PACKAGING OF FRESH FRUITS AND VEGETABLES

The agro climatic conditions of our country are ideal for agriculture and horticulture. Our country's economy is also predominantly agrarian. Agriculture supports 64% of workforce and earns 19% of our exports.

Polymeric Films Used for Packaging of Fruits and Vegetables

India is the largest producer of fruits in the world (46 million tonnes) with a global share of over 10% and the second largest producer of vegetables (80 million tonnes) with a global share of over 15%. India is the largest producer of banana (15% of the world production) and mango (59% of the world production). India is 2nd largest producer of onion with a global share of 12.6% and 3rd largest producer of cauliflower with a global share of 6.3%. The production of major fruits & vegetables is given in Table 1 and 2. Figure 1 shows India's share in the world market.

TABLE 1

Production of Major Fruits in India

Item	Production (In '000mt)		India's Share (Percentage)	India's Position
	INDIA	WORLD		
Total Fruits	43,000	4,13,932	9.8	2
Mangoes	12,000	23,455	51.1	1
Bananas	10,200	58,618	17.4	1
Pineapples	1,100	12,100	9.0	3
Guava	620	7,786	3.0	4
Oranges	2,000	66,212	4.0	NA
Apples	1,200	53,672	2.4	9
Grapes	700	57,397	1.2	15

[Source: FAO, NHB 2000]

TABLE 2

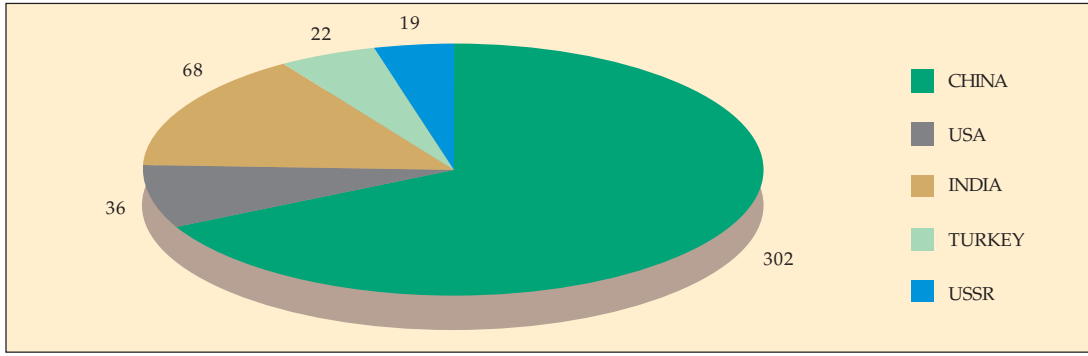
Production of Major Vegetables in India

Item	Production (In '000mt)		Share of India (Percentage)	India's Position
	INDIA	WORLD		
Potato	17,942	2,94,834	6.08	5
Onion	4,058	35,644	11.38	2
Tomato	4,800	84,873	5.65	5
Cauliflower	4,800	12,725	37.72	1
Cabbages	3,300	46,656	7.07	3
Green Peas	270	5,214	5.17	2
All Vegetables	64,672	5,65,523	11.43	2

[Source: FAO Production Year Book]

Figure 1: India's Share in the World Market

(million metric tonnes)



[Source : Indicus Analytics]

