MAP films for postharvest packaging of horticulture products

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Introduction

PACKAGING perishable fruits and vegetables is one of the more important steps in the long journey from "Farm to Fork." Postharvest is the period from harvest of the produce until consumption. Postharvest quality of high standards is therefore often measured in terms of freshness. Consumers' definition of freshness of fruits and vegetables is associated with sensory determined appearance, texture, and physiological age of the product at consumption. At the point of purchase, the consumer uses appearance factors to provide an indication of freshness of the loose or the packaged produce.

In postharvest science, it is important to understand how to preserve good product quality until the products reach the point of consumption. Although harvested and detached from the growing plant, postharvest products are living materials and because fresh fruits and vegetables are living in nature, complete remaining life cycle after harvest, and then naturally spoil. Therefore, fruits and vegetables fall in the category of highly perishable commodities.

Developed countries are in a very good position as they have developed good systems of postharvest management and infrastructure for quality maintenance. At the same time, developing countries are far behind in the same business, i.e., lacking in good postharvest practices and supporting infrastructure for quality maintenance and of course packaging films & systems. The outcome of this lacuna is considerably very high in developing countries. This is one of the reasons that postharvest losses in fresh fruits and vegetables are estimated about 5–35% in developed countries and 20–50% in developing countries.

In both fruits and vegetables, many more additional changes take place after harvesting. Some changes are desirable from consumer point of view, but most of them are undesirable. Development of sweetness, color, and flavor are best examples of desirable changes. These desirable changes persist for few days only. This is the stage liked by almost all consumers.

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At the same time, shelf life decreases and many undesirable changes take place such as water loss, shrinkage, shrivelling, cell wall degradation, softening, physiological disorder, over ripening, disease attack, rotting, and many more. All these changes, if not governed, ultimately affect the quality. These changes in fresh produce cannot be stopped, but these can be slowed down within certain limits if factors responsible for such deterioration can be minimized. This is important because it increases shelf life and marketing period of fresh produce and maintains their quality during postharvest handling. Developed countries have evolved solution to this issue and there are few proven methods and technologies used to slow down the undesirable changes for extended availability such as control of optimum low temperature and humidity during storage, suitable packaging, transportation, and maintenance of storage atmosphere.

Modified Atmosphere Packaging (MAP)

Modified atmosphere packaging known as MAP technology and Controlled Atmosphere Storage (CAS) are novel techniques that are widely applied for preservation of agricultural products especially for fruits and vegetables. These techniques are used to pplement low temperature management to delay ripening, reduce physiological disorders, and suppress decay in many fresh fruits and vegetables.

> MAP is defined as the packaging of a perishable product in an atmosphere which has been modified so that its composition is other than that of air whereas Controlled Atmosphere Storage (CAS) involves maintaining a fixed concentration of gases surrounding the product by careful monitoring and addition of gases,

MAP is divided into passive and active condition.

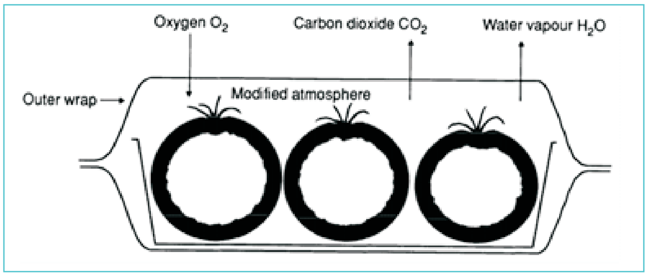
In passive MAP, respiration rate of crop and permeability of the packaging film are the most parameters. Because of the respiration of food material, the consumption of oxygen is proportional to carbon dioxide production in the atmosphere packaging. After a certain time, gas composition in the package of fresh product reaches a definite balance between respiration rate and permeability of packaging film. In equilibrium state, the total amounts of carbon dioxide produced and oxygen consumed by respiration are the same as that permeated through the membrane exchange.

Perfection in Passive Packaging has been achieved by modern, expensive laser technology of making perforations in the film and mathematical modelling. Extensive data has been created by stakeholders by actually monitoring temperature of product after harvest throughout the supply chain for the purpose of modelling.

Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-life of a food. Such new technologies continuously modify the gas environment by removing gases from or adding gases to the headspace inside a package.

The concept of active packaging has been developed to adjust the deficiencies in passive packaging such as when a film is a good barrier to moisture, but not to oxygen, the film can still be used along with an oxygen scavenger to exclude oxygen from the pack. Sometimes, certain additives are incorporated into the polymeric packaging film or within packaging containers to modify the headspace atmosphere and to extend shelf-life.

Figure below shows a schematic diagram of a modified atmospheric packaging.



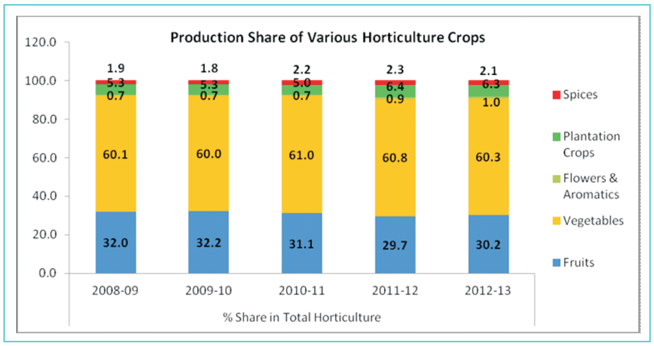
Although the active modification of the atmosphere within the package incurs additional costs, the advantage is that the desired atmosphere is securely achieved in considerably less time.

