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Novel packaging technology for food industry

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Abstract
Packaging has a significant role in the food supply chain and it is an integral part both of the food processes and the whole food supply chain. Active and intelligent food packaging is based on a deliberate interaction of the packaging with the food and/or its direct environment. Active packaging aims at extending shelf life or improving safety while maintaining quality. Intelligent packaging systems which monitor the condition of the packed food or its environment are progressing towards more cost-effective, convenient and integrated systems to provide innovative packaging solutions. Market growth is expected for active packaging with leading shares for moisture absorbers, oxygen scavengers and antimicrobial packaging. The market for intelligent packaging is also promising with strong gains for time-temperature indicator labels and advancements in the integration of intelligent concepts into packaging materials.

Keywords: active packaging, intelligent food packaging, food quality, safety

Introduction
Packaging is defined as a socio-scientific discipline which operates in a society to deliver goods to the ultimate consumer in the best conditions intended for their use. Food packaging performs a number of disparate tasks: it protects the food from contamination and spoilage; it makes it easier to transport and store foods; and it provides uniform measurement of contents. By allowing brands to be created and standardized, it makes advertising meaningful and large-scale distribution and mass merchandising possible.
Food packages with dispensing caps, sprays, Reclosable openings, and other features make products more usable and convenient. A distinction is usually made between the various level of packaging. A primary package is one that is in direct contact with the contained product. It provides the initial, and usually the major, protective barrier. Examples of primary packages include metal cans, paperboard cartons, glass bottles, and plastic pouches. It is frequently only the primary package that the consumer purchases at retail outlets.
A secondary package contains a number of primary packages, for example, a corrugated case. It is the physical distribution carrier and is sometimes designed so that it can be used in retail outlets for the display of primary packages. A tertiary package is made up of a number of secondary packages, the most common example being a stretch-wrapped pallet of corrugated cases. In interstate and international trade, a quaternary package is frequently used to facilitate the handling of tertiary packages. This is generally a metal container up to 40 m in length that can hold many pallets and is intermodal in nature.

Requirements
- Basic requirements are good marketing properties, reasonable price, technical feasibility (e.g., suitability for automatic packaging machines, sealability), suitability for food contact, lower environmental stress and suitability for recycling or refilling.
- Proper convenience to the consumer, like easy opening, reclosable lids and a suitable dosing mechanism.

Smart Packaging
The term smart packaging was coined in the mid-1980s to describe package structures that sensed changes in the internal or surrounding environment & altered some of their relevant properties in response

Active Packaging
According to the Actipak project active packaging changes the condition of the packed food to extend shelf-life or to improve safety or sensory properties, while maintaining the quality of the packaged food. Food condition in the definition of active packaging includes various aspects that may play a role in determining the shelf-life of packaged foods, such a physiological processes (e.g., respiration of fresh fruit and vegetables), chemical processes

(e.g., lipid oxidation), physical processes (e.g., staling of bread, dehydration), microbiological aspects (e.g., spoilage by micro-organisms) and infestation (e.g., by insects). Through the application of appropriate active packaging systems these conditions can be regulated in numerous ways and, depending on the requirements of the packaged food, food deterioration can be significantly reduced.

Active packaging techniques for preservation and improving quality and safety of foods can be divided into three categories; absorbers (i.e. scavengers), releasing systems and other systems. Absorbing (scavenging) systems remove undesired compounds such as oxygen, carbon dioxide, ethylene, excessive water, taints and other specific compounds. Releasing systems actively add or emit compounds to the packaged food or into the head-space of the package such as carbon dioxide, antioxidants

Examples of active packaging systems - Absorbers

1. **Oxygen absorbers:** (sachets, labels, films, corks) – purpose
- Reduction/preventing of mould, yeast and aerobic bacteria growth
- Prevention of oxidation of fats, oils, vitamins, colours
- Prevention of damage by worms, insects and insect eggs
- **Applications in:** Cheese, meat products, ready-to-eat products, bakery products, coffee, tea, nuts, milk powder
- **Examples:** Ferro-compounds, ascorbic acid, metal salts, glucose oxidases

2. **Carbon dioxide absorbers** – Purpose:
- Removing of carbon dioxide formed during storage in order to prevent bursting of a package
- **Applications in:** Roasted coffee, Beef jerkey, Dehydrated poultry products
- **Examples:** Calcium hydroxide and sodium hydroxide or potassium hydroxide, Calcium oxide and silica gel