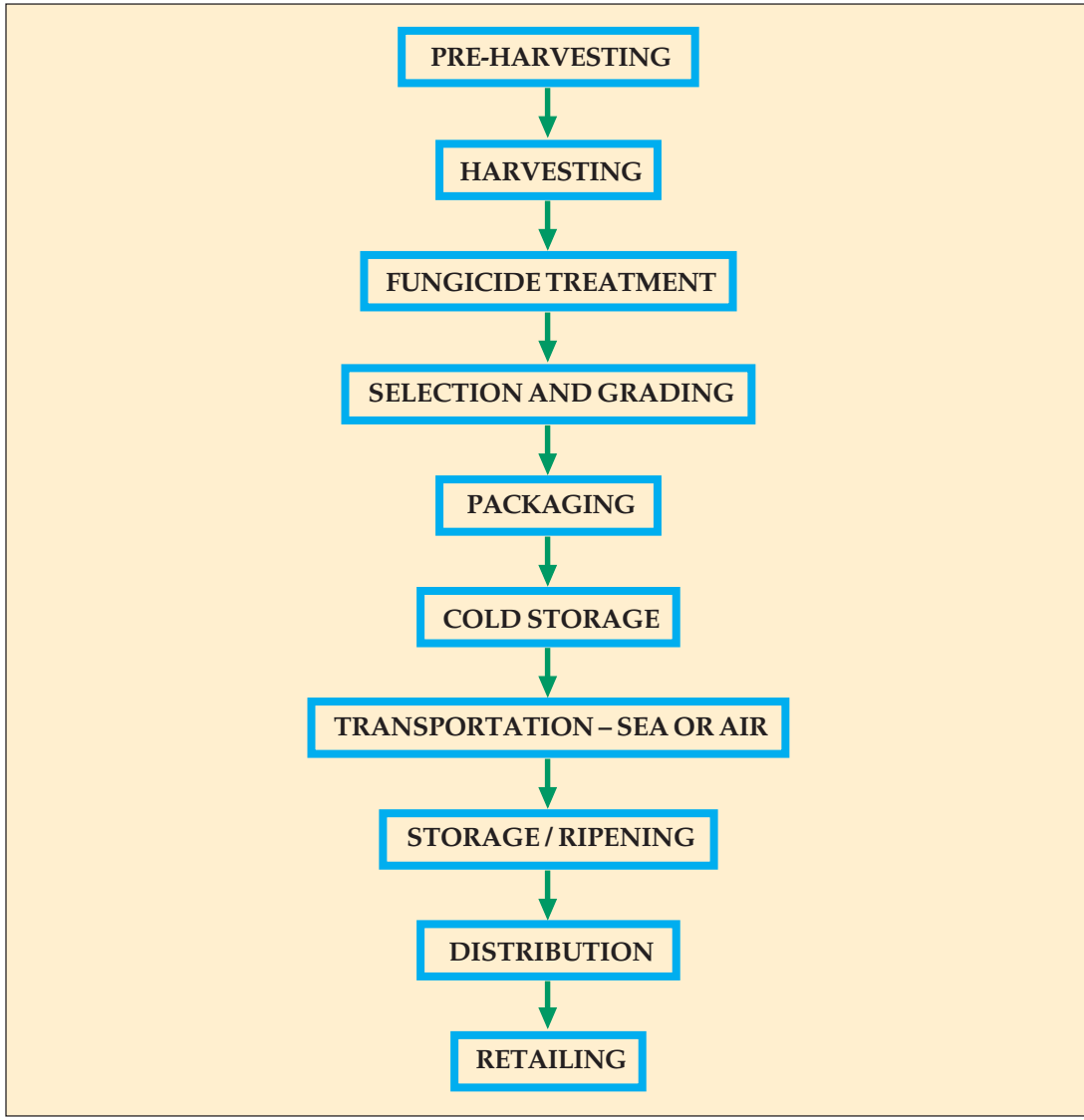
Inspite of all these achievements, agriculture contributes only one-third of the GNP. About 20 to 30% of the produce is lost annually due to lack of adequate infrastructure and less use of modern post harvest technologies. In terms of value, the losses are Rs. 25,000 crores annually. This high level of wastages and value losses are largely due to lack of basic infrastructure like storage and handling facilities. Thus the per capita availability of fruits is reduced to around 80gms per day, which is almost half the requirement for a balanced diet.

Fresh horticultural produce has limited shelf-life ranging from a few hours to few weeks at ambient temperature. Packaging is required not only for food preservation and protection but also has assumed a multi functional role by serving as a symbol of value addition, an assurance of quality and quantity / number, a conveyor of convenience and ultimately a tool for marketing food products. The importance of packaging has gained ground, thanks to the growing consumer awareness and willingness to pay for value and hygienic products. Increasing exports and stringent export market needs have also influenced the packaging trend. Increasing environmental concerns have also imposed newer parameters for package performance giving an impetus to the development of eco-friendly packaging materials.

The marketing cycle starts from the small farmers – large farmers – commission agent – trader – commission agent – wholesaler and finally the retailer. Damage during the transit is one of the main problems in horticultural produce packaging. The main purpose of packaging is to provide the produce with attributes necessary to survive a number of different hazards that can be expected during storage, transportation and distribution. Hence, the first step in selection of a package for a specific product is to obtain a clear picture of the distribution pattern and a drawn up model that qualitatively and quantitatively represents the system through which the produce traverse.

Figure 2 shows the simple logistical chain for export of fresh fruits and vegetables.