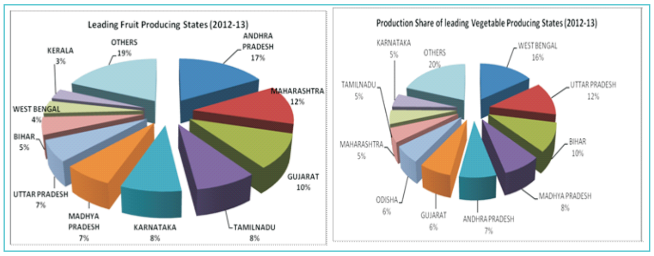
Indian Scenario

The area under horticulture crops which was 12.77 million hectares during 1991-1992 has increased to 23.69 million hectares during 2012-13. The total production during this period has increased by nearly 2.8 times and corresponding productivity has increased 1.5 times.

As compared to 257.1 million tonnes of food grain production during 2012-13, the total horticulture production was 268.9 Million Tonnes. The annual growth rates for area and production of horticulture crops during 2012-13 over 2011-12 were 1.9% and 4.5% respectively. Percentage share of vegetables production in the total horticulture production was highest (60.3% during 2012-13) as compared to other horticulture crops.

The total horticulture production was highest in case of West Bengal (292 lakh MT) followed by Andhra Pradesh (289.13 lakh MT). During 2012-13, the highest production of fruits of 139.39 lakh MT was recorded in Andhra Pradesh (17.1% share) followed by 97.85 lakh MT in Maharashtra (12%). Likewise, the highest production of vegetables (15.7%) was in West Bengal followed by 12.1% in Uttar Pradesh.





Following table gives the potential of this sector for the Indian Plastics industry for MAP films and Mulch films. Additional potential also exists in the form of various other products such as pond liners, green house films, medium and low tunnels, crop covers and shade nets.

	Area, Ha	Production, MT	PE Film Demand for MAP, MT/Year	PE Film Demand for Mulch, MT/Year
Fruits				
Area under Fruit Production	69,82,000	8,12,85,300	–	–
1% Market Penetration	69,820	8,12,853	1,320	12,917
10% Market Penetration	6,98,200	81,28,530	13,208	1,29,167
Vegetables				
Area under Vegetable Production	92,05,200	16,21,86,600	–	–
1% Market Penetration	92,052	16,21,866	2,635	17,030
10% Market Penetration	9,20,520	1,62,18,660	26,355	17,02,962
Total at 1% penetration			3,955	29,946
Total at 10 % penetration			39,563	18,32,129

Above figures area and production are based on the Hand Book on Horticulture Statistics, 2014, Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, New Delhi. These are based on the agriculture commodities traded at various APMCs in the country. The actual arrival of fruits & vegetables are much higher than the above numbers as they are privately sold outside mandies or get processed into further value added products.

Other side of the Coin

Postharvest losses of fruits and vegetables are a subject by itself. However, the latest (September 2013) ASSOCHAM Report mentions...

The ASSOCHAM study has stressed upon the urgent need for developing a conducive environment for exporter community as they have been facing severe supply constraints like high transportation costs, inadequate infrastructure, technology, and others yielding huge gaps and logistical costs thereby hampering India's competitiveness in the world trade market.

In its study, ASSOCHAM has also highlighted that India incurs postharvest fruits & vegetable losses worth over Rs. two lakh crore each year largely owing to the absence of food processing units, modern cold storage facilities and a callous attitude towards tackling the grave issue of postharvest losses.

West Bengal is leading the pack in this regard with annual postharvest losses worth over Rs. 13,657 crore followed by Gujarat (Rs. 11,400 crore), Bihar (Rs. 10,700 crore) and Uttar Pradesh (Rs. 10,300 crore).

Decline in the market arrival of fruits and vegetables is another significant issue highlighted in the chamber's study as just about 22 percent of fruits and vegetables produced in India reach the wholesale market.

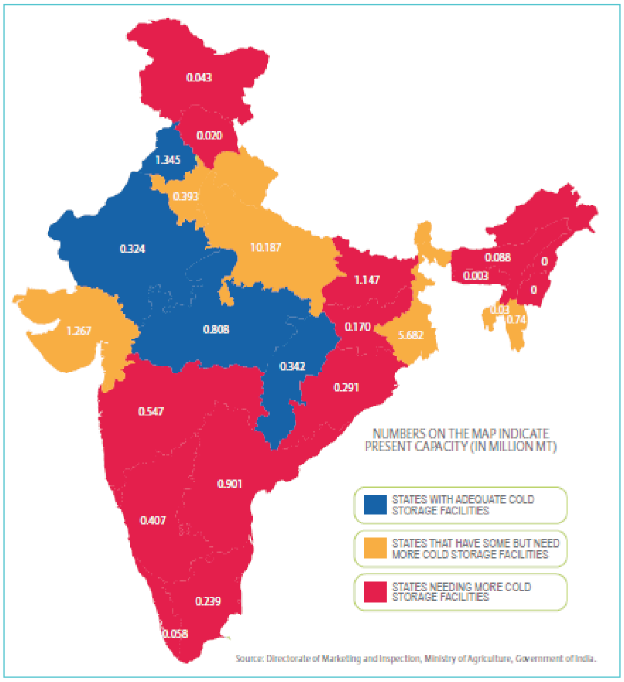
"Developing wholesale markets together with enhancing the cold storage capacities in local and regional markets are key for reducing postharvest fruits and vegetable losses and enhancing their market arrival," according to the ASSOCHAM study.

Banana, mango, citrus, papaya, and guava account for major share in total fruit production across India. Potato, tomato, onion, brinjal, and tapioca account for maximum share in vegetable production in the country.

