Summer School

Cutting Edge Epitome of Processing, Value Addition and Waste Utilization of Horticultural Crops for Augmenting Farmers Income

October 01-21, 2019

Sunil Kumar
Ramesh Kumar
Sandeep Mann

ICAR-Central Institute of Post-Harvest Engineering & Technology
Ludhiana-141004 (Punjab)
(An ISO 9001:2015 Certified Institution)
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COMPENDIUM

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Course Director

Dr. Sunil Kumar

Course Co-Director

Dr. Ramesh Kumar

Dr. Sandeep Mann

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ICAR-Central Institute of Post-Harvest Engineering and Technology

P.O.: PAU, Ludhiana-141 004 (Punjab), India

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Disclaimer

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Ramesh Kumar
Sandeep Mann

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ICAR Sponsored Summer School

Cutting Edge Epitome of Processing, Value Addition and Waste Utilization of Horticultural Crops for Augmenting Farmers Income

October 01-21, 2019

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Cold-Chain Management For Reducing Post-Harvest Losses and Increasing Farmers Income

Ranjeet Singh

Sr. Scientist, AS&EC Division,
ICAR-CIPHET, Ludhiana

Cold Chain helps in transporting seasonal products and also making it available throughout the year. Two main parts of cold chain are transportation and storage systems. The key Indian industries where cold chain logistics play very important role are fruits and vegetables, milk and milk products (ice cream), Poultry and processed meat, marine products, pharmaceutical (mainly vaccines) and chemicals. An efficient cold chain industry ensures availability of food products as well as prevents spoilage of medicines. Country like India, where infrastructure is one of the major challenges, cold chain plays a critical role. Analysis for this study shows that cold supply chain network does not differ significantly from products to products at least in Indian scenario. Some of the challenges to the growth of sector in India are high energy cost, power deficit, rising real estate cost, lack of logistical support and uneven distribution of capacity. All these challenges bring down the operating margin of a company and makes it not so attractive business sector. But during last couple of years there is a positive environment being created for this sector in India. The Indian agricultural sector is witnessing a major shift from traditional farming to horticulture, meat and poultry and dairy products, all of which are perishables. The demand for fresh and processed fruits and vegetables is increasing as urban populations rise and consumption habits change. Due to this increase in demand, diversification and value addition are the key words in the Indian agriculture today. These changes along with the emergence of an organized retail food sector spurred by changes to Foreign Direct Investment laws, are creating opportunities in the domestic food industry, which includes the cold chain sector. As a result of the Government of India's new focus on food preservation, the cold storage sector is undergoing a major transformation. The Government has introduced various incentives and policy changes in order to curtail production wastage and control inflation; increase public private participation and improve the country's rural infrastructure (Fig.1).

Cold chain infrastructure includes cold storage infrastructure, transport infrastructure and point of production infrastructure. There are approximately 6300 cold storages in India designed originally for single commodity storage. Refrigerated transport or cold chain distribution is still in its nascent stage in India and is way behind if compared to world standards for cargo movement. Presently reefer transport business in India is estimated at '10-12 billion which includes reefer transportation demand for both exports and domestic. Various industries covered under cold chain are agriculture, horticulture & floriculture, dairy, confectionery, pharmaceuticals, chemicals, poultry, etc. India has around ~6300 cold storage units, but can only store less than 11percent of the country's total produce. While ~105mn MT of perishable produce is transported across India annually, only ~4mn MT is transported via reefers.

