# Recent developments in food packaging technologies


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### ABSTRACT

***Good packaging plays an important role in supplying hygienic and safe food to the consumers by protecting it from physical, chemical, and microbial damage. Packaging is a crucial link between manufacturers and consumers, unless performed correctly, the products lose quality, and customers also lose confidence. The food packaging industry gets highly competitive due to consumer's desire for tasty and slightly processed food products with longer shelf life at a lower cost than their existing packaging. Recent trend in the change of lifestyle leads food industry well aware about consumer's needs, and therefore, the packaging industry must innovate or stagnate. This condition has posed a great challenge for the food packaging sector to innovate new food packaging techniques. Consumers will often actively seek freshness of the product with the longest remaining shelf life. Nowadays, novel food packaging technologies, such as active packaging, aseptic packaging, intelligent packaging, nano-packaging, and bioactive packaging intentionally associated with the food products have proved to be best technological research areas. Advances in the packaging technology may prevent food spoilage by retarding water penetration, ultra violet interactions, oxygenation, and ripeness. By doing so, it helps in fulfilling the needs of consumers throughout the food supply chain by gearing up toward person's own lifestyle. The consumers are advised to meticulously check that the food purchased from the market is well packaged. It is emphasized that food should be protected at all levels by using good quality of packaging material, which is hygienic, safe, and cost effective.***



**Keywords**: Active Packaging, Functions of Packaging, Intelligent Packaging, Modified Atmospheric Packaging, Nanotechnology, Shelf life


## INTRODUCTION

Food is indispensible for the sustaining life process in all living creatures. In recent years, rapid industrialization, population growth, and changed life style lead to increased demand for processed and packed foods (Pal, 2014). Currently, ready to eat packed food industry is growing very fast. Packaging is considered as the science, art, and technology of protecting the products during transportation, distribution, storage, sale, and use (Pal, 2014). Further, packaging ensures safe and efficient delivery of the commodity to the consumer in good condition. Good packaging attracts the customer to buy the product. It also plays a vital role in reducing the security risks during shipment. Packaged products are easy in displaying, handling, storing, distributing, opening, reclosing, and reusing (Pal, 2014). Food packaging performs four important functions, such as containment, protection, convenience, and communication (Pal, 2014). A wide variety of materials, such as cane baskets, wooden boxes, clay vessels, metal cans, China pots, paper bags, and plastics containers are still used for packaging the products in many areas of the world (Pal, 2014). The packaging material should not cause any environmental pollution. Hence, there is a need to undertake detailed studies to assess the impact of food packaging on the environment.

In this context, Paine and Paine (1983) reported that packaging contains, protects, and preserves as well as informs to create convenience to consumers. It is stated that many companies apply packaging to create values beyond the basic components of containing, protecting, preserving, and informing (Bramklev *et al*., 2001). Recent progresses in food packaging are resulting from rising need of mild processed but with better shelf life food products by the consumers (Dobrucka and Cierpiszewski, 2014). Important reason for innovative packaging is the emergence of food borne microbial outbreaks that demands packaging with anti-microbial products to as certain quality and safety (Peltzer *et al*., 2009). It is crucial that no hazardous components should touch the food within the packaging, and the flavour of the food should not get affected. The food must not change its original appearance and taste. In addition, the food should not cause any discolouring in the packaging. It is pertinent to mention that high-quality films serve to protect a product during transportation, distribution and use (Pal, 2014). It seems that the public health impact of unhygienic packaging of food is not well studied. The new food packaging techniques, such as intelligent packaging, bio-active packaging, and active packaging, which engage deliberate contact with the food or its surroundings and influence on consumer's health has been the most important innovations in the field of packaging technology (Majid *et al*., 2016). Therefore, the main objective of this article is to present an overview on the new innovations in food packaging technology.

*This paper is dedicated in the memory of Dr. Har Gobind Khurana, Indian American Biochemist who won a Noble Prize in the field of Genetics in 1968 for his pioneer research work on discovering the order of nucleotides in DNA. He is also credited to construct synthetic gene. He was also awarded the National Medal of Science during his life.*

## BASIC FUNCTIONS OF PACKAGING

Appropriate and sterile packaging is a necessity for every fresh or processed food. The packaging function is based on the capacity of the process to maintain food integrity during processing, transportation, marketing, and dispensing. Food protection could be based on the type of food product but generally it includes avoiding biological contamination, oxidation, moisture change, unpleasant aroma, and physical damage. The function of good packaging is usually identified through aesthetics and appropriate information on packaging. This information should primarily consider the needs of the consumers to attract their attention, and arouse their desire to buy a product (Baraniecka, 2002).

