Innovations in Packaging for Enhancing Shelf Life of Horticultural Produce

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INTRODUCTION

Packaging is one the essential elements required for protection and to extend the shelf life of food products. However, it is required not only for food preservation and protection but also for safe transportation of products during storage and handling. Increasing exports and developing export market needs have also affects the packaging trend. Packaging requires to contain foods, protect foods from the environmental factors, for convenience in handling, storage and marketing and to communicate information to consumers about the food inside the package. Therefore, it has an active role in retaining the safety and quality of foods throughout the supply chain. The use of properly designed containers for transporting and marketing of horticultural produce can significantly reduce their losses and maintain their freshness and quality for longer period.

Although traditional packaging covers the basic needs of food containment, innovations in food packaging are both anticipated and expected. Innovative packaging is the result of consumers demand for packaging that is more advanced and creative than what is currently available. Traditional food packages are passive barriers designed to delay the adverse effect of the environment on the food product. While, these new innovative packages allow the package to interact with food and environment and play a dynamic role in preservation of food product. All the new packaging technologies have great commercial potential to ensure the quality and safety of food with fewer or no additives and preservatives, thus reducing food wastage and maintaining the quality of the produce. So, various recent techniques regarding packaging of the fresh and processed food materials have been discussed here in this article.

1. CONTROLLED OR MODIFIED ATMOSPHERIC PACKAGING

In controlled atmosphere packaging (CAP), the composition of gas inside the package is altered and continuously monitored/maintained at a preset level with the use of scrubbers or other means. Whereas, in modified atmosphere packaging (MAP), the gas composition within the package is not monitored or adjusted and a predetermined gas mixture is used to flush packages before closing which depends on the oxygen sensitivity and rate of the metabolic activity of the product. It involves changes or modification in atmosphere inside the package with respect to the normal composition of air and ultimately reduces the physiological and microbial decay of perishable produce (Fig 1). The main principle behind MAP is to limit oxygen supply along with elevated level of carbon dioxide which slows down the physiological activity and microbial growth. The various effects of controlled/modified gaseous atmosphere inside a package are as follows:

- Fermentative reactions responsible for the production of off flavour and off odour compounds (acetaldehyde, ethanol, lactic acid and ethyl acetate) are slowed down in MAP resulting in better quality product with extended shelf-life.
- As the oxygen levels are low in MAP, there is a reduction in rate of oxidative reactions which are responsible for the quality deterioration of the commodities. For example browning reactions and reduced softening and discolouration of the produce.
- As most of the spoilage micro-organisms are aerobic in nature, the low O_2 levels (2 to 3%) and high CO_2 (5 to 20%) levels inside a package slow down growth of aerobic spoilage microorganisms.
- Keeping the nutritional composition and antioxidant potential of fresh-cut fruits and vegetables during storage.

Methods of creating modified atmosphere conditions:

a) *Passive MA or Commodity generated:* In this method, the produce is packed in a sealed plastic film. As result of respiration, the produce and non/selective permeability of the package to oxygen, the concentration of the O2 reduced and concentration CO2 increased due to respiration thus generating MA (Fig 1).

b) Active MA condition: This can be done by creating a slight vacuum and replacing the package atmosphere with the desired gas mixture. It ensures rapid establishment of the desired atmosphere. The level of gases can be adjusted by the use of adsorbers or absorbers in the package.

