Compendium of

Model Training Course

on

Relevance of Cold Chain Management of Agri Based Products pertaining to Horticultural Produce

27th Nov. -4th Dec. 2017

Sponsored by

Directorate of Extension, Dept. of Agriculture & Cooperation
Ministry of Agriculture, Govt. of India

सत्यमेव जयते

Dr. R.K.Gupta
Course Director

Dr. Ranjeet Singh
Course Coordinators

Dr. V. Eyarkai Nambi
Course Coordinators

भाकृअनुप - केन्द्रीय कटाई उपरान्त अभियांत्रिकी एवं प्रौद्योगिकी संस्थान,
लुधियाना-141004 (पंजाब)

ICAR- Central Institute of Post-Harvest Engineering and Technology,
P.O. PAU Campus, Ludhiana-141004 (Punjab)

(An ISO-9001:2015 Certified Institute)

With Best Compliments

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हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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भाकृअनुप - केन्द्रीय कटाई उपरान्त अभियांत्रिकी एवं प्रौद्योगिकी संस्थान,
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RK GUPTA
RAJEET SINGH
V E NAMBI

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STATUS OF COLD CHAINS IN INDIA

Dr.R.K.Gupta, *Director*

ICAR-Central Institute of Post-Harvest Engineering and Technology, Ludhiana

Cold chain is a logistic system that provides a series of facilities for maintaining ideal storage conditions for perishables from the point of origin to the point of consumption in the food supply chain. The chain needs to start at the farm level (e.g. harvest, pre-cooling) and cover up to the consumer level or at least to the retail level. A well-organized cold chain reduces spoilage, retains the quality of the harvested products and guarantees a cost efficient delivery to the consumer given adequate attention for customer service. The main feature of the chain is that if any of the links is missing or is weak, the whole system fails. The Cold chain logistics infrastructure generally consists of:

- Pre-cooling facilities
- Cold Storages
- Refrigerated Carriers
- Multi-Modal Transportation
- Packaging
- Information Management System
- Warehouse Management system
- Traceability
- Financial and Insurance Institutions

State of cold chain in India

With a warm tropical climate for most of the year, low temperature storage and refrigerated transportation system are mandatory in India for slower aging, extending shelf life and inhibiting the growth of spoilage organisms. The transportation of produces from farm to pre-coolers, pre-coolers to cold storages and cold storages to market place are very crucial cold chain links. India does not have a comprehensive cold-chain network. More than50% of produce is transported using bullock-cart or trucks with no packaging or packaged in gunny bags. In addition, most of the transportation is done in un-refrigerated open trucks. Lack of cold chain infrastructure breeds many inefficiencies:

- About 6-18% of fruits and vegetables produced in India (Rs. 21845 crores) are wasted.
- The producer's share in the domestic consumer's retail price is only 25%where as it is 50% in developed countries.
- India produces a wide range of both tropical and temperate fruits and vegetables. Only less than 2% of these are processed.

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 and can only store less than 11% of the country's total produce. While about 105 million MT of perishable produce is transported across India annually, only about 4 million MT is transported via reefers.

Cold storage in India has been largely adopted for long-term storage of potatoes, onions and high value crops like apples, grapes and flowers. About 75% of the cold storage capacity issued to store potatoes, while only 23 percent fall in the multi-product category. Cold storages for meat, fish and dairy items and for other items such as chilies and other spices account for only 1% of total cold storage capacity. These cold storages are also usually smaller incapacity. Much of this multi-purpose cold storage capacity is located in the states of Karnataka, Maharashtra, West Bengal, Tamil Nadu and in the National Capital Region (NCR).

Commodity wise distribution of Cold Storage in 2009 in India

	Commodity	**Capacity (Million MT)**	**% Share**	**No. of Cold Storages**
1.	Potatoes	18.43	75.4	2,862
2.	Multi-purpose	5.64	23.1	1,584
3.	Fruits & Vegetables	0.10	0.4	160
4.	Meat and Fish	0.19	0.8	497
5.	Milk/ Milk products	0.07	0.3	191

6.	Others	0.03	0.1	87
	Total	**24.45**	100.0	**5381**
Institution-wise Cold Stores in India				
1	Private	23,406.7	95.7	4,885
2	Cooperative	936.9	3.8	356
3	Public	107.0	0.4	140
	Total	**24450.7**		**5381**
Source: Ministry of Agriculture, Government of India				

In 2010, the cold storage gap of about 37 million MT was worked out on the basis of peak season production and highest arrival/harvesting of storable fruits and vegetables in a month. Against this, normally 50% capacity is required for storable surplus of the identified fruits and vegetables.

Technical Standards Notification

Following Technical Standards for storing fresh fruits & vegetables had been notified for implementation w.e.f. 1.4.2010.

a. Fresh Horticulture produce Not requiring pre-cooling before storage (Technical standards number NHB-CS-Type 01-2010)

b. Fresh Horticulture produce requiring pre-cooling before storage (Technical standards number NHB-CS-Type 02-2010)

c. Control Atmosphere (CA) Cold Storage (Technical Standards Number NHB-CS-Type 03-2010)

d. Fruit Ripening Units (Technical standards number NHB-CS-Type 04-2010)

Cold Chain model for perishables

A model for establishing cold chain in PPP mode is shown below. It comprises of collection centres, pre-cooling centres, refrigerated transport, surface storage and distribution system. The produce has to be transported to collection centres. Collection centres may be made at Block level where framer's group or self-help groups or individual can deliver the harvested produce. Thereafter the produce can be transported to pre-cooling centre. Pre-cooling centres may be located in mandies or at district headquarter. The produce will be cooled to storage temperature in the pre-cooling centres. After pre-cooling, the produce may be transported to cold storage using refrigerated transport. The produce will be stored at required temperature before further distribution for consumption, processing or retailing.

Cold Storage Gap Assessed by National Spot Exchange in 2010

State	Cold Storage Requirement in '000MT	Present Capacity* in '000MT	Gap in '000MT
Andhra Pradesh	2,324	901	1,423
Assam	919	88	831
Bihar	4,241	1,147	3,094
Chhattisgarh	543	342	201
Gujarat	2,748	1,267	1,481
Haryana	804	393	411
Himachal Pradesh	487	20	467
Jammu & Kashmir	737	43	694
Jharkhand	796	170	626
Karnataka	2,404	407	1,997
Kerala	2,771	58	2,713
Maharashtra	6,273	547	5,726
Manipur	80	0	80
Meghalaya	239	3	236
Mizoram	74	0	74
Madhya Pradesh	1,213	808	405
Nagaland	70	6	64
Orissa	1,835	291	1,544
Punjab	1,318	1345	-27
Rajasthan	391	324	67
Tamil Nadu	7,906	239	7,667
Tripura	163	30	133
UP & Uttarakhand	12,228	10,187	2,041
West Bengal	10,566	5,682	4,884
Total	**61,130**	**24,298**	**36,832**

*Present capacity estimates as of 2009
Source: NSE&DMI(present capacity in Delhi– 126,158MT,Goa-7,705MT, A&N-210MT, Puducherry– 85MT)

Financial estimates for establishment of cold chain

The financial estimates for establishing cold chain for some selected perishables is given in Table below. For calculations, the estimated cost for one cold store of 6000 MT capacity was taken as Rs. 5 crore (www.emersions.com). Estimated cost of one refrigerated vehicle of 5 MT capacity was Rs 0.35 crore. It was estimated that fruits and vegetables worth Rs. 13,259 crores can be saved by handling the produce through cold chain logistics.

Commodities	**Production in 2012-13 (mT)**	**% to be placed in cold chain**	**Additional Capacity required (mT)**	**Financial Requirement (Rs. Crores)**		
				Cold Store	**Refrigerated Transport**	**Total**
Potato	45.3	60	8.54	7117	2989	10106
Onion	19.0	20	3.80	3167	1330	4497
Tomato	18.2	25	4.55	3792	1593	5384
Green Pea	4.0	15	0.60	500	210	710
Apple	1.9	40	0.76	633	266	899
Citrus	10.1	15	1.52	1263	530	1793
Banana	26.5	25	6.63	5521	2319	7840
Grapes	2.5	10	0.25	208	88	296
Mango	18.0	40	7.20	6000	2520	8520
TOTAL			**33.84**	**28200**	**11844**	**40044**

Role of CIPHET and other R&D organizations in development of cold chain

Building an efficient and effective supply chain using state of the art techniques is possible to serve the population with value added food while simultaneously ensuring remunerative prices to the farmers. The surplus of fruits, vegetables, milk, fish, meat and poultry products can be processed as value added food products and marketed aggressively both locally and internationally. The role of R&D organizations in cold chain infrastructure may be as below.

1) **Optimization of storage and operating parameters of cold chain:**

Process optimization is important tool to enhance efficiency of any supply chain. There are two kinds of standards in the food supply chain. The storage temperature, RH, time of pre-cooling, type of packaging, controlled/modified atmosphere packaging and storage parameters, handling procedures, duration of storage, quality parameters etc are the major factors that affect the cold chain efficiency. CIPHET and other R&D organization can work on optimizing the conditions for perishables.

2) **Improvements in transportation reefers, pre-coolers, and storage structures:**

The cold chain is in nascent stage in India. The cold chain for horticultural produce is fragmented and operated in isolated manner. Solar concentrators hybridized with biomass gasifier can be used to power cold storage facilities. This type of cold storage design boosts overall efficiency of the agricultural produce value chain by reducing wastage & improving storage conditions for agricultural yield in a rural setup. In addition to the solar technology, there are various other sub-systems required in a solar cooling project including power block, water treatment, balance of plant, plant EPC, O&M, etc. CIPHET is already working on a project of hybrid cold storage and further research projects based on solar technology for low cost cold storage can help to develop the cold chain status of India.

3) **Optimization of pretreatments prior to cold storage:**

Pre cooling, pretreatment of produce using biomolecules are the important for improving the efficiency of cold store and also to reduce field from the produce prior to cold storage to reduce the rate of respiration. Different commodities and even varieties behave differently to pre-cooling and pretreatment. CIPHET alongwith SAU's need to optimize the conditions for different varieties of the horticultural produce to reduce post harvest losses.

4) **Technology for value addition of produce stored in the cold store**:

R&D is required for value addition of produce stored in the cold storage to achieve complete reduction in post harvest losses. The produce deteriorates in quality with a slight change in cold storage environment in the event of power failure or even during prolonged storage. The cold stored produce from such environment may not be suitable for fresh marketing but can be utilized in development of processed products. There is a need for working out a protocol for diverting the part of produce for processing. Technology used to be different for the fresh produce and the produce stored for longer duration. Change in biochemical composition in the cold store like decease in pectin, increase in soluble solid, loss of vitamins and bioactive compounds, change in texture call for detailed studies in tropical and temperate produce for conversion in to processed products. CIPHET and other R&D institutions like SAUs need to work on different commodities in their respective crop growing regions to prepare a protocol for value addition of cold stored produce

5) **Training and consultancy on low cost operation of cold chain:**

Training, consultancy and mentoring is needed to all the personnel in the cold supply chain including farmer groups, upcoming entrepreneurs, educated youths for effective operation and maintenance of controlled/ modified storage, pre-coolers and cold storage structures. CIPHET can impart training in handling procedures, food quality and safety issues. Low cost operation of cold chain is possible with scientific use of alternative with respect to commodity and use of evaporative cooling and other hybrid cooling system techniques.