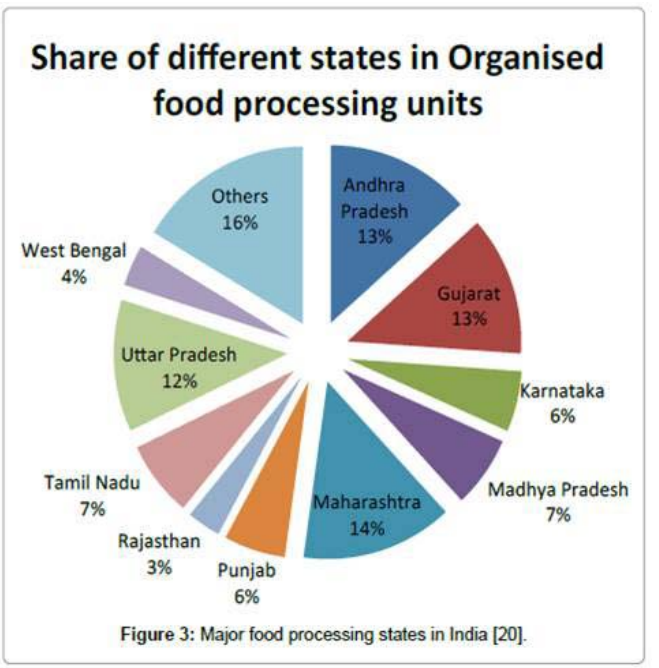

Fig. 1: Cold storage share in India

With initiatives by the Indian government and a steep growth in the consumption of processed foods, cold chain logistics is expected to witness huge growth in the coming years. High growth prospects for the food-processing sector along with attractive government incentives (including 51 percent FDI) make cold chain business a lucrative proposition for foreign investors as well. It should be specifically mentioned that a large number of cold storage projects, located in different parts of the country, are based on old and inefficient technology. The user industry would expect modern plants with more automation, mechanized operations and operating conditions that are more hygienic. Currently, one of the focus areas is to make reefer trucks more energy efficient to withstand the variations in the ambient temperatures at drop-off points.

Contrary to the popular belief, cold chain is not merely refrigeration of perishable commodities. Cold chain is a logistics

system that provides a series of facilities to maintain ideal storage conditions for perishables from the point of origin to the point of consumption in the food supply chain (Fig 2). The chain needs to start at the farm level – post-harvest, pre-cooling, etc. – and reaches to the consumer or at least to the retail outlets. A well organized and efficient cold chain reduces spoilage, retains the quality of the harvested products and guarantees a cost efficient delivery to the consumer. A significant aspect of the system is that if any of the links is missing or weak, the whole system might fail.

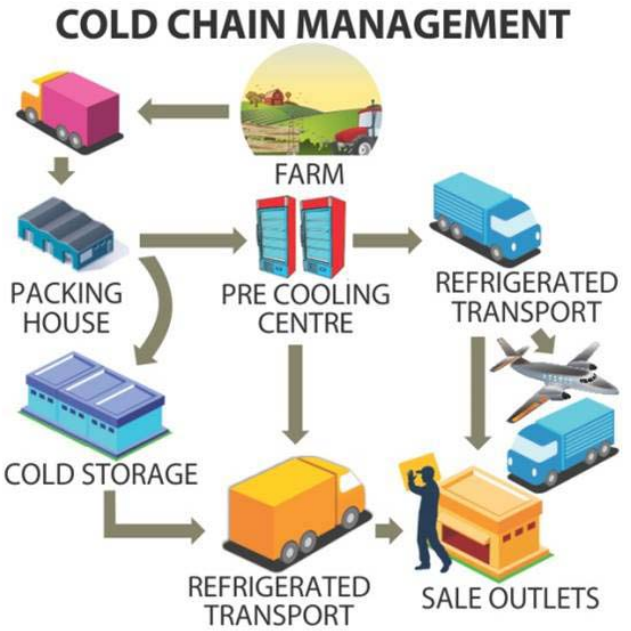

Fig. 2: Cold-chain management in the food supply chain

Cold-chain Market Demand and Market Data

The total value of India's cold chain industry is currently estimated at USD 3 billion and reportedly growing at an annual rate of 20-25 per cent. The total value for the industry is expected to reach at USD 8 billion by 2015 through increased investments, modernization of existing facilities, and establishment of new ventures via private and government partnerships.

India's cold chain industry is still evolving, not well organized and operating below capacity. Most equipment in use is outdated and single commodity based. According to government estimates, India has 5,400 cold storage facilities, with a combined capacity of 23.66 million metric tons that can store less than 11% of what is produced. The majority of cold storage facilities are utilized for a single commodity, such as potatoes. Most of these facilities are located in the states of Uttar Pradesh, Uttaranchal, Punjab, Maharashtra, and West Bengal.