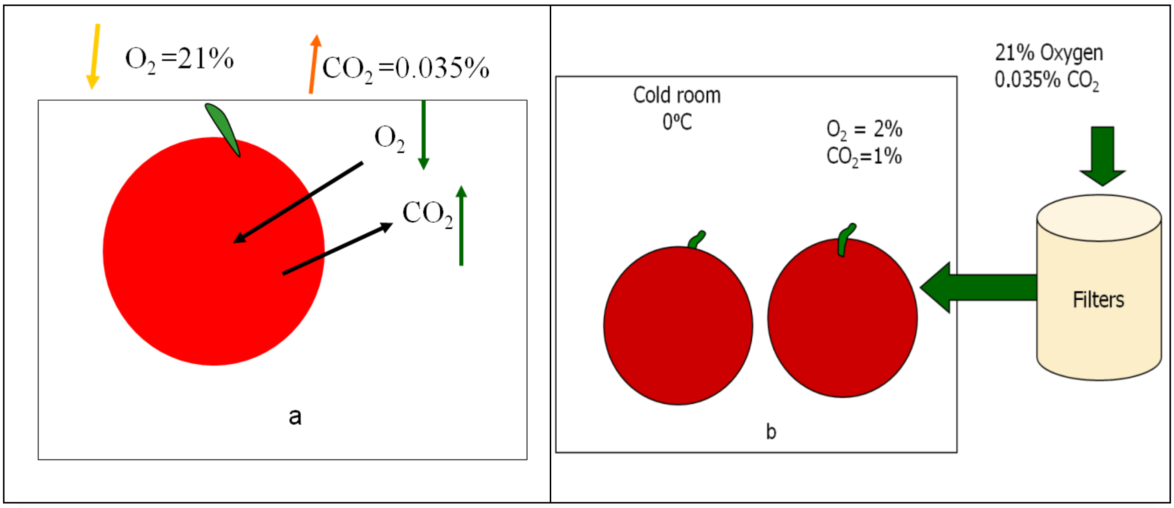


Fig 1. Modification of gases in (a) Modified Atmosphere and (b) Controlled Atmosphere system

Films recommended for MA Packaging: Following mentioned are some of the potentially used film in modified atmosphere packaging of horticultural produce.

- Low Density Polyethylene (LDP)
- High Density Polyethylene (HDP)
- Polypropylene (PP) and Oriented Polypropylene (OPP)

- Rigid Poly Vinyl Chloride
- Ethylene Vinyl Acetate

Storage conditions: The recommended optimum temperature, relative humidity (RH), oxygen level and carbon dioxide level for some of the fruits and vegetables are given in Table 1.

Table 1: Recommended optimal storage conditions for some fruits and vegetables in CA/MA

Commodity	Temperature (°C)	RH (%)	O_2 (%)	CO_2 (%)
Apple	1-4	90-95	1-3	0-6
Banana	12-14	85-95	2-3	8
Kiwi	0-2	85-90	1-2	3-5
Mango	10-15	90	3-7	5-8
Peach and nectarine	0-2	85-90	1-2	3-5
Pear	0-1	90-95	2-3	0-2
Plum	0-2	85-90	1-2	0-5
Tomato	1-13	90	3-5	2-4
Broccoli	0-1	90-95	2-3	8-12
Cabbage	0-1	95	2-3	3-6
Onion	0-2	70-80	1-4	2-5
Spinach	0-2	95	21	10-20

2. ACTIVE PACKAGING

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. The certain components are incorporated into packaging systems that release or absorb substances from or into the packed food or the surrounding environment so as to prolong shelf life and sustain the quality, safety and sensory characteristics of the food. These components have been divided mainly into absorbers (scavengers) and releasers.

A. Absorbers (scavengers)

- **Oxygen Scavengers:** Presence of oxygen in packaged food might accelerate oxidative reactions resulting in food deterioration. Oxygen helps the growth aerobic microbes and molds. Oxidative reactions produce off-odors, off-flavors, undesirable color changes, and reduced nutritional quality of the food. Oxygen scavengers are those agents that remove oxygen, diminishing oxidative reactions. They come in different forms such as sachets, labels, or may be directly incorporated into package material and/or closures. Oxygen scavenging compounds are mostly agents that react with oxygen to reduce its concentration. Some most common oxygen scavengers are ferrous oxide, ascorbic acid, sulfites, catechol and photosensitive dyes.
- **Carbon dioxide Absorbers & Emitters:** Carbon dioxide is added in certain products like baked goods, fresh meat, poultry, cheese, etc. for beneficial effects, as for suppressing microbial growth. It is also used to decrease the respiration rate of fresh produce, to overcome package collapse or partial vacuum caused by oxygen scavengers. Carbon dioxide is found in different forms, like moisture-activated bicarbonate chemicals in sachets and absorbent pads.

