

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



# Advances in Postharvest Packaging Systems of Fruits and Vegetable

*Trina Adhikary and Durga Hemanth Kumar*

## Abstract

The production of vegetables and fruits is at a high rate but the major challenging task is the postharvest handling and processing of the products. Approximately 20–30% of the production is being wasted due to a lack of proper postharvest management. Many developments were made to reduce this wastage such as cold chain development, different storage structures, some drying methodologies to promote the shelf life of produce. But all these systems need to be improved and utilized commercially. The losses still occur due to a lack of sound knowledge on the chemical nature of products and different management techniques (e.g., drying, cooling, blanching). Therefore, the successful design of the cooling, packing, storage transport, and drying processes of fresh food requires linking materials sciences, fluid dynamics, mechanical deformation, food chemistry, and process control.

**Keywords:** packing, advanced packing systems, bio-degradable packing, shelf life

## 1. Introduction

Fruits and vegetables are highly perishable and have a very short shelf-life. During different handling and marketing operations, there is a huge postharvest loss of agricultural produce. Both qualitative and quantitative losses occur in horticultural commodities between harvest and consumption. Qualitative losses like loss edibility, nutritional quality, calorific value, and consumer acceptability of fresh produce are much more difficult to assess than are quantitative losses [1]. Quantitative post-harvest losses in India estimated by different committees ranged between 25 and 33% depending upon the crop. The major cause of postharvest loss is the lack of proper infrastructure for processing and packing. These losses can only be minimized to some extent by proper marketing, handling, and processing of agricultural commodities. According to a national level study conducted under the All India Coordinated Research Project (AICRP) on Postharvest technology of the Indian Council of Agricultural Research (ICAR) the post-harvest losses during different farm handling operations like harvesting, sorting, grading, and packing accounts for about 13%, during farm storage about 6% and during storage at going down, wholesale and retail level about 12% of the produce goes waste. Thus, on average, about one-third of horticulture produce never reaches the ultimate consumer. This results in a considerable gap between gross food production and net availability [2]. Insufficient knowledge of pre and post-harvest operations and lack of proper facilities for handling like pre-cooling, grading, packaging, transport,

storage, processing, and marketing all together compound the post-harvest losses and wastage which in value terms accounts for more than 6,720,000.00 US dollars.

Keeping the huge postharvest losses in mind, there is an urgent need to reduce the postharvest losses of fresh commodities and increase the level of processing as a reduction in post-harvest losses is a complementary means of production [3]. The important strategies for loss prevention include the development of varieties (genotypes) that have longer postharvest life, use of integrated crop management system, and development of cost-effective adaptable technologies for post-harvest handling, value addition, and by-product waste utilization [4]. The value chain in post-harvest management of horticultural crops mainly comprises pre-harvest factors, harvesting, market preparation (pre-cooling, sorting, grading, packaging, and on-farm storage), transportation, storage, value addition, and by-product waste management. The status of R&D carried out pertaining to postharvest management (PHM) and processing in the country by different ICAR institutes like Central Institute of Post Harvest Technology (CIPHET) (Ludhiana) and State Agricultural University (SAUs) on different aspects of post-harvest management and processing of horticultural crops is given ahead. Depending upon the status report, research scientists can find out the gap/missing links in the available technology to suggest future priorities in the area of R&D.

Maturity is the state where the product is ready for picking. Proper identification of maturity of produce is essential so that the product is less prone to various physiological disorders and diseases [5]. Maturity indices have been developed for various fruits such as mango, pomegranate, apple, grapes, ber, aonla, Nagpur mandarin, etc. Technique to determine the maturity of mango on the tree (CIPHET) and non-destructive method for the maturity of Grand Naine banana (NRCB, Trichur) need to be popularized.

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

In this context, Paine and Paine [6] concluded that packaging contains, protects, and preserves as well as informs to create convenience to consumers. It is stated that many companies apply packaging to create values beyond the basic components of containing, protecting, preserving, and informing [7]. Recent progress in food packaging is resulting from the rising need for mild processed but with better shelf-life food products by the consumers. An important reason for innovative packaging is the emergence of food-borne microbial outbreaks that demand packaging with anti-microbial products to ascertain quality and safety. No hazardous components must touch the food within the packaging, and the flavor of the food should not get affected. The food must not change its original appearance and taste. In addition, the food should not cause any discoloring in the packaging. It is pertinent to mention that high-quality films serve to protect a product during transportation,

distribution, and use. It seems that the public health impact of unhygienic packaging of food is not well studied. The new food packaging techniques, such as intelligent packaging, bio-active packaging, and active packaging, which engage deliberate contact with the food or its surroundings and influence on consumer's health have been the most important innovations in the field of packaging technology [8]. Therefore, the main objective of this article is to present an overview of the innovations in food packaging technology.

