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FOOD PACKAGING IN PERSPECTIVE OF MICROBIAL ACTIVITY: A REVIEW

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ABSTRACT

A successful packaging technique demands certain barriers for microbes, achieved through controlled conditions to indicate microbial growth, levels of oxygen, harmful bacterial and fungal toxins, moisture levels, and the indicators for temperature and time. Active food packaging is greatly being applied these days for food safety against harmful microbes. Food is protected from biological, physical, and chemical damages caused by pathogenic microbes through different technologies of packaging including modified atmosphere packaging and controlled atmospheric packaging through antimicrobial films. Moreover, it is essential to use selective materials suitable for different food stuffs for the maintenance of nutritional value of foods. Use of various gas scavengers and bio-based package designing are also greatly helpful towards enhanced shelf life of food products.

Keywords: Active packaging, preservation, antimicrobial packaging, gas scavengers

INTRODUCTION

For many years, advances in food packaging system has revolutionized methods of preservation, trends in distribution, improvement of quality, and prolonged shelf life of food, for good health and safety of consumers. Today, Packaging department dwells next to the Food Industries as an important section with significant 2% Gross National Product (GNP) of developing nations **(Ozdemir and Floros, 2004)**. The downstream processing of foods is greatly dependent on protective antimicrobial processing by optimizing factors including oxygen, moisture and water activity, sunlight exposure, and microbial contaminants. These controlled factors may help us pursue active packaging system through oxygen scavenging, reduction and prevention of food spoiling microbes, moisture absorption, and the adequate generation of ethanol and carbon dioxide **(Suppakul, 2003)**. The packaging material may either be rigid or flexible, to pack different kinds of foods. **Mauriello *et al.* (2005)** interpreted that microbes like *Micrococcus luteus* can be inhibited by effective coatings such as nisin treated films. However, the packaging conditions vary for different types of microbes. New antimicrobials and polymer materials are being introduced to meet regulatory limitations quite viably. Edible films mark another technique to keep food safe for consumption. It makes use of organic acids, salts of organic acids, bacteriocins, fungicides, enzymes, and compounds like silver zeolites **(Quintavalla *et al.*, 2002)**.
The main objective of our study elucidates the best food packaging materials and techniques to prevent microbial food spoilage. In addition, this document gives an overview of better optimization of biological, physical, and chemical parameters towards reduced microbial activity.

TOPICS

Food Safety and Nutritional Quality

Foods are prone to deterioration due to many chemical, physical, biological, and microbiological reactions. Through food safety measures such as freezing, drying, chilling, vacuum packing, acidification, fermentation, preservative agents, modified atmosphere packages helps us prevent microorganisms which cause spoilage of food **(Davidson and Critzer, 2012)**. Spoilage varies from extremely hazardous involving toxicogenic microorganisms to the minor loss of texture or quality such as the loss of flavor or color. To keep food safety and quality up to mark, prevention of infectious pathogenic and toxicogenic bacteria is a must **(Da Cruz Cabral, 2013)**.
Food products subjected to lower temperatures of about 12°C have low microbial growth which is quite useful in chilling process; however, many microbes such as *Listeria monocytogenes* grow rapidly even below 1°C **(Cho and Irudayaraj, 2013)**. Water activity A_w control must be ensured for food safety by reducing it for increased shelf life and reduced microbial activity **(Lopez-Malo and Alzamora, 2015)**. To maintain conditions like water activity and temperature, special packaging is done to create a standardized internal environment for food devoid of any nutritional changes. Microbial activity can also be controlled by selective pH chosen against the optimum pH of microbes that effect specific kinds of foods. For many foods, pH of 4.5 is maintained to restrict multiplication of *Clostridium botulinum* **(Gould, 2000)**.