Figure 2: Logistical Chain for Export of Fresh Fruits and Vegetables



During the journey, the package encounters various types of distribution hazards like mechanical, climatic, biological contamination and other hazards. Packaging materials and the system followed plays an important role in preventing these losses at the farm and during the distribution chain. Packaging reduces wastes, adds value and makes the product qualitatively and quantitatively acceptable. In case of horticultural produce, packaging is required not only to enhance the aesthetic value, but also to keep the produce in good condition for long periods. With the multifarious functions, the prospective of packaging has widened significantly. Today, packaging is considered as one of the most important operations.

In case of horticultural produce, it is required to transport the produce to the site of the storage, and ensure processing or marketing in a sound condition as quickly as possible. In most cases, the fresh produce gets bruised during transportation. Physical injury initiates vigorous bio-chemical reactions in the damaged cells, and as a result, the bruised product begins to deteriorate rapidly. Thus, the transport pack must ensure minimal damage to the packaged commodity during transportation.

Product Characteristics

Horticultural products are highly perishable in nature and are very easily affected by climatic conditions, distribution hazards and microbial decay. Since fruits and vegetables are living organisms even after harvesting, they remain fresh only as long as normal metabolism continues.

In order to develop a suitable package for horticultural produce, it is important to understand the biology of the produce. Since the produce is a living tissue, even after harvesting, the high respiration rate and other metabolic processes associated with maturation and ripening of these products continue throughout the marketing cycle. This creates a special problem in the storage and packaging of fresh produce. While developing a packaging system, following product characteristics have to be considered

Respiration

Fresh produce respire even after harvesting. During this process, oxygen is used and carbon dioxide is released. The rate of deterioration is proportional to the high respiration rate. Rapid respiration results in fast ripening/aging of the produce. If the availability of oxygen is restricted, it results in changes in chemical reactions, breakdown of cells, production of small quantities of alcohol, off-flavour and off odour and finally bringing about decay or spoilage of the fresh produce. Individual fruits and vegetables vary in respiration rates. Horticultural produce classified according to their respiration rate during ripening are given in Table 3.

TABLE 3

Horticultural Commodities Classified According to their Respiration Rate

Class	Range at 5°C (41°F) (mg CO_2 /Kg-hr)	Commodities
Very low	< 5	Dates, Dried fruits and Vegetables, Nuts
Low	5 – 10	Apple, Beat, Citrus, Garlic, Grape, Onion, Papaya, Pineapple, Potato
Moderate	10 – 20	Apricot, Banana, Cabbage, Carrot, Fig, Cucumber, Mango, Tomato, Peach, Plum
High	20 – 40	Avocado, Blackberry, Radish, Cauliflower, Carrot (with top)
Very High	40 – 60	Artichoke, Bean sprouts, Broccoli, Okra
Extremely High	> 60	Asparagus, Mushroom, Peas, Spinach, Sweet Corn

Fruits classified according to their respiratory behaviour are given in Table 4. Table 5 gives the rate of respiration of various fruits and vegetables.

TABLE 4

Fruits Classifieds According to their Respiratory Behaviour During Ripening

Climacteric Fruits	Non-Climacteric Fruits
Apple, Apricot, Avocado, Banana, Breadfruit, Fig, Guava, Jackfruit, Mango, Muskmelon, Papaya, Peach, Passion fruit, Pear, Plum, Sapota, Tomato, Rambutan, Kiwifruit, Durian, Blueberry, Cherimoya, Quince, Watermelon	Blackberry, Cacao, Carambola, Cashew apple, Cherry, Cucumber, Date, Eggplant, Grape, Grapefruit, Lemon, Lime, Okra, Olive, Orange, Peas, Pepper, Pineapple, Raspberry, Pomegranate, Strawberry

TABLE 5

Rates of Respiration of Various Fruits and Vegetables

Commodity	Rate of Respiration	Storage Life
Potato, Onion, Cabbage, Apple, Citrus fruit	Low	Long
Lettuce, Cauliflower, Strawberry, Pear, Peach	Moderate	Short/Moderate
Brussels Sprout, Spinach, Artichoke	High	Short
Asparagus, Broccoli, Mushroom	Very High	Very Short

Moisture

Fruits and vegetables have very high moisture content - 75% to 95% . Under ambient conditions, loss of moisture causes rapid drying of the product causing wilting, shrivelling and loss of rigidity. Loss in moisture results in weight loss during storage and transportation.

Micro-organisms

Another common type of spoilage of fresh fruits and vegetables is caused by micro-organisms such as yeast, bacteria, molds. If there is a surface bruise or injury to the fruit, micro-organisms invade through this and cause internal decay. Hence sorting, of fruits and vegetables is necessary before packaging.