3. **Ethylene absorbers** – Purpose:
- Prevention of too fast ripening and softening
- **Applications in:** Fruits like apples, apricots, mango, tomatoes, avocados and vegetables like carrots, potatoes and Brussels sprouts
- **Examples:** Aluminium oxide and potassium permanganate (sachets), Activated carbon + metal catalyst, Clay

4. **Humidity absorbers:** (drip-absorbent sheets, films, sachets) - purpose
- Control of excess moisture in packed food
- Reduction of water activity on the surface of food in order to prevent the growth of moulds, yeast and spoilage bacteria
- **Applications in:** Meat, fish, poultry, bakery products, cuts of fruits and vegetables
- **Examples:** Polyacrylates, Propylene glycol, Silica gel, Clay

5. **Lactose remover -** Purpose
- Serving milk products to the people suffering lactose intolerance
- **Applications in:** Milk and other dairy products
- **Example:** Immobilised lactase in the packaging material

6. **UV - light absorbers -** Purpose
- Restricting light-induced oxidation
- **Applications in:** Light-sensitive foods such as ham, Drinks
- **Examples:** Polyolefins like polyethylene and polypropylene doped with a UV-absorbent agent

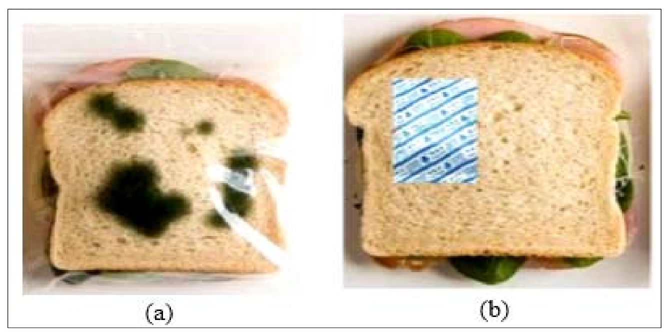
7. **Cholesterol remover -** Purpose
- Improving the healthiness of milk products
- **Applications in:** Milk and other dairy products
- **Example:** Immobilised cholesterol reductase in the packaging material

Principles on which scavengers are based

Oxygen scavenging sachets: Principle- In general, O_2 scavenging technologies are based on one of the following concepts: iron powder oxidation, ascorbic acid oxidation, catechol oxidation, photosensitive dye oxidation, enzymatic oxidation (e.g. glucose oxidase and alcohol oxidase), unsaturated fatty acids (e.g. oleic acid or linolenic acid) or immobilised yeast on a solid material (Floros *et al*., 1997) [2]. The majority of presently available oxygen scavengers are based on the principle of iron oxidation (Nakamura and Hoshino, 1983; Rooney, 1995; Vermeiren *et al*., 1999) [22, 25].

- **Iron Powder Oxidation:** Mechanism**:**

$$Fe \longrightarrow Fe^{2+} + 2e^-$$
$$\tfrac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$
$$Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2$$
$$Fe(OH)_2 + \tfrac{1}{4} O_2 + \tfrac{1}{2} H_2O \longrightarrow Fe(OH)_3$$