Major Food Borne Pathogenic Bacteria

Of many bacterial pathogens which cause damage to different foods and hence illnesses, the major ones include *Salmonella, Escherichia coli O157, Campylobacter, Listeria monocytogenes, Clostridium perfringens, Staphylococcus, Shigella,* and *Bacillus* **(Dhama *et al.*, 2013)**. The European Commission has set criteria with certain reference methods for permissible limits to govern the presence of microbes in foods and feedstuffs **(De Jong *et al.*, 2013)**.
The presence of microbes in foods is tested analytically by through different protocols accepted by the international bodies. The emergence of lab based technologies such as PCR (Polymerase Chain Reaction), HPLC (High performance Liquid Chromatography), ELISA (Enzyme Linked Immunosorbent Assay), flow cytometry, and biosensors have made it easier for us to identify and quantify the pathogens. Progress has also been made in determining the presence of toxins produced by various bacteria in foods. Bacterial microbes in a food sample are measured in CFU (Colony Forming Units)/ml or CFU/gm. The permissible limit of *E. coli* 0157 is 1000 CFU/g in the ready to eat foods such as vegetables and fruits **(McGrath *et al.*, 2012)**.

Active Packaging and Techniques

Active Packaging, a significant system of actively functioning packaging for foods, results in an extended shelf life for upkeep of the freshness of food, seek information regarding food quality, enhancement of food safety, and the convenience in shipping and transport of food. It is also linked to the smart packaging and intelligent packaging with dire importance for short lived and demanded refrigerated fresh foods **(Dainelli *et al.*, 2008)**. The technical approach is to consider a contact between package film and food along with specific internal atmospheric gases **(Kour *et al.*, 2013)**. This packaging system is gold standard and is being improved day by day due to advancements in packaging, material science, biotechnology, and new customer demands **(Kinsey, 2001)**.

In the U.S, actively packaged foods are termed as 'ESL' or extended shelf life refrigerated foods **(Holley and Patel, 2005)**. Actively packaged foods include conventional products such as luncheon meat and cured meats, partially processed refrigerated foods such as seafood, egg, meat, vegetable salads, fresh pasta and pasta sauces, high moisture fruits, and vegetables **(Vanderroost *et al.*, 2014)**. Active packaging is the sum of interacting factors occurring between foods products and intrinsic environment within the food packages, with the goal of increasing shelf life of food products **(Vercammen *et al.*, 2012)**. These factors exhibit great ability towards the removal of excess gases, absorption of excess moisture; introduction of antimicrobial substances directly into the matrix of the packaging material, highly monitored release of anti-oxidants minerals, and the control of vitamin activity since fresh foods respire and have microbial activity **(Garcia-Lomillo, 2014)**.

Some basic technologies used in active food packaging involves the control of temperature, irradiation, chemical treatment of food, modified atmosphere packaging (MAP), and the controlled atmosphere packaging (CAP) **(Caleb *et al.*, 2012)**. The MAP and CAP systems of packaging are accomplished either in completely taped up warehouses, shipping tanks, or even in an individual package. Different atmospheric factors are controlled and modified in a combination by vacuum puling linked to internal atmosphere. Certain conditions are met through regulation of the level of ethylene, increase in level of carbon dioxide from 0.03% up to 3-5%, and the lowering of oxygen level from normal 21% to 2-3%. However, the limitations associated with these technologies are risks of explosion and dehydration. In commercial processes, chilling treatment is given before filling the cans with food **(Rigaux *et al.*, 2014)**.

Later they are sealed and then gas generators are used to provide a controlled atmosphere. It is mostly done for fruits to extend shelf life. Some sellers have also manufactured portable units for shipping short shelf lived fruits. For example, polar-stream shipping system use liquid nitrogen (LN_2) to blush out and to keep transport vehicles cool for ensuring fresh production **(James *et al.*, 2015)**. Advancement in CAP storage is to use selectively permeable packaging films for maintaining specific inside atmosphere in required composition which is practiced at the harvest level **(Labuza and Breene, 1989).**

Smart Packaging

Intelligent packaging is a package function which switches on and off spontaneously with respect to the changes in environmental conditions and hence gives the idea about the status of the product to the customers or end users **(Butler, 2001)**. There are several chemical sensors and biosensors which have been used over several decades with their applications in various areas including food technology. Use of such sensors in the food packaging has resulted in a new type of technology called smart or intelligent packaging. This technology consists of multidisciplinary systems that require the expertise from different fields like chemistry, biochemistry, biotechnology, physics and food science and technology. Smart packaging monitors the food quality and safety till its consumption by utilizing various chemical or biosensor. These sensors can monitor food quality and safety, such as its freshness, microbial contamination, leakage, carbon dioxide level, oxygen level, pH, time or temperature. Thus, smart packaging can be considered as a system that helps in monitoring the conditions of packaged food during its storage, transport and distribution to provide the information about its quality **(Park *et al.*, 2015)**. In general, the term can be used for features concerning about product identity, its authenticity and traceability and theft protection as well as quality and safety related issues.