## **2. Functions of packaging**

It is essential to minimize physical damage to fresh produce to obtain optimal shelf-life. The use of suitable packaging is vital in this respect [9]. The most frequently used one is the fibreboard carton, however, they may vary depending on the product and its physical nature, for example, tissue paper wraps, trays, cups or pads, are required to reduce damage from abrasion. Individual packing of the product is most suitable as it ensures its microenvironment and also reduces physical contact with others which improves its texture and nature and prevents the spread of disease-causing pathogens. Molded trays may be used which physically separate the individual piece of produce. Packing plays a crucial role in enhancing the post-harvest life of produce and ideal packing material should possess some characters:

- Readily available
- Easy to handle i.e., less weight
- Cost-effective
- Provide adequate ventilation for produce
- Eco friendly

When packaging is required at the source or when an extended storage life is desired, the packaging film should have high gas permeability and anti-fog properties.

The most commonly used packing material at local markets or for retail purposes is polyethylene (PE) bags. The packaging of fresh vegetables and fruit provides the largest single use of printed PE bags. But they do not have their presence in long-distance transport as they are not firm enough and may cause destruction to the product that results in decay and economic loss to the marketer. During packing the principal factor to be taken into consideration is free movement of air so that the temperature within the enclosure does not increase and shelf life is not affected. Light does not seem to be an essential factor for packing, however, some green leafy vegetables perform photosynthesis by absorbing carbon dioxide and release oxygen upon exposure to light. Vibrations and shock may cause damage to cells that leads to increased respiration rate and enzymes to be released that cause browning reaction to getting started.

## **3. Requirements of efficient food packaging process**

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

- It should protect from physical damage.

- It should safeguard from contamination.
- It should protect from bad smells and external toxicants.
- It should be nontoxic.
- It should not affect the food packaging.
- It should be easy to open.
- It should act as a barrier for moisture and oxygen ingress.
- It should filter harmful ultraviolet light.
- It should meet the required physical requirements.
- It should be transparent and resistant or tamper.
- It should have appearance and printability features.
- It should be of low cost.
- It should have handling features.
- It should be disposed of easily.

## **4. Different types of packing systems**

### **4.1 Modified atmosphere packaging (MAP)**

Polymeric films are regularly used because of their advantages and their availability, the chief factor in their control of movement and concentration of gasses by lowering the oxygen concentration and raising carbon dioxide concentration that abridges the respiration rate and promotes produce shelf-life (controlled atmospheric (CA) packing). Temperature control plays a crucial role in modified atmosphere packaging (MAP) packing as it directly influences respiration rate that shows an effect on the shelf life of produce. The major drawback of MAP packing is that the concentration of O<sub>2</sub> is reduced to a greater extent that may result in the fermentation of tissues producing undesirable off-flavors.

MAP can be done in 2 ways:

1. **Active:** it involves creating a vacuum within the product and replacing it with desired gaseous concentration. Some absorbers may also be used to control gas concentration (**Tables 1 and 2**).
2. **Passive:** the atmosphere within the product is attained because its respiration, final equilibrium depends on the characters of the commodity.

However, the packing material used may not satisfy all the properties required, so they are combined to provide a wide range of characters by lamination and co-extrusion. The concentration of gasses accumulated depends on many variables

Film	Permeability (cm <sup>3</sup> /m <sup>2</sup> day atm) for 25 μm film at 25°C			WTR (g/m <sup>2</sup> /day/atm) at 38°C, 90% RH
	O <sub>2</sub>	N <sub>2</sub>	CO <sub>2</sub>	
Ethylene-vinyl alcohol (EVAL)	3–5	—	—	16–18
Polyvinylidenechloride (PVdC)- PVC copolymer (Saran)	9–15	—	20–30	—
Low-density polythene (PE-LD)	7800	2800	42,000	18
High-density polyethylene (PE-HD)	2600	650	7600	7–10
Polypropylene cast (PPcast)	3700	680	10,000	10–12
Polypropylene, oriented (OPP)	250,000	400	8000	6–7
Polypropylene, oriented, PVdC coated (OPP/PVdC)	10–20	8–13	35–50	4–5
Rigid poly (vinyl chloride) PVC	150–350	60–150	450–1000	30–40
Plasticized poly(vinyl chloride) (PVC-P)	500– 30,000	300– 10,000	1500– 46,000	15–40
Ethylene-vinyl acetate (EVAC)	12,500	4900	50,000	40–60
Polystyrene, oriented (OPS)	5000	800	18,000	100–125
Polyurethane (PUR)	800–1500	600–1200	7000– 25,000	400–600
PVdC-PVC copolymer (Saran)	8–25	2–2.6	50–150	1.5–5.0
Polyamide (Nylon-6), (PA)	40	14	150–190	84–3100

[10–15].

