

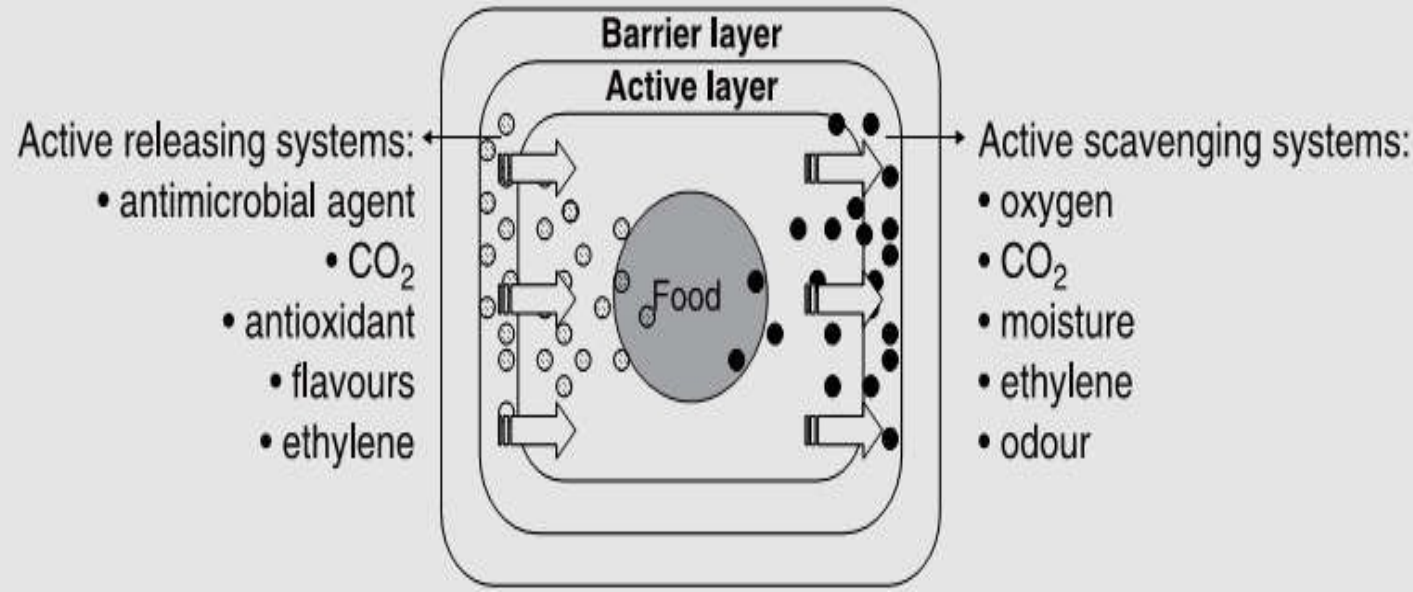
Concept of active packaging and role in bio-preservation



Concept of Active Packaging

- **Active packaging is an innovative approach to enhance the shelf-life of food stuffs while improving their quality, safety and integrity.**
- **It can be defined as a packaging system that interacts with the package components and the food to extend the shelf-life or to improve the safety or sensory properties of the food as well as quality of the packaged product.**

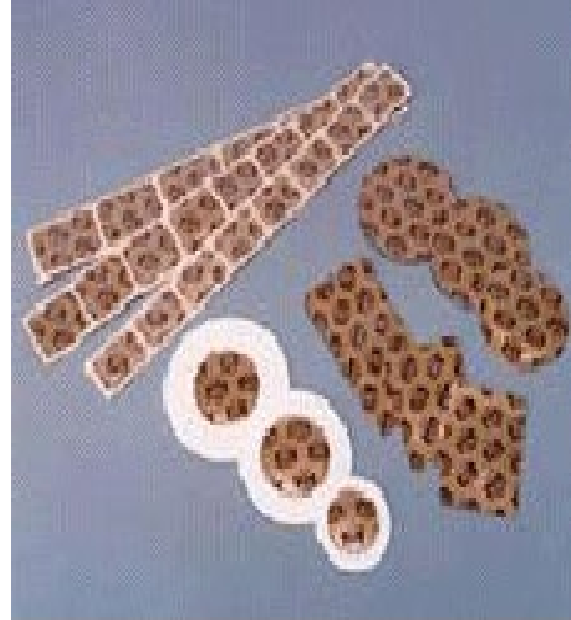
Active packaging systems can be classified into active-releasing systems (emitters) which add compounds to the packaged food or into the headspace, or active scavenging systems (absorbers), which remove undesired compounds from the food or its environment.