SCOPE OF COLD CHAIN MANAGEMENT OF FRUITS AND VEGETABLES IN INDIA

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Introduction

India is an agricultural-based economy. More than 52 percent of India's land is cultivable, compared to the global average of 11 percent. Each year, India produces 63.5 million tons of fruits and 125.89 million tons of vegetables. India is also the largest producer of milk (105 million metric tons per year). India produces 6.5 million tons of meat and poultry, as well as 6.1 million tons of fish a year. The perishable products transaction volume is estimated to be around 230 million metric tons. Although India has the potential to become one of the world's major food suppliers, the country's inefficient cold chain network results in spoilage of almost 40 percent of its total agricultural production. The total value of the cold chain industry is estimated to be as high as USD 3 billion and growing at 20-25 per cent a year. The total value is expected to reach USD 8 billion by 2015 through increased investments, modernization of existing facilities, and establishment of new ventures via private and government partnerships.

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.

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.

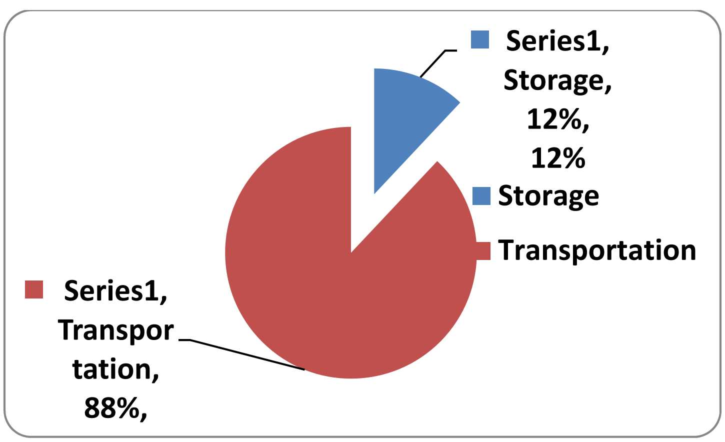

Fig.1 Cold storage segment in India

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.

- Cold Chain Logistic
- Modelling food quality and safety
- Temperature Monitoring
- Monitoring food freshness
- Intelligent Packaging Solutions

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.

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%)

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.

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;

• A National Food Security Bill was approved.

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^oC and frozen temperatures those lower than 0ºC temperature. Typically fresh meat, poultry, seafood, milk, flowers, fruits and vegetables are held at 4ºC 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 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.

DESIGN AND CONSTRUCTION OF EVAPORATIVE COOL ROOM FOR STORAGE OF FRUITS & VEGETABLES

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ABSTRACT

The quality and storage life of fruits and vegetables may be seriously compromised within a few hours of harvest unless the crop has been cooled promptly to control deterioration. The major problem during storage is the change in the quality parameters of the produce especially the physical characteristics such as; the color, texture, and freshness in which the price sometimes depend on. In order to extend the shelf life, fruits and vegetables need to be properly stored. Proper storage means controlling both the temperature and relative humidity of the storage area. Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooling structure depends on the humidity of the surrounding air. Therefore, this article reviews the theory, advances, principles, methods of evaporative cooling, design considerations and also the optimum storage temperature, relative humidity and shelf life of fruits and vegetables. An Evaporative cooler reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby keeping the fruits and vegetables fresh. It can be use for short term preservation after harvested. Thus, an evaporative cooling is a low cost technology for storage of fruits and vegetables. The Technology of evaporative cooling is cost effective and could be used to prolong the shelf-life of agricultural produce.

1. Introduction

The vegetables and fruits are important food items that are widely consumed because they form an essential part of a balanced diet. Fruits and vegetables are important sources of minerals and vitamins especially vitamin A and C. They also provide carbohydrates and protein, which are needed for normal healthy growth However, the quality and storage life of fruits and vegetables may be seriously compromised within a few hours of harvest unless the crop has been cooled promptly to control the deterioration. The major problem during storage is what happens to the quality parameters of these produce especially the physical characteristics such as; the color, texture, and freshness in which the price sometimes depends on. In order to extend their shelf life, fruits need to be properly stored. Proper storage means controlling both the temperature and relative humidity of the storage area.

Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs. Generally, an evaporative cooling structure is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air. Aeration, temperature and relative humidity management, microorganisms control, sanitation and preventing moisture loss greatly improves the storability of produce by maintaining a cool and uniform environment throughout the storage period. Low temperature prolongs storage life by reducing respiration rate as well as reducing growth of spoilage microorganisms. Temperature, relative humidity and atmospheric composition during prestorage, storage, and transit could control decay. For optimum decay control, two or more factors often are modified simultaneously and these are temperature and relative humidity. Proper management of temperature is so critical to post harvest disease control that all other treatments can be considered as supplements to refrigeration . However, temperatures as low as possible are desirable because they significantly slow growth and thus reduce decay.

Respiration is one of the basic physiological factors, which speeds up ripening of fresh commodities and is directly related to maturation, handling, and ultimately to the shelf life. Generally, the loss of freshness of perishable commodities depends on the rate of respiration. A common acid found in fruit includes citric, malic and ascorbic acid. During ripening, organic acids are among the major cellular constituents undergoing changes. Studies have shown that there is a considerable decrease in organic acid during ripening of fruits. An aspect to consider when handling fruits and vegetables is the temperature and relative humidity of the storage environment. For fresh harvested produce, any method of increasing the relative humidity of the storage environment (or decreasing the vapour pressure deficit (VPD) between the commodity and its environment) will slow the rate of water loss and other metabolic activities. This will slow both the respiratory processes and activities of micro-organisms (pathogens) which are the most destructive activity during storage of fruits and vegetables Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive.

FAO (1983) advocated a low cost storage system based on the principle of evaporative cooling for storage of fruits and vegetables, which is simple, and relatively efficient. The basic principle relies on cooling by evaporation. However, sometimes when evaporative cooling system is used in preservation, it is used with shade on top.

1.1 Advances in Evaporative Cooling Technology

Different designs of evaporative coolers have been reported in literature for the preservation of fruits and vegetables. The design ranges from straw packing house to some sophisticated design. FAO (1986) reported that the packing houses of typical evaporative coolers are made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning which is tedious creates conditions for evaporative cooling of the packing house. The major problem of these structures is the constructing material which deteriorates quickly and is susceptible to rodent attack. An evaporative cooler for preservation of fruit and vegetable which complements natural air with forced air to cool small lots of produce. The report also showed some other evaporative cooler which he called drip coolers and can be constructed from simple material such as burlap and bamboo. They operate solely through the process of evaporation without the use of fan. These coolers are cumbersome and have the same problem of the packing house.

A cheap cool store in Kenya, with the help of local grass for storage of vegetables was developed. The roof and walls wet by dripping water from the top of the roof. Evaporative coolers, which rely on wind pressures to force air through wet pads, have also been designed and constructed, especially in some developing countries like India, China and Nigeria.

Construction of various evaporative systems was done by using available materials as absorbent (pads). Materials used include canvas, jute curtains and hourdis clay blocks. Also a mechanical fan was introduced to some of the coolers constructed.

The development of hexagonal wooden evaporative cooling systems and the system could be sub-divided into three parts head tank and pipe lines work ,the through and the frame work made of woods and its adjoints. The pipe line works at the top of the hexagonal frame supplied water constantly to wet the pad which is made of jute fibre. Wind pressure forced the air through the wetted jute pad. Limitation of this design is that the sufficiency of the evaporative cooler depends on wind velocity. An evaporative cooled structure for storage of fruits and vegetables with a double wall made of baked bricks and the top of the storage space covered with *khaskhas*/gunny cloth in a bamboo framed structure. Sanni, (1999) did a research on the development of evaporative cooling system on the storage of vegetable crops .The major development was implemented by adding a regulated fan speed, water flow rate and wetted-thickness .This was possible as a result of varying temperature and relative humidity within the facility. Dzivama, (2000) researched on the performance evaluation of an active cooling system using the principles of evaporative cooling for the storage of fruits and vegetables. He developed mathematical models for the evaporative process at the pad-end and the storage chamber and a stem variety of sponge was considered to be the best pad material from the local materials tested as pad material.

Olosunde, (2006) also did a research on the performance evaluation of absorbent, materials in evaporative cooling system for the storage of fruits and vegetables. Three materials were selected to be used as pad materials: jute, Hessian and cotton waste. The design implemented a centrifugal fan, high density polystyrene plastic, Plywood used as covering for the walls and basement and the top and the main body frame was made of thick wood. The performance criteria included the cooling efficiency, amount of heat load removed and the quality assessments of stored products. The result showed that the jute material had the overall advantage over the other materials. The cooling efficiency could be increased if two sides were padded. Sushmita et al., (2008) researched on Comparative Study on Storage of Fruits and Vegetables in Evaporative Cooling Chamber and in Ambient. An evaporative cool chamber was constructed with the help of baked bricks and riverbed sand. It was recorded that weight loss of fruits and vegetables kept inside the chamber was lower than those stored outside the chamber. The fruits and vegetables were fresh up to 3 to 5 days more inside the chamber than outside.

Acedo (1997) developed two simple evaporative coolers with jute bag and rice husk as the cooling pad in the Philippines for cooling and storage of vegetables. He prevented decay by washing the product first in the chlorinated water. Jain (2007) presented a two stage evaporative cooler for fruits and vegetable which incorporated a heat exchanger. This design is expensive but he could only achieve a storage life of 14 days for tomato. Anyanwu (2004) developed a porous wall (pot in pot) evaporative cooler for preservation of fruits and vegetables. He got a storage life of less than four days (93hours) on tomato. In this research work, an evaporative cooler with locally sourced materials for the construction was developed and evaluated. The evaporative cooler fabricated with mud (clay) directly excavated from the swamp is not electricity dependent will help farmers and marketers of fruits and vegetables to be able to store and preserve efficiently their products.

2.Factors Affecting the Shelf Life of Fruits and Vegetables

There are various factors that do affect the shelf life of fruits and vegetables which would lead to their spoilage. The various factors include:

i) Ambient Condition : The environmental condition has a great influence on the shelf life of fruits and vegetables and the factors can be sub-divided into temperature and relative humidity.

ii) Temperature : Temperature is defined as the degree of hotness or coldness of a material. Temperature has a great influence on the shelf life of agricultural products. FAO, (1998) found that all produce are subject to damage when exposed to extreme temperatures which will lead to increase in their level of respiration. Also, it was further disclosed that agricultural products vary in their temperature tolerance.