Changes in Colour, Texture, Odour and Flavour

During normal ripening, alterations takes place in the colour, texture, odour and flavour of the fresh produce. Beyond the ideal point of ripeness its quality deteriorates. Hence, the aim should be to reach the fruits to the consumers in a perfect stage of ripeness.

Temperature

The process of respiration is dependent on temperature, therefore, it is necessary to slow down the reaction by storing the produce under refrigeration. Each fruit has an ideal storage temperature. Very low temperature causes chilling injuries which damages the delicate tissues of the fresh produce. List of ideal temperature for different fruits and vegetables is given Table 6.

TABLE 6
Life of Fruits and Vegetables at Best Storing Temperatures

Temperature (in °C)	Fruits / Vegetables	Approximate Life (in weeks)
-1.0	Grapes	6
-1.0	Pears	28
-1.0 to 3.0	Apples	28
- 0.5	Figs	3
- 0.5	Peaches	6
- 0.5	Garden Peas	3
- 0.5	Beet Root	20
- 0.5	Carrot	20
- 0.5	Onions	28
0.0	Cauliflower	4
0.0	Lettuce	2
0.0	Spinach	2
0.0	Mushroom	3
0.0	Cabbage	6
5	Melons	3
5-7	Oranges	12
7	Mangoes	3
7	Cucumber	4
7	Tomatoes	3
7	Potatoes	16 - 24
10	Pineapple	5
10 – 12	Pumpkin	24
10 – 12	Bananas	3

Volatiles

Some fresh produce give off volatile compounds such as ethylene during ripening. If these volatiles are not allowed to escape, unacceptable odour develop and the produce ripens rapidly. Ethylene production rate depends upon variety, maturity stage, temperature, oxygen level, carbon dioxide level of the fresh produce. Table 7 gives product groups sensitive to ethylene.

TABLE 7

Product Groups Especially Sensitive to Ethylene

Commodity Group	Effects of Ethylene
Leafy vegetables	Turn yellow, Russet spotting on leaves and Abscission of leaves
Cucumbers	Turn yellow and become soft
Unripe fruits	Accelerates ripening
Flowers	Wilt and / or drop off

Ventilation

Since the horticultural products respire even after harvesting, the package should be provided with ventilation holes during transportation. Cold air is constantly circulated through the container to remove the heat transmitted during the cooling process.

The quality of the fresh produce, when presented to the consumer depend on:

- Initial quality of the harvest
- Care taken during physical handling
- Length of the time since harvest
- Storage environment

Pre-cooling

The aim of pre-cooling is to slow down the enzymatic and respiratory activity, minimize susceptibility to micro-organisms and to reduce water loss and ethylene production. Pre-cooling helps in removing the field heat prior to storage. It reduces the respiration heat, and decreases the rate. The different methods used for pre-cooling are forced-air cooling, vacuum cooling and hydro cooling.

Packaging Requirements

Different horticultural products need different types of packages depending on their physical, anatomical and physiology (mainly transpiration, respiration and ethylene production rate)

nature and susceptibility to microbial decay. Temperature, relative humidity and ventilation also plays a very important role in determining the post-harvest life of the fresh produce. Thus, the packaging requirements for fresh produce can be summarised as:

- Protection against bruising and physical injury
- Protection against microbial contamination and deterioration
- Provide ventilation for respiration and exchange of gases
- Protect against moisture / weight loss
- Slow down respiration rate, delay ripening and increase storage life
- Control ethylene concentrations in the package

Packaging Materials

The packages for fresh fruits and vegetables can be classified as:

- Consumer / Retail packs
- Transport / Bulk packs

Consumer Packs

Consumer packages are small in size and designed to hold ½ dozen – 1 dozen fruits or ½ kg to 2 kg of vegetables. Many types of packages in terms of forms and materials are used as consumer packs. The selection criterion for the type of consumer pack depends on marketing characteristics of the product. The most commonly used packages are listed below:

- **Flexible Plastic Films:** Different types of flexible plastic films like LDPE (Polyethylene), PVC (Poly Vinyl Chloride), PP (Polypropylene) and cellulose acetate films are used for packaging of horticultural produce.

  These films are mostly used as pouches with holes punched at regular intervals to allow respiration. They are available in a wide range of thicknesses and grades and can be engineered to control the environmental gases inside the pouch. LDPE is the most widely used material.

- **Trays with Overwrap:** The trays used are usually made of moulded pulp tray or plastic material like EPS, PVC and PP. The produce is placed in individual cavities so that abrasion and bruising is avoided during transportation. The trays also provide cushioning effect to the produce.