Existing Cold Storage Infrastructure in India (2012)

- There are about 6,300 cold storage facilities in India, with an installed capacity of 30.11 million metric tonnes.
- It is estimated that cold storage capacity in India needs to double, to a total of 61.13 million metric tonnes of cold storage to minimize food wastage.
- An investment of INR 550.74 billion in new cold storage capacity by 2015–16 is required to keep up with the fruit and vegetable production increase.

State-Wise Present Capacity of Cold Storage (2010)



As of 2012, India had approximately 6,300 cold storage facilities, with a capacity of 30.11 million metric tonnes. Of the total number of facilities, about 60 percent are located in just four states: Uttar Pradesh, Gujarat, West Bengal, and Punjab. Uttar Pradesh has the highest present capacity of 10.187 million metrictonnes with a gap of 20 percent pegged at 2.041 million metric tonnes. Theremaining 24 states and the bulk of the country remain under served. In 2010,Tamil Nadu had only 0.0239 million metric tonnes of actual cold storage capacity but had a need for 7.906 million metric tonnes of capacity, leaving a 97 percent shortfall.

India's cold storage market has a multitude of players, with over 3,500 companies in the value chain. Cold chain solution provider companies constitute 85 percent of the market, while transportation services, such as refrigerated trucks (known as reefers), account for the remaining 15 percent. In 2010, for the transportation of perishable products, there were 250 reefer transport operators running around 25,000 vehicles in India. Of these vehicles,80 per cent were utilized for the transportation of milk, leaving only 5,000 vehicles for other produce such as fruits and vegetables.

According to ASSOCHAM, during the period of 2009-2017, the cold chain industry in India is expected to grow at a CAGR of around 25.8 percent to reach INR 64 billion. The National Horticulture Board (NHB) recommends that investments worth INR 550.74 billion in new cold storage capacity are needed by 2015-16 to keep up with the increasing production of fruits and vegetables.

One of the emerging solutions at the macro level is Controlled Atmosphere Storage (CAS). These facilities are mainly used for long-term storage of highly perishable items. This method regulates the temperature along with the concentration levels of oxygen, carbon dioxide, ethylene, and nitrogen to maintain a specific atmosphere for that particular product or fruit. This method helps increase shelf life while ensuring the quality and freshness of the produce. However it is beyond reach of individual farmers who are spread over the length and breadth of the country.

Marketing of fruits and vegetables

Marketing of horticultural crops is quite complex and risky due to the perishable nature of the produce, seasonal production and bulkiness. The spectrum of prices from producer to consumer, which is an outcome of demand and supply of transactions between various intermediaries at different levels in the marketing system, is also unique for fruits and vegetables. Moreover, the marketing arrangements at different stages also play an important role in price levels at various stages viz. from farm gate to the ultimate user. These features make the marketing system of fruits and vegetables to differ from other agricultural commodities, particularly in providing time, form and space utilities. While the market infrastructure is better developed for food grains, fruits and vegetables markets are not that well developed and markets are congested and unhygienic.

Retail sector in India is at the crossroads today. A shift between organised and unorganised retail sector is apparent, especially in the vegetable retailing zone. This shift is a call for transfer of consumerism towards organised retailing. The penetration of organised retail in the field of vegetable retailing will face fierce resistance from traditional retailers with their existing strong foothold. This resistance from the traditional vegetable retail cannot be ignored. The most important thing to note is that the traditional retail format supports a larger population and provides direct employments. So, there is no way that government or anyone can discount these foundation stones of Indian economy. The role of government and its policyare vital in supporting, improving, and developing traditional vegetable retailers.

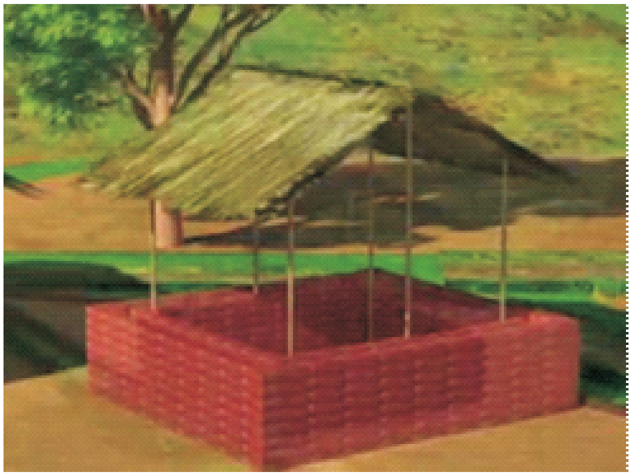
Traditional Indian retailers account for 12 million retail outlets all over India and morethan 40 percent of them sell vegetable and grocery. Indian food retail consists of staple commodities comprising grains, pulses, and vegetables. The Indian food retail business, especially vegetable retailing is witnessing a rapid growth in India's organised retail sectors. The traditional retailing of vegetables is not very much organized, amounts to 97% of the total market, is extremely localised and highly fragmented with large number of intermediaries. The intermediaries between the customers and farmers aretraditional retailers with different outlet formats-mom and

pop shops, non-permanent shops inthe market, pavement vendors, roadside vendors and push cart vegetable sellers, wholesale traders, commission agents and auctioneers.

Wholesale market is a vital link in fruits &vegetable supply chain. Both the traditional and organised retailers are dependent on wholesale market with different propositions.

Passive and Active Technologies are the solution when we consider large pool of Indian farmers. Passive MAP technology is something mastered in the developed countries where the farmers have reach to the cold chain and while the produce reaches the equilibrium stage gradually. As the organized retail will gain momentum with support of cold chain, demand for the Passive technology will rise. On the other hand in Active Technology the desired equilibrium is reached faster and India farmers can use the traditional cooling methods to keep the produce cool.