Smart packaging is different from active packaging in many ways as shown in the table 1. In case of active packaging the package functions get activated in response to some triggering event i.e. exposure to ultraviolet radiations, decrease in pressure etc., and the process continues unless the product is protected while in case of smart packaging intimate food quality is monitored by a variety of sensors. The main focus in case of active packaging is to prevent the product from deterioration or spoilage. While in case of smart packaging major goal is to inform the buyer or consumer about the product quality packaged inside.

Table 1 Model of the Packaging Functions, Source: Yam *et al.*, 2005

Active packaging	Smart packaging
Contain anti-microbial component	Have time and temperature indicators
Ethylene scavenging occurs	Contain microbial spoilage sensors/indicators
Automated heating or cooling processes	Physical shock indicators are present
Moisture absorbing	Have allergen sensor
Odor and flavor absorbing mechanisms	Leakage indicator
Oxygen scavenging occurs	Microbial growth sensors
Spoilage retarders are present	Pathogens and contaminants sensors/indicators

There are varieties of sensors and indicators which are used to monitor the food quality like TTIs (Time Temperature Indicators), ripeness indicators, chemical sensors, biosensors and RFID (Radio Frequency Identification Tags). Some of them are not commercialized yet but the most common among them are TTIs and RFID **(Heising *et al.*, 2014)**. TTIs play a critical role in measuring the safety and quality of a food product. They monitor the food quality and communicate the consumer whether the food product is safe to intake or not. This becomes extremely important when food is stored in conditions other than the recommended conditions for that particular food item.

For a food item that is recommended to be frozen TTI indicates if the food had been improperly placed under high temperature along with the duration of exposure and vice versa **(Pavelková, 2013)**. RFID on the other hand assist in the wireless monitoring of the packaged food items through various tags, readers, and by using computer systems. It is widely used on the industrial scale due to its numerous and wide range applications. It provides the facility to trace the packaged food items as well as it helps in improving the productivity of supply chains. Further improvements in RFID and its integration with food science are still require in order to develop smart food packaging for food safety **(Potyrailo *et al.*, 2012)**.

Antimicrobial Packaging and Efficacy

Active packaging, comprising of antimicrobial packaging, interrelates well with the product and space among food and packaging **(Zhou *et al.*, 2014)**. Antimicrobial packaging through antimicrobial agents have several types including the addition of pouches or pads, covering and adsorbing antimicrobials on polymer planes, holding antimicrobials onto polymer surfaces by ion or covalent bonds, and the utilization of polymers with the naturally occurring antimicrobial agents **(Rhim *et al.*, 2013)**.

Comprehending the technique of adding pouches or pads first, they are present at the bottom, either tightly attached or loosely bound at any interior of the package **(Wani *et al.*, 2015)**. They have addition of volatile antimicrobial chemicals into packages; or the addition of non-volatile antimicrobial chemicals directly into the polymers. Used in mainly three forms, usually oxygen absorber, moisture absorber, and vapor generators, they have several other characteristics. Oxygen absorber reduces the oxidation and growth of aerobic microbes; whereas, the moisture absorber decreases water content lower than that required by the microbes specially molds **(Erkmen, 2012)**. The vapor generators can either be of ethanol or other organic acids. These vapors accumulate to all free space and also inhibit microbial growth **(Rooney, 1995)**.

Secondly, most of the food spoilage occurs due to surface contamination, which gets inhibited by the addition of antimicrobial compounds like lactoperoxidases, lactoferrins, cecropins, hydroquinones, and metals such as copper which causes disruption. A well-off example also includes the synthesis of microbial enzyme which inhibits their growth **(Pereira de Abreu *et al.*, 2012)**.

Thirdly, there may be adsorption or coverings of antimicrobials in the polymer packages to prevent microbes. When polymers are subjected to very high temperatures, there are antimicrobial agents which cannot withstand high temperature during the formation. So, they are adsorbed onto the polymers after the heating process. Agents like these involve nisin methylcellulose coverings for polyethylene films or the nisin zein coats **(Appendini and Hotchkiss, 2002)**. Pretreatment of polymer structures before coating or adsorption increases the adsorption power. Moreover, NaOH treated films not only increases its adsorption capacity but they also have top inhibitory result against molds **(Weng *et al.*, 1999)**.