The information shown on package is a multi-dimensional process which consists of cognitive phase (convey information), affective phase (produce emotions), and behavioural phase (action). These phases are supposed to result in location of the product in the hierarchy of alternative products taking into account its quality, price as well as brand, and arouse the desire of having and buying it (Han *et al*., 2005). Food labeling generally means putting information on the container that concerns about the food packed. It can be putted in letters, words, logos, images, figures or symbols. It can contain information regarding to shelf-life, methods of preparation, consumption, nutritional value, and other commercial concerns (Agriopoulou, 2016). The most important function of food packaging is protection. Protection creates a barrier to safeguard food from the environment. Utility or providing convenience to a consumer is another function of packaging. Convenience includes range of sizes, easy handling and opening, dispensing, and food preparation in the package (ICAR Online e-course).

Unitization is assembling or grouping of products into a single entity to make it more dispensable, and marketable as a single unit. It reduces tedious physical distribution, and damage Packaging also contains brand communication to the consumers using letters, symbols, descriptions and color to have visual impact. Packaging helps to promote the food as it informs to consumers about many offers i.e. free extra product, new product, money off etc. The package is considered as a critical part of the manufacturing process that is adequately and efficiently done to save costs. It must use affordable materials that provide the required protection during transportation, and distribution (ICAR Online e- courses).

## REQUIREMENTS OF EFFICIENT FOOD PACKAGING PROCESS

The important requirements of food package are given as follows (ICAR Online e- courses).

1. It should protect from physical damage.
2. It should safeguard from contamination.
3. It should protect from bad smell and external toxicants.
4. It should be nontoxic.
5. It should have no effect on the food packaged.
6. It should be easy to open.
7. It should act as a barrier for moisture and oxygen ingress
8. It should filter harmful ultra violet light.
9. It should meet the required physical requirements.
10. It should be transparent and resistant or tamper.
11. It should have appearance and printability features.
12. It should be of low cost.
13. I should have handling features.
14. It should be disposed easily.

## SHELF LIFE

The Institute of Food Technologists in the United States has defined shelf life as "The period between the manufacture and the retail purchase of a food product, during which time the product is in a state of satisfactory quality in terms of nutritional value, taste, texture, and appearance" (Potter an Hotchkiss 1995) . The Institute of Food Science and Technology in the United Kingdom has stated shelf life as "The period of time during which the food product will remain safe; be certain to retain desired sensory, chemical, physical, microbiological, and functional characteristics; and comply with any label declaration of nutritional data when stored under the recommended conditions" (Potter and Hotchkiss, 1995). Various factors affecting shelf life are product characteristics, which include intrinsic factors, such as water activity, pH, microflora, availability of oxygen, reduction potential; and extrinsic factors, such as temperature, rainfall, humidity, light etc., enzymic reactions, chemical reactions, and non-enzymic reactions.

There are various chemical, biochemical and physical reactions that lead to food quality deterioration. These include enzymic and non-enzymic browning, fat oxidation, hydrolysis, lipolysis, and proteolysis that change the physical and chemical composition of food (Robertson, 2012).

## MODERN PACKAGING SYSTEM

### 1. Active Packaging

Active packaging emerged with the objective of consumer satisfaction in regard to demand for natural, recyclable, and bio-degradable packaging materials (Lesiów and Kosiorowska, 2006). In this packaging system, intrinsic conditions of the package are changed due to interaction of packaging material, food product, and the environment. Wholesomeness, safety, and aesthetic values are ensured by this condition, which provides longer shelf life (Hernik , 2013; Kit *et al*., 2005; Pal, 2017). Unlike to the traditional one, active packaging extends the shelf life, and improves safety by avoiding contamination (De Kruijf *et al.,* 2002; Gomez-Estaca *et al*., 2014). The principle behind using active packaging is due to the presence of important components, and the intrinsic characteristics used in the packaging process (Gomez-Estaca *et al*., 2014).

Gas absorbents and emitters control the atmospheric balance inside packaging. The controlled supply of active substances into the food via packaging helps to extend shelf life, and avoids unnecessary flavor (Paine and Paine 1983). Selection of synthetic additives should be done very carefully considering all the possible characteristics of product, and packaging material; and should be able to form homogeneous distribution inside. The use of artificial anti-oxidants is reduced due to migration of toxic substances into the food products (Farmer, 2016). However, natural additives have bioactive phenol compounds that are excellently used in meat products active packaging because they have antimicrobial effects (Bakkali *et al*., 2008; Lopez-Rubio *et al*., 2004; Restuccia *et al*., 2010). The antimicrobial agents in active packaging inhibit the microbial growth, and become effective either by direct addition to food surface for gradual diffusion or infused in vapor form (Stefania and Vicini, 2001). During storage, the atmospheric oxygen diffusing through the packaging material is absorbed by oxygen scavengers in which its response is based on oxidation of iron compounds. Most often, the agents that absorb oxygen via iron compounds are placed in sachets permeable to oxygen (Duncan, 2011). Carbon dioxide reduces respiration of fresh goods, and prevents collapsing of package because of the presence of oxygen absorbers (Sekhon, 2010). Moisture scavengers present in form of sachet, absorbent tray, and absorbent pads control humidity and excess of moisture present inside the package (Hernik., 2013). Antimicrobial packaging is performed in the form of solutions, which contain active component inside the packaging material. During the plastic films production processes, antimicrobial substances are introduced. Antimicrobial packaging can be done using compounds with natural antimicrobial activity, such as enzymes, and bacteriocins, which can be activated due to chemical or physical modifications (Cierpiszewski, 2016).