Bread packaged without (a) and with (b) oxygen scavenger

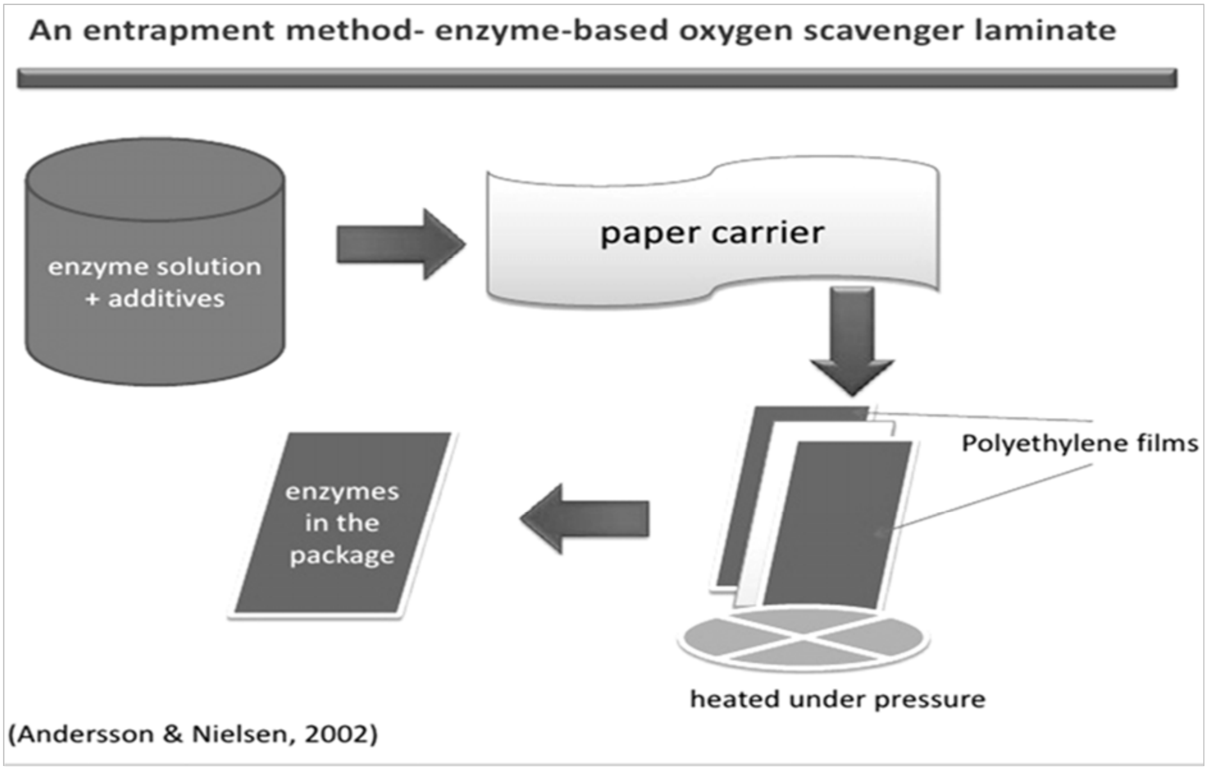
- **Enzymatic Oxidation**

A combination of two enzymes - glucose oxidase and catalase, has been applied for oxygen removal. The reaction is:

$$\textbf{2 Glucose + 2 } O_2 \textbf{ + 2 } H_2O \longrightarrow \textbf{2 Gluconic Acid+2 } H_2O_2$$

Since H_2O_2 is an objectionable end product, catalase is introduced to break down the peroxide (Rooney, 1995; Vermeiren *et al.,* 1999) [22, 25]:

$$\textbf{2 } H_2O_2 \textbf{ + Catalase} \longrightarrow \textbf{2 } H_2O + O_2 \textbf{ + Catalase}$$



Enzyme-based oxygen scavengers

Oxygen scavenging films

Incorporation of oxygen scavenger sachets in the food package suffers from the disadvantage of possible accidental ingestion of the contents by the consumer. Another concern is that the sachet could leak out and contaminate the product. When sachets are used, there also needs to be a free flow of air surrounding the sachet in order to scavenge headspace oxygen (Rooney, 1995) [22]. To eliminate this problem, oxygen removing agents can be incorporated into the packaging material such as polymer films, labels, crown corks, liners in closures. These oxygen scavenging materials have the additional advantage that they can be used for all products, including liquid products.

Ethylene Scavenging Technology

To prolong shelf-life and maintain an acceptable visual and organoleptical quality, accumulation of ethylene in the packaging of fruits and vegetables should be avoided.

Commonly used ethylene adsorbers are based on potassium permanganate. The oxidation of ethylene with potassium permanganate can be thought of as a two-step process. Ethylene (CH_2CH_2) is initially oxidised to acetaldehyde (CH_3CHO), which in turn is oxidised to acetic acid (CH_3COOH). Acetic acid can be further oxidized to carbon dioxide and water:

$$3CH_2CH_2 + 2KMnO_4 + H_2O \rightarrow 2MnO_2 + 3CH_3CHO + 2KOH \quad (1)$$

$$3CH_3CHO + 2KMnO_4 + H_2O \rightarrow 3CH_3COOH + 2MnO_2 + 2KOH \quad (2)$$

$$3CH_3COOH + 8KMnO_4 \rightarrow 6CO_2 + 8MnO_2 + 8KOH + 2H_2O \quad (3)$$

Combining eq. 1–3, we get:

$$3CH_2CH_2 + 12KMnO_4 \rightarrow 12MnO_2 + 12KOH + 6CO_2$$

Potassium permanganate adsorbers change from purple to brown as the MnO_4^- is reduced to MnO_2, indicating the remaining adsorbing capacity.

Carbon dioxide scavengers

Carbon dioxide is formed in some foods due to deterioration and respiration reactions. The produced CO_2 has to be removed from the package to avoid food deterioration and/or package destruction. Fresh roasted coffee can release considerable amounts of CO_2 due to the Strecker degradation reaction between sugars and amines (Labuza and Breene, 1989) [16]. Unless removed, the generated CO_2 can cause the packaging to burst due to the increasing internal pressure.