In addition, India has about 250 reefer transport operators (this includes independent firms) that transport perishable products. Of the estimated 25,000 vehicles in use, 80% transport dairy products (wet milk); only 5,000 refrigerated transport vehicles are available for all other commodities.

India's greatest need is for an effective and economically viable cold chain solution that will totally integrate the supply chains for all commodities from the production centers to the consumption centers, thereby reducing physical waste and loss of value of perishable commodities. For this reason, the Government of India has prioritized the development of the cold chain industry. The government has laid out elaborate plans and incentives to support large scale investments essential for developing an effective and integrated cold chain infrastructure.

Table 1: Distribution of cold storage facilities by commodity:

Commodity	Capacity (millions tons)	% of Total	No of Cold storages
Potato	18.43	75.4	2862
Multi-purpose produce	5.64	23.1	1584
Fruits & Vegetables	0.10	0.4	160
Meat	0.19	0.8	497
Fish	0.07	0.3	191
Milk & Dairy Products	0.03	0.1	87
Others	24.46		5381

Table 2: Region wise Number and Capacity of Cold Storages in India (2011)

Cold Storages	Central	East/North East	North	South	West	All India
Number	430(7.0%)	975(15.8%)	2895(47.0%)	866(14.1%)	990(16.1%)	6156(100%)
Capacity(Million MT)	1.71(6.0%)	7.82(27.3%)	14.95(52.1%)	1.95(6.8%)	2.25(7.9%)	28.68(100%)

Opportunities and constraints

Value addition of food products is expected to increase from 8 percent to 35 percent and that of fruits and vegetable processing from the current 2 percent to 25 percent by the end of 2025. The dairy sector, which currently comprises the highest share of the processed food market, will experience marked growth. One of the most critical constraints in the growth of the food processing industry in India is the lack of integrated cold chain facilities. According to the government's estimates India has 5,400 cold storage facilities of which 4,875 are in the private sector, 400 in the cooperative sector and 125 in the public sector. Although the combined capacity of the cold storage facilities is 23.66 million metric tons, India can store less than 11% of what is produced. Most of the infrastructure used in the cold chain sector is outdated technology and is single commodity based. Many are designed for storing potatoes. The controlled atmosphere (CA) and modified atmospheric (MAP) storage facilities and other cold storage facilities with the technology for storing and handling different types of fruits and vegetables at variant temperatures would have a very good potential market in India.

It is recognized that development of cold chain is an essential next step in upgrading our food processing industry. A series of measures to reduce the production and supply chain bottlenecks in the agricultural sector in order to facilitate modernization, ease importation of foreign equipment, and attract foreign investment in India were undertaken. Some of these measures are listed below:

- Accorded infrastructure status to post-harvest storage, including cold chain;
- Raised the corpus of Rural Infrastructure Development Fund and the additional allocation would be dedicated to the creation of warehousing facilities;
- The Viability Gap Funding Scheme is extended for public private partnership projects to set up modern storage capacity;
- Air-conditioning equipment and refrigeration panels for setting up cold chain facilities would be exempted from excise duty beginning in the next fiscal year. Conveyor belts for equipment used in cold storage, wholesale markets and warehouses would be also exempted from excise duty;
- Creation of an additional 15 million tons capacity of storage capacity through public private partnerships put on a fast track;
- The National Horticulture Mission has sanctioned 24 cold storage projects with a capacity of 140,000 metric tons;
- An additional 107 cold storage projects with a combined capacity of over 500,000 metric tons have been approved by the National Horticulture Board;
- Promised full exemption from service tax for the initial set up and expansion of cold storage, cold room (including farm pre-coolers for preservation or storage of agriculture and related sectors produce) and processing units. In addition, full exemption from customs duty for the manufacture of refrigerated vans or trucks have also been promised;
- A package of measures to improve the availability of storage and warehouse facilities for agricultural produce and to incentivize food processing;
- Announcement to set up 15 more mega food parks in the country;
- States asked to reform the Agriculture Produce Marketing Act urgently to improve the supply chain;