Snap Peas in PP Pouches with Ventilation Holes

Asparagus Stretch Wrapped

The overwrap film is a transparent see through food-grade, odourless plastic film with the property of clinging to the product packed when stretch wrapped. This film can be applied without the application of heat. It is usually made of LDPE, LLDPE or PVC. The films are semi-permeable and allow exchange of gases for respiration of the product.

- **Plastic Punnets:** These are strong, versatile, clear, bright containers, which offer product visibility and are provided with holes for ventilation, which keeps the produce fresh.

  These containers are food-grade, odourless, light weight, stackable and recyclable and give good presentation. They are either made of PET, PVC or PP.

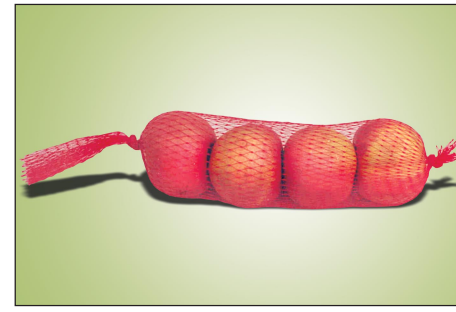
- **Plastic Net bags (Extruded & Woven):** The plastic net bags have the feature to stretch and accommodate all sizes and shapes of produce. These bags are available in roll form or in pre-cut lengths with stretch width of 200 mm – 400 mm. By allowing air to circulate in and around the produce, these net bags prolong the freshness and shelf-life of the fresh produce.

  They also eliminate pack condensation thereby preventing spoilage and wastage. They make a colourful point of sale display by allowing clear visibility of the contents, enhancing the natural colours of fresh produce. These are generally made of HDPE (High Density Polyethylene) or PA (Polyamide).

- **Foam Sleeve:** This is a plastic tubular film made of polyethylene foam available in different colours, diameters and lengths. It can be easily slipped over the individual fruits in a snug fit form. It provides a cushioning effect and protects the fresh produce against abrasion and scratches during transit. It is hygienic, non-toxic and odourless.

Strawberries in Plastic Punnet – Stretch Wrapped

Strawberries in Plastic Punnet with Lid

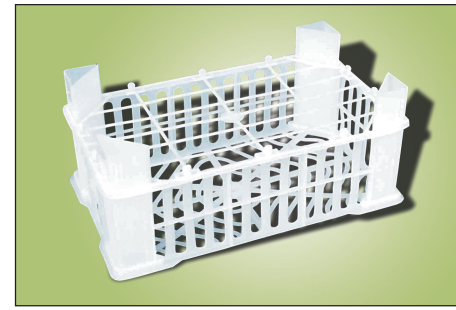


Apples in Plastic Tubular Net

Apples in Foam Guard Sleeve

- **Light Weight Plastic Crates:** These are lightweight crates, which need not be put into an outer pack for transportation. The perforations provide ventilation and keep the produce fresh.

  The crates are stackable and have high compression strength and therefore provide adequate protection to the fresh produce packed inside. These crates are hygienic, clean, reusable and can be recycled. They can be made of HDPE or PP.



Light Weight Plastic Crate

- **Shrink Wrap:** One of the newest trends in fresh produce packaging is the shrink wrapping of individual produce. The greatest advantage of individual shrink wrapping is its ability to control moisture loss. By reducing the transpiration rate and maintaining the fruit firmness the film forms a barrier which increases the resistance to water vapour. The transpiration rate can be reduced 5 to 20 times using selective permeable plastic films. The individual fruit is loosely sealed in a flexible film. The film is then shrunk tightly around the produce by passing these packs through a heat shrunk tunnel where they are exposed to hot blown air for a very short period (few seconds). The fresh produce is then cooled by rapid ventilation. The films most commonly used are LDPE or LLDPE.

- **Corrugated Boxes/Cartons:** Many fruits like mangoes, apples, grapes, etc. are packed in small packs of 2-4 kgs, either in corrugated boxes made of paper board or polymers like polypropylene. These boxes/cartons are light-weight with good compression strength. They can be printed to have a good shelf appeal.

Transport Packs

Transport packages are designed for long distance transportation in capacities ranging from 4 – 5 kgs to 20 – 25 kgs. These packs must withstand impacts, compression and vibration during transport.

Bamboo Baskets

Kilta

The transport packages can be broadly categorized as rigid containers made of wood, corrugated fibre board or plastics and flexible containers such as sacks made of plastic. Along with these materials some traditional materials used are jute (jute sacks), wooden boxes and bamboo baskets.