Gravani, (2008) observed that for every 18°F (-7.7°C) rise in temperature within the moderate temperature range (50°F-100°F)/(10°C-37.8°C) where most food is handled, the rate of chemical reactions is approximately doubled. As a result, excessive temperatures will increase the rate of natural food enzyme reactions and the reactions of other food constituents.

iii) Relative Humidity : This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. It has a great effect on the deterioration of fruits and vegetables because it has a direct relationship with the moisture content in the atmosphere which determines whether the shelf life will not be exceeded. The relative humidity of storage unit directly influences water loss in produce.

iv) Variety and stage of ripening: Post-harvest operation does not stop the fruits and vegetables from respiring which if not controlled will lead to the over-ripening of the fruits which will lead to early deterioration. Depending on the stage the fruits are harvested, which in practice varies from mature green to fully ripened, the commodities have different storage conditions

2. Principles of Evaporative Cooling

Evaporative Cooling with Psychrometric Chart

Cooling through the evaporation of water is an ancient and effective way of cooling water. He further disclosed that this was the method being used by plants and animals to reduce body temperature. The conditions at which evaporative cooling would take place which are stated below:

(1) Temperatures are high

(2) Humidity is Low

(3) Water can be spared for its use

(4) Air movement is available (from wind to electric fan)

Also the change of liquid stage to vapour requires the addition of energy or heat. The energy that is added to water to change it to vapour comes from the environment, thus making the environment cooler.

Therefore, the use of the psychrometric chart is of great importance in order to discover whether evaporative cooling has taken place. Air conditions can be quickly characterized by using

Properties on the chart include dry-bulb and wet-bulb temperatures, relative humidity, humidity ratio, specific volume, dew point temperature, and enthalpy Beiler, (2009).

When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect (Wikipedia.com).

Therefore for optimum cooling efficiency using the evaporative cooling technique temperature and the relative humidity measurement is needed to be taken and the psychrometric chart defines these variables at various stages.

B. Factors Affecting Rate of Evaporation

Evaporative cooling results in reduction of temperature and increase in relative humidity (Olosunde, 2006).It is necessary to understand the factors that can limit the efficiency of the system from producing the intended results. There are four major factors that affect the rate of evaporation which was analysed. He later added that though they are discussed separately but it is important to keep in mind that they all interact with each other to influence the overall rate of evaporation, and therefore the rate of cooling. These factors discussed by including:

(1) Air Temperature:

Evaporation occurs when water is absorbs sufficient energy to change from liquid to gas. Air with a relatively high temperature will be able to stimulate the evaporative process and also be capable of holding a great quantity of water vapour. Therefore, areas with high temperatures will have a high rate of evaporation and more cooling will occur. With lower temperature, less water vapour can be held and less evaporation and cooling will take place.

(2) Air Movement

Air movement velocity either natural (wind) or artificial (fan) is an important factor that influences the rate of evaporation. As water evaporates from wet surface, it raises the humidity of the air that is closest to the water surface (moist area) .If the humid air remains in place, the rate of evaporation will start to slow down as the humidity rises. On the other hand if the humid air near the water surface is constantly being moved away and replaced with drier air, the rate of evaporation will either increase or remain constant.

(3) Surface Area

The area of the evaporating surface is another important factor that affects the rate of evaporation. The greater the surface area from which the water evaporates, the greater the rate of evaporation.

(4) Relative Humidity of the Air

This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. When the relative humidity of the air is low, this means that only a portion of the total quantity of water which the air is capable of holding is being held. Under this condition, the air is capable of taking additional moisture, hence with all other conditions favourable, the rate of evaporation will be higher, and thus the efficiency of the evaporative cooling system is expected to be higher.

VI. Methods of Evaporative Cooling

Rusten, 1985 specified that there are two main methods of evaporative cooling namely:

(1) Direct evaporative cooling (2) Indirect evaporative cooling

(1) Direct Evaporative Cooling

This is a method by which air is passed through a media that is flooded with water .The latent heat associated with the vaporizing of the water cools and humidifies the air streams which now allows the moist and cool air to move to its intended direction. (Sellers, 2004) Sanjeev, (2008) disclosed that direct evaporative cooling has the following major limitations:

i) The increase in humidity of air may be undesirable.

ii) The lowest temperature obtainable is the wet-bulb temperature of the outside air,

iii) The high concentration and precipitation of salts in water deposit on the pads and the other parts, which causes blockage, and corrosion, and requires frequent cleaning, replacement, and servicing.

(2) Indirect Evaporative cooling:

A heat exchanger is combined with an evaporative cooler and the common approach used is the passes return/exhaust air through an evaporative cooling process and then to an air-to air heat exchanger which in turn cools the air, another approach is the use of a cooling tower to evaporatively cool a water circuit through a coil to a cool air stream (Sellers, 2004) and Sanjeev, (2008) also said indirect cooling differs from direct cooling in the sense that in indirect cooling the process air cools by the evaporation of water but there is no direct contact of water with process air. Instead a secondary airstream is used for evaporation of water. So the moisture content of process air remains the same

VII. Forms of Direct Evaporative Cooling

Dzivama, (2000) did a study on the forms of evaporative cooling process and discovered that there are two forms in which the evaporative cooling principle can be applied. The difference is based on the means of providing the air movement across/through the moist materials .These is the passive and non-passive forms. The passive form of evaporative cooling relies on the natural wind velocity, to provide the means of air movement across/through the moist surface to effect evaporation. This form can be constructed on the farm, for short term on farm storage while the non- passive form uses a fan to provide air movement.

A. Passive-direct evaporative cooling system

Construction and design varies but the general principles are the same. The main components include:

i) The cabinets where the produce is stored.

ii) The absorbent material used to expose the water to the moving air

iii) An overhead tank/through which the water seeps down on to and wet the absorbent material. The absorbent material covering the cabinet absorbs water from the tank on top of the cabinets, the entire cloth that was used as cabinet is soaked in water and the air moves past the wet cloth and evaporation occurs. As long as evaporation takes place, the contents of the cabinet will kept at a temperature lower than that of the environment and the temperature reduction obtained in this type of cooler ranged from 5°C to 10°C. Different researches have been done by researcher: to designed various forms of coolers.

B. Non- passive direct evaporative cooling system

This uses a small fan, a water pump which is powered by electricity. The products are kept in storage cabins inside the coolers, Absorbent material which receives the water and expose it to evaporation with the help of the fan which draws air through the pad and a overhead tank which is constantly supplying water to the absorbent material. Materials used as the absorbent materials are hessian materials, cotton waste and celdek and the body frame is made of wood. The pad and the fan are directly opposite to each other.

VIII Design construction and impact assessment of evaporative cooler

A charcoal evaporative milk cooler was designed and fabricated, with inner dimensions being 1.00 m long x 1.00 m wide x 0.75 m high (Figs. 1 and 2). Apilot study in the area indicated that the daily quantities of marketed milk by individual traders ranged from 40 to 160 litres (Wayua, unpublished data). The capacity of the cooler was, therefore, chosen in relation to the daily quantities of marketed camel milk in the region. The target was to cool approximately 200 litres of milk per producer/trader to temperatures less than 10°C, which is necessary to reduce microbial milk spoilage in the ASALs, characterised by high ambient temperatures (>25°C). The frame was constructed from 25 mm x 25 mm x 4 mm angle iron, reinforced with 3 mm thick steel wire mesh and chicken wire inside and out, leaving a 10 cm wide cavity which was filled with charcoal. The cooler was provided with a side door which opened outwards. The charcoal walls were on all four sides. Charcoal was selected as the pad material because it has a very porous structure that can hold water, is light, durable for repeated wetting and drying, is inexpensive and locally available in the study area, essential requirements for a good pad material water reservoir (white 50 litre plastic tank) linked to the cooler at the top through a perforated pipe (holes 3 mm diameter, 10 cm apart) maintained the charcoal walls uniformly wet by water being properly distributed along the upper edge of the walls through a drip system. The water flow rate from the reservoir was measured by a flow meter and its flow rate adjusted by a manual valve. Water seeps through the charcoal walls and evaporates at the wall outer surfaces, keeping the storage space temperature below ambient temperature consistently during the cooler operation. Any excess water dripping from the bottom was collected into a water reservoir and re-used. To prevent heat absorption from the ground, the base of the cooler was made of galvanised iron sheet with a layer of water-soaked charcoal underneath. Four caster wheels of 15 cm diameter were fixed at each corner of the framework to make the unit portable.

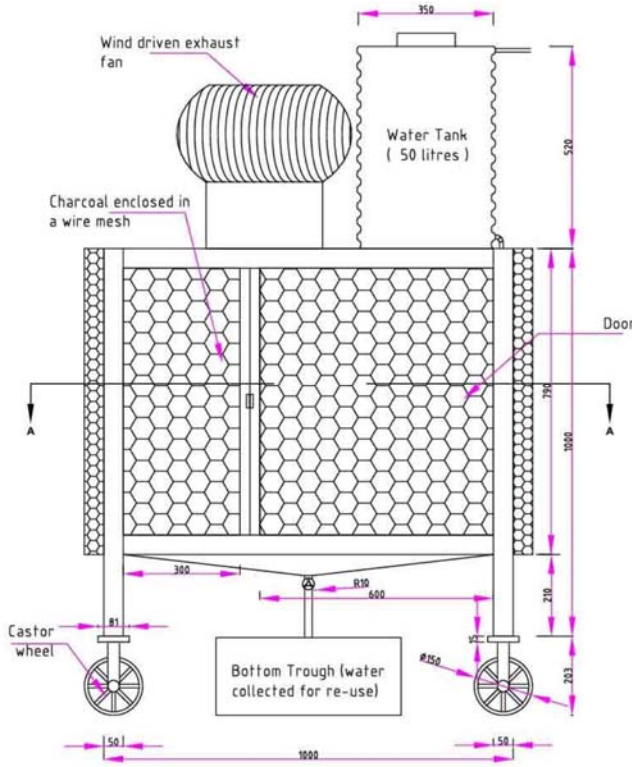

Fig.1. Front view of the drip type charcoal evaporative cooler (all figures in mm)

The roof was made of galvanised iron sheet (painted white) over which was placed grass thatch to prevent overheating of the cooler interior by direct solar radiation. An opening of 0.30 m diameter was left at the centre of the roof to accommodate a wind-driven turbine) which enhanced air movement through the charcoal walls by sucking out air from the cooler. The ventilator consisted of a number of vertical curved vanes in a spherical dome (0.25 m in height) mounted on a frame. A shaft and bearings connected the top moving section to a base duct. The ventilator works on the principle that when wind blows on the aerofoil vanes

the resulting lift and drag forces cause it to rotate. This rotation produces a negative pressure inside which extracts warm air that has risen to the top of the cooler to the outside, therefore, drawing new cool air through the wet charcoal walls. In the absence of wind, the ventilator works on the principle of stack effects The ventilators are inexpensive to run and can be used in remote locations without electricity supply.

IX Zero Energy Cool Chamber

It is a semi-underground chamber. Out of the total height of 67.5 cm, 30.0 cm is above the ground and the rest is underground. The sidewalls and the floor is cemented. The sidewalls are made of double layer of bricks leaving 7.5 cm space between the walls. The cavity between the walls is filled with riverbed sand. About 400 bricks are required to make a chamber of 165 cm x 115 cm x 67.5 cm dimension. The top of the storage area of the chamber is covered with gunny cloth over a bamboo frame. The bricks of the walls and floor, the sand used in the cavity and the top cover made of gunny cloth are saturated with water. The sand in the cavity is made saturated by fixing a drip system with plastic pipes connected to an overhead water source.