Zero Energy Cold Chamber (ZECC)



Zero Energy Cool Chamber has been designed by IARI, Pusa, New Delhi on the principle of evaporative cooling i.e. cooling effect created due to evaporation of water.

The cool chamber maintains relatively lower temperature as compared to ambient temperature and unlike outside fluctuation in mercury, the temperature variations inside the cool chamber happen to be very low. Similarly, the relative humidity inside the cooling chamber is also relatively higher than that of outside. The Zero Energy Cool Chamber (ZECC) can be constructed easily with materials like bricks, sand, bamboo, thatch grass, etc.

It was constructed by following steps:

- Selecting of an elevated space having a nearby source of water supply.
- Constructing of floor of 165 cm X 115 cm with bricks.

- Erecting of double brick wall up to height of 67.5 cm leaving gap of 7.5 cm in between two walls.
- Soaking of fine river bed sand with water.
- Filling up of the cavity between the double walls with wet sand.
- Making a top cover with bamboo straw and other locally available material to protect the chamber from direct sun or rain.

MAP sector needs strong scientific assistance in terms of packing of every postharvest commodity. This will be elaborated later as it is the subject under review.

Modified atmosphere packaging should always be considered as a supplement to proper temperature and relative humidity management. The differences between beneficial and harmful concentrations of oxygen and carbon dioxide for each kind of produce are relatively small, so great care must be taken when using these technologies. Temperature has been identified as the most important external factor influencing respiration.

The internal factors affecting respiration are the type and maturity stage of the commodity. Vegetables include a great diversity of plant organs such as fruits, roots, tubers, seeds, bulbs, sprouts, leaves, and stems that have different metabolic activities and consequently different respiration rates. Different varieties of the same product exhibit specific respiration rates. The success of modified atmosphere packaging greatly depends on the accuracy of the predictive particularly on aspects of the respiration process, usual methods of measuring respiration rates and factors can be affect the respiration rate.

Optimum storage of fruits and vegetables

The right storage conditions can increase the shelf life for fruits and vegetables with 300-800%. The important parameters for this shelf life extension are temperature, moisture and a modified atmosphere (oxygen, carbon dioxide, and ethylene). The optimum storage conditions vary according to the product type, processing and ripening degree, time of harvest and much more.

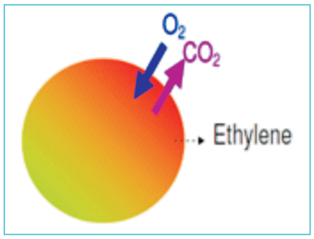
Following table gives representative numbers for select commodities.

Product	Temp in °C	% relative moisture	% O_2	% CO_2	Ethylene Expels	Ethylene Sensitive
Banana	12-15	85-100	2-5	3-5	+	+
Bean sprouts	0	90-98	5	15	+	
Mushrooms	0-5	90-98	5	10		+
Tomato (ripe/green)	12-20	90-98	3-5	5-10	+	+
Tomato (ripe)	8-12	85-98	3-5	5-10	+	+
Cauliflower/broccoli	0-5	90-95	2	5	+	++
Cucumber	8-12	90-95	3-5	0		++
Head of lettuce	0-5	95	2-5	0		++
Capsicums	8-12	90-95	3-5	2	+	+
Grape fruit	10-15	85-90	3-10	5-10		
Peach	0-5	90	1-2	5	+++	+
Apple	0-5	90	2-3	1-2	+++	+
Pear	0-5	90-95	2-3	0-1	+++	+
Plum	0-5	90-95	3	8		+
Strawberry	0-5	90-95	10	15-20		

Respiration and ripening process

Fruits and vegetables are living products undergoing a ripening and at the end an ageing process, in which the plant tissue is broken down. The products undergo various biological processes, which also continue after the products have been harvested. The processes cause gradual changes in the quality.

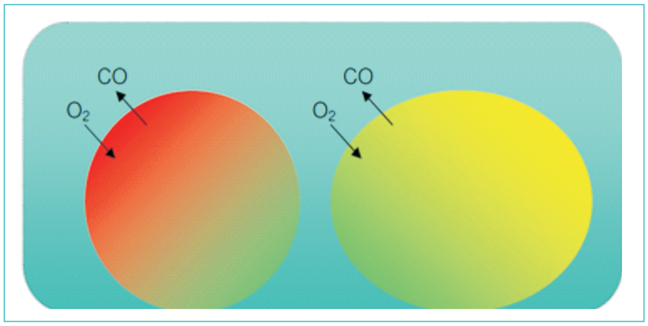
An important part of the process is the product's respiration, in which the product consumes oxygen and expels carbon dioxide, water and heat. In this way, carbohydrates and other substances important to the product's freshness, taste and health quality are broken down.



Fruit and vegetables expel ethylene. Ethylene is a gas which accelerates the ripening process in fruit and vegetables, even in small quantities. The ethylene liberation and sensitivity to ethylenevaries from product to product.

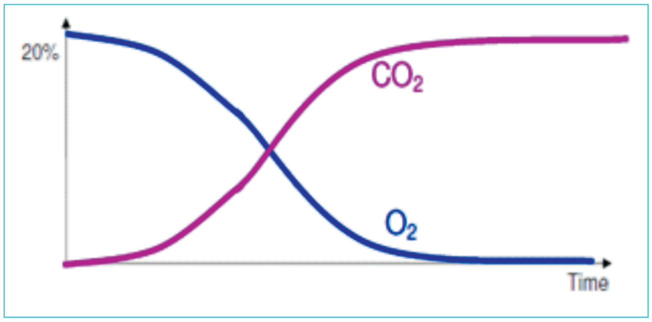
Both the respiration and the liberation of ethylene depend on the temperature. Low temperatures give a slow respiration and low ethylene liberation.