Another CO_2 producing food product is kimchi, a general term for fermented vegetables such as oriental cabbage, radish, green onion and leaf mustard mixed with salt and spices. Because kimchi cannot be pasteurised for its sensory quality, the fermentation process still continues with the concomitant production of CO_2. The accumulation of CO_2 in the packages causes ballooning or even bursting. Scavengers might therefore be useful.

Principle

The reactant commonly used to scavenge CO_2 is calcium hydroxide, which, at a high enough water activity, reacts with CO_2 to form calcium carbonate:

$$\mathbf{Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O}$$

Examples of sachet and film type releasing active packaging systems:

1. **Carbon dioxide emitters** (sachets) - Purpose
   - Growth inhibition of gram-negative bacteria and moulds
   - Applications in: Vegetables and fruits, fish, meat, poultry
   - Examples: Ascorbic acid, Sodium hydrogen carbonate

2. **Ethanol emitters** (sachets) - Purpose
   - Growth inhibition of moulds and yeast
   - Applications in: Bakery products, Dry fish
   - Examples: Ethanol/water mixture absorbed onto silicon dioxide powder generating ethanol vapour

3. **Antimicrobial preservative releasers** (films) **-** Purpose
- Growth inhibition of spoilage and pathogenic bacteria
- Applications in: Meat, poultry, fish, bread, cheese, fruit and vegetables
- Examples: Organic acids, e.g. sorbic acid, Spice and herb extracts, Allylisothiocyanate

4. **Sulphur dioxide emitters** (sachets) **-** Purpose
- Inhibition of mould growth
- Examples: Sodium - metabisulfite incorporated in microporous material
- Applications in: Fruits

5. **Antioxidant releasers** (films) - Purpose
- Inhibition of oxidation of fat and oil
- Examples: BHA, BHT, Tocopherol
- Applications in: Dried foodstuffs, Fat-containing foodstuffs

6. **Flavouring emitters** (films) - Purpose
- Minimisation of flavour scalping
- Masking off-odours
- Improving the flavour of food
- Examples: Various flavours in polymers

7. **Pesticide emitters** (the outer or inner layer of packaging material) - Purpose
- Prevention of growth of spoilage bacteria
- Fungicidal or pest control
- Examples: Imazalil, Pyrethrins
- Applications in: Dried, sacked foodstuffs, e.g., flour, rice, grains

Other examples of active packaging systems

1. **Self-heating cans:** A Self-heating can is an enhancement of the common food can. Self-heating cans have dual chambers, one surrounding the other, making a self-heating food package. The inner chamber holds the food or drink, and the outer chamber houses chemicals that undergo an exothermic reaction when combined. When the user wants to heat the contents of the can, a ring on the can when pulled breaks the barrier that keeps apart the chemicals in the outer chamber from the water. In another type, the chemicals are in the inner chamber and the beverage surrounds it in the outer chamber. To heat the contents of the can, the user pushes on the bottom of the can to break the barrier separating the chemical from the water. This design has the advantages of being more efficient (less heat is lost to the surrounding air) as well as reducing excessive heating of the product's exterior, causing possible discomfort to the user. These are usually made up of aluminium or steel.

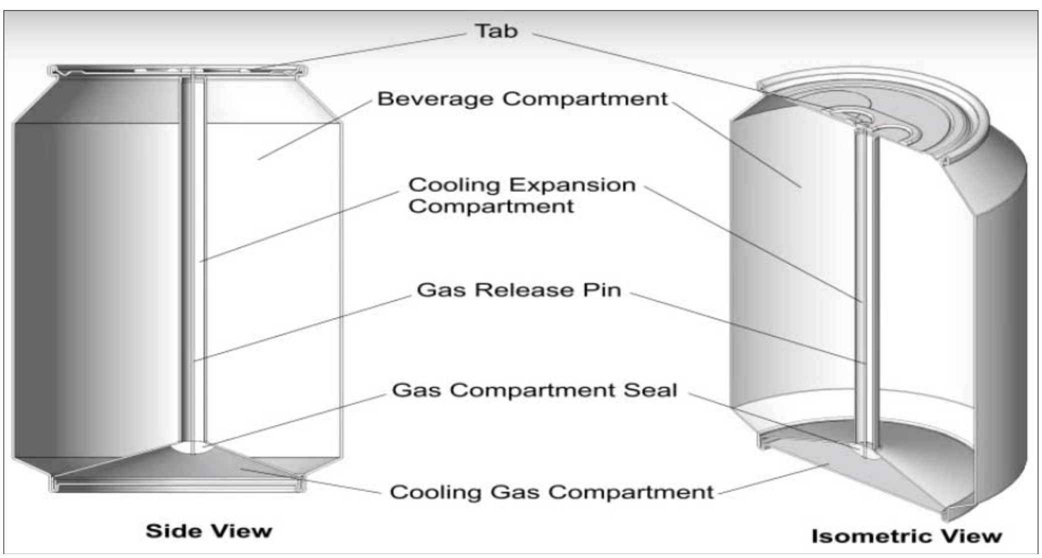
The heating agent and responsible reaction vary from product to product. However, calcium oxide is mostly used. The reaction is:

$$\mathbf{CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2\,(s)}$$

Copper sulphate and powdered zinc can also be used, but this process is less efficient:

$$\mathbf{CuSO_4(s) + Zn(s) \longrightarrow ZnSO_4(s) + Cu(s)}$$

2. **Self-cooling cans:** These are also made up of aluminium or steel. These are based on liquid nitrogen or other cooling gas. The beverage can has a built- in Heat Exchange Unit (HEU) which contains the technology necessary to chill the drink in under a minute. Upon activation (pressing the button at the base of the can), activates the environmentally safe reclaimed Co_2, or other cooling gas being used, in the HEU that leads to the chilling of the beverage.



Self-cooling can

Intelligent Packaging

Intelligent packaging systems monitor the condition of packaged foods to give information about the quality of the packaged food during transport and storage. They are of two types - external indicators, i.e., indicators which are attached outside the package (time-temperature indicators), and internal indicators which are placed inside the package, either to the head-space of the package or attached into the lid (oxygen indicators for indication of oxygen or package leak, carbon dioxide indicators, microbial growth indicators and pathogen indicators).

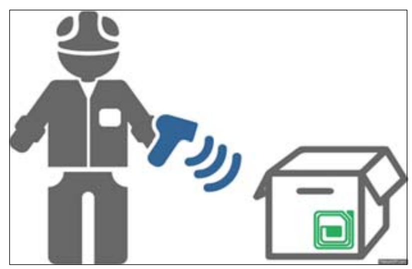
Examples of Intelligent Packaging

Indicator	Principle/reagents	Gives information about	Application
Time-temperature indicators (external)	Mechanical Chemical Enzymatic	Storage conditions	Foods stored under chilled and frozen conditions
Oxygen indicators (internal)	Redox dyes pH dyes Enzymes	Storage conditions Package leak	Foods stored in packages with reduced oxygen concentration
Carbon dioxide indicator (internal)	Chemical	Storage conditions Package leak	Modified or controlled atmosphere food packaging
Microbial growth indicators (internal/external) i.e. freshness indicators	pH dyes All dyes reacting with certain metabolites (volatiles or non-volatiles)	Microbial quality of food (i.e. spoilage)	Perishable foods such as meat, fish and poultry
Pathogen indicators (internal)	Various chemical and immunochemical methods reacting with toxins	Specific pathogenic bacteria such as *Escherichia coli* O157	Perishable foods such as meat, fish and poultry

Other examples of intelligent packages that increase convenience are

- **Thermochromic inks:** Thermochromic inks can be printed onto labels or containers that are to be heated or cooled prior to consumption to indicate the ideal drinking temperature for the product. Thermochromic ink reacts to changes in temperature by exhibiting a colour change. These inks are available with colour change activation at temperatures from -10°C up to 70°C and are reversible, changing either way as the ink warms or cools. If appropriate colors are chosen, then hidden messages such as “DRINK NOW” or “TOO HOT” become visible.

- **Microwave Doneness Indicators (MDIs):** MDIs detect & indicate visually the state of readiness of foods heated in a microwave/ oven. In products that heat non uniformly, the hottest regions will trigger a doneness indicator long before the cooler regions have achieved an acceptable temperature. The preferred location for an indicator is on the lid or dome of a container directly above the food. There are various drawbacks of these indicators like - False indications due to non- uniform heating, difficulty in observing the colour change without opening the oven etc.
- **Radio Frequency Identification (RFID):** RFID is the use of radio frequencies to read information on a small device known as tag. RFID is the term used for any device that can be sensed at a distance by radio frequencies with few problems from disorientation. RFID tags provide information regarding history and details of the product making traceability of the product easier. These are used to increase convenience/efficiency in supply chain management, and are being normally applied to secondary or tertiary packaging. If costs can be reduced significantly, then they could find application on individual consumer packages.