**Table 1.**  
 Gas permeability and water transmission rate (WTR) of polymeric film available for packaging of MAP produce.

Fruits	O <sub>2</sub> (%)	CO <sub>2</sub> (%)	N <sub>2</sub> (%)	Vegetables	O <sub>2</sub> (%)	CO <sub>2</sub> (%)	N <sub>2</sub> (%)
Apple	1–2	1–3	95–98	Artichoke	2–3	2–3	94–96
Apricot	2–3	2–3	94–96	Beans, snap	2–3	5–10	87–93
Avocado	2–5	3–10	85–95	Broccoli	1–2	5–10	88–94
Banana	2–5	2–5	90–96	Brussels sprouts	1–2	5–7	91–94
Grape	2–5	1–3	92–97	Cabbage	2–3	3–6	81–95
Grapefruit	3–10	5–10	80–92	Carrot	5	3–4	91–95
Kiwifruit	1–2	3–5	93–96	Cauliflower	2–5	2–5	90–96
Lemon	5–10	0–10	80–95	Chili peppers	3	5	92
Mango	3–7	5–8	85–92	Corn, sweet	2–4	10–20	76–88
Orange	5–10	0–5	85–95	Cucumber	3–5	0	95–97
Papaya	2–5	5–8	87–93	Lettuce (leaf)	1–3	0	97–99
Peach	1–2	3–5	93–96	Mushrooms	3–21	5–15	65–92
Pear	2–3	0–1	96–98	Spinach	Air	10–20	—
Pineapple	2–5	5–10	85–93	Tomatoes	3–5	0	95–97
Strawberry	5–10	15–20	70–80	Onion	1–2	0	98–99

[2, 11, 16].

**Table 2.**  
 Recommended gas mixtures for MAP.

such as the chemical composition of products, packing material permeability, product respiration, and the influence of temperature on them. A lot of commercial interest has been focused on developing packing materials with high gas transmission rates. For major polythene films have more permeability to CO<sub>2</sub> than O<sub>2</sub>, thus aid in maintaining a proper gaseous ratio. Thus, packaging film of the correct permeability must be chosen to realize the full benefits of MAP of fresh produce [17].

Typical packing material should have a 2–10% O<sub>2</sub>/CO<sub>2</sub> ratio to maintain the freshness of produce and enhance its shelf life. Highly respiring produce must not be loaded in traditional packing material such as poly(vinyl chloride) (PVC), low-density polythene (PE-LD), polypropylene, oriented (OPP), instead kept in the highly permeable micro-perforated film so that the gaseous concentration is maintained. Ceramic films have high oxygen, carbon dioxide, ethylene permeability [18]. Films that have high gas permeability are usually a mixture of two or more non-numeric units each contributing a specific character such as strength, transmission, durability, permeability, etc. Furthermore, films can be laminated to achieve desired traits. Films using micro-perforations can attain very high rates of gas transmission [19]. Films with micro-perforations are preferred, generally, the size ranges from 40 to 200 µm, and by making modifications to them we can regulate the gaseous concentration to meet product requirements. Based on the release of gasses from perforations of film, suitable packing materials have been identified for mushrooms. Perforated packing materials also proved good to store nectarines, apples, asparagus, etc. Macro perforated material can also be used to pack some strawberries and raspberries. Micro-perforated material is expensive and may also allow entry of some pathogens during wet handling conditions [17].

The most effective and efficient way for packing high respiring produce is by combining high O<sub>2</sub> MAP and low O<sub>2</sub> MAP, because of high oxygen concentration there is the prevention of off-flavors and odd odors that result due to fermentation [11, 17]. Macro perforated material can also be used to pack some strawberries and raspberries. Micro-perforated material is expensive and may also allow entry of some pathogens during wet handling conditions [17].

The most effective and efficient way for packing high respiring produce is by combining high O<sub>2</sub> MAP and low O<sub>2</sub> MAP, because of high oxygen concentration there is the prevention of off-flavors and odd odors that result due to fermentation [11, 17].

- Proper movement of air must be ensured for enhancing the shelf life of produce and also increase resistance to gas diffusion. Ethylene is known as a natural ripening hormone and is active at trace concentrations, it is observed that its activity is reduced at oxygen levels of 2–10%, thus low oxygen enhances shelf life.
- Biological reactions increase by 2–3 times for every 10°C rises in temperature, film permeability also increases with fluctuations in temperature hence temperature control is crucial for successful MAP, temperature fluctuations may result in browning of tissues, loss of firmness, increased ethanol content, all in combination deteriorate the quality of produce packed.
- Relative humidity (RH) also has to affect produce packed, more RH invites disease-causing pathogens thus reduces the quality of produce, whereas low RH increases transpiration damage and leads to desiccation. A mathematical model was developed for estimating the changes in the atmosphere and humidity within perforated packages of fresh produce [18, 20, 21]. This model depends on the concentrations of O<sub>2</sub>, CO<sub>2</sub>, N<sub>2</sub>, and H<sub>2</sub>O vapors in the package. A different procedure was developed to maintain the concentrations of O<sub>2</sub> and CO<sub>2</sub> inside packages that are exposed to different environmental conditions [22].