Shelf life of banana, khasi mandarin, tomato, pointed gourd, betelvine and *lai* (*Brssica rugosa*) were evaluated. The shelf life of these fruits/vegetables could be extended by 25, 21, 13, 31 and 9 days respectively, which was more or close to double compared under room condition. Temperature difference between the structures and the ambient has been observed to be about 8 degree C during summer months and about 3 degree C during winter months. It can accommodate about one quintal of fruits / vegetable at a time.

1. Current status of the technology

i. Whether commercialized : Demonstrated at farmers field

ii. No. of licensees : No

iii. No. of units sold so far (till date) : No

iv. Profit from sale of single prototype/ process : NA

v. IP status (whether patented / patient application filed) : No

2. Improvement over conventional practice

Advantage	Unit	
Output advantage/ Higher recovery	Kg/ hr. or q/ day	NA
Reduction in PH losses	10 Kg/ q	0
Labour cost reduction	Rs./ q	NA
Energy saving	Rs./ q	NA

Time saving (in terms of capacity)	Hr. /day or days/ yr	NA
Improvement in storage life (extended period)	Days	Tomato : 13 Betelvine : 11 Pointed gourd : 4 Khasi mandarin : 15 Lai(*Brssica rugosa*): 9
Decrease in maintenance cost	Rs./ machine	NA
Benefits in case of custom hiring	Rs./q	NA
Value addition	NA	
Any other		

3. Cost involved : Rs.2940.00
4. Employment generation (mandays/ annum, no. of persons): NA
5. Anticipated Market demand for the equipment or product developed

Suitable for farmers.

6. Cost economics and benefits over conventional technology (Rs. /unit)

Sr. No.	Assumptions and cost/ benefits	Technology (equipment/ process developed)	Conventional technology (Bamboo *khasa*)	Remarks (if any)
A.	**Assumptions**			
i.	Capacity	1 q/batch	1 q/batch	
i.	Cost	2940.00	150.00 x 10 = 1500.00	Buy 10 times at present cost to match life
i.	Life or degeneracy period (in years)	5	0.5	
v.	Annual use (Hours of hiring to be shown separately)	12 months	12 months	
v.	Salvage value	35 %	0	
i.	Interest rate	12%	12%	
i.	Labour charges (Rs./h or day)	x	x	
i.	Cost of fuel (Rs./l)	x	x	

.	Cost of electricity (Rs./unit)	x			x			
B.	**Fixed cost**							
i.	Depreciation on all machinery	@15%: Rs.36.75			@20%: 25.00			Per month
i.	Interest on fixed capital	@12%: Rs.29.40			@12%: 15.00			-do-
	Sub total (B)	56.00			40.00			
C.	**Variable cost**							
i.	Cost of raw material	x			x			
i.	Repair and maintenance (Rs/year)	100.00			60.00			
i.	Fuel and electricity charges (Rs.)	x			x			
.	Other expenses (Rs.)	x			x			
	Sub total C	100.00			60.00			
D.	**Total cost (B+C)**	156.00			100.00			
E.	**Returns**							
a.	Final product (main) recovery	Qty	Rate (Rs./unit)	Total (Rs.)	Qty	Rate (Rs./unit)	Total (Rs.)	• Compared for Tomato. • @Rs.20/kg
		90 kg	1800	1800	75 kg	1500	1500	
b.	By product	x	x	x	x	x	x	
c.	Custom hiring	x	x	x	x	x	x	
	Total returns (a+b+c)	1800.00			1500.00			
F.	**Profit (E-D)**	1644.00			1400.00			
G.	**Saving over conventional practice** (Rs./unit)	244.00						Av. per batch per month

X. Recommended minimum temperature to increase storage time

There is no ideal storage temperature 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 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 such as asparagus, beans, broccoli, and Brussels sprouts at -1-4°C for 1-4 weeks; cauliflower at 5-9°C for 2-4 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. Similarly, sweet potatoes can be stored at 10°C for 16-24 weeks. The storage life of produce is highly variable and related to the respiration rate; there is an inverse relation between respiration rate and storage life in that produce with low respiration generally keeps longer. For example, the respiration rate of a very perishable fruit like ripe banana is 200 mL $CO2.kg^{-1}h^{-1}$ at 15°C, compared to a non-perishable fruit such as apple, which has a respiration rate of 25 mL $CO2.kg^{-1}h^{-1}$ at 15°C.

Exposure of fruits and vegetables to high temperatures during post-harvest reduces their storage or shelf life. This is because as living material, their metabolic rate is normally higher with higher temperatures. High temperature treatments are beneficial in curing root crops, drying bulb crops, and controlling diseases and pests in some fruits. Many fruits are exposed to high temperatures in combination with ethylene (or another suitable gas) to initiate or improve ripening or skin colour.

XI. CONCLUSION

When fruits and vegetables are exposed to high temperatures during post-harvest it reduces the storage or shelf life and as such, the shelf life of most fresh vegetables can be extended by prompt storage in an environment that maintains product quality. Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive. Hence the need for an evaporative cooling structure for storage of fruits and vegetables.

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PCM APPLICATIONS IN COLD STORAGE

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Introduction

Energy is the soul of the modern world. Economic growth and technological advancement of every country depends on it. With time, energy requirement is increasing rapidly in all the sectors. Agricultural sector, which used to be less dependent on non-renewable energy sources, also requires large amount of energy to carry out different agricultural and postharvest operations. No any postharvest operation is now possible without adequate amount of energy. Among various postharvest operations, storage of agricultural produce has become one the most important postharvest operations as far as energy requirement is concerned. Moreover, it is the most pressing problems in a tropical country like India. Considerable amount of energy is required in the storage of fresh and processed foods. Low moisture produce such as cereals, pulses etc. require less amount of energy as compared to perishables that includes fruits, vegetables, milk, meat, fish etc. Perishables are either stored in cold rooms or controlled atmosphere storage rooms at low (≤10°C) to very low temperatures (<0°C). Desired temperatures and relative humidity (RH) are maintained in such cold storage to extend the shelf life of stored produce. Quality deterioration of perishables takes place if one fails to provide desired temperature and RH conditions.

Mechanical compression systems are the major source of attaining desired temperatures in cold storage. However, they are energy intensive and require uninterrupted source of electric power for considerable period of time. Consequently, they are directly or indirectly responsible for present energy crisis as their excess use in cold storage as well as household, industrial and transportation sectors is increasing rapidly. It is important to maintain constant temperatures inside the cold storage facilities as most of the frozen and chilled foods are sensitive to temperature fluctuations. The mechanical refrigeration systems are, therefore, run continuously to maintain desired temperatures, but if there is a power failure, cooling is not provided to the stored product that leads to spoilage.

Mechanical refrigeration systems based cold storages are heavily dependent on electrical and non-renewable energy sources. These systems in combination with air-conditioning systems take up over half the electricity usage. Excessive use of non-renewable energy harms the environment and contributes to climate change. According to the International Energy Agency, current trends in energy supply and use are economically, environmentally and socially unsustainable as energy-related emissions of CO_2 will be doubled by 2050 and fossil energy demand will increase over the security of supplies. Consequently, more emphasis is being given on using the renewable energy in cooling applications. Numerous efforts are being undertaken to implement different novel technologies in refrigeration systems of cold storage rooms. Sizeable amount of energy is now produced from renewable sources, especially from solar energy, all over the world. The application of clean solar energy has potential to avoid the problem of environmental pollution. Researchers are also forced to go deeper to find some materials and systems to make sure the presence of energy storage in the domestic, transport and industry sectors to support energy security and climate change goals (Gasia et al., 2016). Efforts are being made to lower the energy requirement in cooling applications by using newer technologies like phase change materials (PCMs). There is an urgent need to shift from non-renewable energy based cold storages to PCM based cold rooms if we really concern about environment and our future generations.

Present document discuss about the use of PCMs based cooling systems in cold storage rooms for storage of perishable products.

Phase Change Materials (PCMs)

PCMs are latent heat storage materials and are the most efficient thermal storage mediums. They absorb significantly higher amount of latent heat during their phase change (Fig.1). PCMs have high heats of fusion (kJ/kg) so they can absorb lot of heat energy before melting or solidifying. Heat of fusion is the amount of energy required to melt/solidify 1 kg of PCM. Heat required to be removed from 1 kg water at 5°C to reduce its temperature to 2°C is 12.6 kJ whereas heat required to be removed from 1 kg liquid PCM at 5°C to make a frozen PCM at 2°C is 233.3 kJ. It shows that PCM absorbs almost 19 times more energy than water at the same temperature conditions. In general, PCMs stores 5 to 14 times more heat energy (per unit volume) than sensible heat storage materials like water, sand, rock, gravel, masonry etc. PCMs also have longer Duration Index (J/cm^3-°C) compared to other materials. Duration index is the comparison of how long a PCM will remain at a constant temperature during its phase change.

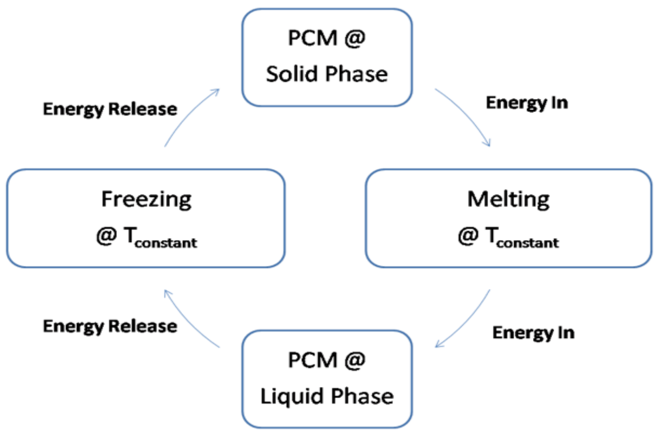

Fig.1 Working principle of PCMs

PCM temperature remains almost constant during phase change, which is useful for keeping the subject at uniform temperature. PCMs are generally used where heat energy is to be absorbed from the surrounding without rise in their temperature. PCMs are selected in different applications on the basis of their melting point temperature. Various PCMs that melt between 14ºC and 91ºC temperatures are used for different applications. Large number of PCMs are available in the market that works below sub-atmospheric temperatures (<23ºC) and hence can be used to develop PCM based cold stores. Some of the PCMs that have been used in various studies are listed in Table 1.

Table 1 PCMs used in various studies for cooling applications

S. No.	PCM	Phase change point (°C)
1	NaCl.Na2SO4.10H2O	18
2	Paraffin 16-carbons	16.7
3	Paraffin 17-carbons	21.7
4	Glycerin	17.9
5	PG 600	20

6	SaveE OM 21 (pluss)	21
7	SaveE FS 21 (pluss)	21
8	SaveE HS 21 (pluss)	21
9	Na2CrO4.10H2O	18
10	Dimethyl sulfoxide (DMS)	16.5
11	PEG E 600	22
12	S 21 salt hydrated (pluss)	22
13	S 19 salt hydrated (pluss)	29
14	A 22 organic (pluss)	22
15	A 22 H organic (pluss)	22
16	A 23 organic (pluss)	23

Important applications of PCMs are given below.