Fourthly, there may be antimicrobials bound with polymers through ionic and covalent bonds. There is an interaction between polymers and the antimicrobials which requires functional groups on antimicrobial agent and the polymers. These functional groups make a unique boding pattern with each other whereby which the antimicrobial agent becomes stuck to polymer surfaces. Antimicrobials having functional groups could be peptides, enzymes, polyamines, and organic acids **(Basterrachea *et al.*, 2015)**. Polymers having functional groups could be acetyl butyl or propyl. Binding may require a spacer molecule which links the polymer's exterior to the antimicrobials. These spacers help sufficient liberty of motion so that active part of agent can interact with microorganisms in the food. Spacers could be dextrans, ethylenediamine, or polyethylene Glycol (PEG). Reduction in antimicrobial activity could be possible due to charged protein or peptide configuration or denaturalization due to other components **(Lopez-Rubio *et al.*, 2004)**. Protection of active sites and introduction of dendrites to increase surface area of package are some good remedies for higher microbial control. Some examples include covalently immobilized chitinase, Lysozyme, or both, used against Gram positive bacteria **(Appendini and Hotchkiss, 1997).**

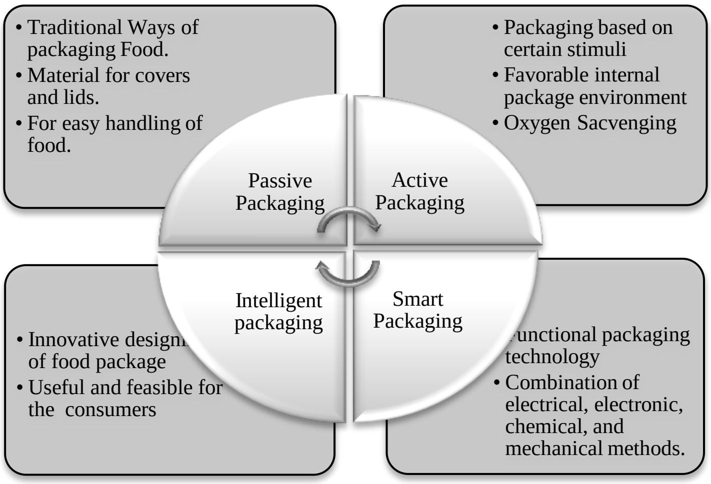

Figure 1 Distinctive types of Food Packaging Source

Significant food packaging parameters

There are many biological, physical, and chemical factors which directly affect the food properties. Chemical treatment is usually carried out for the shelf life extension of fruits and vegetables which involves spraying plant surface with hormones like gibberellins, auxins, and cytokines before harvesting to regulate ripening and other effects **(Vermeiren, 2003)**. However, chemicals used must get approval under Food and Drug Administration (FDA) regulations. Antimicrobial sprays, washes, fumigants like sulfur dioxide, and wraps that have been impregnated with antimicrobials to control rotting are also practiced. The use of carbon dioxide and chlorine dioxide gases for some foods is also mentioned **(Marsh, 2007)**.

Irradiation is another important parameter in which low dosage (<0.1 M Rad=1KGy=100kRad) of radiations can be used for shelf life extension of fresh foods. Fresh foods may always not be unprocessed. They may include fruits and vegetables and mushrooms capable of growing and maturing further but can be irradiated to inhibit these processes **(Siegrist, 2007)**. FDA regulated that any irradiated food must be labeled "treated by gamma rays or electrons" and there should be an international symbol for food products that undergo radiation treatment **(Moura *et al.*, 2004)**. Ultra violet radiations can also be used but only in wavelength range of 2200-3000nm with no ozone production. Subsequently, high fat foods must be treated under vacuum or inert gas to limit surface microbial growth. Chemical system also involves factors like control of carbon dioxide, ethylene, and water activity along with chemical agents, antimicrobial preservatives, and temperature **(Han, 2003)**.

