packaging research must address the environmental problems derived from the uncontrolled consumption and management of non-biodegradable materials, developing new alternative materials with lower environmental impact. This way, biodegradable natural polymers are the focus of a wide range of research to apply them as alternatives to petroleum-based synthetics. Biodegradable natural polymers widely studied for prospective applications in food packaging industry are chitosan, starch, whey protein or gelatin among others. Among the available natural biodegradable materials, chitosan has aroused great interest in recent decades. Food packaging has a crucial function in the modern food industry. New food packaging technologies seek to meet consumers' and industrial demand. This review describes the main concept and type of active and intelligent food packaging, focusing on recent progress and new trends using biodegradable and bio based polymers.

## II. ACTIVE AND INTELLIGENT/ SMART PACKAGING:

ACTIVE PACKAGING: An active package is the one that modifies the condition of packaged food to extend shelf life or improve its safety or sensorial properties, keeping its quality. Sometimes this is achieved by the intrinsic properties of the polymer and others adding some specific additive in the packaging material or in the headspace in order to attain a better package yield. In this sense the European community regulation defines such components which are designed to release or absorb substances towards or from the packaged foods and the environment surrounding the foods. $O_2$ scavengers and moisture absorbers are by far the most commercially important sub-categories of active packaging and the market has been growing steadily for the last ten years and is predicted to grow even further. All other active packaging technologies are also predicted to be used more in the future, particularly ethylene scavengers, $CO_2$ scavengers and emitters, moisture absorbers and temperature control packaging.

INTELLIGENT PACKAGING: An intelligent packaging is the packaging system capable of carrying out intelligent functions such as detecting, registering, locating, communicating and applying scientific logics, in order to ease decision making , extend shelf life, improve safety and quality, provide information and warn of possible problems. These systems which are attached as labels or printed on the food packaging materials offer better possibilities to check product quality and provide detailed information during all the food supply chain. Intelligent packaging does not aim at releasing their components onto the foods. The advancement in novel food packaging technologies involves retardation in oxidation, hindered respiratory process, prevention of microbial attack, prevention of moisture infusion, use of $CO_2$ scavengers/emitters, ethylene scavengers, aroma emitters, time-temperature sensors, ripeness indicators, biosensors and sustained release of antioxidants during storage. Intelligent packaging devices include sensors, time-temperature indicators, gas sensing dyes, microbial growth indicators, physical shock indicators, freshness indicators etc., self-heating or self-cooling containers integrated with electronic displays indicating important information on nutritional qualities and expiry dates . Also includes some microwave packaging as well as packaging that have absorbers built in to remove oxygen from the atmosphere surrounding the product or to provide antimicrobials to the surface of the food. The action of indicators used in smart packaging should be able perceive and understand without the use of any external apparatus

## III. **ANTI-MICROBIAL PACKAGING**:

Anti microbial packaging is a system that can kill or inhibit the growth of microorganism and thus extend the shelf life of perishable products and enhance the safety of packaged products. The major potential food applications of anti microbial films include some for sensitive foods like bakery products, dairy products, fresh produce such as fruits and vegetables, and meat, fish and poultry products. It can be constructed by using anti microbial packaging materials, food products, and the headspace atmosphere. Anti microbial such as algaecides, bactericides and fungicides can be added to polymers to prevent the growth of microorganisms inside the food package. Anti microbial packaging systems are intended to provide controlled release of anti microbial. To accomplish this, classic polymer, new hydrogels with functionalized surfaces, and highly swell able bio polymer are excellent prospects as antimicrobial carriers. Engineering advances are moving towards nanotechnology and micro and nano encapsulation as innovative solutions to providing safer, healthier and more nutritional food products. Among others food bio polymers and specially hydro colloids are promising material to produce micro and nano scaled carriers of bio active compounds, such as the incorporation of pro biotic in active packages is expected to expand the possibilities for packages, in area related to consumer well being and consumers health. In the future, it will be necessary to study complex food matrices and analyze all environmental variables and material characteristics to identify the most suitable strategies.