Active packaging	Example of benefits	Possible food applications
Antimicrobial releasers	Inhibition of growth of pathogens and spoilage microorganisms on food	Fresh meat, processed meat, fish, bread, cheese, cakes
Carbon dioxide releasers	Inhibition of growth of aerobic bacteria and moulds	Fresh meat, fish, cakes
Antioxidant releasers	Inhibition of oxidation of fats and oils	Snack foods, dried foods, meat
Flavour releasers	Enhancing the flavour of food	Cereals, dried foods
Ethylene releasers	Accelerated ripening	Fruits, vegetables
Oxygen absorbers	Inhibition of oxidation of food components. Inhibition of growth of aerobic bacteria, yeast and moulds	Bread, snack foods, dried foods, wine, cakes, tea, nuts, milk powder
Moisture absorbers	Remove the excess moisture	Snack foods, cereals, dried foods, sandwiches
Ethylene absorbers	Reduce the rate of ripening	Fruits, vegetables
Carbon dioxide absorbers	Prevention of bursting of the package	Coffee
Odour absorbers	Improving the flavour of the food	Fried snacks

Oxygen Scavengers

- Oxygen scavenging systems included the use of self-adhesive labels or loose sachets in the packaging containers along with food.
- Oxygen scavenging compounds react with oxygen to reduce its concentration inside the package.
- Ferrous oxide is the most widely used scavenger.
- Non-metallic oxygen scavengers (ascorbic acid) has been developed to eliminate the potential for metallic taints being imparted to food products.
- The presence of mixed enzymes such as glucose oxidase and catalase also scavenge oxygen in food.
- Glucose oxidase is a potential enzyme for oxygen-adsorbing processes where it catalyzes the oxidation of glucose to gluconic acid and H_2O_2 which is further degraded by catalase to water and oxygen.



CO₂ Scavengers:

- CO₂ scavengers avoid gas pressure buildup inside rigid packaging by absorbing CO₂ produced by fermented or roasted foods.
- CO₂ (60-80%) curbs microbial activity in modified atmosphere packaging, but it is undesirable when present in excess in natural cheeses, coffee or kimchi. A proper concentration of CO₂ is required for packaged fresh produce or fermented foods.
- Moderate or low CO₂ concentration is desirable for the best quality preservation. Since the permeability of CO₂ is 3-5 times >O₂ in most plastic films, it must be continuously produced to maintain the desired concentration within the food package.
- CO₂ scavenging materials can be enclosed in a sachet that is placed in the food package or fabricated as a sheet or coating.
- Ca(OH)₂ is the CO₂ scavenger that is used in food packaging. Activated carbon and zeolite are important due to their practical potential in food packaging applications. CO₂ gas can be adsorbed onto physical adsorbents such as zeolite and activated carbon.

Moisture Absorbers:

- **Moisture absorbers (sachets, pads, sheets or blankets) are used for packaging dried foods that include desiccants like silica gel, calcium oxide, activated clays and minerals as they are tear resistant in permeable plastic sachets.**
- **Apart from moisture absorber sachets for humidity control in packaged dried foods, moisture drip absorbent pads, sheets and blankets for water control in high water activity foods (fish, poultry, fruit and vegetables).**
- **They consist of two layers, a micro porous nonwoven plastic film like polyethylene or polypropylene between which a superabsorbent polymer (polyacrylate salts, CMC and starch copolymers) is placed that is capable of absorbing up to 500 times its own weight.**
- **Moisture drip absorber pads are placed under packaged fresh meats, fish and poultry to absorb unsighted tissue drip exudates. Larger sheets and blankets are used for absorption of melted ice from chilled seafood during air freight transportation.**