The variety of packaging materials used for transport packaging of horticultural produce are listed:

- **Bamboo Baskets:** Bamboo baskets are widely used even today as transport packs in domestic market. They are available in various shapes, sizes and designs but they do not have rigidity and stackability during long distance transport. Today plastic baskets or Kilta's have also been developed and used for storage & transportation of fruits & vegetables.

- **Wooden Boxes:** The conventional baskets have been replaced by wooden boxes as they give better protection to the fresh produce against transportation hazards. They have high puncture resistance, good tensile strength as well as compression strength; but they occupy more space and add on to the tare weight. Also, the nails cause injuries to the produce during long transportation. However, the use of wooden boxes is discouraged now-a-days as it directly promotes deforestation.

Wooden Boxes

- **Corrugated Fibre Board/Plastic Boxes:** Corrugated fibreboard boxes are widely used as transport/ shipping containers for fresh produce because of the following advantages :
  - Low cost to strength and weight ratio
  - Good cushioning properties
  - Smooth and non-abrasive surface
  - Good printability on the outer surface of the board
  - Easy to set up and collapsible for storage
  - Reusability and recyclable
  - Can be manufactured in high volumes
  - Can be provided with ventilation by punching holes

Corrugated Fibre Board Box

Since the CFB boxes have poor wet strength, now-a-days they are laminated with plastic film like LDPE, PP or PVC.

Plastic corrugated boxes made of PP and HDPE are partly replacing CFB boxes because of their low weight to strength ratio, high degree of water resistance and re-usability. However, its cushioning properties are not comparable to CFB.

- **Plastic Crates**: These are usually made of HDPE or PP by injection moulding. Polyethylene has higher impact strength and a low degradation by ultra-violet

radiation while polypropylene has a better scratch resistance. The performance of both materials can be improved by adding anti-oxidants and UV protectants (for sunlight protection).

Light Weight Plastic Crate

The advantages of plastic crates are:

- As these crates are strong and rigid they can be used for many journeys, making the cost per journey relatively low
- Different sizes and shapes are available
- They can be easily cleaned and disinfected
- They are strong and weather resistant and because of this they can be used in humid areas

These crates are either of stackable, stack-nest or collapsible in design. Collapsible plastic crates are the most expensive crates followed by stack-nest and then the stacking crates. The collapsible crates reduce the storage space requirement and transport cost of empty containers. The normal capacity varies between 20 – 40 kgs.

- **Sacks:** These are generally used to bring the raw materials from the field.

Plastics Woven Sack

Jute Sacks

The commonly used materials are cotton, jute, plastic (HDPE, PP). They are very useful because of low cost, high strength, re-useability and require less space for empties.

However, they have low protection against puncture, compression, vibration and impact injuries. They are poor in stackability. These sacks are usually combined with bamboo baskets and wooden boxes to improve cushioning and reduce bruise injuries and losses during transportation.

New Trends in Fresh Produce Packaging

Many of these traditional packaging materials have been modified and new materials/ technologies in terms of rigidity, stackability, longer storage, ventilation, cushioning

have been developed for transport packaging of fresh produce. Salient features of these materials are discussed here.

Jute Reinforced Plastics (JRP)

Jute fibres and wood are combined with thermoplastic materials like LDPE, HDPE, for making semi-rigid as well as rigid boards. The film layer is placed on both sides of non-woven jute. The composite layers are pressed in a hydraulic press at the required temperature for a certain period of time depending upon the thickness of the end product and the type of film used. These boards have good tensile strength, puncture resistance and moisture barrier property. JRP are now being increasingly used for transport packaging of horticultural products.

Modified Atmosphere Packaging (MAP)

Modified atmosphere packaging is a form of packaging involving the removal of air from the package and replacing it with a single or mixture of gases. The gas mixture used depends on the type of the produce. The gaseous atmosphere changes continuously throughout the storage due to factors like respiration and other biochemical changes of the produce and the permeation of gases through the package.

Fresh fruits and vegetables are living organisms having high levels of respiration and other metabolic processes associated with maturation, ripening and senescence. The MAP system is a dynamic one where respiration and permeation occur simultaneously. Factors affecting both of these must be considered when designing a package.

The respiration in a package is influenced by:

- Quantity of the produce
- Stage of maturity
- Temperature
- Concentration of ethylene gas
- Light intensity

The permeation of the package is influenced by:

- Type and nature of material
- Thickness and surface area of the material
- Temperature and relative humidity
- Partial pressure gradients of O_2 and CO_2

All the above factors interact to create equilibrium levels of O_2 and CO_2 inside the sealed package. The selection of a film or a combination of more than one film (laminate) depends on the expected transpiration and respiration rates of the produce. For most of the fresh produce the film selected should be more permeable to CO_2 than to O_2. Most of the commercially available films are as indicated in Table 8.