Examples of the common active packaging applications that are used within the food industry are oxygen scavengers, carbon dioxide scavengers/emitters, ethylene scavengers, preservative releasers, ethanol emitters, moisture absorbers, flavor/odor absorbers, and temperature control packaging (ICAR Online e- courses).

**2. Intelligent Packaging**

According to the American Heritage Dictionary, the word "intelligent" is defined as "showing sound judgment and rationality" and as "having certain data storage and processing capabilities" (Kerry *et al*., 2006). Intelligent packaging is happened with advance in time and facilities, such as biosensors, temperature regulators, radio frequency indicators, and ripeness monitors (Peltzer *et al.,* 2009). It performs sensing, detecting, recording, and communicating for decision making, and to extend storage time, and to enhance safety and quality.

According to above definition, a package is "intelligent" since it has the above aforementioned extraordinary capacity to communicate with humans, and provide early warning to the consumer or food manufacturer (Kerry *et al*., 2006). This packaging system in turn helps to evaluate effectiveness of the packaging process (Brennan, 2006). In addition, it includes indicators that are used for quality control of packed food. The external attachment outside the package (time-temperature indicators), and the internal inside the package are the two indicators that are attached to the head-space or into the lid.

**a.** *Time Temperature Indicator*

It is defined as a simple device that gives a clue about time-temperature change of a food product. The operation can be physical, chemical or biological irreversible change expressed by physical deformation including color change (Pavelkova, 2013; Robertson, 2013).

**b.** *Freshness Indicators*

In fresh food products, two types of changes can happen, which includes:

(i) Microbiological changes, such as formation of toxic compounds, unpleasant odor, and pH changes
(ii) Lipid and pigments oxidation producing off flavors/odors, discoloration, and other adverse chemical/biological reactions

A freshness indicator can directly reveal quality of a food product. Microbiological quality can be indicated due to the reaction between the indicator and the metabolites produced during growth of microorganisms in the product. In addition to temperature abuse or package leaks, an indicator that specifically shows spoilage (lack of freshness) of a product would be ideal for the quality control of packed products. Therefore, it is advised that consumers should not use such products regardless of the "use-by" date (Gontard, 2000). Such indicator in the package is used to ensure freshness of products during purchasing, and consumption. It can be used on packed perishable foods, such as milk, vegetables, fruits, cakes, and other chilled foods (Wilson, 2007).

**c.** *Pathogen Indicators*

This helps to check the availability of pathogenic bacteria by detecting immobilized antibodies. Commercially available Toxin Guard ™ is a substance to produce polyethylene-based packaging material with this type of indicator. This works when the analyte (toxin, microorganism), which is in contact with the material, and first bound to a specifically labeled antibody then to a capturing antibody printed as a specific pattern (http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/food_technology/food_packaging_technology/25.active_and_intelligent__packaging/et/2665_et_m25.pdf)

**3. Nanotechnology**

Nanotechnology is a new system, which uses devices or materials with a dimension having 1-100 nm in length (Duncan, 2011). Nanotechnology and nanomaterials have very small dimensions of less than 100 nanometers. Nanomaterials are materials with external dimension on the nanoscale having nanoparticles, nanofibers, and nanoplates as three clusters (Pal, 2017). Mixture of inorganic polymers, and additives having certain geometrics are nanocomposites. Nanotechnology has diversified and wide applications in areas of packaging, cosmetics, biomedical, electronics, textiles, papers, veterinary medicines, water treatment etc. Currently, over 400 global companies are using nanotechnology for food processing, and packaging (Pal 2017; Neethirajan *et al*., 2011). Nanopaticles based sensors, array biosensors, nanocantilevers, nano-test strips, nanoparticles in solution, and electronic noses are the various types of nanosensors used in the food packaging plants.