Applications of PCMs (Pathak et al., 2017)

1) Cooling of heat and electric engines.
2) Cooling: use during off-peak rates.
3) Cooling of food, milk products, greenhouses etc.
4) Thermal protection of food during transport, hotel trade, ice-cream, etc.
5) Thermal protection of electronic devices (integrated in the appliance).
6) Heating and hot water during using off-peak rates.
7) Medical applications: transportation of blood, operating tables, hot–cold therapies.
8) Solar power plants.
9) Spacecraft thermal systems.
10) Thermal comfort in vehicles.
11) Thermal storage of solar energy.

Advantages of PCMs

1) A PCMs embedded walls are capable of minimizing the effect of large fluctuations in the inside temperature due to ambient temperature.
2) In case of a power failure to conventional cooling systems, PCMs minimise use of diesel generators.
3) PCMs take benefit of latent heat that can be stored or released from a material over a narrow temperature range.

4) PCM based cold storage system helps to reduce the mismatch between the energy supply and demand.

5) The use of the composite PCM as a storage medium can reduce the weight of the thermal storage.

6) PCMs are given as a possible solution for reducing the energy consumption of buildings. By storing and releasing the heat under a certain temperature range, They raise the building inertia and stabilizes indoor climate.

Disadvantages of PCMs

1) Some organic PCMs have adverse characteristics like corrosion, instability, improper re-solidification suffer from decomposition and super cooling.

2) The initial cost of PCMs is quite higher.

3) Some PCMs have low thermal conductivity, changes in volume are high during phase change

4) Some are flammable and may generate harmful fumes on combustion.

5) PCMs not always have re-solidified properly as some PCMs get separated and stratify when in their liquid state.

PCMs containment

Embedding the PCMs into building materials, walls, roofs etc. is very important in order to achieve maximum efficiency. There are two ways to contain/embed PCMs in building/cold room walls and roof:

1) Direct impregnation into building materials/walls
2) Encapsulation: macro and micro encapsulation

Direct impregnation is accomplished by either dipping porous building materials into a PCM bath or mixing PCM into the materials during manufacturing process. Encapsulation involves containing the PCM with another material. It is categorized as micro and macro-encapsulation. Micro-encapsulated PCMs are contained by microscopic polymeric capsules which form a powder-like substance that can be incorporated into various building materials (Pasupathy at al., 2008; Baetens et al., 2010). Previous studies demonstrated that micro-encapsulated PCMs can be successfully incorporated into wallboard, concrete, insulation and acoustic ceiling tiles, but tend to be costly (Cabeza et al.2007; Borreguero et al., 2010; Shrestha et al., 2011). On the contrary, macro-encapsulation contains the PCM in larger pouches, tubes, or panels that interact with other building materials through conduction and convection. Macro-encapsulated PCMs are less costly, but may not release stored heat as effectively due to solidification of the PCM around the edges of the capsule (Pasupathy at al., 2008). Examples of micro and macro-encapsulated PCMs are shown in Fig.2.

(a) (b) (c)

Fig.2 (a) BASF Micronal® microencapsulated PCM powder (www.basf.com), (b) Phase Change Energy Solutions macro-encapsulated BioPCmat™ (www.phasechange.com), (c) PCM-impregnated ThermalCORE™ Panel by National Gypsum (www.thermalcore.info).

Classification of PCMs

PCMs are classified into three main groups based on their composition: organic, inorganic and eutectic compounds (Fig.3). The phase change temperature range and the enthalpy change are the key thermal properties of PCMs. Not all the PCMs have applicability in all the places. Hence, suitability of PCMs for particular application is determined from their thermo-physical properties.

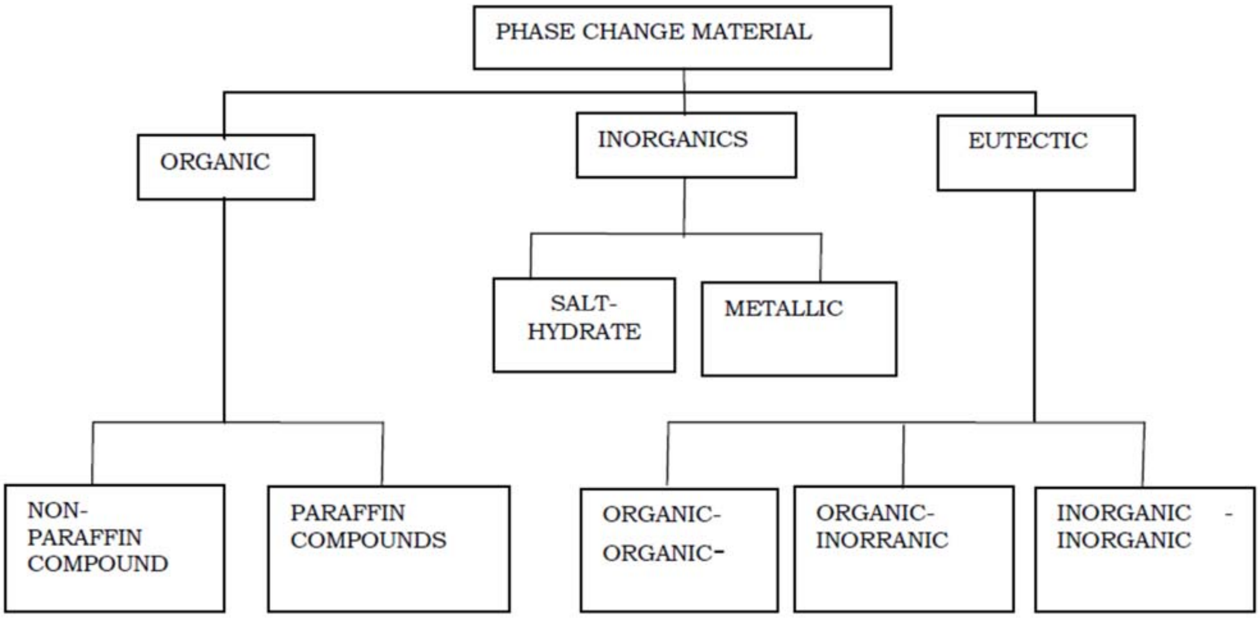

Fig.3 Classification of PCMs

Desirable thermo-physical properties of PCMs

1) High latent heat of solidification
2) High thermal conductivity
3) Occupy small space
4) No super cooling
5) High density
6) Small change in volume during phase transmission
7) Low vapour pressure
8) Sufficient crystallization rate
9) Long term chemical stability
10) Compatibility with materials of construction

Potential application of PCMs in cold storage rooms

PCMs are being widely used in packaging systems. They are also being used in cold storage roofs, refrigerator walls, refrigerated container walls etc. However, there use is still not so common in cold rooms. They have also applications in mobile containers of medicines, ice cream etc. Reports indicate that some of the refrigerators are equipped with PCM embedded walls to reduce the temperature fluctuations during power failure. Studies have been conducted to incorporate PCMs in walls and roofs of small scale cold rooms. One of such attempt has been conducted by Ahamed et al. (2013) where they incorporated PCM (ethylene glycol having melting point of -23°C) in the walls of cold room. Study observed that application of PCM into a cold room could maintain the desired inside temperature for significant time during power failure. With PCM, the inside air temperature was kept constant at -8°C for 8 h, compared to without PCM where inside temperature increased continuously and raised above -8°C in just 1 hour. The PCM temperature increased slowly as the PCM melted over 8 h period. Once the PCM finished melting, the inside air and PCM temperatures increased steeply. Similar types of studies are also available in literature indicating the possibility of incorporation of PCMs in the cold rooms to reduce the power requirement and to maintain the desired temperature during power failure.

Most of the cold storage systems operate near 0°C temperatures. Such low temperature may not be achieved without application of large amount of energy. However, PCM based cold rooms can be developed that can work at sub-atmospheric temperatures (20-25°C). Many PCMs like paraffins, PEG, salt hydrates etc. are available that work at sub-atmospheric temperatures. Due to the range of use being between 20 and 25°C, paraffin or salt hydrates can be used to develop PCM based cold rooms. Such rooms would be alternative to Evaporative cooled rooms which are otherwise not advantageous in hot and humid climates. These cold rooms may work using PCMs and proper insulation only. No other energy source of energy would require in operating such rooms and thus large amount of non-renewable (electrical) energy would be saved. Pre-cooling as well as transit storage may be achieved at farm level using such PCM based cold rooms.

Another potential application of PCMs would be in mobile cooled chambers that can operate at 20-25°C. Such mobile structures would be useful in short distance transportation of perishables. They may also be useful to the vendors and hawkers of fruits and vegetables in hot and humid regions.

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PRIMARY AND MINIMAL PROCESSING OF FRUITS AND VEGETABLES

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Introduction

Processing activities are of critical importance to expansion and diversification within the fresh produce sector as they increase market opportunities and add value while minimizing postharvest losses. Furthermore, processing improves the viability, profitability and sustainability of fresh produce systems by increasing farm incomes, and generating rural employment and foreign exchange. Primary processing technologies such as thermal processing (bottling and canning), freezing, dehydration (salting, brining and candying) drying, and fermentation are widely applied in the processing of vegetables at various levels. Canned vegetables, tomato paste, purees and pulps and dried mushrooms are examples of vegetable products produced using primary processing technologies and which are increasingly entering in international trade. Dried and canned mushrooms produced in China, currently account for 52% of world trade in processed mushrooms. Shelf-life extension of vegetables is a major technological need to overcome the post-harvest losses owing to their perishable nature. In recent years, there has been a considerable increase in the demand for processing of vegetables, coupled with convenience and safety. Minimal processing is a growing processing trend that offers the consumer, convenience, "freshness" of quality, nutrition, and safety. Consumers have also become more critical of the use of synthetic additives to preserve food or enhance characteristics such as colour and flavour. Minimal processing technologies, specialized packaging and natural preservation systems are increasingly being applied in the preservation of vegetables for both developed and developing country markets, in response to growing consumer demand for convenience and for "fresh-like" fruits of high quality which are nutritious, flavorful and stable. These processing technologies focus on adding value with comparatively little product transformation while increasing product diversity. While minimal and traditional processing technologies present considerable opportunities for innovation and vertical diversification in the fruit and vegetable sector, relatively few small and medium enterprises (SMEs) are able to tap into and benefit from these opportunities. Many SMEs lack the capacity to operate competitively in the current globalized market environment owing to problems of scale, the poor quality of input supplies, poor access to technology, limited technical expertise and research capacity, low production. Minimally processed foods can be kept safe with partial or minimal preservation treatment. In addition, it results fewer possible alterations to the food quality. As it involves removing or reducing the natural barriers to deterioration, it offers scientists an enormous challenge in trying to extend the shelf life of minimally processed fresh produce. However, the consumer demand for minimally processed products, changes in perception of the consumers for "freshness" of quality of fresh produce, and the convenience of such products warrant further research and developments in this area.