- Cucumbers that are not packaged experienced severe chilling injury compared to those packed in 31.75  $\mu\text{m}$  PE-LD when they are stored at 5°C and 90–95% RH [3]. The influence of MAP on the sensory characteristics and shelf life of shiitake mushrooms (*Lentinula edodes*) was also studied using PE-LD, polypropylene (PP), and macro perforated film.
- Some fresh vegetable shelf life has been enhanced by packing them with nitrogen gas.

## 4.2 Edible coatings and films

Increased use of synthetic packing material poses an environmental threat during its disposal, hence some coating techniques evolved that satisfy both the product shelf life and less threat to nature (**Table 3**). The materials used or coating must full fill some features such as acceptable sensorial characteristics, appropriate barrier properties, good mechanical strength, reasonable microbial, biochemical, and physicochemical stability, safety, low cost, and simple technology for their production [23].

Mostly used coating materials are polysaccharides of starch, proteins, the cellulose that does not pose any harm to human health. Carboxymethylcellulose is one of the materials that gained attention because of its wide applications. The materials used may be extracted from plants such as (corn zein, wheat protein, soy protein) or from animals (casein, whey protein). Pullulan, produced by *Aureobasidium pullulans*, is capable of forming edible films but it is been largely exploited as a coating material, because of its high water solubility. One example of pullulan used as a coating hydrocolloid was for strawberries and kiwifruit [23].

Film	Thickness (mm)	Permeability at 0% RH ( $10^{-15}$ l/m <sup>2</sup> s Pa)		Permeability ratio (CO <sub>2</sub> /O <sub>2</sub> )
		O <sub>2</sub>	CO <sub>2</sub>	
Corn-zein	0.12–0.31	0.36 30°C	2.67 21°C	7.5
Wheat gluten	0.23–0.42	0.20 30°C	2.13 21°C	9.5
Methyl cellulose low level (MC (L))	0.04–0.07	2.17 30°C	69.00 21°C	31.6
Hydroxypropylcellulose low level (HPC (L))	0.05	3.57 30°C	143.99 21°C	40.6
HPC/lipids	0.15	3.44 30°C	81.75 21°C	23.7
Cozeen	0.09	0.89 37.8°C	5.25 22.8°C	5.9
Wheat gluten	0.14	0.09 37.8°C	0.03 22.8°C	0.3
Corn-zein	0.08	0.16 25°C	—	—
Wheat gluten	0.15	0.08 25°C	—	—

[10].

**Table 3.**  
 Oxygen and carbon dioxide permeabilities of edible films.

### 4.3 Antimicrobial packaging

It's the combination of edible packing material with some antimicrobial agents that aid in inhibiting the growth of microbes. There are several categories of antimicrobials that include, organic acids (acetic, benzoic, lactic, propionic, sorbic), fatty acid esters (glyceryl monolaurate), polypeptides (lysozyme, peroxidase, lactoferrin, nisin), plant essential oils (cinnamon, oregano, lemongrass), nitrites and sulfites, among others [24]. But their use is limited in fresh-cut fruits, only organic acids, and plant essential oils are used. The drawback is that fruits are losing their natural flavor and aroma due to the usage of essential oils. To confer antimicrobial activity, antimicrobial agents may be coated, incorporated, immobilized, or surface modified onto package materials [25].

Antimicrobial films are of 2 types: (a) mobile-which includes an antimicrobial agent that migrates on the surface of produce and prevents pathogenic growth (b) static that does not migrate and inhibits pathogen growth on the surface of produce. Packing materials with grapefruit seed extract in combination with a polyamide binder had an impact on microbial activity compared to grapefruit seed extract (GFSE) alone. When only GFSE is used it should antimicrobial activity against few microbes, but when used in association with a binder it is found effective against several microbes. But these when used alone may not be much effective, hence must be combined with other techniques such as pulsed light, high pressure, and irradiation could reduce the risk of pathogen contamination and extend the shelf-life of perishable food products.