Key Suppliers

The following is a partial list of companies currently supplying cold chain technology/equipment/services in India: Ingersoll Rand (USA); Rinac; Walco Engineering; Frick India; Carrier; Bluestar; Lamilux; Dupont; Emerson Climate Technologies; Parker Hannifin; Snowman; R.K. Foodlands; Schaefer Systems International Pvt. Ltd.; Metaflex Doors India Pvt. Ltd.; Alfa Laval (India) Limited; Tolsma Storage Technology, Snowman Frozen Foods; Fresh and Healthy Enterprises, and Apollo-Everest Cool Solutions

Prospective Buyers

Following is a partial list of prospective businesses which are buyers of cold chain technology/equipment/services in India: fruit and vegetable sellers; food processors; warehouse / cold storage owners; refrigeration and cold chain equipment and technology suppliers. Others include Cold Logistics firms such as shipping lines, transporters, container companies, warehousing agents, supply chain solution providers, ports (Indian and international), large format retailers and wholesalers, academic and research institutions, government organizations, packaging service providers, specialized equipment providers, India's Cold Chain Industry refrigeration solution providers, seafood companies, and food testing laboratories.

Cold chain components

The term "cold chain" and the components thereof, refer to steps from harvest to consumption that extends the natural shelf life of a produce by controlling temperature. Typical components of a cold chain may include post-harvest handling, refrigerated transport, refrigerated storage, controlled atmosphere storage (CA), and modified atmospheric packaging (MAP), chilled or frozen processing, cold storage holding and/or distribution, retail refrigeration, institutional refrigeration, and home refrigeration.

Any food begins to deteriorate or lose quality upon harvest whether it is meat, poultry, seafood, dairy, fruit or vegetable.

Most also continue to produce heat and in some cases ripening gases, even after harvest. Removing the heat from these products and maintaining product temperature and/or storage atmospheric composition, by chilling, refrigerated storage, CA/ MA storage or freezing reduces the rate of deterioration and extends the shelf-life of the product. In addition to protecting quality, application of the appropriate cold chain components provides flexibility by making it possible to market products at the optimum time.

Temperatures maintained in cold chain storage facilities may be divided into "refrigerated" and "frozen" categories. Refrigerated temperatures are typically those above 0°C and frozen temperatures those lower than 0°C temperature. Typically fresh meat, poultry, seafood, milk, flowers, fruits and vegetables are held at 4°C while some products such as strawberries, mango, cucumbers and tomatoes are held at higher temperatures due to sensitivity issues. Temperatures used to freeze products are normally lower than storage temperatures. Proper storage and warehousing is not only integral to maintaining quality, but to increasing prices for producers and/or distributors and providing consumers the benefit of longer consumption seasons.

The major cold chain components are described below.

Harvesting, Collection and pre-cooling:

Harvesting is one of the important operations, that decide the quality as well as storage life of produce and helps in preventing huge losses of fruits. Harvesting of fruits should be done at optimum stage of maturity. During harvesting operation, a high standard of field hygiene should be maintained. It should be done carefully at proper time without damaging the fruits. The harvesting operation includes.

i) Identification and judging the maturity of fruits.

ii) Selection of mature fruits.

iii) Detaching or separating of the fruits from tree, and

iv) Collection of matured fruits.

Method of Harvesting:

Different kinds of fruit and vegetables require different methods after harvesting. The methods of harvesting are:

1. Manual Harvesting and 2. Mechanical Harvesting

1. Manual Harvesting:

Harvesting by one's own hand is called manual harvesting. It is done in several ways:

a. Ladder / bag picking method

b. Poles/ Clippers method

c. Harvesting by means of cutting knives

d. Harvesting by means of digging tools.

2. Mechanical Harvesting:

In this method numbers of mechanical devices are used for harvesting the produce on commercial scale.

Maturity of Fruits and Vegetables

It refers to the attachment of final stage of biological function by a plant part or plant as a whole or It is the particular stage in life of plant of fruit at which they attain maximum growth and size.