Primary Processing of fruits and vegetables

Primary processing relates to conversion of raw agricultural produce into a commodity that is fit for human consumption. It involves steps such as cleaning, grading, sorting, packing, etc. Secondary and tertiary processing industries usually deal with higher levels of processing where new or modified food products are manufactured. The primary processing of vegetables can involves various processing methods as mentioned below:-

Asepsis (Absence of infection)

Asepsis means preventing the entry of microorganisms. Maintaining of general cleanliness while, picking, grading, packing and transporting of fruits and vegetables increases their keeping quality and the products prepared from them will be of superior quality. Washing or wiping of the fruits and vegetables before processing should be strictly followed as dust particles adhering to the raw material contain microorganisms and by doing so the number of organisms can be reduced considerably.

Use of Sugar

Syrups containing 66 per cent or more of sugar do not ferment. Sugar absorbs most of the available water with the result that there is very little water for the growth of microorganisms hence their multiplication is inhibited, and even those already present die out gradually. Dry sugar does not ferment. Thus sugar acts as a preservative by osmosis and not as a true poison for microorganisms. Fruit syrup, jam, jelly, marmalade, preserve, candy, crystallized fruit and glazed fruit are preserved by sugar.

Use of salt

Salt improves the taste and flavour and hardness the tissues of vegetables and controls fermentation. Salt content of 15 per cent or above prevents microbial spoilage. This method of preservation is generally used only for vegetables which contain very little sugar and hence sufficient lactic acid cannot be formed by fermentation to act as preservative. However, some fruits like lime, mango, etc., are also preserved with salt.

Pickling

Microorganisms are always on vegetables. Proper home canning prevents the growth of the microorganisms that cause spoilage and illness. When the acidity of a canned food is high, harmful bacteria such as *Clostridium botulinum* cannot grow. That is why pickling (adding acid) prevents spoilage.

There are two types of pickles:

- •Brined (fermented) pickles require several weeks of "curing" at room temperature. During this period, colors and flavors change. Acid is produced as lactic acid bacteria grow.
- •Quick (unfermented) pickles are made in 1 or 2 days by adding acid in the form of vinegar. It is critical to add enough vinegar to prevent bacterial growth

Fermentation

Decomposition of carbohydrates by microorganisms or enzymes is called 'fermentation'. This is one of the oldest methods of preservation. By this method, foods are preserved by the alcohol or organic acid formed by microbial action. The keeping quality of alcoholic beverages, vinegars and fermented pickles depends upon the presence of alcohol, acetic acid and lactic acid, respectively. Care should be taken to seal the fermented products from air to avoid further unwanted or secondary fermentation. Wines, beers, vinegar, fermented drinks, fermented pickles, etc., are prepared by these processes. Fourteen per cent alcohol acts as a preservative in wines because yeasts, etc., cannot grow at that concentration. About 2 per cent acetic acid prevents spoilage in many products.

Aseptic Canning

Aseptic canning is a technique in which food is sterilized outside the can and then aseptically placed in previously sterilized cans which are subsequently sealed in an aseptic environment.

The method is basically a short-time, high-temperature sterilization process. It combines flash pasteurization and cooling with aseptic packaging of fluid and semi-fluid products, thus eliminating the retorting and subsequent cooling phases. This process consists of four separate operations, carried out one after another in a closed interconnected apparatus: (i) sterilization of product by appropriate quick eating, holding and cooling, (ii) sterilization of containers and covers with superheated steam, iii) aseptic filling of cooled, sterile product into sterile containers, and (iv) aseptic sealing of the containers with sterile covers. The temperature employed may be as high as 149°C and sterilization takes place in 1 or 2 seconds to yield products of the highest quality.

Use of High Temperature

Inactivation of their metabolic enzymes by the application of heat leads to the destruction of microorganisms present in foods. Further, heating can also inactivate the enzymes present in the food. Heating food to high temperatures can, therefore, help to preserve it. The specific treatment varies with: Thermal Death Time (TDT) of bacteria. Enzymes also require air (oxygen) at normal temperature for their action and can, therefore, be destroyed at a moderate temperature by removing air from the juice. Pectic enzymes which cause changes in flavour and also. bring about the clotting of particles in the juice can be destroyed by heating the juice for about 4 minutes at 85°C, or for one minute at 88°C. Usually juices, R.T.S. and nectar are pasteurized at about 85°C for 25 to' 30 minutes

Low Temperature

Microbial growth and enzyme reactions are retarded in vegetables stored at low temperatures. The lower the temperature, the greater the retardation. Low temperatures can be produced by (i) cellar storage (about l5°C), (ii) refrigeration or chilling (0 to 5°C),and (iii) freezing (-18 to -40°C).

(i) Cellar storage (about 15°C) : The temperature in cellars (under- ground rooms) where surplus food is stored in many villages is usually not much below that of the outside air and is seldom lower than l5°C. It is not low enough to prevent the action of many spoilage organisms or of plant enzymes. Decomposition is, however, slowed down considerably. Root crops, potatoes, onions, apples and. similar foods can be stored for limited periods during the winter months.

(ii) Refrigeration or chilling (0 to 5°C): Chilling temperatures are obtained and maintained by means of ice or mechanical refrigeration. Fruits and vegetables and their products can be preserved for a few days to many weeks when kept at this temperature. The best storage temperature for many foods is slightly above O°C but his varies with the product and is fairly specific to it. Besides temperature, the relative humidity and the composition of the air can affect the preservation of the food. Commercial cold storages with proper ventilation and automatic control of temperature are now used throughout the country (mostly in cities) for the storage of semi-perishable foods such as potatoes and apples. This has made such foods available throughout the year and has also stabilized their prices.

Drying

Microorganisms need moisture to grow so when the concentration of water in the food is brought down below a certain level, they are unable to grow. Moisture can be removed by the application of heat as in sun-drying or by mechanical drying (dehydration). Sun-drying is the most popular and oldest method of preservation. In 'these days, mechanical drying has replaced sun-drying. This is a more rapid process as artificial heat under controlled conditions of temperature, humidity and air flow is provided and fruits and vegetables, e.g., green peas, cauliflower, mango, mahua, etc., are dried to such an extent that the microorganisms present in them fail to survive. In this method, juices are preserved in the form of powder. The juice is sprayed as a very fine mist into an evaporating chamber through which hot air is passed. The temperature of the chamber and the-flow of air are so regulated that dried juice falls to the floor of the chamber in the form of a dry powder. The powder is collected and packed in dry containers which are then closed airtight. The powder when dissolved in water makes a fruit drink almost similar to the original fresh juice. Fruit juice powders are highly hygroscopic and require special care in packing. All juices cannot, however, be dried readily without special treatment. Mango juice powder is prepared by this technique but the method is very expensive and not popular in India.

Carbonation

Carbonation is the process of dissolving sufficient carbon dioxide in water or beverage so that the product when served gives off the gas as fine bubbles and has a characteristic taste. Carbonation adds to the life of a beverage and contributes in some measure to its tang. Fruit juice beverages are generally bottled with carbon dioxide content varying from 1 to 8 g per litre. Though this concentration is much lower than that required for complete inhibition of microbial activity (14.6 g/litre), it is sufficient for supplementing the effect of acidity on pathogenic bacteria. Another advantage of carbonation is the removal of air thus creating 'an anaerobic condition, which reduces the oxidation of ascorbic acid and prevents browning.

Moulds and yeasts require oxygen for their growth and become inactive in the presence of carbon dioxide. In ordinary carbonated drinks, the oxygen which is normally present in solution in water in sufficient amount to bring about fermentation, is displaced by carbon dioxide. Although carbonated beverages contain sugar much below 66 per cent, the absence of air and the presence of carbon dioxide in them help to prevent the growth of moulds and yeasts. High carbonation should, however, be avoided as it usually destroys the flavour of the juice. The keeping quality of carbonated fruit beverages is enhanced by adding about 0.005 per cent sodium benzoate. The level of carbonation required varies according to the type of fruit juice and type of flavour.

Minimal Processing

The term 'minimal processing' has been defined in various ways, for example very broadly as 'the least possible treatment to achieve a purpose' (Manvell, 1996). A more specific definition which addresses the question of purpose describes minimal processes as those which 'minimally influence the quality characteristics of a food whilst, at the same time, giving the food sufficient shelf-life during storage and distribution' (Huisin't Veld, 1996). An even more precise definition, which situates minimal processing methods within the context of more conventional technologies, describes them as techniques that 'preserve foods but also retain to a greater extent their nutritional quality and sensory characteristics by reducing the reliance on heat as the main preservative action' (Fellows, 2000).

Minimal processing of raw vegetables has two purposes

- keeping the produce fresh, without losing its nutritional quality
- ensuring a product shelf-life sufficient to make distribution feasible within a region of consumption.

The microbiological, sensory and nutritional shelf-life of minimally processed fruits and vegetables should be at least 4–7 days, but preferably up to 21 days depending on the market.

Operations carried out in Minimal Processing of Fruits and Vegetables

Most of the fresh produce requires the processing operations in order to produce the products. These are discussed below:

Sorting: Sorting is the preliminary step for segregating the acceptable and non-acceptable products. It is done to remove the physiological defects from the produce. Commonly, manual sorting results in high quality results in comparison to sorting by equipment in terms of peculiar minute defects.

Peeling: It is one of the common operations used for fruits and vegetables, such as carrots, potatoes, pumpkin, bottle and onion. Methods used for peeling directly influence the quality parameters of the final products. Peeling is usually carried out by hand or by abrasive peelers. Hand peeling provides the high quality product but often leads to expensive labour. However, abrasive peelers are also used for producing fine quality products, but they tend to damage the fresh products by causing scaring on the surface and edible portion can also be damaged. Engineering intervention has resulted in innovative mechanisms of peeling operations and automatic peelers for continuous operations of peeling are available for handing large volumes of vegetables in developed countries. AICRP on PHT with it Centres had come up with peelers for selected commodities such as potato, ginger etc.

Cutting and Shredding: The unwanted parts of the plant based foods, such as seeds and stems need to be discarded before further processing. Therefore, trimming of the unwanted parts with eroded knives, cutters can pose a threat to the quality. The cutting tools should be cleaned and stored under good conditions. In addition, the overripe area or contaminated area should be discarded during initial sorting in order to prevent the growth of microbes and to avoid contamination of other infecting agents. Cutting and shredding must be performed with knives or blades that are as sharp as possible, these being made from stainless steel. Sharp blades are always better than blunt and dull blades. Blunt blades and knives impair the retention of quality because these rupture cells and release tissue fluid to a great extent. Mats and blades that are used in slicing operations can be disinfected with 1% hypochlorite solution. Cutting of vegetables should be preferably done under water. Because the internal liquid of injured cell is removed by water flow, browning is markedly compared to any commercial cutting technique.

Washing: Washing is an important step for minimally processed fruits and vegetables and the following factors need to be considered. Proper washing of fresh cut fruits and vegetables is the utmost desired immediately after cutting. Washing is done in ice-cold water (< 5ºC). Washing the produce in flowing or air-bubbling water is preferable to simplify dipping it in water. Both the microbiological and the sensory qualities of washing water must be good and its temperature is low, preferably < 5ºC. The recommended quantity of water that should be used is 5-10 l/kg of product before peeling and/or cutting and 3 l/kg after peeling and/or cutting. Preservatives can be used in the washing water to reduce microbial numbers and retard enzymatic activity, thereby improving both the shelf-life and sensory quality of the product. This step removes the dirt and some microbes present on the surface of products. Usually chlorinated water is used for rinsing the peeled fruits and vegetables. Therefore, the contact time during washing, pH and temperature of the rinsing water play a key role for assuring the quality of products.