The packaging system



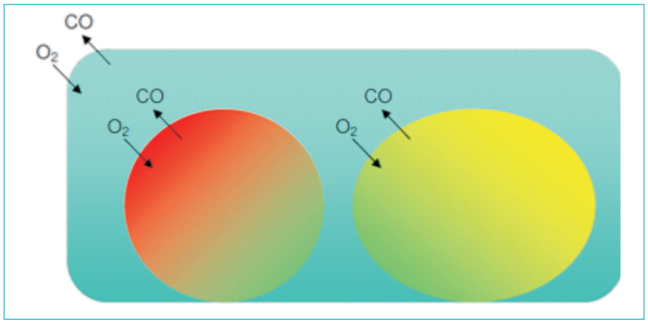
Maintaining the right temperature, gas mix and moisture in the packaging are important elements to create an efficient extension of the shelf life for fruit, and vegetables.

If fruit and vegetables are kept in airtight packaging or another closed container with atmospheric air (20.9% oxygen, 78.1% nitrogen and 0.04% carbon dioxide etc.) the oxygen will be converted into carbon dioxide due to respiration.



The figure shows the oxygen and carbon dioxide concentrations in packaging with fruits and vegetables.

The respiration rate or the rate by which the oxygen is converted into carbon dioxide depends on the oxygen concentration. At low oxygen concentrations the respiration usually takes place slower than at high oxygen concentrations. This means that at low oxygen concentrations the ageing process takes place slower, and that the shelf life is extended. If the oxygen contents become very low, the product cannot breathe. Consequently, the product dies and becomes worthless.



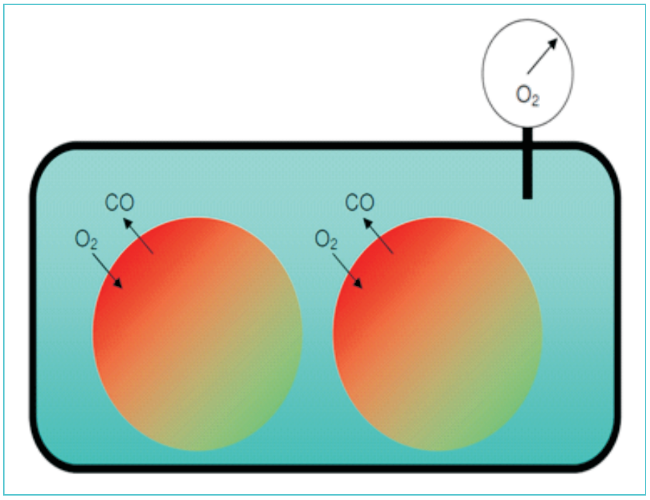
Packaging film for fruits and vegetables are never quite impervious to oxygen, carbon dioxide and water vapours. Even though the packaging film is welded quite tight, these gasses will be transported through the film (dissolved on the one side and liberated on the other). The rate depends on the type of plastic, thethickness of the film and the area, temperature and pressure differences of the gasses on each side of the film.

To obtain a sufficient mechanical strength of the packaging, acertain thickness of the packaging is necessary. For quick/rapidrespiring/breathing products it is impossible to make films so thin that the permeability (the transport of gas) becomes high enough to prevent a lack of oxygen inside the packaging. If the product consumes the oxygen in the packaging faster than new oxygen is supplied, the oxygen concentration in the packaging will become so low that the product dies.

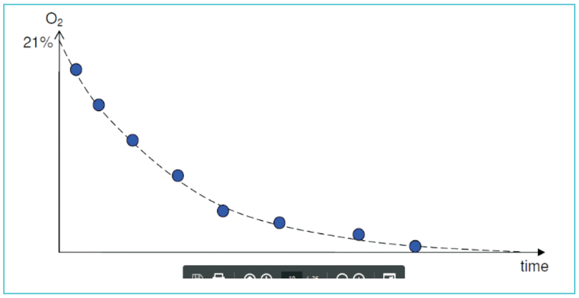
Measuring the respiration rate

To be able to calculate the respiration rate the product's oxygen consumption must be measured in a completely airtight container atvarious oxygen concentrations. In addition, when you know the volume of the container and the weight of the product inside the container, you can calculate the respiration rates at various oxygen concentrations.

The respiration rate of a product can be determined by placing the product you wish to examine in a container with a lid. The container must be of either stainless steel or glass and have a volume of ½-5 litres, depending on the product and the quantity to be examined. Ordinary glass jars can be used. The lid must be easy to attach, and must seal completely tight. The lid must have a device for extracting gas samples. It is important that the extraction does not make the container leak. The oxygen concentration is measured over a known period of time, and the respiration rate is calculated.

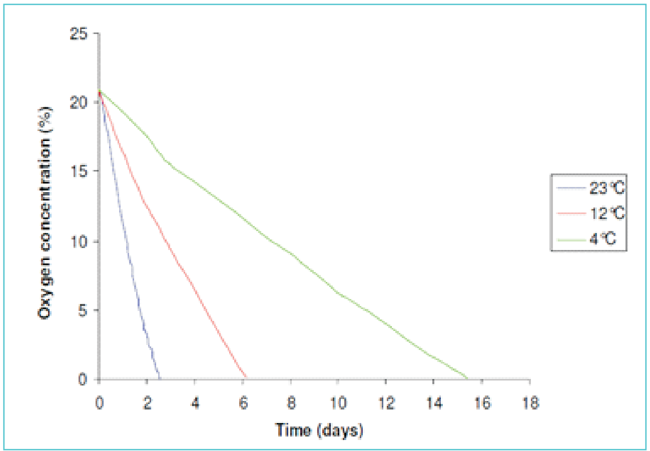


The picture below shows a set-up with respiration vessel and an instrument which measures the oxygen and carbon dioxide contents of the container in which post harvest produce is kept for measuring the respiration rate.