### 4.4 Active packaging

It is the most efficient technique for packing products that had a dual purpose of maintaining quality and also reduced pathogen damage. It is based on the technique of modifying the internal gas environment by removing or adding gasses to the headspace inside the package. It is done through various ways such as:

- Ethylene scavenging: ethylene is known as a ripening hormone and in very minor concentrations it shows its action, so by eliminating ethylene from packing material we can avoid the further maturation of produce and prevent enzyme action that results in extended shelf life.
- Oxygen scavenging: the presence of oxygen enhances aerobic microbial growth and also enzymatic action. It also results in nutrient loss, off flavor development. Mostly it is used to check mold growth.
- Carbon dioxide release: higher concentrations of carbon dioxide check microbial growth, hence it is essential to maintain it at the needed level, and it is more permeable to plastic films than oxygen, so it must be regulated timely to get quality produce.
- Sulfur dioxide: most commonly used for the packing of grapes, grapes packed in the carton are intermittently fumigated with sulfur dioxide, it must be properly regulated to prevent excess accumulation of sulfur dioxide. Flexible packaging materials such as PE-LD and linear low-density polyethylene (PE-LLD) when impregnated with potassium permanganate and cinnamic acid, respectively become ethylene scavengers.

#### 4.5 Biodegradable packaging

Many biobased polymers are available in the market, like certain kinds of polyester, polyvinyl alcohol, polyesteramides, which are mainly used as films or moldings (**Table 4**). Polyhydroxy acid is very expensive as it is produced in limited quantities at the commercial level. Polylactic acid (PLA) is gaining importance in recent times as it performed better than many synthetic ones. There is always a great demand in searching for biodegradable packing material that serves the dual purpose of being ecofriendly and also less damage to the products stored in it.

The preference of these bio-based packing materials is for those products that need short time storage such as fruits and vegetables. To achieving in this platform the packing material must meet the quality and safety standards of products and also promote its shelf life and fetch good market price to justify the additional costs incurred.

#### 4.6 Application of nanocomposites

They are the nanoscale structures the improve the macro properties of food. Some of the nanocomposites used are silica nano clay and polymer clay nano clay. Silver nano clay have good interactions with other particles and also provides a large surface area to volume ratio, enhanced bacterial activity control, whereas polymer nano clay provide more strength and stiffness, smaller cell size, and is a flame retardant.

Polymer nano clay has recently emerged due to its wide-ranging properties such as providing mechanical strength, less shocking treatments, etc. The properties of biopolymer-based coatings were shown to act as hurdles for gas and solutes thereby increasing the shelf life of produce. But they showed poor performance in mechanical resistance and water vapor exchange. To achieve these characters hybrid materials were developed consisting of bio-based polymer and layered silicates such as montmorillonite (MMT). These exhibited great and good results in the chemical, physical and physiological aspects of the product in comparison to the pure one [27].

Nanocomposite constituents are composed of a nanoscale structure that enhances the macroscopic properties of food products. Polymer clay nano clay and silica nanocomposites of nanosilver are the two common nanocomposites utilized in the food packaging industry. Increased stiffness, strength, nucleating agent in foams, smaller cell size, higher cell density, and flame retardant are the impacts of nano clay in polymers. Nanosilver has great antibacterial characteristics which are made out of de-ionized water suspended in silver. Silver nanoparticles have a large surface area relative to volume, so, they interact well with other particles, increasing their antibacterial efficiency. As a result, they are widely utilized in the food

Material	Film preparation	Moisture barrier	Oxygen barrier	Mechanical properties
Starch/polyvinyl alcohol (PVAL)	Extrusion	–	+	+
Polyhydroxybutyrate/valerate (PHB/V)	Extrusion	+	+	+/-
Polylactic acid (PLA)	Extrusion	+/-	–	+

[26].

**Table 4.**  
*Properties of some biodegradable plastics [26].*

packaging business. Although the application of nanotechnology in the food industry was initiated later than other industries, many nanoscientists and technologists have recognized the immense potential of food nanotechnology, particularly in the areas of increasing food quality and ensuring food safety [4].

Polymer/clay nanocomposites are one of the potential applications of nanotechnology in food packaging; they have recently emerged due to their capacity for improving mechanical, barrier, and chemical properties of packaging materials with a small amount of nano clays reinforcement (less than 5% by weight). However major work done on clay polymers concentrated on synthetic polymers majorly. Biopolymers act as a hurdle to solute and gas thereby enhancing the shelf life of produce. However, due to their hydrophilic qualities, these films do not retain good mechanical and water vapor barrier capabilities. To overcome these issues, an innovative approach has been developed, by using hybrid materials consisting of polymers and layered silicates such as montmorillonite (MMT) clay mineral, result from the stacked arrangement of negatively charged silicate layers and contain a platelet thickness of about 1 nm with a high aspect ratio (ratio of length to thickness) [28]. The layered silicate filled polymer composites exhibit extraordinary enhancement of mechanical, thermal, and physicochemical properties at a low level of filler concentration when compared to pure polymer and conventional micro composites [27].