Draining: Washing water should be gently removed from the product. Centrifugation seems to be the best method. It is important to choose the centrifugation time and rate carefully. CIPHET has developed a Basket Centrifuge which operates at 450 RPM and can remove the wash water efficiently from the fresh leafy vegetables etc.

Dipping in anti-browning agents: Browning inhibition: Browning is the main quality problem in pre-peeled or cut vegetables. What happens to the peeled potato, if you leave them open in air. You will find that after sometimes, the outer tissues start getting brown. This browning is basically a type of enzymatic browning, caused due to action of enzyme known as polyphenol oxidase (PPO). Oxidation of phenols in the presence of PPO causes these tissues to brown. Dipping the tissues in water or in salt water can reduce browning to some extent but cannot totally eliminate browning. US Food and Drug Administration (FDA) has partly restricted the use of sulphites in 1990, and since then there is increasing interest in substitutes for sulphites. In India, however, they continued to be used. Citric acid (CA) combined with ascorbic acid (AA) alone or in combination with potassium sorbate in case of potato, or Hexyl-resorcinol in the case of apple, seem to be promising alternatives for sulphites, particularly when hand peeling is used. Potatoes when heated for 5-20 min in a solution containing 1% ascorbic acid and 2% citric acid at 45-55ºC, cooled and then dipped for 5 min in a browning inhibitor solution containing 4% ascorbic acid. The combined treatment inhibits potato discolouration for 14 days at 4ºC, compared with 3-6 days with the browning inhibitor treatment alone.

Packaging: It the last operation in the production of minimally processed vegetables. The most appropriate packaging method for pre-cut vegetable is modified-atmosphere packaging (MAP). The basic principle in MAP is to create a modified atmosphere either passively or by using permeable packaging materials and by using a specified gas mixture with permeable packaging. The main purpose is to create an optimal gas balance inside the package, where the respiration activity of a product is as low as possible, but the levels of oxygen and carbon dioxide are not detrimental to the product. In general, the aim is to have a gas composition of 2-5% CO_2, 2-5% O_2 and the rest nitrogen. However, Optimal O_2-CO_2 atmosphere cannot be maintained by use of most of the films, especially when the produce has a very high level of respiration. One solution to this problem is to make microholes of a defined size and defined number in the matter to avoid anaerobiosis.

Selection of the most suitable atmosphere depends on cultivars, stage of maturity, environmental and cultivation parameters. No one atmosphere is best for all reduce, specific recommendations and cautions must be determined for each crop over the range of storage temperature and periods.

Storage: Chilling is an important preservative hurdle, as is the control of humidity. Storage at 10°C or above allows most bacterial pathogens to grow rapidly on fresh cut vegetables. Storage temperature is also important when MAP or vacuum packaging is used. Toxin production by *Clostridium botulinum*, or growth of other pathogens such as *Listeria monocytogenes*, is possible at temperatures above 3°C because of increased oxygen consumption in the package. Processing, transport, display and intermediate storage should all be at the same low temperature (preferably

2–4°C) for produce not vulnerable to chilling injury. Changes in temperature should be avoided. Higher temperatures speed up spoilage and facilitate pathogen growth. Fluctuating temperatures cause in-pack condensation which also accelerates spoilage. Temperature abuse is a widespread problem in the distribution chain, whether in storage, transportation, retail display and consumer handling. Where this is a significant problem, it may be necessary to restrict shelf-life, for example to 5–7 days at a temperature of 5–7°C, when psychrotrophic pathogens have insufficient time to multiply and produce toxin. If the shelf-life of vacuum or MAP products is greater than 10 days, and there is a risk that the storage temperature will be over 3°C, products should meet one or more of the following controlling factors:

- a minimum heat treatment such as 90°C for 10min
- a pH of 5 or less throughout the food
- a salt level of 3.5% (aqueous) throughout the food
- a_w, water activity value of 0.97 or less throughout the food.
- any combination of heat and preservative factors which has been shown to prevent growth of toxin production by *C. botulinum.*

Factors affecting the washing of fresh-cut fruits and vegetables

Contact time: The contact period needs to be consider for an effective operation. Generally, chilled water is required for rinsing the peels and fresh-cut fruits and vegetables. Thus it is one way to cool the products before further processing and their packaging.

Temperature: Temperature needs to be controlled for avoiding the spoilage at preliminary step. It should be maintained at around 0 °C.

Chlorination: Optimum concentration of chlorine needs to be used. The concentration of chlorine should be kept between 50 and 100 ppm. However, higher concentration of chlorine can affect the quality of the peeled fruits and vegetables.

Proper kits for chlorine testing should be used for controlling chlorine level in water.

pH: Optimum controlled pH is required for maintain the bactericidal activity of chlorinated water. If the pH rise above 7.5, the antibacterial effect would be vanished and spoilage of the products can occur due to microbial growth.

Effect of minimal processing on nutrition

In addition to sensory attributes, nutritional and health functional components also determine products' key quality parameters. These further rely on the climatic conditions, harvesting operations, and methods of harvesting as well as the processing steps used, such as cutting, shaping, packaging, speed of operations as churning, cooling, and mixing. Functionality of the treated products is largely dependent on the bioactive compounds and antioxidant capacity.

Microbial safety of fresh-cut minimally processed fruits and vegetables

During peeling, cutting and shredding, the surface of the produce is exposed to the air and to contamination with bacteria, yeasts and moulds. In minimally processed fruits and vegetables, most of which fall into the low acid range category (pH 5.8–6.0), high humidity and the large number of cut surfaces can provide ideal conditions for the growth of microorganisms. The populations of bacteria found on fruits and vegetables vary widely. The predominant microflora of fresh leafy vegetables are *Pseudomonas* and *Erwinia* spp., with an initial count of about 10^5 cfu g^{-1}, although low numbers of moulds and yeasts are also present. During cold storage of minimally processed leafy vegetables, pectinolytic strains of Pseudomonas are responsible for bacterial soft rot. An increase in storage temperature and carbon dioxide concentration in the package will shift the microflora towards lactic acid bacteria. The high initial load of microbes makes it difficult to establish the cell number threshold beyond which the product can be considered spoiled. Many studies show that a simple correlation does not exist between spoilage chemical markers such as pH, lactic acid, acetic acid, carbon dioxide, sensory quality and total microbial cell load. In fact, different minimally processed vegetable products seem to possess different spoilage patterns in relation to the characteristics of the raw materials. Because minimally processed fresh vegetables are not heat treated, regardless of additives or packaging, they must be handled and stored at refrigerated temperatures, at 5°C or under in order to achieve a sufficient shelf-life and microbiological safety. Some pathogens such as *Listeria monocytogenes*, *Yersinia enterocolitica*, *Salmonella* spp. and *Aeromonas hydrophila* may still survive**.**

Key requirements in the minimal processing of fruits and vegetables

- Raw material of good quality (correct cv. variety, correct cultivation, harvesting and storage conditions)
- Strict hygiene and good manufacturing practices, HACCP
- Low temperatures during working
- Careful cleaning and/or washing before and after peeling
- Water of good quality (sensory, microbiology, pH) used in washing
- Mild additives in washing for disinfection or browning prevention
- Gentle spin drying after washing
- Gentle peeling
- Gentle cutting/slicing/shredding
- Correct packaging materials and packaging methods
- Correct temperature and humidity during distribution and retailing

Application of Non-thermal Methods in Minimal Processing

Non-thermal processing techniques are emerging in the food industry. These techniques are extended their potential to food preservation with limiting losses of the nutritional and sensory characteristics. These are high hydrostatic pressure, pulsed electric fields, high intensity pulsed light, pulsed white light, high power ultrasound, oscillating magnetic fields, irradiation, and microwave processing. All these techniques have provided a reliable alternative for processing of liquid foods, such as beverages, juices, soups, purees along with solid whole fruits and vegetables and packaged foods. Numerous reports have been published on the high hydrostatic pressure and pulsed electric fields for inactivating the lethal micro-organisms and enzymes. Apart from their microbial inactivation, these are used to extract bioactive compounds, such as polyphenols, flavonoids, hydroxycinnamic acids and. These are termed as non-thermal methods & temperature of processing remained within 30–55 °C. The low temperature safeguards the heat labile components, such as vitamin C, and pigments (e.g. carotenoids).

Pulsed electric field processing: The concept of treating foods with pulsed electric fields was introduced in 1960. Initially the technique was confined to kill microorganisms with optimized parameters such as electric field, pulse shape, pulse width and treatment time. In PEF processing, food products are subjected to a high voltage electrical field such as 20–70 kV/cm for a few microseconds. Earlier the principle of electroporation was proposed stating puncturing the cell membrane of the organisms. Afterwards, PEF was tested on the juices instead of the buffer solutions to inactivate the microorganisms and to have the increased shelf life of juices. PEF technology inactivates or kills a number of vegetative bacteria however; it is not effective to inactivate the spores at ambient temperatures. During the last decade, the new scope of PEF has been evolved for enhanced mass transfer.

Hazards, critical control points, preventative and control procedures in processing and packaging of ready-to-use fruits and vegetables

Critical operational step	Hazards	Critical control point(s)	Preventative and control measures
Growing	Contamination with faecal pathogens	Cultivation techniques	– Inspect the sources of – irrigation water
	Insects and fungal invasions		– Use pesticides
Harvesting	Microbial spoilage and insect invasion	Assesment of produce maturity	– Harvest prior to peak maturity – Minimise mechanical injuries
		Handling practices Temperature control	– Harvest in the morning or at night
	Cross-contamination	Sanitation	– Employ pickers trained in elementary hygiene
Transporting	Microbial growth	Time/temperature	– Keep the temperature – low Avoid long distance transport – Maintain uniform cooling in transport – containers Avoid
	Cross-contamination	Loading practices	damage, do not – overload the containers Separate sound and injured
		Produce	produce in the field

		Containers	– Use well washed/disinfected metal or plastic containers
Washing	Contamination from water	Water	– Use potable water, test routinely for the presence of coliform
		Washing practices	– bacteria Control microbial contamination by chlorination and – antimicrobial dipping Do not overload the
		Dewatering	washing tanks/change – the water periodically Remove excess water
Sorting	Cross-contamination	Sorter	– Employ sorters who have experience on the inspection of produce
		Lighting	– Provide adequate lighting
		Conveyer	– Clean and disinfect periodically
Packaging	Microbial growth	Packaging film	– Choose the permeability of film correctly – Analyse gas composition routinely by using simple techniques – Use fungicide impregnated film
		Relative humidity and temperature control	– Dewater the drenched produce carefully – Use films which have antifogging properties – Check product/storage temperature at regular

			intervals
Storage/ Distribution	Growth and spread of micro-organisms	Temperature control	– Maintain the refrigeration of produce in the range of 0–5°C
			– Prevent moisture condensation by proper temperature control
		Light	– Take the effect of light into consideration
		Consumer practice	– Provide labelling with instructions for storage conditions

(Source: Gorris, 1996)

PEF was advanced for inactivating or killing of organisms in the juices to an accepted level, and it was diverted to apply for retaining the nutritional parameters. Since PEF is one of the non-thermal processing techniques, the temperature remains between 30 and 50 °C that enables the significant retention of nutrients. There are several reports, which described the potential of preservation or pasteurization of a variety of liquid foods; however, it still seems premature to recommend its use in fresh cut fruits and vegetable products.