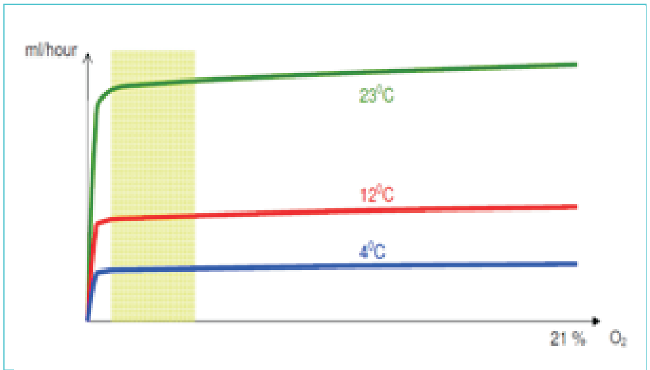
If the oxygen concentration is measured regularly until all oxygen has been consumed, a curve similar to the above can be outlined.

The Significance of Temperature to the Respiration Rate.



The above curve shows the oxygen consumption of 120 grams of fruit by respiring in a 5 litre container. The measurements were taken at 4 °C, 12 °C and 23 °C, respectively. The curves show how important temperature is to respiration.

When the oxygen concentration is measured until all oxygen has been consumed, you can calculate the respiration rate of the product and relate it to the oxygen contents in the air surrounding the product.



As shown above, it is important to consider temperatures when designing packaging. For this reason test tubes and subsequently test packages must be kept at the right temperature during tests. The right temperature is the highest temperature, at which the product is kept for a longer period during distribution.

Equipment for Measuring Oxygen Concentration in the Packaging

There are various measuring instruments on the market formeasuring the oxygen and carbon dioxide contents in packaging.Samples are extracted with a small needle through a septum toensure that the hole is closed after taking the sample.

Polymeric films for map of fruits and vegetables

Although an increasing choice of packaging materials is available to the MAP industry, most packs are still constructed from four basic polymers: Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), Ppolyproylene (PP) and polyethylene (PE), for packaging of fruits and Vegetables. These materials provide a range of permeability to gases and water vapour together with the necessary package integrity needed for MAP.

The most commonly used polymeric films for MAP are based on Polyolefins however, the packaging films, do not singly offer all the properties required for a MAP and to achieve the best properties of polymeric films, a combination of materials is used. Therefore, in these cases the plastic packaging films are combined with one another or with other materials such as paper or aluminium through coating, lamination, co-extrusion and metallization processes. For selecting the packaging materials, considering the following parameters would be helpful.

- The type of package (i.e. flexible pouch or rigid orsemi-rigid lidded tray).
- The barrier properties needed (i.e. permeability of individual gases and gas ratios when more than one gas is used).
- The physical properties of machinability, strength, clarity and durability.
- Integrity of closure (heat sealing), fogging of thefilm as a result of product respiration.
- Sealing reliability.
- Water vapor transmission rate.
- Resistance to chemical degradation.
- Nontoxic and chemically inert.
- Printability.
- Commercial suitability with economic feasibility.

Following parameters need to be understood.

T_g : Glass transition temperature (°C)

T_m : Melting temperature (°C)

T_h : Heat distortion temperature, at 455 kPa (°C)

F_T : Tensile strength (Mpa)

WVTR : Water vapor transmission rate at 37.8°C and 90% RH (g μm/m² day)

P_{O_2} and P_{CO_2} : permeability at 25°C for O_2 and CO_2 respectively (cm³ μm/m² -h-atm)

$E^P_{O_2}$ and $E^P_{CO_2}$: permeability activation energy of films for O_2 and CO_2, respectively (kJ/mole)

$Q_{10}^{P_{O_2}}$ and $Q_{10}^{P_{CO_2}}$: permeability quotients for 10°C rise in temperature of films for O_2 and CO_2 respectively

Properties of the material are given in the table below.