Fresh salads and prepared foods require shelf life extension of minimum a week which can be accomplished by controlling the temperature. The United States mostly uses temperature control techniques to extend shelf life of fresh salads and prepared foods **(Norton and Sun, 2008)**. The use of open refrigerated cabinets should be prevented because they can cause rapid decay and can allow pathogens to grow. So closed refrigerated cabinets coupled with time temperature integrators to monitor distribution are mandatory for usage **(LeBail *et al.*, 2002)**. Biological parameters includes enzyme systems such as glucose oxidase used to oxidize glucose, whereas, alcohol oxidase utilized to oxidize ethanol. These systems involve controlled oxidation of reduced iron, photo catalysis with a dye, or the catalytic conversion of oxygen to water vapors by platinum in presence of hydrogen gas **(Hodges and Forney, 2000)**. Physical parameters include the usage of appropriate packaging material for different food products as well as absorption and adsorption through scavenging **(Siracusa *et al.*, 2008)**.

Packaging of Meat, Fish, and Fruits

Meat is one of those food products which require special packaging since it has short shelf life and in turn requires great attention. In its packaging, either absorbing pads or films with adsorbed antimicrobial agents are used. Absorbing pads makes use of organic acids or surfactants incorporated to avert microbial growth **(Hansen *et al.*, 1989)**. In case of antimicrobial films, there's adsorption of antimicrobial agents onto those films. Most films are prepared by polysaccharides, lipids, and proteins due to their advantages like biodegradability, endurance of physical stress, biocompatibility, and barrier properties against oxygen, edibility or aesthetic appearances **(Vasconez *et al.*, 2008)**. Films for meat products are also prepared due to its usefulness in many aspects. They may help lessen the problem of water loss during storing of frozen meats, hold fluid of new meat cuts when packed in selling plastic dishes, and decreased lipid oxidation processes which leads to rancidity **(Cutter, 2006)**.

There may be reduction of tan coloration by myoglobin oxidation, decrease in load of decay and pathogen microbes on the exterior of covered meats, and it may also restrict volatile flavor loss and external odor pick-up. **Ming *et al.*, (1997)** highlighted complete protection against *Listeria monocytogenes* in ham, beef or turkey breast obtained using nisin or pediocin immobilized on a cellulose casing. The package is a polymer film having heat resistant Pediococcus-derived bacteriocin synergistic to chelating agent to kill *L. monocytogenes* in food**.** Besides, in fish packaging, the initial quality of fish and the conditions in which it is stored, determines its shelf life. Empirical shelf life models have been suggested for initial product quality **(Tittlemier *et al.*, 2007)**. These models are not based on information of spoilage actions but beneficial shelf life estimation can be gained from time temperature profiles or quick methods of early product condition **(Koutsoumanis *et al.*, 2000)**.

Role of ethylene, oxygen, and other scavengers

There are many ways to remove undesirable substances present at the head-space of packaged food products. The top priority includes scavenge of oxygen, ethylene, carbon dioxide, and undesirable odors. Ethylene is absorbed onto oxidizing agents or organometallic substrates for antimicrobial activity. Ethylene is a growth hormone released by climacteric fruits during metabolism. It stimulates ripening and senescence. This in turn leads to fruit spoilage. So there is a need to control ethylene pressure as well **(Lopez-de-Dicastillo *et al.*, 2010)**.

Oxygen scavenging from the package within inner atmosphere involves the lowering of metabolism rate with reduced oxygen pressure for extended shelf life of food with only an exception of growth of anaerobic bacteria. However, growth of aerobic bacteria and molds can be prevented just like meat pigments exhibit purple color under low oxygen pressure and red under high oxygen pressure **(Brewer, 2004)**. Modified atmospheric packaging through vacuum conditions is commonly implied. Oxygen scavengers prevent rancidity, discoloration, loss of flavor, and loss of nutritional value. These scavengers are selected on the basis of greater absorption, non-toxicity, low cost, and great rate or absorption. Since oxygen scavenging sachets can be dangerous to human health so nowadays these oxygen removing components are being introduced in the films, crown corks, labels, and liners of packaging materials **(Lanciotti, 2004)**.