Good quality of fruits and vegetables are obtained when harvesting is done at the proper stage of maturity. It is the stage where any organ of the plant attains full growth and development. So it is the stage of fruit development beyond which no further growth take place. After maturity of any organ it starts its decline stage i.e. called as "Ripening". Earlier the harvest, longer is the time of ripen. Greater the maturity, lesser are the number of days required for the fruit ripen. But the ripe fruits from early harvests and poor quality indicated by lower organoleptic ratings and with increasing maturity, quality improved. The maturity indices are also called as "Maturity Standards" or "Signs of Maturity". Maturity signs help in judging maturity of fruits and vegetables. The signs are based on experience and skill and judgment. As the market value depends upon quality of the produce, the knowledge regarding maturity indices of right stage of harvest caries vital importance. Secondly shelf life of the produce in some fruits depends upon maturity stage of harvested produce.

There are five types of indices to judge the maturity of the fruit.

1. Visual means
2. Physical means
3. Chemical analysis
4. Computation
5. Physiological method.

1) Visual Means:

Skin colour, size, persistence of style portion, drying of outer leaf, drying whole plant body, change in smell or flavour, dropping down of ripe fruits.

2) Physical Means:

Fairness easy separation or abscission, specific gravity, weight of the fruit.

3) Chemical Analysis:

T.S.S , acids, starch, sugar, etc.

4) Computation:

Days for harvesting fruits from fruit set till maturity.

5) Physiological Method:

Respiration rate, internal ethylene evolution.

Collection

Depending on the type of fruit or vegetable, several devices are employed to harvest produce. Commonly used tools for fruit and vegetable harvesting are secateurs or knives, and hand held or pole mounted picking shears. When fruits or vegetables are difficult to catch, such as mangoes or guava, a cushioning material is placed around the tree to prevent damage to the fruit when dropping from high trees. Harvesting bags with shoulder or waist slings can be used for fruits with firm skins, like citrus and avocados. They are easy to carry and leave both hands free. The contents of the bag are emptied through the bottom into a field container without tipping the bag. Plastic buckets are suitable containers for harvesting fruits that are easily crushed, such as tomatoes. These containers should be smooth without any sharp edges that could damage the produce. Commercial growers use bulk bins with a capacity of 250-500 kg, in which crops such as apples and cabbages are placed, and sent to large-scale packinghouses for selection, grading, and packing.

Several methods of cooling are applied to produce after harvesting to extend shelf life and maintain a fresh-like quality. Some of the low temperature treatments are unsuitable for simple rural or village treatment but are included for consideration as follows:

Pre-cooling

Fruit and vegetables are pre-cooled by lowering the temperature from 3 to 6°C (5 to 10°F) for safe transport. Pre-cooling may be done with cold air, cold water (hydrocooling), direct contact with ice, or by evaporation of water from the product under a partial vacuum (vacuum cooling). A combination of cooled air and water in the form of a mist called hyraircooling is an innovation in cooling of vegetables.

Air pre-cooling

Pre-cooling of fruits with cold air is the most common practice. It can be done in refrigerator cars, storage rooms, tunnels, or forced air-coolers (air is forced to pass through the container via baffles and pressure differences).

Icing

Ice is commonly added to boxes of produce by placing a layer of crushed ice directly on the top of the crop. An ice slurry can be applied in the following proportion: 60% finely crushed ice, 40% water, and 0.1% sodium chloride to lower the melting point. The water to ice ratio may vary from 1:1 to 1:4.

Room cooling

This method involves placing the crop in cold storage. The type of room used may vary, but generally consists of a refrigeration unit in which cold air is passed through a fan. The circulation may be such that air is blown across the top of the room and falls through the crop by convection. The main advantage is cost because no specific facility is required.

Forced air-cooling

The principle behind this type of precooling is to place the crop into a room where cold air is directed through the crop after flowing over various refrigerated metal coils or pipes. Forced air-cooling systems blow air at a high velocity leading to desiccation of the crop. To minimize this effect, various methods of humidifying the cooling air have been designed such as blowing the air through cold water sprays.