## IV. **MICRO PACKAGING:**

Micro packaging refers to the integration of nano materials such as nano coatings and films to form a high barrier packaging solutions, resistant to light, air and heat. It is a relatively new concept that presents numerous opportunities especially in the field of food industries. The micro packaging solution could be switched back and forth between polymers, depending on food contact approval. Customizability of this technology, coupled with the excellent gas barrier properties drew the attention of various food companies to its discovery. By utilizing nano materials in food, presents potential benefits such as improved bio availability, anti microbial effects, enhance sensory acceptance and targeted delivery of bio active compounds.

Nanosensors are extremely small device than can bind to whatever is wanted to be detected and send back a signal. These tiny sensors are capable of detecting and responding to physicochemical (sensors) and biological signal (biosensors), transferring that response into a signal or output that can be used by humans. Various nanosensors were developed for detection of internal and external conditions in food packaging. Nanosensors can be used to determine microbes, contaminants, pollutants, and ultimately the freshness of the food. Nano particles can reduce the amount of material used and improve packaging function. It can also increase tensile strength up to 40%, and this decreases the amount of film used in pouch producing. Nano particles can increase thermal stability up to 35 %, and that keeps food fresh and can be reheated it in its original packaging. It can enhance barrier properties against gas permeations such as oxygen and carbon dioxide, ultraviolet permeation, moisture, and volatile compounds, develop active antimicrobial surfaces, and create nano-biodegradable packaging materials.

Despite the tremendous benefits of nano particles in food industry, there is great public concern regarding toxicity in human and the environment. Lack of knowledge about the effectiveness and impact of nano particles on the environment and on human health is of great concern due to potential risk resulted from migration of nano particles into the food. The migrants may likely react with oxygen and produce toxic substance. There is growing scientific evidence, which indicates that some free nano particles may cause harm to biological systems because of their ability to penetrate cellular barriers, and induce oxyradical generation that may cause oxidative damage to the cell. There is an urgent need for regulation of nano materials before their incorporation into food processing, packaging, and food contact. Before releasing any new product with the nanotechnology in food system, manufacturers must thoroughly assess its risk on human, animal and environmental health.

## V. **EDIBLE PACKAGING**:

There is a trend towards environmentally sustainable and edible forms of packaging. Edible packaging typically uses sustainable, bio degradable material that is applied as a consumable wrapping or coating around the food, which generates no waste and to create novel applications for improving product stability, quality, safety, variety and convenience for consumers.

There are two types of edible packaging: films, and coatings. The difference between the two is that films are first formed separately and then applied to the food product, while coatings are formed and applied directly to the food. They can be superficial coatings or layers between compartments of the same food product. Polysaccharides, proteins, and lipids are biopolymers used to fabricate edible films or coatings as packaging. While the polysaccharide (starch and derivatives, gums, etc.) and proteins (gelatin, gluten, etc.) offer edible films with satisfactory mechanical and optical properties, they are hypersensitive when it comes to moisture which constitutes a crucial issue in the food industry since the moisture content can cause rapid deterioration of the food. Contrarily, films composed of lipids (waxes, lipids or derivatives) provide good water vapor barrier properties, yet they are non-transparent, inflexible and prone to rancidity.

There are various mechanism to the film formation which are:

**Simple co-acervation**: in this mechanism a hydrocolloid dispersed in water is precipitated or undergoes a phase change after solvent evaporation (drying), after addition of hydrosoluble non-electrolyte in which the hydrocolloid is insoluble.

**Complex co-acervation**: here, two hydrocolloid solutions with opposite electron charges are mixed and thus causing interaction and precipitation of the polymer complex.

**Gelation or thermal coagulation**: heating if macromolecules lead to its denaturation followed by gelation or precipitation or even cooling of hydrocolloid dispersion causes gelation.

Edible films and coatings are generally used to improve the mechanical properties of the food, minimize respiration in fruits and vegetables, limit the movement of moisture and other gases, provide antimicrobial or antioxidant capabilities to the product, enhance the sensory properties, and extend the shelf life of the product. Combination of different materials improve mechanical properties and demonstrate higher permeability than the single-component films. Edible coatings and films can serve as a carrier for antimicrobial and antioxidant compounds in order to keep high concentration of preservatives on the food surfaces. Their presence could avoid moisture loss during storage, reduce the rate of rancidity causing lipid oxidation and brown coloration, reduce the load of spoilage and pathogen microorganism on the surface of foods and also, restricting the volatile flavor loss. They can also serve as carrier to food ingredients, improve the mechanical integrity and make product handling easier.