In specific, these nanocomposites offer good barrier characteristics, because, the presence of clay layers inhibits the diffusing molecule pathway due to tortuosity [29, 30]. Some of the works done with biopolymer-based nanocomposites were based on starch or polysaccharides, such as chitosan [31, 32], thermoplastic starch and wheat and maize starch. A few studies on protein-based nanocomposites have been available, including whey protein soy protein [31], and wheat gluten. Nanocomposites along with biopolymers exhibited a greater impact when compared nanocomposites alone. The most popular biopolymer is whey protein that has gained popularity due to its transparent coating and effective oxygen barrier. Unlike chitosan film, whey protein films have not shown any antimicrobial activity; therefore, incorporation of antimicrobial agents, such as lysozyme, sorbic acid, and p-aminobenzoic acid and is desirable to induce this feature. Rhim et al., reported that cloister 30R and some chitosan-based nanocomposites showed action against gram-positive bacteria.

#### **4.7 Smart or intelligent packaging**

It is of two types: the one which incorporates integrated circuits and the one that does not (chipless smart packing). The type of packing that includes diagnostic indicators also falls under this umbrella. They can be used for some functions such as humidity, light, heat, mechanical shock, biological agents such as bacteria or viruses as they come in contact.

The conventional packing material use is limited to only some fresh produce and it can not come up with tolerating the high rates of respiration of fresh produce, however, some breathable polymer films were in use for cut vegetables and fruits. Packing films with acrylic side chains is more beneficial as the side chains melt which results in increased gas permeability and also ensures proper carbon dioxide to oxygen ratio that usually varies with the product. In this way, packing becomes smart as the concentrations of gasses are controlled automatically around the product during storage and transportation and provide the products with high quality to the consumers.

Intelligent packaging technique indicates the freshness of produce by changing colors, so the consumer can know its quality and can check it if any deterioration occurred during the transit. Time-temperature integrators (TTI's) are instruments

that display irreversible changes in characters such as shape or color. They work based on different principles such as physical, chemical, and biological. The first two types are based on the response towards time, temperature, melting, polymerization, etc... The latter depends on the activity of biological organisms.

Fresh-Check® Life Lines integrator is available as self-adhesive labels, that are attached to the packing material of perishable produce to assure the quality of products to customers. It is based on the principle of color change, which is due to a polymer that has diacetylene monomeric units. It includes a small ring of polymer surrounded by another ring for color reference, the rate of change of color depends on the rate of food quality loss. The color changes from light to dark as the temperature increases.

Vitsab® indicator is based on enzymatic reactions. It has two compartments, one for enzyme plus a dye and the other for substrate (primarily triglycerides). It consists of a bubble-like dot and it is activated by applying pressure, which results in the compartments getting mixed. Because of the reaction between enzyme and substrate, there will be a change in pH and also a change in color. Initially, the dot is in green color and slowly changes to yellow as the product reaches the end of shelf life. The reaction is irreversible and the rate of reaction is directly proportional to

Food/treatment	Packaging materials/methods	Shelf life
Peach, cauliflower, truffle	Tray: PP; Cover: PE-LD/polyethylene terephthalate (PET) (40 µm), 0–14 microperforated package, all wrapped in PE	4 days at 4°C
Strawberry	Stretch PVC	8 days at 1°C
Minimally processed fruits (kiwi, banana and prickly pear)	1. PE/Al/PET 2. Coex. polyolefinic high permeable film	4–12 days at 5°C
Sweet cherry	5% O <sub>2</sub> + 10% CO <sub>2</sub>	80 days at 1°C
	PE: 13–18% O <sub>2</sub> + 2–4% CO <sub>2</sub>	40 days at 1°C
	70% O <sub>2</sub> + 0% CO <sub>2</sub>	20 days at 1°C
	Air	30 days at 1°C
Cactus pear fruits	Cryovac MY 15 Plastic box	9 days at 4°C
Carrots, minimally processed	PP + cPP/OPP in: 5% O <sub>2</sub> /10% CO <sub>2</sub> /85% N <sub>2</sub>	2 days at 4°C
	80% O <sub>2</sub> /10% CO <sub>2</sub> /10% N <sub>2</sub>	7 days at 4°C
Cabbage, shredded	OPP (30 µm)	9–10 days at 3°C
Cabbage, shredded	Glass jar; PE (30 µm); PP (30 µm) in: Air	7 days at 0 and 10°C
	100% N <sub>2</sub> ,	
	MAP 1: 100% N <sub>2</sub> ,	
	MAP 2: 5% O <sub>2</sub> /95% N <sub>2</sub> ,	
	MAP 3: 10% O <sub>2</sub> /90%	
	MAP 4: 70% O <sub>2</sub> /30% N <sub>2</sub> and 100% O <sub>2</sub>	

[12].