- **Moisture Control Agents:** Excess moisture in moisture-sensitive foods can have adverse results, for example, softening of crispy products, caking in powdered products, and moistening of hygroscopic products. Too much moisture loss from food may result in product desiccation. Adding moisture control agents help control water activity, removing melting water from frozen products, reducing microbial growth, prevent condensation from fresh produce, and keep the rate of lipid oxidation in check.
- **Others**

✓ **Ethylene Absorbers (Sachets, Films):** These are mainly used in fruits and vegetables for extending shelf life.

✓ **Humidity Absorbers (Drip absorbent Sheets, Films, Sachets):** These play important role in the preservation of meat, fish, poultry, bakery products, cuts of fruits and vegetables

✓ **Absorbers of off Flavours, Amines and Aldehydes (Films, Sachets):** These are used in fruit juices, Fish Oil-containing foods such as potato chips, biscuits and cereal products

B. Releasers

- **Carbon dioxide emitters (sachets):** Used for growth inhibition of gram-negative bacteria and moulds (e.g. Ascorbic acid, Sodium hydrogen, carbonate and ascorbate). It is used in vegetables and fruits, fish, meat and poultry.
- **Antimicrobial Preservative Releasers (Films):** Growth inhibition of spoilage and pathogenic bacteria (e.g. Organic acids like sorbic acid, Silver zeolite, Spices and herb extracts, Allyl-isothiocyanate and Enzymes like lysozyme). It is used in Bakery, Meat, poultry, fish, bread, cheese, fruit and vegetables.
- **Sulphur Dioxide Emitters (Sachets):** Helps in the inhibition of mould growth (e.g. Sodium metabisulfite incorporated in microporous material). It is used in fruits and vegetables.
- **Flavouring Emitters (Films):** Minimization of flavour scalping, masking off-odours improving the flavour of food (Various flavours in polymers).
- **Pesticide Emitters (The Outer or Inner Layer of Packaging Material):** These help in the prevention of growth of spoilage bacteria, Fungicidal or pest control (e.g. Imazalil, Pyrethrins). They are used in d*ried, sacked foodstuffs, e.g., flour, rice, grains etc.*

C. Other examples of active packaging systems

- **Insulating materials:** Temperature control for restricting microbial growth (Special non-woven plastic with many air pore spaces)- *Use in various foods to be stored refrigerated*
- **Self-heating Aluminium Or Steel Cans and Containers:** Cooking or preparing food via built-in heating mechanism (The mixture of lime and water)- *Used in Sake, coffee, tea, ready-to-eat meals*
- **Temperature sensitive films:** To avoid anaerobic respiration (The gas permeability of the polymer is controlled by filler content, particle size of the filler and degree of stretching of the film)- *Used in fruits and vegetables*
- **UV-irradiated Nylon Film:** Growth inhibition of spoilage bacteria (The use of excimer laser 193 nm UV irradiation to convert amide groups on the surface of nylon to amines)-*Used in Meat, poultry, fish, bread, cheese, fruit and vegetables*

3. 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. The two important functions performed by intelligent packaging are to monitor both internal and external conditions that are to record changes occurring both outside and inside the packaging. The other function of intelligent packaging that is assessing the quality of the food product directly within package involves intimate association with the headspace or food which necessitates the use of indicators for the safety and quality of packaged food item. Different indicators along with their applications for intelligent packaging of packed food are summarized in Table 2.

Features of Intelligent Packaging System:

- Designed to monitor the condition of the packed food or the environment surrounding the food.
- Capable of detecting, sensing, recording, tracing, or communicating information about the quality and/or state of the product during the whole chain
- Contributes to prevent food waste and improves logistics and traceability
- Labels or tags that facilitate communication throughout the supply chain, so that appropriate actions may be taken to achieve benefits in food quality and safety
- Indicators: used to monitor the external environment and issue warnings. Provide visual, qualitative (or semi-quantitative) information by color change, increase in color intensity or diffusion of a dye.