In many foods carbon dioxide is produced as a result of respiration and deterioration reactions. Increased pressure of this gas can cause package to burst. Carbon dioxide scavengers are henceforth used to omit excess gas through the usage of sachets. Many unlikely odors get trapped inside food packages and get released when packages are opened by the consumers. Activated carbon and silica gels are used as a remedy against such odors **(Skandamis, 2002).**

Use of Bio-based composites in food Packaging

Bio-based materials, derived from renewable resources like starch and other polymeric structures, are categorized according to the method by which they are produced. It may include production of the polymers from natural resources like starch, cellulose and wheat gluten from plants. Chemical synthesis of renewable bio-derived sources includes polylactate, a biopolyester produced by the polymerization of lactic acid, whereas, lactic acid is itself produced by the fermentation process of carbohydrate feedstock **(Hunjanen *et al.*, 1996)**. Polymer synthesis of bio-based materials is carried out with the help of microorganisms or genetically modified organisms. The best known polymers synthesized by this method are polyhydroxyalkonates, specifically polyhydroxy-butyrates, hydroxyl-valerate and hydroxy butyrate **(Siracusa, 2008)**. Polymers are being used directly or indirectly for packaging purposes.

Presently, cellulose is one of the bio-based materials being used for the exterior packaging layer in the form of paper and cardboard. Again, paper has limited advantages due to its poor water resistivity and therefore, can only be used for the packing material of dry products. In future, bio-based materials will be used as packaging material, because of its several benefits on mineral oil derived polymers **(Farris *et al.*, 2009)**. The food packaging industries are trying to produce such bio-based materials for food packaging as are more durable and resistant to environmental conditions such as water, pH, and temperature with better shelf life of product **(Weber *et al.*, 2002)**.

Bio-based materials should be stable, without any changes in its physical, mechanical and barrier properties. These materials must have efficient biodegradability which is the degradation of packaging material with the help of microbes, done either aerobically or anaerobically, after its disposal. The natural polymeric materials vary in their process of degradation while some proteins are considered to be non-degradable according to some definitions **(Cooke, 1990)**. Parameters affecting the stability of biodegradable material include water activity, oxygen, nutrients, pH, temperature, and storage time. Dry products can efficiently be stored for longer period of time; whereas, moist products have limited storage time **(Miller and Krochta, 1997)**. Before using bio-based materials for food packaging, its effect on food quality as well as on food safety must be examined.

For an improved mechanical strength of bio-based packaging of food, natural polymeric material is mixed with synthetic or chemically modified polymers **(Guilbert and Gontard, 1997)**. Recently hybrid organic and inorganic materials are used especially those which have silicates layer dispersed in polymeric matrix at nano-metric level **(Giannelis, 1996)**. These nano-hybrid composites are responsible of improved mechanical and oxidation stability, decreased solvent uptake, self-extinguishing behavior and biodegradability. In addition, inorganic particles can impart different properties like color and odors and also act as reservoirs. Researchers are working with the objective to improve delivery methods of medicines or micronutrients in daily foods by making tiny edible capsules, or nano-particles that release their contents on demand at infected spots in the body. Nano-composites offer extra benefits to the packaging like low density, transparency, good flow, better surface properties and recyclability **(Koo *et al.*, 2005)**.

Future concepts of food Packaging

Many novel techniques apart from sterilizing and pasteurizing include new methods which give protection more than that obtained by inactivation **(Barbosa-Canovas *et al.*, 2008)**. A few techniques from a whole big list of new methods comprise of electric discharges of high voltage, ionization radiation, high light intensity, high hydrostatic pressure, ultrasonication through high heat and pressure, and the addition of bacteriocins **(Urzica, 2004)**. Researchers are now focusing on those procedures of food delivery which are of higher quality, free from additives but have natural composites, and are nutritionally healthier **(Gould, 2000)**. Of many novel packaging materials, cellulose based filter paper, graft copolymerized, along with silver nanoparticles has been studied for better antimicrobial safety of food especially against *E.coli* bacteria. **(Tankhiwale *et al.*, 2009)**.

RESULTS AND DISCUSSION

Antimicrobial preservation of foods

The ever increasing population has raised the demand for food to a dangerously higher level. Better and carefully selected packaging material with the use of latest technologies can save tons of food which is otherwise wasted every year due to improper packaging. To overcome the issues, companies have emerged in a competition to provide best food products and have raised great concern for a biotechnologist towards quality control. These companies have made use of various techniques to upgrade and maintain the nutritional quality of food products, and have devised efficient food packaging methods. It has been observed that safe packaging requires various composites incorporated in the polymers to prevent microbes. The most efficient methods to reduce microbes involve the control of biological, chemical, and physical parameters through active packaging. According to the findings, one of the most efficient packaging systems is the usage of bio-composites for bio-based packaging leading towards reduced microbial activity.