**Table 5.**  
*Packaging materials and methods effect on the shelf life of fruits and vegetables.*

the temperature. Single dot tags are used at consumer level packing for monitoring pallets and cartoons. *ripeSense* is the world's first intelligent ripeness indicator.

The Institute of Food Technologists in the United States has defined shelf life as "The period between the manufacture and the retail purchase of a food product, during which time the product is in a state of satisfactory quality in terms of nutritional value, taste, texture, and appearance". Various factors affecting shelf life are product characteristics, which include intrinsic factors, such as water activity, pH, microflora, availability of oxygen, reduction potential; and extrinsic factors, such as temperature, rainfall, humidity, light, etc., enzymic reactions, chemical reactions, and non-enzymic reactions (**Table 5**).

There are various chemical, biochemical and physical reactions that lead to food quality deterioration. These include enzymic and non-enzymic browning, fat oxidation, hydrolysis, lipolysis, and proteolysis that change the physical and chemical composition of food [33].

## 5. Conclusion

Recently, the food packaging process, biotechnology, sensor science, information technology, nanotechnology, and other scientific disciplines are coming together to develop a breakthrough in postharvest packaging systems. These improved postharvest handling techniques are continuously getting advanced by creating new opportunities in food industries to utilize technologies in the future. Proper and good packing is essential in providing quality products to customers. It is the connecting link between producers and consumers, so it must be done so perfectly to retain the product quality and also customer confidence. The food packaging industry gets highly competitive due to consumer's desire for tasty and slightly processed food products with longer shelf life at a lower cost than their existing packaging. The recent trend in the change of lifestyle leads the food industry well aware of consumer's needs, and therefore, the packaging industry must innovate or stagnate. This condition has posed a great challenge for the food packaging sector to innovate new food packaging techniques. Consumers will often actively seek the freshness of the product with the longest remaining shelf life. Nowadays, novel food packaging technologies, such as active packaging, aseptic packaging, intelligent packaging, nano-packaging, and bioactive packaging intentionally associated with food products have proved to be the best technological research areas. Advances in packaging technology may prevent food spoilage by retarding water penetration, ultraviolet interactions, oxygenation, and ripeness. It is predicted that the future packing material includes radio frequency identification tags. Radio-frequency identification (RFID) tags are advanced forms that can trace and identify a product. Therefore, continuous innovations in active and intelligent packaging systems are expected to secure food quality, safety, and stability and to satisfy the ever-growing need of consumers.

IntechOpen

### Author details

Trina Adhikary<sup>1\*</sup> and Durga Hemanth Kumar<sup>2</sup>

1 College of Horticulture and Forestry, Punjab Agricultural University,  
Ludhiana, Punjab, India

2 College of Horticulture, Dr. Y.S.R. Horticultural University,  
Venkataramannagudem, Andhra Pradesh, India

\*Address all correspondence to: [trinaadhikaryhort@gmail.com](mailto:trinaadhikaryhort@gmail.com)

### IntechOpen

© 2021 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

## References

- [1] Geeson JD. Modified atmosphere packaging of fruits and vegetables. In: International Symposium on Postharvest Handling of Fruits and Vegetables. Leuven, Belgium: Proceeding copy; 1988. pp. 143-147
- [2] Moleyar V, Narasimham P. Modified atmosphere packaging of vegetables: An appraisal. *Journal of Food Science*. 1994;**31**:267-278
- [3] Wang CY, Qi L. Modified atmosphere packaging all eviates chilling injury in cucumbers. *Postharvest Biology and Technology*. 1997;**10**(3):195-200
- [4] Tarver T. Food nano technology. *Food Technology*. 2006;**60**(11):22-26
- [5] Smith JP, Ramaswamy HS. Packaging of fruits and vegetables. In: *Processing Fruits: Science and Technology*. Lancaster, PA: Technomic Publishing Co.; 1996. pp. 379-427
- [6] Paine FA, Paine HY. *A Handbook of Food Packaging*. Leonard Hill; 1983
- [7] Bramklev C, Olsson A, Orremo F, Wallin C. Unveiling the concept of packaging logistics. In: *Conference Proceeding of NOFOMA*. Proceeding copy; 2001
- [8] Majid I, Ahmad Nayik G, Mohammad Dar S, Nanda V. Novel food packaging technologies: Innovations and future prospective. *Journal of the Saudi Society of Agricultural Sciences*. 2016;**17**(4):454-462. DOI: 10.1016/j.jssas.2016.11.003
- [9] Thompson AK. *Postharvest Technology of Fruit and Vegetables*. Oxford: Blackwell; 1996
- [10] Chung D, Yam KL. Antimicrobial packaging material containing propyl Paraben. In: *IFT Annual Meeting Technical Program: Book of Abstracts*. Chicago: Institute of Food Technologists; 1999. p. 21
- [11] Day BPF. Recent developments in active packaging. *South African, Food & Beverage Manufacturing Review*. 1999;**26**(8):21-27
- [12] Guilbert S, Gontard N, Gorris LGM. Prolongation of the shelf life of perishable food products using biodegradable films and coatings. *Food Science and Technology*. 1996;**29**:10-17
- [13] Han JH. Antimicrobial food packaging. *Food Technology*. 2000;**54**(3):56-65
- [14] Krochta JM, Baldwin EA, Nisperos Carrido M. *Edible Coatings and Films to Improve Food Quality*. Lancaster, PA: Technomic Publishing Co; 1994
- [15] Lee DS, Kang JS, Renault P. Dynamics of internal atmosphere and humidity in perforated packages of peeled garlic cloves. *International Journal of Food Science and Technology*. 2000;**35**:455-464
- [16] Powrie WD, Skura BJ. Modified atmosphere packaging of fruits and vegetables. In: Ooraikul B, Stiles ME, Horwood E, editors. *Modified Atmosphere Packaging of Food*. New York, USA; 1991. pp. 169-245
- [17] Day BPF. Novel MAP. A brand-new approach. *Food Manufacture*. 1998;**73**:22-24
- [18] Lee DS, Hagggar PE, Lee J, Yam KL. Model for fresh produce respiration in modified atmospheres based on principles of enzyme kinetics. *Journal of Food Science*. 2006;**56**(6): 1580-1585
- [19] Alique R, Martinez MA, Alonso J. Influence of the modified atmosphere packaging on shelf life and quality of