Nowadays, a variety of nanomaterials are introduced as functional additives to food packaging, such as nano-titanium dioxide, titanium nitride nanoparticle, silver nanoparticle, nanoclay, and nano-zinc oxide (Tager, 2014; Pal, 2017). Nano-sensors in package are important to trace the conditions of containers, and products. They can detect gases in the food if there is food spoilage and package color change (Pal, 2017). Film packed with silicate nanoparticles keeps freshness of food by reducing oxygen flow into the package, and avoiding leaking of moisture out of package. It also prevents mold growth inside refrigerators. This packaging technology detects the presence of microbial pathogens, toxins, pesticides, and other food spoiling agents in food within 2-7 days (Wesley *et al*., 2014). Supermarkets can keep food for longer periods of time before sale, as nano-antimicrobials extend shelf life longer (Sekhon, 2010). These days, nanotechnology came with a revolution in the food industry due to its several applications in all areas of food science, agriculture, food processing and packaging, nutrition, and neutraceuticals (Wesley *et al*., 2014). Therefore, this newly emerged food packaging technology extends storage time, improves safety and quality of food, and reduces packaging waste (Vermeiren *et al*., 1999; Pal, 2017).

### 4. Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) is a system of constituting air in the package by a prepared mixture of gases before sealing. Once the package is sealed, no further control is exercised over the composition of the in-package atmosphere (Wyrwa1 and Barska, 2017). However, this composition may change during storage as a result of respiration of the contents and/or solution of some of the gas in the product. Whereas, vacuum packaging involves withdrawing air from package before sealing but no other gases are introduced. Therefore, this technique is not usually regarded as a form of MAP but used in food products, such as cured meats, and cheese for many years (Wyrwa1 and Barska, 2017).

Gases, such as nitrogen, carbon dioxide, and oxygen are applied commercially in modified atmosphere packaging. Carbonic acid that is product of carbon dioxide and water lowers the pH of the food and inhibits microbial growth mainly molds, and some aerobic bacteria (Brody, 1994). Lactic acid bacteria are resistant to the gas, and may replace aerobic spoilage bacteria in modified atmosphere packaged meat. Most of the yeasts are also resistant to carbon dioxide. Anaerobic bacteria, including food poisoning organisms, are little affected by carbon dioxide. Consequently, there is a potential health hazard in MAP products from these microorganisms. Molds and some Gram negative, aerobic bacteria are inhibited by carbon dioxide concentrations in the range 5–50% (Brennan, 2006). In general, the higher the concentration of the gas, the greater is its inhibitory power. The inhibition of bacteria by carbon dioxide increases as the temperature decreases (ICAR Online e- courses).

However, nitrogen has only a role to inhibit the oxidation of fats by replacing oxygen. It is used as a bulking material to avid collapse of MAP packages when the carbon dioxide dissolves in the food since its solubility in water is low (Pal,2017; Wyrwa1 and Barska ,2017) .

This is also important in packaging of sliced or ground food products, such as cheese, which consolidates under vacuum. Due to oxidation of myoglobin pigments, oxygen is included in MAP packages of red meat to maintain the red color, and in white fish to reduce the risk of botulism (ICAR Online e- courses). Other gases have antimicrobial effects by which sulphur dioxide has been used to inhibit the growth of molds and bacteria in some soft fruits, and fruit juices. Argon, helium, xenon, and neon, have also been used in MAP of some foods (Brody, 1994). MAP packages are either thermoformed trays with heat-sealed lids or pouches. With the exception of packages for fresh produce, these trays, and pouches need to be made of materials with low permeability to gases ($CO_2$, $N_2$, and $O_2$). Laminates made of various combinations of polyester (PET), polyvinylidene chloride (PVdC), polyethylene (PE), and polyamide are used (ICAR Online e- courses).

## CONCLUSION

Recently, food packaging process, biotechnology, sensor science, information technology, nanotechnology, and other scientific disciplines are coming together to develop a breakthrough in packaging technology. These improved packaging techniques are continuously getting advanced by creating new opportunities in food industries to utilize these technologies in the future. Active packaging is a booming area of food packaging process that has preservation benefits on many food products. Because of timely advances in packaging process, growth in biotechnology and new consumer demands, active packaging has developed a trust in the consumers. This technology extends shelf life; maintain sensory quality besides ensuring quality and safety of food products. Nowadays, oxygen absorbers can be added as small separate sachets in the package to have the most commercial significance in active food packaging. Sachets are not well accepted by consumers since there is a possibility of accidental consumption with package contents by children. In the coming decades, the use of active packaging systems in the form of thin films would be becoming universal. Intelligent packaging is another packaging system, which can help in food quality control. This technology incorporates nanosensors that provide information on the condition of the food inside the package. Nanopackaging is also highly recommendable since it releases different substances such as flavors, enzymes, antioxidants, antimicrobials, and nutraceuticals to extend the shelf life of the food products. For efficient, effective, and safe development of nanotechnologies in the food industry, there is a need to conduct further toxicological, and other scientific investigations. Finally, an intelligent food quality and safety control system, which enables efficient production with reduced complains from retailers, and consumers is mandatory. Therefore, continuous innovations in active and intelligent packaging systems are expected to secure food quality, safety, and stability and to satisfy the ever growing need of consumers.

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