Ethanol Emitters:

- Ethanol emitters are preservative releasing technologies used in sachet forms.
- Ethanol is effective against molds but can also inhibit the growth of yeasts and bacteria.
- Mold free shelf-life of bakery products can be significantly extended after spraying with 95% ethanol (0.5–1.5% w/w) on the products.
- Practical way of generating ethanol is through the use of ethanol emitting sachets where, size and capacity of the ethanol emitting sachet is dependent on the weight of food, its water activity and the desired shelf-life.
- When food is packed with an ethanol emitting sachet, moisture is absorbed from the food and diffused as ethanol vapour into the package headspace.

Ethylene Scavengers:

- **Mechanisms to reduce or eliminate ethylene from packages and thus delay the ripening process to extent the shelf-life of fruit are being pursued.**
- **Polymeric matrix is introduced into the packaging material or can be applied as a coating (dispersion).**

Aroma releasers:

- **The addition of pleasant aroma compounds can mask unpleasant and bothering odors and avoid flavor scalping by modifying the equilibrium conditions.**
- **Improvement in the consumer appeal of the food products. However, currently most aroma emitting products**
- **are applied in plastic products for non-food applications.**

Odour Removers:

- Applications for scavengers of undesirable odours includes removal of amines produced due to oxidation of protein rich foods like fish, removal of aldehydes by oxidation of fatty acids in biscuits, fried foods and cereals as well as removal of bitter tasting components like limonene in fruit juices.
- Commonly, off odours are produced during protein breakdown due to sulphurous compounds like hydrogen sulphide and during lipid oxidation and of fats and oils. The off-odours can be sensed at very low levels and cause an unpleasant smell when opening packages.
- Another reason to use odour scavengers is that odours may be developed in packaging material especially during plastic processing like extrusion and molding.

Antioxidant Releasers:

- Lipid oxidation causes loss of both sensorial and nutritional quality, formation of toxic aldehydes and spoilage in nuts, fish, meats, whole milk powders, sauces and oils.
- Direct addition of antioxidants to the food surface posed some limitations such as once the active compounds are consumed,
- protection ceases and the degradation in the quality of the food occurs at an increased rate.
- It has been reported that delay of lipid oxidation and protein denaturation in fresh sierra fish fillets by the incorporation of butylated hydroxytoluene (BHT) into low-density polyethylene package (LDPE).
- The inclusion of natural antioxidants (tocopherols, polyphenol, plant extracts and essential oils) to active packaging materials is high but larger mol. wt of α -tocopherol incorporated in HDPE layer led to slower release into a food in comparison to BHT.

Antimicrobial Packaging

- A subset of active packaging that interacts with the food product or the surrounding headspace to inhibit growth or kill pathogenic microorganisms that might be present in the food product or in the food package.
- These packaging systems either contain antimicrobial agents in a sachet or pad or impregnate the antimicrobial into the food packaging film (polymeric) material.
- The antimicrobials are subsequently delivered within time to kill the microorganisms contaminating food products thus, enhancing the shelf-life to severe folds. Meat, dairy, bakery products, fruits and vegetables easily attacked by microorganism can be protected from spoilage.



Addition of sachets (pads)



Incorporating directly into the packaging films



Coating of packaging with a matrix that acts as a carrier for antimicrobial agent

Constituents of Antimicrobial Packaging:

Antimicrobial packaging material: Categorized into biodegradable packaging and non-biodegradable packaging.

- **Non-biodegradable packaging:**

- Polymeric packaging materials from nylon, synthetic polymers, LDPE, HDPE and polystyrene do not undergo degradation into fragments by microorganisms.
- In spite of the low permeability of packaging materials (polypropylene and polystyrene), they are effective in packaging probiotic cheeses with long shelf life.

- **Biodegradable packaging:**

The edible coating and films from proteins (wheat gluten, collagen, gelatin, soya, casein and whey proteins used as film forming polymers), lipids (beeswax, acylglycerols and fatty acids), starch, chitosan, polylactic acid and polyhydroxy butyrate undergo degradation into low mol. wt fragments by the action of naturally occurring microorganism such as bacteria, fungi and algae.