## VI. WATER SOLUBLE PACKAGING:

Water-soluble packaging is a type of packaging that can dissolve in hot water. The main ingredient in this bio-based material is polyvinyl alcohol, or PVOH, which is a synthetic polymer created without the heavy toxic metals that are often damaging to the planet. It's also odorless, biodegradable, and water-soluble. A U.S company has developed a food packaging technology that dissolves edible film pouches which are engineered to disappear and release their contents when they are exposed to water. The pouch, which dissolves faster in hot water by the plastic melting away, leaves no notable taste or odor when consumed and there is no left over primary packaging. The technology could be used in oatmeal, cereal, instant tea or coffees, soups, gravies and sauces, hot chocolate, pre portioned spice packs and dry ingredients, workout proteins and supplements. A suitable secondary packaging such as a standard pouch or an injection molded tub will be required to prevent contamination of the edible pouches during transportation and storage prior to use. This secondary packaging will also serve to protect edible pouches from moisture during storage.

Water-soluble packaging technology does seem to have the potential to offer a new sustainable packaging option, with an amazing end-of-life solution. There are however clearly some challenges that should be considered. Rain and general moisture are commonplace during the shipping of a package. This is the primary reason why plastic has been so widely used by the logistics industry, as no one can question its effectiveness in protection against moisture. As a product designed to dissolve in water, there would need to be clear testing done to ensure its ability to perform as an e-commerce satchel.

## VII. SELF HEATING AND SELF COOLING FOOD PACKAGING:

**Self-heating food packaging:** it is active packaging with the ability to heat food contents without external heat sources or power. Packets typically use an exothermic chemical reaction. Packets can also be self-cooling. These packages are useful for military operations, during natural disasters, or whenever conventional cooking is not available. These packages are often used to prepare main courses such as meat dishes, which are more palatable when hot. The source of the heat for the self-heated can is an exothermic reaction that the user initiates by pressing on the bottom of the can. The can is manufactured as a triple-walled container. A container for the beverage surrounds a container of the heating agent separated from a container of water by a thin breakable membrane. When the user pushes on the bottom of the can, a rod pierces the membrane, allowing the water and heating agent to mix. The resulting reaction releases heat and thus warm the beverage surrounding it.The heating agent and responsible reaction vary from product to product. Calcium oxide is used in the following reaction:

$$CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2(s)$$

Commercial heat sources for self-heating food packaging use an exothermic (heat releasing) reaction, for which there are several common formulations. These include:

- Quicklime also known as calcium oxide, and water. Quicklime, inexpensive and readily available, is generally recognized by the FDA as safe. The product of the reaction is calcium hydroxide.
- Finely powdered magnesium metal alloyed with a small amount of iron, and table salt, actuated by adding water, as in an MRE flameless ration heater.

**Self cooling food packaging**: The principle was the same as employed for so many mechanical refrigeration systems: evaporation of fluorocarbon liquid. The can contained a closed internal chamber that, when punctured, would release the liquid as a gas with the latent heat of evaporation removing heat from the contents and cooling it by about 30°F for a 500-mL can. Because of environmentalist objections to the release of fluorocarbons into the atmosphere, the internal coolant was switched to carbon dioxide gas activated by charcoal. In cooling by endothermic reaction, the outer container will contain ammonium nitrate and water while the inner container will contain the drink. Cooling is achieved by reactions such as dissolution of ammonium nitrate and ammonium chloride in water followed by shaking—not a recommended procedure for chilling cans of carbonated beverages or beer when the consumer demands his or her beverage cold.