Selection of efficient packaging material

For better control and reduction of microbes, several packaging materials are being made for a variety of food stuffs. Figure 2 shows the estimated production of packaging materials in tons through a specific period, from 1960 to 2005. Based on these statistics it was inferred that the most abundantly used materials are paper and paperboard materials and that there are more packaging materials designed for non-durable materials than durable ones. Rigid packaging materials are least produced whereby which it can be inferred that flexible materials including polymers with films are more preferably being manufactured than the rigid ones for the antimicrobial packaging.

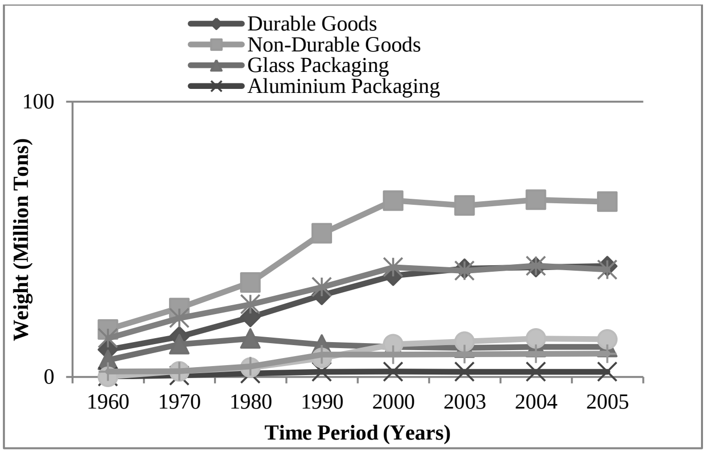

Figure 2 Weight of the Packaging Material Generated from 1960 to 2005. Source: (EPA 2006).

Intelligent Packaging Systems

Active and intelligent packaging systems require special treatments with specific substances. These treatments have great applications towards the preservation of a variety of foods as demonstrated in (Tab 2).

Table 2 Packaging systems and its applications

Microbial Species	Packaging Requirement & Treatment	Applications
Bacteria	BHT, BAH, and Tocopherol.	Dried and sacked food products are protected by special packaging conditions including flour and rice.
	Organic acids including sorbic acid and enzymes including lysozyme.	Meat and poultry products are well preserved.
Moulds	Ascorbic acid.	Maintain quality and freshness of vegetables and fruits.
	Sodium hydrogen carbonate.	Useful for fish, poultry, and meat department.
Yeast	Mixture of water and ethanol absorbed on SiO_2 powder	Preservation of bakery products.
	Ethanol vapors.	Preservation of dry fish.
Infectious Microbes	Preservative agents including bacteriocins, organic compounds, and inorganic compounds.	Reduced reductive and oxidative discoloration
	Control of humidity and water activity through adsorbents.	To maintain crispiness of food
Toxicogenic Microbes	Control of microstructure.	Reducing the movement of compounds with low MW.
	Vacuum modified atmospheric packaging.	To prevent oxidative rancidity
Other Growth Spoilage Microbes	Aluminum and stainless depositions on polyester films.	Foods subjected to refrigeration have good shelf life.
	Aluminum and stainless depositions on paperboard.	Ready to eat foods like popcorns and pizzas are preserved.

Legend: BHT – Butylated hydroxytoluene, BHA – Butylated hydroxyanisole, and MW – Molecular weight.
Source: (Tian *et al.*, 2013; Cooksey, 2005; Vermeiren *et al.*, 1999; and Kruijf *et al.*, 2002)

CONCLUSION

Microorganisms require specified parameters for their growth and development to cause the disease and effect the system and for those different requirements like carbon sources, moisture content, vitamins, and other important metabolites are to be controlled. By reducing one of these factors or optimum conditions we can reduce the microbial activity. Environment is the major factor for introducing the microbial activity in the container or the store of food. Through active packaging these microbes can be reduced or eliminated; however, it is important to choose best packaging material and antimicrobial control technique in accordance to the type of food. Bio-based material packaging is now on the rise in food packaging industries due to its advantageousness.

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