RFID

Antimicrobial Food Packaging

Antimicrobial functions which are achieved by adding antimicrobial agents in the packaging system or using antimicrobial polymeric materials show generally three types of mode; (i) release; (ii) absorption; and (iii) immobilisation.

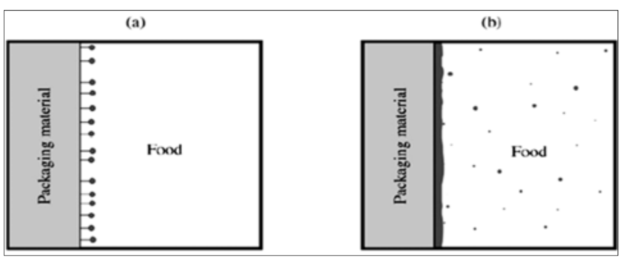
Antimicrobial agents and packaging systems

Table 1

Antimicrobial	Packaging materials	Food	Microorganisms
Benzoic acids	PE	Culture media	Total bacteria
Parabens	LDPE	Simulants	*S. cerevisiae, Asp. niger, Pen. spp.*
Benzoic & sorbic acids	PE	Culture media	*S. cerevisiae*
Acetic, propionic acid	Chitosan	Water	*Pen. spp.*
Lysozyme, nisin, EDTA	SPI, zein	Culture media	*E. coli, Lb. plantarum*
Imazalil	LDPE	Cheese	Moulds
Clove extract	LDPE	Culture media	Microorganisms
Eugenol, cinnamaldehyde	Chitosan	Ham	Enterobac., lactic acid bacteria
Allyl isothiocyanate	PE film	Chicken, meat	*E. coli, L. monocytogenes*

Non-Migratory Bioactive Polymers (NMBP) In Food Packaging

Non-migratory bioactive polymers (NMBP) are a class of polymers that possess biological activity without the active components migrating from the polymer to the substrate. This concept has existed for some time and has been applied primarily to immobilized enzyme processing. It is only now becoming of interest in packaging applications. Bioactive materials are based on molecules that elicit a response from living systems. The goal is to use bioactive materials for which the response is desirable from the standpoint of the package or the product, for example inhibition of microbial growth or flavour improvement. Enzymes are classic examples of bioactive substances, as are many peptides, proteins, and other organic compounds. The definition, from the perspective of packaging, is based on function: the way the substance interacts with living systems. Purely physical processes, for example adsorption or diffusion, are excluded from this definition. Bioactive polymers can be formed by attachment of bioactive molecules to synthetic polymers, as in the case of enzyme immobilization, or may result from an inherent bioactive effect of the polymer structure, as with chitosan. They have potential applications in the packaging of food and other biological materials, in food processing equipment, on biomedical devices and in textiles. Non-migratory bio polymers are defined to be those for which the bioactive component does not migrate out of the polymer system into the surrounding medium. Typically this is achieved through covalent attachment of the active component to the polymer backbone, inherently bioactive polymer backbones, or entrapment of the active component within the polymer matrix.



Simplified visual comparison of (a) non-migratory and (b) migratory bioactive packing. Adapted Form Han (2000) [12].

Inherently bioactive synthetic polymers: Types and Applications

There are two main types of NMBP – inherently bioactive polymers and polymers with covalently immobilised bioactive agents. For inherently bioactive polymers, the structural polymer itself is bioactive. For example, polymers containing free amines have been shown to be antimicrobial. Included in this definition are structural polymers with modified backbones. These polymers differ from those with immobilized bioactive compounds in that no previously synthesised bioactive compound is attached to the polymer chain. Most examples of inherently bioactive polymers involve antimicrobial activity.

1. **Chitosan** Chitosan is probably the most studied inherently bioactive NMBP to date. It possesses broad spectrum antimicrobial activity in simple media and is available commercially as an antifungal coating for shelf-life extension of fresh fruit. Chitosan is the deacetylated form of chitin (poly-β-(1,4)-*N*-acetyl-D-glucosamine), a common natural biopolymer extracted from the shells of crustaceans. Production of chitosan from chitin involves demineralisation, deproteinisation, and deacetylation (Oh *et al*., 2001). The properties of chitosan films, including antimicrobial efficacy, mechanical and barrier properties, are significantly affected by the degree of deacetylation. The key feature of the antimicrobial effect of chitosan is probably the positive charge that exists on the amino group at C-2 below pH 6.3. The positive charge on this group creates a polycationic structure, which may interact with the predominantly negatively charged components of the gram-negative outer membrane. They investigated the membrane interactions of chitosan with *E. coli*, *P. aeruginosa* and *S. typhimurium.*

Chitosan causes leakage of glucose and lactate dehydrogenase from bacterial cells. The activity involves interaction between polycationic chitosan and anions on the bacterial surface, resulting in changes in membrane permeability. A similar mode of action can be assumed against grampositive bacteria, fungi and yeasts.