Property	Polyethylene films			Polypropylene		Polyvinyl chloride (PVC)	Polyethylene terephthalate (PET)		Polyvinylidene chloride (PVDC)		Ethylene-vinyl alcohol (EVOH)		Polyamide	
	LDPE	LLDPE	HDPE	PP	BOPP		Unoriented	Oriented	General purpose	High barrier	32 mol % ethylene	44 mol % ethylene	Nylon-6	Nylon-11
T_g (°C)	-120	-120	-120	-10	-10	75-105	73-80	73-80	-15 to +2	-15 to +2	69	55	60	-
T_m (°C)	105–115	122–124	128-138	160-175	160-175	212	245-265	245-265	160-172	160-172	181	164	210-220	180-190
T_h	40–44	-	62-91	107-121	-	57-82	38-129	-	-	-	-	-	-	-
Density (g/cm³)	0.915–0.94	0.915–0.935	0.94-0.97	0.89-0.91	0.89-0.91	1.35-1.41	1.29-1.40	1.4	1.6-1.71	1.73	1.19	1.14	1.13-1.16	1.03-1.05
Tensile modulus (Gpa)	0.2–0.5	-	0.6-1.1	1.1-1.5	1.7-2.4	To 4.1	2.8-4.1	-	0.3-0.7	0.9-1.1	2.6	2.1	0.69-1.7	1.3
FT (Mpa)	8–31	20–45	17-45	31-43	120-240	10-55	48-72	220-270	48-100	83-148	77	59	41-165	55-65
Elongation (%)	100–965	350–850	10-1200	500-650	30-150	14-450	30-3000	70-110	40-100	50-100	230	380	300	300-400
WVTR	375–500	-	125	100-300	100-125	750-15700	390-510	440	79	20	1535	724	3900-4300	1000-2000
P_{O_2}	6666–8750	2916–8333	1666-3041	2083-3916	1541-2416	154-10000	50-100	45	13-18	1.3	0.325	1.25	20-42.5	521
P_{CO_2}	41662–54687	15105-43165	9979-18215	11706-22008	8368-13119	939-61000	255-510	221	62-86	4.95	10.10	37.5	84-179	2084
$\frac{P_{CO_2}}{P_{O_2}}$	6.25	5.18	5.99	5.62	5.43	6.1	5.1	4.91	4.76	3.81	31.0	30.0	4.21	4.0
$E^P_{O_2}$	35.1	37.4	43.1	39.5	38.3	40.5	56.8	60.4	66.5	73.2	-	-	43.5	47.60
$E^P_{CO_2}$	30.3	31.6	34.3	32.7	33.9	30.5	40.4	42.8	51.5	56.7	-	-	40.5	42.40
$Q_{10}^{P_{O_2}}$	1.96	1.84	1.73	1.81	1.77	1.78	1.52	1.5	2.82	2.87	-	-	1.97	-
$Q_{10}^{P_{CO_2}}$	1.71	1.65	1.6	1.62	1.58	1.54	1.5	1.47	2.23	2.26	-	-	1.88	-

In the developed countries MAP technologies are studied seriously and mathematical models have been developed to zero in on correct packages.

Mathematical models can integrate the film permeability to O_2, CO_2 and H_2O, and the respiratory response of the commodity to O_2, in some cases, CO_2, along with its lower O2limit and upper CO_2 limit. These models permit the identification of limiting features of the film, package design, and product and environment conditions.

Three types of polymeric films have been developed for MAP,

- Micro Perforated
- Macro Perforated polymeric films
- Non Perforated Films

These films cater to two mechanisms for MAP technology.

Passive Mechanism uses Micro & Macro perforation whereas Active Mechanism uses Non Perforated films. In both technologies packages must be sealed.

Passive mechanism & micro perforated films

The microperforated films allow the rapid development of proper CO_2 and O_2 concentrationsin the package head space to extend produce shelflife. The gas permeability of amicroperforated film is controlled by the number and dimensions of the perforations. By altering the size and density of the micro hole, packaging films with specific flow rates can be adjusted for aspecific product. The size of the perforations normally used in MAP is between 50 and 200 μm in diameter. These materials are suitable for less CO_2 to lerant commodities such as mango, banana, grapes and apples. The gas permeability in microperforated polymeric films is temperature dependent and this dependence is commonly described by Arrhenius-type equations.

S. Arrhenius, was the first scientist, in 1887 to study the basis for the increase in rate of reactions. He developed an empirical approach showing that the rate increase as an exponential function of temperature. Rest of the science is beyond the scope of present paper.

Macro Perforated films have higher permeability rate than those of micro perforated materials. Such films are used for commodities tolerating simultaneously low O2 and high CO2 levels such as fresh-cut products and commodities having high respiration rate. The package head space dynamics vary with the number of macroperforations. This techniqueis simple and involves only the punching of desired macroperforations in the ordinary film package to affect higher gaseous diffusion across the film packages. However, the attainment of ideal steady-state head space partial pressures of O_2 and CO_2 under any type of MAP is still a difficult taskin the design of MAP and often requires repetitive experimentation; which increases the cost of experiment.

MAP Technology as well as Post Harvest practices are science by itself and it is a Herculean task for Indian Packaging Industry as the knowledge of Indian Fruits and Vegetables w.r.t. climatic conditions needs to be evolved. Different fruits and vegetables, and even different varieties of a given fruit or vegetable have different respiration rates. Moreover, developed countries have evolved perforation technology considering their cold chain which is as good as non-existent in developing country like India. There are case studies available but all those are beyond the scope of this paper. The technology which is relevant to India is of active packaging where the advantage is that the desired atmosphere is securely achieved in considerably less time.

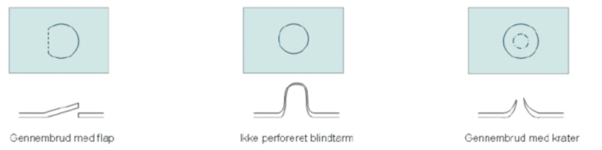
Perforation Technology

Consistency of micro holes are very important for post harvest applications.

Needle Perforation

Micro perforation can be achieved in a number of ways. Mechanical needle perforation has been practiced for some time. Small needles on a fabricated drum pushes holes on the film as it is being converted and rewound. These needles can be applied with or without heat. The processing for hot needle operation is slow. The hole size tends to be big and visibly noticeable. Cold needle perforation punches the film without removing the film material. The partially torn material collapses back onto the hole and consequently results in very inconsistent hole.