Types of Intelligent Packaging System:

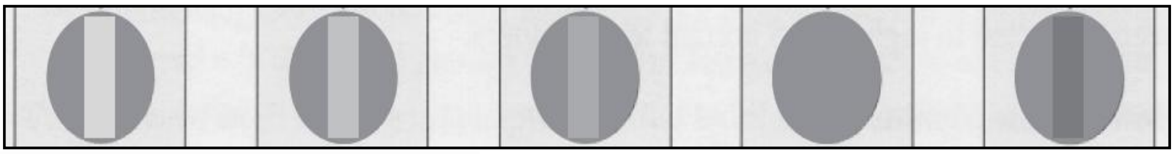
a) Smart package devices: Smart package devices are defined as small, inexpensive labels or tags that are attached onto primary packaging (for example, pouches, trays, and bottles), or more often onto secondary packaging (for example, shipping containers), to facilitate communication throughout the supply chain so that appropriate actions may be taken to achieve desired benefits in food quality and safety enhancement.

b) Radio frequency identification (RFID) tags: The RFID tag is an advanced form of data carrier for automatic product identification and traceability. In a typical RFID system, a reader emits radio waves to capture data from an RFID tag, and the data is then passed onto a host computer for analysis and decision making. Now a days, RFID tags with embedded temperature sensors as well as integration of these tags with physical and chemical sensors are used as temperature managed traceability systems.

c) Biosensors: Biosensor is a compact analytical device that detects, records, and transmits information pertaining to biochemical reactions. This smart device consists of 2 primary components: a bioreceptor that recognizes a target analyte and a transducer that converts biochemical signals into a quantifiable electrical response.

d) Time temperature indicators (TTI): Time-temperature indicators are another area of application in active or intelligent packaging. Because temperature abuse is common during storage, transportation and handling, these indicators are designed to monitor temperature abuses in a food product's shelf life. Time-temperature indicator" or "time–temperature integrator" (TTI) are small devices that, attached to the package, will indicate the combined time and temperature history of that product with a gradual change in color. TTIs integrate the time and temperature by specific enzymatic or chemical reactions that ideally, have an identical rate constant to the quality or safety feature of the packed product (Fig 2).

Fig 2. Diffusion based TTI: *The lighter colour of centre bar represents that the product has been*



stored at proper temperature conditions.

The key features of TTIs system are given below:

- Continuous monitoring of storage conditions (time & temperature history throughout the food chain)
- Systems: based on physical (diffusion), chemical (compounds of variable colors), enzymatic or biological processes
- Disposable, irreversible color change
- Simple, relatively economic

Table 2: Different indicators along with their applications for intelligent packaging of packed food

Indicator	Checks	Application
Time-temperature Indicators (TTI)	Storage conditions	Foods stored under low temperature conditions
Oxygen indicators	Storage conditions Package leak	Foods stored in packages with reduced oxygen concentration
Carbon dioxide indicator	Storage conditions Package leak	Modified or controlled atmosphere food packaging
Microbial growth indicators	Microbial quality of food (i.e. spoilage)	Perishable foods such as meat, fish and poultry
Pathogen indicators	Specific pathogenic bacteria such as *Escherichia coli* O157	Perishable foods such as meat, fish and poultry

4. ANTIMICROBIAL FOOD PACKAGING

Antimicrobial food packing is used to retain the quality and safety by reducing microbial contamination of the commodity. Antimicrobial agents incorporated directly into packaging materials for slow release to the food surface or may be used in vapour form and they further reduce the growth rate by extending the lag phase of the micro-organisms. The basic principle of antimicrobial packaging involves hurdle technology. The antimicrobial component/property is an extra function of the packaging system to act as a hurdle to prevent the degradation of quality of packaged foods while satisfying the conventional functions of moisture and oxygen barriers as well as physical protection. The microbial hurdle may not contribute to the protection function from physical damage. However, it provides tremendous protection against microorganisms, which has never been achieved by conventional moisture and oxygen barrier packaging materials like LDPE etc. (Fig 3).