Antimicrobial agents:

The direct surface application of antibacterial substances in many food products is an ineffective strategy due to the association-interactions with some components of the food system.

- **Chemical antimicrobial agents:** Food-grade chemical agents should be mixed with food ingredients, incorporated into packaging additives or inserted into the headspace atmosphere.
- However, the utilization of chemical antimicrobial agents as food ingredients should be controlled regardless of their positioning inside packaging system.
- Non-food- grade chemicals are incorporated into the food packaging system through immobilization (chemical binding of the antimicrobial agents to packaging material polymers), so regulation are enforced to prevent the migration of the non-food-grade chemical in the food products.
- Sodium benzoate and potassium sorbate and their salts, sulphites, nitrites, antibiotics and alcohols are the most used chemicals as synthetic antimicrobial agents.

Natural antimicrobial agents: Herb extracts (oregano, thyme and sage), spices (clove extract, eugenol and cinnamaldehyde), essential oils (clove essential oil), enzymes (lysozyme and glucose oxidase) and bacteriocins (nisin, pediocin, lacticin and propionicin) are the naturally obtained antimicrobial agents used to extend the shelf-life of foods. These alternative preservatives against chemical additives without direct contact with the food can minimize the organoleptic deterioration of the food.

Probiotics: Incorporation of probiotics into edible films or coatings has become comparatively popular in the last years. Probiotics ($\sim 10^{8-9}$ viable cells) may be carried within edible polymer matrices to develop bioactive food packaging materials to control pathogenic microbes. The application of probiotic edible films in food matrices improved food stability and safety by controlling the growth of spoilage microorganisms as well as consumers health.

Application of Antimicrobial Packaging for Biopreservation



- **Addition of Sachets**



- **Direct incorporation of antimicrobial agent into the packaging film**



- **Coating or dipping**



- **Antimicrobial macromolecules with film-forming properties or edible matrices**

Biopreservation is an approach that extends shelf-life and food safety by the use of natural microbiota and/or their antimicrobial compounds.

- **LAB naturally dominates the microbiota of raw materials and fermented foods, they do not pose health risk for humans (“Generally recognized-as-safe” (GRAS) status).**
- **They are regarded as microbial cell factories producing natural antagonistic antimicrobials for biopreservation of food such as organic acids (lactic, acetic, formic, propionic, butyric and phenyllactic acid), bacteriocins (nisin, pediocin, lactacin, enterocin etc.), diverse antagonistic compounds (carbon dioxide, ethanol, hydrogen peroxide, fatty acids, acetoin, diacetyl, reuterin) and antifungal compounds (propionate, phenyl- lactate, hydroxyphenyl-lactate, phenyllactic acid and 3- hydroxy fatty acids)**

Bacteriocins:

- Bacteriocins are peptidic toxins or small proteins produced by lactic acid bacteria strains to inhibit growth of similar bacterial strains or Gram-positive spoilage bacteria.
- They are potent food preservatives due to non-toxicity to humans, non-alterations in nutritional and organoleptic properties of food, effective at low concentrations and stability during storage.
- Nisin has been granted GRAS status. This (3.3 kDa) commercially valuable bacteriocin produced by *L. lactis* subsp. *lactis* occurs naturally in raw milk and fermented foods. It exerts antimicrobial activity against *B. cereus* and *C. botulinum* either as only or in conjunction with other antimicrobials. Its low mol. wt facilitates its release after contact with food or liquid.
- It can be successfully integrated into methylcellulose films, PVC, polyethylene-based plastic, edible alginate gels, corn zein films, whey protein, soy protein films and LDPE. Nisin-activated antimicrobial packaging materials is effective in extending the shelf-life of milk, vegetables, cereal-based products, cream milk and cheese.