## VIII. CHITOSAN FOR FOOD PACKAGING:

Chitosan is synthesized by deacetylation of chitin (poly (β-(1 → 4)-N-acetyl-D-glucosamine)), an important natural polysaccharide known since 1884. Chitin is synthesized by many living organisms. It can be obtained from multiple renewable sources, mainly waste from the seafood industry. Hence, chitosan is a cheap and commercially available polysaccharide. In solid phase, chitosan is semi-crystalline, and generally soluble in dilute organic acid such as acetic, citric, formic, lactic, malic or tartaric acid among others. Barrier properties play a key role in maintaining the food product quality. Properties values depend on the type of chitosan used. Mechanical and barrier properties of pure chitosan films are suitable for food packaging and active packaging. These properties can be modified by combining chitosan with other components such as plasticizers, other polysaccharides, proteins and lipids. These combinations adapt the properties of the final polymer to the needs of the food to extend its useful life, while maintaining the quality properties of food and the bio degradability of the polymer. Anti microbial property against a food born filamentous fungi, yeast, gram negative, gram positive bacteria and film forming capacity has made chitosan the reference polymer. Regarding the optical properties, pure chitosan films in the visible range show high transmittance values, being optically transparent films. This is an important parameter related to the acceptability of the films by the consumers. Chitosan based films exhibit UV absorbance, which allows to protect food from lipid oxidation induced by UV radiation.

Table 1- Examples of chitosan based nanocomposites and their applications

| Chitosan Molecular Weight/Viscosity | Type of Nanomaterials in Composite | Name of Nanomaterial/ Polymer/Clay | Preparation Method of Chitosan Nanocomposite | Form of Chitosan Nanocomposites | Specific Application | Key/Enhanced Properties | Application Field |
|---|---|---|---|---|---|---|---|
| 100 kDa | Metal | Ag nanoparticles | In situ reduction on chitosan | Thin film coating on bandage | Antibacterial activity against *E. coli* and *S. aureus* | Inactivation bacterial metabolism | Antimicrobial |
| Medium molecular weight | Metal | Ag nanoparticles | In situ reduction on chitosan | Ag nanoparticles anchored on chitosan particles | Sensing of ammonia in solution | Sensitive in optical absorption intensity and wavelength | Environment |
| Medium molecular weight | Metal oxide | ZnO nanoparticles | Blending | Thin film coating | Antifouling prevention | Anti-diatom activity and antibacterial activity against the marine bacterium | Anti-biofouling |
| Low viscosity | Metal oxide | $SiO_2$ nanoparticles | In situ Stöber method grown on chitosan | Slurry packed in liquid chromatography (LC) column | Adsorption of rare-earth elements | High adsorption efficiency, selectivity, and reusability | Environmental |
| 190–310 kDa | Carbon | Graphene oxide | Cross-linking | Thin film | Antimicrobial against *E. coli* and *B. subtilis* | Improved mechanical and antimicrobial properties | Antimicrobial |
| 300 kDa | Carbon | Graphene oxide | Cross-linking | Hydrogel | Removal of dyes and metal ions from water | Tunable surface charge; efficient removal of pollutants | Environmental |
| N/A | Polymer | low density poly-ethylene (LDPE) film | Grafting | Coating | Significant changes in surface wettability | Improved anti-thrombogenic properties | Antifouling |
| N/A | Clay | Halloysite clay nanotubes | Electrostatical adsorption | Coating | Anticorrosive protective | Improved passive barrier protective and self-healing | Environmental |
| 50–190 kDa | Clay | Bentonite and sepiolite | Blend | Thin film | Winemaking application | Enhanced immobilization of protease but negatively affected catalytic properties | Antimicrobial |
| Medium molecular weight | Clay | Bentonite | Gelation and lyophilization | Bead | Carbon dioxide adsorption | High adsorption capacity under moderate condition | Environmental |

## IX. CONCLUSION:

Food packaging has a crucial function in modern food industry, since it contributes to preserve food products, quality and guarantee food safety during its shelf life. Due to the change in lifestyle of people and to provide consumer with convenience and quality these advances were necessary. Also due to the rise in environmental awareness among the people, the concept sustainable packaging was introduced and all this led to further innovations in the field of food packaging. Some modern techniques include smart packaging, anti microbial packaging, use of nanotechnology in food packaging, food packaging using edible film and coatings, water soluble packaging, self heating and self cooling packaging and chitosan based films and many more to come in the near future. These innovative packaging technologies contributed towards the enhancement of food quality, safety, feasibility and bio activity of functional components. These techniques are growing widely because of their health impact and thus resulted in reduced consumer complaints.

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