Hydro-cooling

The transmission of heat from a solid to a liquid is faster than the transmission of heat from a solid to a gas. Therefore, cooling of crops with cooled water can occur quickly and results in zero loss of weight. To achieve high performance, the crop is submerged in cold water, which is constantly circulated through a heat exchanger. When crops are transported around the packhouse in water, the transport can incorporate a hydrocooler. This system has the advantage wherein the speed of the conveyer can be adjusted to the time required to cool the produce. Hydrocooling has a further advantage over other precooling methods in that it can help clean the produce. Chlorinated water can be used to avoid spoilage of the crop. Hydrocooling is commonly used for vegetables, such as asparagus, celery, sweet corn, radishes, and carrots, but it is seldom used for fruits.

Vacuum cooling

Cooling in this case is achieved with the latent heat of vaporization rather than conduction. At normal air pressure (760 mmHg) water will boil at 100°C. As air pressure is reduced so is the boiling point of water, and at 4.6 mmHg water boils at 0°C. For every 5 or 6°C reduction in temperature, under these conditions, the crop loses about 1% of its weight (Barger, 1961). This weight loss may be minimized by spraying the produce with water either before enclosing it in the vacuum chamber or towards the end of the vacuum cooling operation (hydro vacuum cooling). The speed and effectiveness of cooling is related to the ratio between the mass of the crop and its surface area. This method is particularly suitable for leaf crops such as lettuce. Crops like tomatoes having a relatively thick wax cuticle are not suitable for vacuum cooling.

Recommended minimum temperature to increase storage time

There is no ideal storage for all fruits and vegetables, because their response to reduced temperatures varies widely. The importance of factors such as mould growth and chilling injuries must be taken into account, as well as the required length of storage (Wills et al., 1989). Storage temperature for fruits and vegetables can range from -1 to 13°C, depending on

Table 1: Storage temperatures for fruits and vegetables

Fruit	Temperature Ideal (°C)	Storage Life (weeks)	Vegetables, herbs & other	Temperature Ideal (°C)	Storage Life (weeks)
Apple	-1 - +2	12-52	Amaranth (Rau Dai)	0	2
Apricot	0	4	Artichoke	0	3
Avocado	7	4	Asparagus	2	3
Banana	13	4	Bean (French)	7	2
Bitter melon	10	3	Bean (Snake, Yardlong)	5	2
Blackberry	0	1	Beetroot	0	2
Blueberry	0	3	Broccoli	0	2
Breadfruit	13	4	Brussels Sprout	0	5
Cactus (Prickly) Pear	5	3	Buk choy	0	3
Capsicum (Bell Pepper)	5	3	Cabbage	0	4
Carambola	10	4	Carrot	0	26
Casaba melon	7	4	Cauliflower	0	4
Cherry	0	3	Celery	0	8
Chilli	5	3	Celeriac	0	40
Coconut	0	8	Chi Qua (Hairy melon)	7	4
Cucumber	10	2	Chives	0	3
Custard Apple (Cherimoya)	13	4	Coriander (Cilantro)	0	2
Durian	5	8	Corn	0	2
Eggplant (Aubergine)	10	2	Choy Sum	0	2
Feijoa	5	3	Dong Qua (Winter melon)	13	12
Fig	0	2	En Choy	0	2
Finger lime	5	5	Endive	0	4
Grape	0	26	Eschallot	0	26
Grapefruit	13	8	Fennel	0	8
Guava	5	3	Gai Choy	0	2
Honeydew melon	5	4	Gai Lan	0	2
Jackfruit	13	4	Galangal	7	2
Kiwifruit (Gooseberry)	0	12	Garlic	0	30
Lemon	10	26	Ginger	13	26
Lime	10	8	Horseradish	0	52
Litchi (Lychee)	2	5	Kang Kong	0	2
Longan	5	4	Kholrabi	0	12
Loquat	0	3	Leek	0	8
Mandarin	5	8	Lettuce (Iceberg)	0	4
Mangosteen	13	4	Lettuce (leaf)	0	2
Mango	13	3	Lotus Root	0	4
Nectarine	0	4	Mushroom	0	2
Okra	10	2	Onion	0	8
Olive	5	6	Pak Choy	0	3
Orange	5	12	Parsley	0	8
Papaya (Paw Paw)	13	3	Parsnip	0	26
Passionfruit	7	4	Pea	0	2
Peach	0	3	Potato	7	26
Pear	-2 - 0	30	Radish	0	4
Pineapple	10	4	Rhubarb	0	4
Pepino	5	4	Seng Qua	10	3
Persimmon	0	16	Shallot	0	4
Pitaya (Dragon Fruit)	7	4	Shui Qua	10	3
Plantain	13	5	Silverbeet	0	2
Plum	0	5	Sin Qua	10	3
Pomegranate	0	16	Snow Pea	0	3
Pumpkin	13	18	Spinach	0	2
Quince	0	12	Sprouts	2	2
Rambutan	13	3	Sweet Potato	13	30
Raspberry	0	1	Taro	7	16
Rockmelon (Cantaloupe)	2	3	Tung Ho	2	1
Sapodilla	13	2	Turmeric	7	3
Sapote	13	3	Turnip (Swede)	0	20
Squash (button)	7	3	Watercress	0	3
Star Apple	2	3	White Radish (Daikon)	0	16
Strawberry	0	2	Whitloof	2	4
Tamarillo	5	10	Wombok (Chinese cabbage)	0	12
Tangelo	2	4			
Tangerine	0	4			
Tomato	13	3			
Watermelon	10	3			
Zucchini	5	2			