Applications of chitosan: It's used in

- Dentistry and pharmaceuticals, and textiles
- Food packaging
- In microbial growth broths, chitosan has been found effective against gram-positive and gram-negative bacteria, along with some moulds and yeasts
- As an edible antimicrobial film for fish fillets

2. **UV irradiated nylon:** A recent development is surface modification of polymers leading to antimicrobial activity, for example treatment of nylon with an excimer laser at UV frequencies (193 nm). This has been described as a physical modification, although the actual change which leads to the induced antimicrobial activity is a chemical change: amides on the nylon surface are converted to amines, which remain bound to the polymer chains, as observed with X-ray photoemission spectroscopy (XPS). Antimicrobial nylon-6,6 is prepared by irradiating with an UV excimer laser at 193 nm for a total exposure of 1-3 J/cm^2. This results in conversion of approximately 10% of the surface amides and some etching of the film surface. The antimicrobial effect is strongly dependent on the wavelength of the laser used, with films treated at 193 nm showing a 5 log reduction in *K. pneumoniae* in one hour, while film treated at 248 nm has no antimicrobial effect. XPS analysis of the surface of film treated at 193 nm indicated that surface amide groups were converted to amines, while film treated at 248 nm showed no such change. The mechanism of antimicrobial activity is presumably similar to that of chitosan, poly-L-lysine and other cationic polymers, involving interaction with negatively charged microbial membranes leading to membrane disruption and leakage of cellular constituents.

Green Plastics for Food Packaging

1. Polylactic acid (PLA)

Polylactic acid (PLA) is a polymer of lactic acid. It behaves quite similarly to polyolefins. PLA, a fermentation product of low cost polysaccharides, is a product which is produced from a combination of biotechnology and chemical technology, and can be converted into plastic products by standard processing methods such as injection moulding and extrusion. It has potential for use in the packaging industry as well as hygiene applications. The current global market for lactic acid demand is 100,000 tons per annum, of which more than 75% is used in the food industry. Perhaps the biggest opportunities for PLA lie in fibres and films. An important market niche for PLA can be found in the agricultural industry such as crop covers and compostable bags. Biodegradations of PLA have been a subject of interest and so far proteinase K (EC 3.4.21.64) is the only reported enzyme that will degrade PLA amorphous regions of low MW (Reeve, *et al.*, 1994) [21]. Microbial degradation studies of PLA have been inclusive (Torres, *et al.*, 1996) [24]. Although most microorganisms studied can utilise lactic acid and its dimer, microbial degradation of oligomers and polymers of PLA have not yet been observed at appreciable rates. A microbial degradation study on PLA/CL only showed the degradation of the PCL segments (Lostocco, *et al.*, 1998). Compost, field and environmental degradations of PLA are primarily due to hydrolysis (Ho, *et al.*, 1999) [14].

2. Native starch

Starch is nature's primary means of storing energy and is found in granule form in seeds, roots and tubers as well as in stems, leaves and fruits of plants. Starch is totally biodegradable in a wide variety of environments and allows the development of totally degradable products for specific market needs. The two main components of starch are polymers of glucose: amylose (MW 10^5-10^6), an essentially linear molecule and amylopectin (MW 10^7-10^9), a highly branched molecule. Amylopectin is the major component of starch and may be considered as one of the largest naturally occurring macromolecules. Starch granules are semi-crystalline, with crystallinity varying from 15 to 45% depending on the source. The term 'native starch' is mostly used for industrially extracted starch. It is an inexpensive (< 0.5 Euro/kg) and abundant product, available from potato, maize, wheat and tapioca.

3. Thermoplastic starch

Thermoplastic starch (TPS) or destructurised starch (DS) is a homogeneous thermoplastic substance made from native starch by swelling in a solvent (plasticiser) and a consecutive 'extrusion' treatment consisting of a combined kneading and heating process. Due to the destructurisation treatment, the starch undergoes a thermo-mechanical transformation from the semi-crystalline starch granules into a homogeneous amorphous polymeric material. Water and glycerol are mainly used as plasticisers, with glycerol having a less plasticising effect in TPS compared to water, which plays a dominant role with respect to the properties of thermoplastic starch.