TABLE 8
Barrier Properties of Plastic Films

Films	WVTR	GTR		
		O_2	CO_2	N_2
Polyethylene, LD	18	7800	42000	2800
Polyethylene, HD	7 – 10	2600	7600	650
Polypropylene Cast	10 –12	3700	10000	680
Polypropylene, Oriented	4 – 5	2015	–	–
Polybutylene	8 – 10	5000	–	–
Onomer	25 – 35	4650 – 6975	–	–
Ethylene-Vinyl Acetate	40 – 60	12000	50000	4900
Cellulose acetate	–	325	13640	–
Polystyrene	100 – 125	5000	18000	800
Ethyl cellulose	–	31000	77500	–
Methyl cellulose	–	1240	6200	–
Polyvinyl alcohol	–	<1	<1	–
Polyester	25 – 30	50 –130	180 – 390	15 – 18
Nylon 6	84 – 3100	40	158 – 190	14
Rigid PVC	30 – 40	150 – 350	450 – 1000	60 – 150
Plastised PVC	15 – 40	500 – 30000	1500 – 40000	300 – 10000
PV-DC-Copolymer	1.5 – 5.0	8 – 25	50 – 150	2 – 2.6
Polyacylonitrile	78	12	17	3

[Source: Packaging India, Feb-Mar 1998]

WVTR - Water Vapour Transmission Rate
g/m^2 24 hrs. atm. at 38°C and 90% RH for 25µ film.

GTR - Gas Transmission Rate
ml / m^2 24hrs. atm. at 25°C for 35µ film.

Some of the characteristics of plastic films for MAP of fresh produce are:

- Required permeabilities for the different gases
- Good transparency and gloss
- High tear strength and elongation
- Good thermal and ozone resistance
- Commercial suitability
- Ease of handling

The advantages of MAP for a few fruits and vegetables, based on the R&D work carried out at CFTRI are given in Table 9.

TABLE 9

Shelf-Life of Fruits and Vegetables Under MAP

Commodity	RoomTemperature			Temp. (°C)	Low Temperature		
	Shelf-life (Days)	O_2(%)	CO_2(%)		Shelf-life (Days)	O_2(%)	CO_2(%)
Banana (Robusta hands)	11 (6)	12 - 15	2.7 - 5.0	13	42	9.7 - 16.0	4.7 - 7.0
Plantains (Nendran)	11 (3)	4.2	5.3	13	18 (10)	–	–
Carrots	10	12.0	4.0	–	–	–	–
Bell Peppers	10 – 13 (5)	7.7	4.5	9	28 (14)	14.0	4.5
Chillies	5 (3)	8.4	8.0	12	23 (14)	15.0	2.5
Okra	6 (2)	7.0	8.0	–	–	–	–
Tomatoes	16 – 18 (8)	9.3	3.4	12	30 – 35 (21)	–	–
Figures in bracket indicate shelf-life without MAP							

[Source: Packaging India Feb-March '98]

MAP has a good potential as an alternative to low temperature storage for preserving fresh fruits and vegetables, particularly tropical fruits and vegetables which possess a high respiration rate and are sensitive to chilling injury. However, there are still practical and theoretical difficulties limiting the commercial use of modified atmosphere packaging for fresh produce.

Active Packaging

Another way of modifying the atmosphere pack is by using "Active Packaging". Packaging is termed as "Active" when it performs some desired role other than to provide an inert barrier to the external environment. The goal of developing such packaging is to create a more ideal match of the properties of the package to the requirements of the food. A wide variety of materials have been used for this purpose and the manner in which they "act" is given in Table 10.

Active Packaging can be created by using oxygen scavangers, carbon dioxide absorbents / emitters, ethanol emittors and ethylene absorbents. The appropriate absorbent material is placed alongside the fresh produce. It modifies the headspace in the package and thereby contributes to the extension of shelf-life of the fresh produce.