Navalinda sweet cherry. *European Food Research and Technology*. 2003;**217**(5): 416-420

[20] Montanez JC, Rodriguez FAS, Mahajan PV, Frias M. Modelling the effect of gas composition on the gas exchange rate in perforation-mediated modified atmosphere packaging. *Journal of Food Engineering*. 2010;**96**(3): 348-355

[21] Montanez JC, Rodriguez FAS, Mahajan PV, Frias M. Modelling the gas exchange rate in perforation-mediated modified atmosphere packaging: Effect of the external air movement and tube dimensions. *Journal of Food Engineering*. 2010;**97**(1):79-86

[22] Silva FM, Chau KV, Brecht JK, Sargent SA. Modified atmosphere packaging for mixed loads of horticultural commodities exposed to two postharvest temperatures. *Postharvest Biology and Technology*. 1999;**17**(1):1-9

[23] Diab T, Biliaderis C, Gerasopoulos D, Sfakiotakis E. Physicochemical properties and application of pullulan edible films and coatings in fruit preservation. *Journal of the Science of Food and Agriculture*. 2001;**81**:988-1000

[24] Franssen LR, Krochta JM. Edible coatings containing natural antimicrobials for processed foods. In: Roller S, editor. *Natural Antimicrobials for the Minimal Processing of Foods*. Boca Raton, Florida: CRC Press; 2003

[25] Suppakul P, Miltz J, Sonneveld K, Bigger SW. Active packaging technologies with an emphasis on antimicrobial packaging and its applications. *Journal of Food Science*. 2003;**68**:408-420

[26] Berkesch S. Biodegradable Polymers. *A Rebirth of Plastic*. 2005. pp. 1-14. Available from: <https://www.iopp.org/files/public/BerkeschShellie>

MSUBiodegradablePlastic.pdf  
[Accessed: April 12, 2010]

[27] Uyama H, Kuwabara M, Tsujimoto T, Nakano M, Usuki A, Kobayashi S. Green nanocomposite from renewable resources: Plant oil-clay hybrid materials. *Chemistry of Materials*. 2003;**15**:2492-2494

[28] Sorrentino A, Gorrasi G, Vittoria V. Potential perspectives of bio-nanocomposites for food packaging applications. *Trends in Food Science and Technology*. 2007;**18**:84-95

[29] Bharadwaj. Modeling the barrier properties of polymer layered silicate nano composites. *Macromolecules*. 2001;**34**(36):9189-9182

[30] Sorrentino A, Gorrasi G, Tortora M, Vittoria V. Barrier properties of polymer/clay nanocomposites. In: Mai Y-W, Yu Z-Z, editors. *Polymer Nanocomposites*. Cambridge, UK: Wood-head Publishing Ltd.; 2006. pp. 273-292

[31] Rhim JW, Lee JH, Kwak HS. Mechanical and barrier properties of soy protein and clay mineral composite films. *Food Science and Biotechnology*. 2006;**14**:112-116

[32] Xu Y, Ren X, Hanna MA. Chitosan/clay nano-composite film preparation and characterization. *Journal of Applied Polymer Science*. 2006;**99**:1684-1691

[33] Robertson GL. *Food Packaging-Principles and Practice*. 3rd ed. Boca Raton: CRC Taylor and Francis Group; 2012