4. Chitin and chitosan

Chitin is the second most abundant naturally occurring biopolymer (after cellulose) and is found in the exoskeleton of crustaceans, in fungal cell walls and other biological materials (Andrady and Xu, 1997) [1]. It is mainly poly (ß-(1-4)-2-acetamide-D-glucose), which is structurally identical to cellulose. Chitosan is derived from chitin by deacetylation in the presence of alkali. Chitosan can form semi-permeable coatings, which can modify the internal atmosphere, thereby delaying ripening and decreasing transpiration rates in fruits and vegetables. Films from aqueous chitosan are clear, tough, flexible and good oxygen barriers (Sandford, 1989; Kalplan *et al.*, 1993) [7, 23, 15]. Carbon dioxide permeability could be improved by methylation of polymers. Butler *et al.* (1996) observed that films from chitosan were rather stable and their mechanical and barrier properties changed only slightly during storage. Chitosan coatings are usually used on fruit and vegetable products such as strawberries, cucumbers, bell peppers as antimicrobial coating (El Ghaouth *et al.*, 1991a, 1991b) [8, 9], and on apples, pears, peaches and plums as gas barrier (Elson and Hayes, 1985; Davies *et al.*, 1989) [7].

5. Cellulose

Cellulose is the most abundant occurring natural polymer on earth, being the predominant constituent in cell walls of all plants. Cellulose is composed of a unique monomer: glucose under its β-d-glucopyranose form (Credo and Berthelot, 2014) [5]. Due to its regular structure and array of hydroxyl groups, it tends to form strong hydrogen bonded crystalline microfibrils and fibers and is most familiar in the form of paper, paperboard and corrugated paperboard in the packaging context (Cruz-Romero and Kerry, 2008; Babu, *et al.*, 2013) [6, 3].

6. Shellac resins

Shellac is a resin secreted by the female lac bug (*Laccifer lacca*), on trees in the forests of India and Thailand. It is processed and sold as dry flakes and dissolved in ethanol to make liquid shellac, which is used as a brush-on colorant, food glaze and wood finish. Shellac functions as a tough natural primer, sanding sealant, tannin-blocker, odour-blocker, stain, and high-gloss varnish. Shellac is a natural bio-adhesive polymer and is chemically similar to synthetic polymers, and thus can be considered a natural form of plastic. It can be turned into a moulding compound when mixed with wood flour and moulded under heat and pressure methods, so it can also be classified as thermoplastic. This resin is soluble in alcohols and in alkaline solutions. Shellac is not a GRAS substance; it is only permitted as an indirect food additive in food coatings and adhesives. It is mostly used in coatings for the pharmaceutical industry (Hernandez, 1994) [13]. Shellac is also used as a coating on citrus fruits as it has good gas barrier properties. Shellac- and wood resin-based coatings also tend to increase prevalence of post-harvest pitting (Petracek *et al.*, 1997, 1998) [19, 20].

Modified Atmosphere Packaging

Modified atmosphere is the practice of modifying the composition of the internal atmosphere of a package (commonly food packages, drugs, etc.) in order to improve the shelf life. The modification process often tries to lower the amount of oxygen (O_2), moving it from 20.9% to 0%, in order to slow down the growth of aerobic organisms and prevent oxidation reactions. The removed oxygen can be replaced with nitrogen (N_2), commonly acknowledged as an inert gas, or carbon dioxide (CO_2), which can lower the pH or inhibit the growth of bacteria. Carbon monoxide can be used for preserving the red color of meat.

Re-balancing of gases inside the packaging can be achieved using active techniques such as gas flushing and compensated vacuum or passively by designing "breathable" films known as equilibrium modified atmosphere packaging (EMAP). Packets containing scavengers may be used.

Conclusion

The food industry has been under growing pressure to feed an exponentially increasing world population and challenged to meet rigorous food safety laws and regulations. The plethora of media consumption has provoked consumer demand for safe, sustainable, organic, and wholesome products with "clean" labels. The application of active and intelligent packaging has been commercially adopted by food and pharmaceutical industries as a solution for the future for extending shelf life and simplifying production processes; facilitating complex distribution logistics; reducing, if not eliminating the need for preservatives. Similarly antimicrobial packaging can play an important role in reducing the risk of pathogen contamination, as well as extending the shelf-life of foods; it should never substitute for good quality raw materials, properly processed foods and good manufacturing practices. It should be considered as a hurdle technology that in addition with other non-thermal processes such as pulsed light, high pressure and irradiation could reduce the risk of pathogen contamination and extend the shelf-life of perishable food products. Participation and collaboration of research institutions, industry and government regulatory agencies will be key on the success of antimicrobial packaging technologies for food applications.

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