TABLE 10

Active Packaging Principles Applied to Perishables

Principle	Application
Porosity Control	Gas Pressure Release, Gas Composition Balance
Polymer Permeability Control	Gas Compensation Balance, Temperature Compensation*
Melting of Waxes	Temperature Compensation
Inorganic / Organic Oxidation	Oxygen Scavenging, Oxygen Permeation Barrier Oxygen Indicator, Carbon Dioxide Generation, Ethylene Scavenging
Enzyme Catalysis	Oxygen Scavenging
Acid / Base Reaction	CO_2 Absorption, CO_2 Generation, Odour Absorption
Adsorption	Taint Removal, Oxygen Scavenging, Ethylene Scavenging, Water Removal
Absorption	Condensation Control, Drip Collection
Hydrolysis	Sulfur Dioxide Release
Desorption	Ethanol Release, Hinokitiol Release, Water Release
Organic Reactions	Ethylene Removal, Oxygen Barrier

* Addressing the differing temperature-dependencies of fruit respiration rate and the gas permeability of polymers.

Studies Conducted at IIP

Shelf-life studies of few fruits and vegetables were carried out at the Institute for development of consumer packaging system(s).

Fruits and Vegetables in EPS Trays

The following fruits and vegetables were considered for developing consumer packs:

Fruits: Strawberries, Lychees

Vegetables: Okra, Beans

The alternate consumer packs considered for vegetables were :

1. Flexible Plastic pouch
2. Woven net bag – string pull type
3. Plastic punnet with lid
4. Plastic punnet stretch wrapped
5. EPS tray – stretch wrapped

The alternate consumer packs considered for fruits were :

1. Plastic punnet with lid
2. Plastic punnet stretch wrapped
3. Bamboo basket stretch wrapped

The consumer packages were exposed to room conditions of 27°C and 65% RH. The flexible pouches as well as plastic punnets were provided with ventilation holes to enable the fresh produce to respire. The results of the studies conducted are given in the Table 11.

TABLE 11

Shelf-life Studies of Fruits & Vegetables at Ambient Conditions of 27°C & 65% RH

Sr. No.	Packaging Materials	Shelf-life in Days			
		Okra	Beans	Strawberries	Lychees
1.	Without Packaging	1	1	< 1	3
2.	Flexible Plastic Pouch	3 – 4	3	–	–
3.	Woven net bag - String pull type	3 – 4	2	–	–
4.	Plastic Punnet with Lid	3 – 4	2	2	6
5.	Plastic Punnet Stretch Wrapped	4	2	< 2	5
6.	EPS Tray – Stretch Wrapped	–	3	< 2	5

Studies Conducted at Indian Institute of Horticultural Research, Bangalore

Indian Institute of Horticultural Research, Bangalore has carried out detailed studies on effect of individual shrink wrapping of fruits and vegetables like cucumber, cabbage, brinjal, lemon, mango, pomegranate, mandarin and green ball pepper. The fruits and vegetables were shrink wrapped tightly around each piece of the produce and stored at ambient conditions as well as low temperature. The effect of individual film wrapping on the weight loss of wrapped and unwrapped fruits and vegetables during storage is given in Table 12.

TABLE 12

Effect of Individual Film Wrapping on the Weight Loss of Wrapped and Unwrapped Produce During Storage

Commodity	Storage Temperature (°C)	Storage Period (Weeks)	Weight Loss (%)	
			Film Wrapped	Non-Wrapped
Cucumber	10	2	0.4	5.5
Cabbage	0 25	12 3	<1 <2	20 25
Brinjal	7	3	0.5	3.6
Lemon	21	3	0.8	3.2
Mango	12	2	0.2	7
Pomegranate	8 25	12 3.5	< 1.5 <2	20 14
Mandarin	30	3	5	40
Green bell Pepper	7	3	0.3	3

The results of the study indicate that by individually shrink wrapping the fruits and vegetables, the moisture loss can be controlled to a large extent by reducing the transpiration rate and maintaining the fruit firmness. It also reduces shrinkage of fruits and vegetables at ambient conditions and increases the shelf-life.

It prevents contamination of adjacent fruits from spores and drip from rotten ones. The overall advantages of individual shrink wrapping are:

- Reduction in weight loss
- Maintenance of firmness
- Reduction in deformation
- Alleviation of chilling injury
- Reduction of decay from secondary infection
- Delay in colour development and senescence
- Elimination of the need to maintain high humidity during storage / transit
- Extending the market season
- Consumer appeal: The whole surface of the produce can be examined prior to purchase.

Conclusion

Packaging fresh fruits and vegetables is one of the most important steps in the long and complicated journey from grower to consumer. Bags, crates, hampers, baskets, cartons, bulk bins and palletized containers are convenient containers for handling, transporting, and marketing fresh produce.

Plastics have placed a significant role as an efficient packaging material. Apart from cost effectiveness they protect the fruits from microbial contamination, moisture, weight loss and also control ethylene concentration in the package.

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