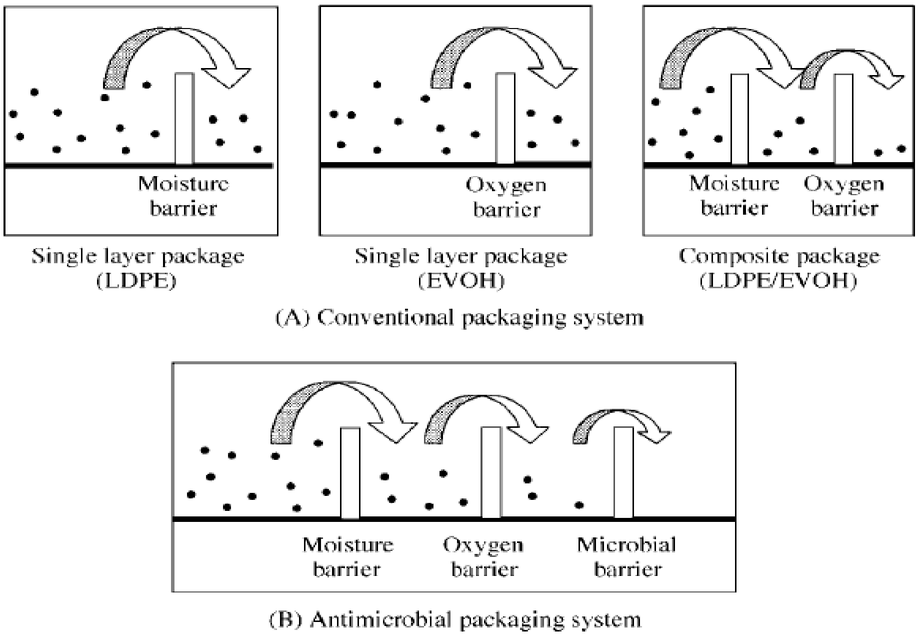


Fig 3. Comparison of conventional packaging (a) and antimicrobial packaging system (b)

Antimicrobial agents and packaging systems:

- **Organic acids:** Organic acids such as Benzoic acids, Parabens, Sorbic acids, Sorbates, Propionates, Acetic acid and Propionic acid are used as antimicrobial agents.
- **Silver ions:** Research on the use of silver nanoparticles as antimicrobial agent in food packaging is going on.
- **Enzymes:** Lysozyme, Propyl parabens, Glucose oxidase
- **Bacteriocins:** Lacticins and Pediocin act against lactic acid bacteria (LAB)
- **Fungicides:** Benomyl, Imazalil
- **Polymers:** Chitosan, herb extract, UV/ excimer laser irradiated nylon
- **Natural extract:** Grapefruit seed extract, Clove extract, Herb extract, Ag-Zirconium, Eugenol, Cinnamaldehyde, Horseradish extract, Allyl isothiocyanate

5. VACUUM PACKAGING

Vacuum packaging is also an effective approach to increase the shelf life of food commodities. The air is completely removed from the package and the sealed pack is made air-tight. This method involves (manually or automatically) placing items in a plastic film package, removing air from inside and sealing the package. Shrink film is sometimes used to have a tight fit to the contents. The low levels of oxygen inside the package inhibit the growth of aerobic microorganisms and the product spoilage is reduced. Due to negligible oxygen levels various oxidative reactions are also reduced inside the package leading to extended shelf life of the product. Vacuum packaging is mainly used in meat and poultry products, where the exclusion of air helps to reduce freezer burn. It can also be used to store dry foods over a long period of time, such as nuts, cheese, smoked fish, coffee and potato chips (crisps). However, with respect to fruit and vegetables, packaging under moderate vacuum has been found to improve microbial and sensory quality of these perishables. Moderate vacuum packaging (MVP) is a variation of traditional vacuum packaging, used for respiring products such as prepared fruits and vegetables. The product is packed in a rigid airtight container or a pouch and is surrounded by normal air, but at a reduced pressure (around one-third of normal atmospheric pressure). This slows down the metabolism of the product and the growth of spoilage organisms.

FUTURE TRENDS

The food industry has witnessed number of advances in the packaging sector since its inception in 18th century with most recent innovations occurred during the past century only. These new innovations especially active and intelligent packaging have mostly focussed on delaying oxidation and controlling moisture migration, microbial growth, respiration rate etc. These also contribute towards the enhancement of food quality, feasibility and bioactivity of functional compounds. Further, nano technology is likely to play an important role in providing innovative packaging solutions. Therefore, it seems that, in response to consumer preferences, the traditional packaging will completely be replaced by such innovative food packaging techniques in near future.

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