Calculations show that a single cylinder hole of this diameter will allow far too large quantities of oxygen to pass through the hole, but needles do not make cylindrical holes in a packaging film. Packaging film is tough, so depending on the film material, the shape of the needle and the piercing technique, the whole is as follows:



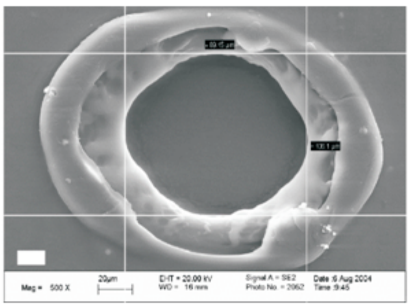
Drawing texts: Piercing with flap - Non-perforated appendix - Piercing with crater

It is important to be absolutely sure that the film is pierced. If the packaging film is elastic and tough, an “appendix” may appear increasing the permeability of the film, because the area is increased and the film becomes thinner, but the film is still far too airtight. If the film is pierced, very different types of holes will appear depending on the type of needle and material. Common to these holes is that the film has withdrawn, making the hole considerably smaller than expected. At the same time a “valve” has been made which will partly close when the pressure goes against the perforating direction of the needle.

Perforation with Electrostatic Energy

Perforations can also be obtained by electrostatic discharge. A packaging film is passed through high electrostatic voltage. Sparks are generated through the film, causing micro holes. The electrostatic process is slow and only works for thinner polymer materials. The arcing process is also hard to control, making it difficult to obtain the desirable number of holes or the desirable flow rate.

Laser Perforation



The ultimate solution for perforation plastic film is with a laser, but it is also the most expensive of the existing solutions, as it requires expensive specialist equipment. It is possible to make holes down to approx. 10 μm thicknesses and up to 200 μm. Laser perforation will typically make slightly oval holes. The advantage of laser perforation is that it is proportionately easy to control the size of the hole.

In the developed world packers are insisting on supplier of perforated film for written specifications, as many films are sold as something else than they actually are.

Leafy Vegetables in perforated Packages

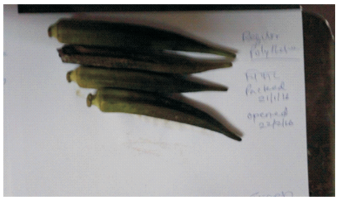
Cooling Shelves in Mall with vegetables in micro perforated bags.

Active Packaging

Active packaging is an emerging and exciting area of food technology that is developing owing to advances in packaging technology, material science, biotechnology and new consumer demands. This technology can confer many preservation benefits on a wide range of ambient-stable and chilled food products. The intention is to extend the shelf-life of foods, whilstat the same time maintaining nutritional quality and assuring microbial safety. The use of active packaging is becoming increasingly popular and many new opportunities will open up for utilising this technology in the future. A review of the history of active packaging shows that most of the advances in research in this field have occurred during the last decade.

Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-lifeof a food. Such new technologies continuously modify the gas environment (and may interact with the surface of the food) by removing gases from or adding gases to the head space inside a package.

The concept of active packaging has been developed to adjust the deficiencies in passive packaging such as when a film is a good barrier to moisture, but not to oxygen, the film can still be used along with an oxygen scavenger to exclude oxygen from the pack. Sometimes, certain additives are incorporated into the polymeric packaging film or within packaging containers to modify the headspace atmosphere and to extend shelf-life. Although the active modification of the atmosphere within the package incurs additional costs, the advantage is that the desired atmosphere is securely achieved in considerably less time.



OKRA packed for 30 days in plain PE bag

OKRA packed in Active Packaging bag after 30 days

Fresh fruits and vegetables, such as mango, tomato, banana, and papaya exhibit more shelf-life of two to three weeks when packed in such ethylene scavenging films. The incorporation of ethylene scavengers improves the physico-mechanical properties of the packaging materials considerably.

Active Packaging is often referred as "Disruptive Technology" as it does not need expensive infrastructure of Passive Packaging. The bags carefully formulated and made in which farmers or packers can pack and heat seal the produce and either send to market or cold storage. This is more suited to developing country like India having poor infrastructure. The produce will get the required active environment quickly due to the active technology.

Climatic condition and the horticulture produce in India will need immediate attainment of desired atmosphere and therefore we will need active packaging and macro perforated films for packaging our fruits and vegetables.

Major cities and towns have large malls where the fruits and vegetables are transported stored, displayed and finally sold. These malls are generating lot of wastages on daily basis and hence it is necessary to introduced MAP packages w.r.t. the temperature produce is exposed throughout the supply chain. The concept of "Farm to Fork" is not a marketing gimmick as there is lot of in depth knowledge and practical experience that all stake holders have developed to give freshness to consumers and minimise the wastage for themselves.

Promotion of Mulch Film along with MAP film will help growers to get greater productivity due to mulching and better price due to MAP. It will help in extending marketing days of the produce.

At 10% penetration levels area that needs to be covered across India is 7 lakh Ha which produces 82 lakh MT of fruits and similarly 9 lakh Ha which produces 162 lakh MT of vegetables. While supplying high value MAP films of 13,000 MT for fruits and 26,000 MT vegetables produce, Indian plastic industry through sustained organized efforts should attempt to promote mulch film. With 10% penetration level 1.3 lakh MT of mulch film may be used by farmers for fruit crops and 17 lakh MT for vegetables.

This would be the new market of 19 lakh MT for plastic raw materials, machinery sector, processors. Spread over 16 lakh Ha.

Challenge

Market spread over 16 lakh Ha.all over India with 4000 major markets all over India. There are 305 Main APMC Markets a d 603 sub markets only in the state of Maharashtra.

India has vast cultivable land all across the country.

Opportunity

With only 10% penetration following markets would be available
MAP Films – 40,000 MT
Mulch Films – 19 Lakh MT

As Mahatma Gandhi, Father of Nation said,

"Be the change you want to see in the world."

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