Enzymes:

- Antimicrobial enzymes (glucose oxidase and lysozyme) not only immobilized but also some enzymes such as naringinase, invertase, lactase and cholesterol reductase are suitable in-package “processing and production of functional foods”.
- Lysozyme is studied for direct-contact antimicrobial packaging food applications. It is a natural food preservative because of its specific hydrolytic activity against bacterial cell walls and exerting no toxic effects to humans.
- Application of lactoperoxidase into whey protein films can significantly reduce the population of *L. monocytogenes* on smoked salmon by 3 log CFU/g after 5 days storage.
- Glucose oxidase reacts with glucose to form gluco- δ -lactone and H_2O_2 . Lactone converts to gluconic acid in the presence of water. The antimicrobial properties of the produced gluconic acid make their suitability for antimicrobial packaging.

Essential oils:

- Derived from aromatic plants (clove, basil, cinnamon, rosemary, ginger and lemongrass)are produced naturally as secondary metabolites and being a natural product, reveal benefits in food and in human health.
- The major components exerting antimicrobial activity are phenolic compounds, terpenes, aliphatic alcohols, aldehydes, ketones and iso-flavonoids.
- Since these bioactive components are less soluble, susceptible to oxidation and strong aroma of essential oils limit their applications in foods therefore, essential oils are added through sachets containing oils or incorporating in the packaging material.
- Example: Incorporation of natural antimicrobial components of basil into LDPE-based polymers inhibits microbial growth in cheddar cheese systems.
- Combination of edible films made from milk proteins, chitosan incorporated with oregano, rosemary, garlic and cinnamon essential oils exert good antimicrobial properties.

Natural plant extracts:

- Plant extracts (containing aromatic and phenolic compounds) provide a healthy alternative against microbial activity.
- Grapefruit seed extract is a natural extract derived from the seeds, pulps and peel of grapefruit possess various polyphenolic compounds like flavonoids (quercetin, kaempferol), citric acid, ascorbic acid, tocopherol and limonoid. The attributes of antibacterial and antioxidant properties helps in preservation of vegetables, strawberry, pork and fishery products.
- Grapefruit seed extract incorporated into LDPE or multilayered polyethylene films reduced the growth of aerobic bacteria and yeast in ground beef and soybean sprouts.

- **Allyl isothiocyanate is another aliphatic sulfur-containing compound with a volatile and pungent character naturally occurring in plants. This flavoring compound of horseradish and mustard is a naturally derived preservative and in food packaging applications.**
- **It reveals strong antimicrobial activity against Gram-positive, Gram-negative bacteria, yeast and fungi at concentrations in the ng/liter range in liquid media.**
- **Being a natural component of mustard oil, the compound can be incorporated into label adhesive and released into the package through a porous surface.**

Chitosan:

- **Chitosan is a linear polysaccharide having an important role in the food packaging as it is nontoxic, biodegradable, biocompatible, antimicrobial ability with excellent film properties.**
- **The positively-charged chitosan binds to the negatively-charged bacterial surface leading to alterations in membrane permeability thus, causing leakage of intracellular elements and ultimately to cell death.**
- **Different other functional materials have been added into chitosan to fabricate composite films and applied in packaging foods such as meat, fruits, seafood, bread, dairy products, sausages and vegetables. It can be a carrier of other natural antimicrobials such as lysozyme, essential oils and nisin.**

Organic Acids:

- Acetic, ascorbic, benzoic, citric, propionic, sorbic, succinic and tartaric acids are being used in many food products as preservatives due to their inhibitory properties in the growth of most microorganisms. They affect the integrity of microbial cell membrane/macromolecules or interfere with nutrient transport and energy metabolism, causing bactericidal effect.
- Sorbic acid incorporated packaging films inhibited the growth of *E. coli*, *L. monocytogenes*, *S. cerevisiae* on the surfaces of Gouda cheese.
- Incorporation of benzoic acid with LDPE films wrapped around bread and cheese improved shelf-life of the products due to the antimycotic efficiency of the acid.

Future Perspectives of Antimicrobial Packaging

Consumer demand for production of minimally processed food led to development of antimicrobial food packaging systems. The use of antimicrobials in food packaging systems motivated the safety and stability challenges of conventional food packaging. The major potential food application includes some of the sensitive foods like bakery products, dairy products, fresh products such as fruits and vegetables, meat and fish products.