their perishability. Extremely perishable fruits such as apricots, berries, cherries, figs, watermelons can be stored at -1 to 4°C for 1-5 weeks; less perishable fruits such as mandarin, nectarine, ripe or green pineapple can be stored at 5-9°C for 2-5 weeks; bananas at 10°C for 1-2 weeks and green bananas at 13°C for 1-2 weeks. Highly perishable vegetables can be stored up to 4 weeks. Green tomato is less perishable and can be stored at 10°C for 3-6 weeks and non-perishable vegetables such as carrots, onions, potatoes and parsnips can be stored at 5-9°C for 12-28 weeks (Table-1).

Variables affecting storage life

Key variables affecting the storage life and eating quality of fruit and vegetables are:

- time from harvest
- temperature
- relative humidity
- atmosphere composition
- ethylene
- pest and disease
- pre- and postharvest treatments

Time from harvest is a key determinant for many fresh produce types, particularly leafy green vegetables, mushrooms and berry fruit. Products with high metabolic rates and water loss deteriorate rapidly and have short storage life capabilities. Postharvest research has identified the optimum storage conditions required for all the different types of produce and maintaining these conditions along the supply chain will ensure minimal loss in quality. Temperature is a key determinant of chemical reaction rates and, therefore, produces metabolic rates. Perhaps the most important factor in extending the storage life for most fresh produce types is correct temperature management. Because fresh produce is a living organism this does not always mean that the lower the temperature the longer the storage life. Produce quality can be irreversibly damaged by applying the wrong temperature. When detached from the growing plant fresh produce continues to transpire and lose water. Maintaining high relative humidity in the storage atmosphere will minimize water loss, although in practice this can be difficult to achieve depending on air exchange rates. Most refrigeration systems operate at low relative humidity which has a rapid drying effect. Fresh produce cooling facilities need to be specially designed to provide water vapor management at a high relative humidity. Controlled atmospheres and modified atmospheres are strategies designed to control the metabolic rates of fresh produce through altering the composition of atmospheric gases in contact with the produce. They create high carbon dioxide/low oxygen atmospheric concentrations relative to normal atmospheric concentrations. For example, controlled atmospheres for many apple varieties range in the concentrations of 2-5% carbon dioxide / 2-3% oxygen, compared to normal atmospheric concentrations of 0.04% carbon dioxide / 21% oxygen. Increasing carbon dioxide concentrations and reducing oxygen concentrations has the effect of slowing respiration rates, but needs to be closely monitored and controlled along with temperature to ensure any negative effects on quality are avoided.

Conclusion

Cold chains are fundamental for developing the time frame of realistic usability, time of showcasing, staying away from over limit, and diminishing transport bottlenecks amid pinnacle time of generation and to keep up the nature of deliver. The advancement of cold chain industry has a vital part to play in diminishing the wastages of the perishable items and therefore giving gainful costs to the producers. Additionally, it acts like a spine for reducing post-harvest losses and keeps up the viability of the food industry all through the inventory network by giving temperature controlled environment to delicate food items.