High pressure processing (HPP) It is also referred to "high hydrostatic pressure processing" or "ultra-high pressure processing", in which the elevated pressures (up to 600 MPa), with or without the addition of external heat (up to 120 °C), is used to achieve microbial inactivation or to alter food attributes without affecting flavor compounds and vitamins. It is mainly based on the inactivation of the microbial and enzymatic spoilage by exerting pressure. High pressure induces stress on the membranes and prevents them to come in their active state. However, the microbial resistance to pressure varies significantly as per the range of the applied pressure and temperature, treatment period, and types of microbes. It also effects texture of the foods and various researchers are in the process of overcoming hindering aspects in order to make usage of the HPP technology. Interestingly, HHP is used to restructure the food proteins and it results in denaturation, aggregation or gelation of the protein. The microbial infection and enzymatic browning have been identified as major challenges in fresh cut processing, which directly influence the consumers' acceptance. HPP inactivates vegetative microbial cells at ambient temperature conditions without affecting the nutritional and sensory qualities. Enzymes such as polyphenol oxidase (PPO), peroxidase (POD), and pectin methylesterase (PME) are highly resistant to HPP and are at most partially inactivated under commercially feasible conditions, although their sensitivity towards pressure depends on their origin as well as their environment. Polygalacturonase (PG) and lipoxygenase (LOX) on the other hand are relatively more pressure sensitive and can be substantially inactivated by HPP at commercially feasible conditions. The retention and activation of enzymes such as PME by HPP can be beneficially used for improving the texture and other quality attributes of processed fruit and vegetable products as well as for creating novel structures that are not feasible with thermal processing.

Natural Antimicrobials

Although synthetic antimicrobial and antioxidant agents are approved in many countries, the use of natural safe and effective preservatives are in demand by the consumers and producers. Therefore, many European and Asian countries are exploiting natural ingredients that can protect the food against the deterioration. There are a great number of natural antimicrobials derived from animal, plant, and microbial sources. The bioactive functional compounds known as secondary metabolites, obtained from plant sources, are considered as good alternatives to synthetic antimicrobial and antioxidant food additives. These constitute polyphenols, tannins, and flavonoids, which are mostly derived from plants and their antimicrobial and antioxidant in vitro effects have been reported in many publications in the last decade. The antimicrobial and antioxidant properties of bioactive molecules are mainly due to their redox properties, ability to chelate metals, and quenching reactive species of singlet oxygen. Compounds can either be coated or sprayed on the food products for their quick absorption and action. It is also important to keep the desired sensory properties when additives are used. However, the selection of the plant sources to extract these compounds must be guided for the safe use of food additives. Some key issues must be considered during the application of these natural antimicrobial agents into food products. The form of the antimicrobial, the type of food, storage conditions, types of processes used, and the target microorganism(s) are some of the important factors that could affect the efficacy of these agents.

Edible films and coatings

Another method for extending the postharvest storage life of fruits and vegetables is the use of edible coatings, that is, thin layers of material that can be eaten by the consumer as part of the whole food product. The idea is not new; edible films were already in use in 12th-century China for citrus fruit. However, once the minimal processing of foods started to gain popularity and it was recognized that packaging should be minimized for environmental reasons, interest in edible coatings increased significantly throughout the world. At least theoretically, edible coatings have the potential to reduce moisture loss, restrict the entrance of oxygen, lower respiration, retard ethylene production, seal in flavour volatiles, and carry additives that retard discoloration and microbial growth. Some patented and commercially available edible film solutions are those based on sucrose polyesters of fatty acids and the sodium salt of carboxymethylcellulose delayed water loss or browning; those based on cellulose derivatives retarded the discoloration of cut mushrooms, and the development of a physiological disorder of peeled carrots known as white blush. Carrageenan and chitosan coatings are also new coatings that have shown good shelf life extension for minimally processed fruit and vegetables.

Conclusion

The market of minimally processed foods has grown rapidly in recent years due to the health benefits and convenience associated with these foods. Its growth has increased the awareness regarding microbiological and physiological aspects associated with the quality. The consumerism tendency depends on multi-factors as nutritional value, simplicity, safety, and convenience. All these characteristics must be considered in minimal processing. There are emerging technologies and opportunities that will have far reaching impact on the market place. Advanced packaging systems and edible films, as well as more permeable plastic films which better match with the respiration of fruits and vegetables, are particularly active areas for development. Issues such as sustainability in packaging and the impact that packaging has on current food safety issues are already providing both tremendous challenges and opportunities. Much research is still needed to develop minimally processed fruits and vegetable products that have a high sensory quality, microbiological safety and nutritional value. Products intended for retailing are in particular need of further development. It seems that it is possible to achieve a shelf life of 7-8 d at refrigeration temperatures (5°C), but for some markets this is not enough: a shelf life of 2-3 weeks is sometimes necessary. More information about the growth of pathogenic bacteria and the occurrence of nutritional changes in minimally processed fruits and vegetables with long shelf life is needed. The challenge will be how to incorporate all of the desired requirements into a better and shelf-stable minimal processing solution for fresh-cut fruits and vegetables.

Suggested Books

- Robert C. Wiley (1994). Minimally processed refrigerated fruits and vegetables Chapman & Hall. England.
- Thomas Ohlsson and Nils Bengtsson (2002). Minimal processing technologies in the food industry. Woodhead Publishing Limited and CRC Press LLC. North America.

NEW PACKAGING TECHNIQUES FOR SELECTED HORTICULTURAL PRODUCE

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Abstract

Modified atmospheric packaging is a common practice to minimise postharvest losses and extend shelf life of the produce. Even under modified atmosphere the control of respiration rate of the produce is limited. Optimal packaging micro environment can be adversely affected by dynamic changes in temperature and relative humidity throughout the storage period and under transportation. As an alternative, active packaging technologies provide interactive controls between the produce, package and surrounding environment to achieve and retain optimal atmospheric conditions inside the packages. Various active packaging technologies have been developed and are commercially available for a range of food products including horticultural produce and the combination of these with other postharvest management strategies offers benefits to extend shelf life.

Modified atmospheric packaging (MAP)

Modified atmosphere packaging (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'. MAP is the replacement of air in a pack with a single gas or mixture of gases; the proportion of each component is fixed when the mixture is introduced. No further control is exerted over the initial composition, and the gas composition is likely to change with time owing to the diffusion of gases into and out of the product, the permeation of gases in to and out of the pack, and the effects of product and microbial metabolism **(Church, 1994).** The normal composition of air is 21% oxygen, 78% nitrogen and less than 0.1% carbon dioxide (Fig. 2). Modification of the atmosphere within the package by reducing the oxygen content while increasing the levels of carbon dioxide and/or nitrogen has been shown to significantly extend the shelf-life of perishable foods at chill temperatures.

The application of novel high oxygen (O_2) MAP is a new approach for the retailing of fresh prepared produce items and is capable of overcoming the many inherent shortcomings of current industry-standard air packaging or low O_2 MAP. The results from an extensive European Commission and industry funded project have shown that high O_2 MAP is particularly effective at inhibiting enzymic discolorations, preventing anaerobic fermentation reactions and moisture losses, and inhibiting aerobic and anaerobic microbial growth.

Gases used in MAP

The three main gases used in MAP are O_2, CO_2 and N_2. The choice of gas totally depends upon the food product being packed. It can be used as single or in combination, these gases are commonly used to balance safe shelf life extension with optimal organoleptic properties of the food. Noble gases such as argon are in commercial use for products such as coffee and snack products, however, the literature on their application and benefits is limited. Experimental use of carbon monoxide (CO) and sulphur dioxide (SO_2) has also been reported.

Effect of the gaseous environment on the chemical, biochemical and physical properties of foods

Food spoilage can also be caused by chemical and biochemical, including enzyme-catalysed, reactions in food. The packaging technologist should have an awareness of these effects and understand the extent to which modified atmospheres can mitigate them. Of the gases involved in MAP, O2, because of its reactivity, has been extensively studied. Because of the significance of O2, this section will largely be concerned with the influence of this gas. However, CO_2, and to a lesser extent CO and ethylene (C2H4), have also been investigated.

Fig 2. MAP storage of cut fruits and vegetable in Punnets boxes

Machine Systems for MAP

The first element for optimum gas packaging is appropriate equipment. There are two different techniques to replace the air:

1) Gas flushing

2) Compensated vacuum.

The gas flush technique is normally accomplished on a form fill-seal machine. The replacement of air inside a package is performed by a continuous gas stream. This gas stream dilutes the air in the atmosphere surrounding the food product. The package is then sealed. Since the replacement of air inside the package is accomplished by dilution, there is a limit on the efficiency of this unit. Typical residual oxygen levels in gas flushed packs are 2-5% O2. Therefore, if the food item to be packaged is very oxygen sensitive, the gas flush technique is normally not suitable. So when considering a packaging system it is important to consider the oxygen sensitivity of the food product. The great advantage of the gas flush technique is the speed of the machine. Since the action is continuous, the product rate can be very high. The compensated vacuum technique removes the air inside by pulling a vacuum on the atmosphere inside the package and then breaking the vacuum with the desired gas mixtures. Since the replacement of the air is accomplished in a two-step process, the speed of operation of the equipment is slower than the gas flush technique. However, since the air is removed by vacuum and not simply diluted, the efficiency of the unit with respect to residual air levels is better. Therefore, if the food product is extremely sensitive to oxygen, a compensated vacuum machine must be used.

Passive modified atmosphere: Modified atmospheres can passively evolve within a hermetically sealed package as a consequence of a commodity's respiration, i.e. O2 consumption and CO2 evolution. If a commodity's respiration characteristics are properly matched to film permeability values, then a beneficial modified atmosphere can be passively created within a package. If a film of correct intermediary permeability is chosen, then a desirable equilibrium modified atmosphere is established when the rates of O2 and CO2 transmission through the package equal a product's respiration rate.

Active packaging: By pulling a slight vacuum and replacing the package atmosphere with a desired mixture of CO_2, O2 and N2, a beneficial equilibrium atmosphere may be established more quickly than a passively generated equilibrium atmosphere. Another active packaging technique is the use of O2, CO_2 or ethylene scavengers/emitters. Such scavengers/emitters are capable of establishing a rapid equilibrium atmosphere within hermetically sealed produce packages.

Table 2. MAP gas composition of selected fruits and vegetables.

Type of product	Package film	MA composition		Temp. (°C)	Storage time in MAP	References
		% O_2	% CO_2			
Apple (cv. Bravo de Esmolfe)	Polyproplylene (PP)	5	3	2	6.5 months	Rocha et al. 2004
Apple (cv. Cox's Orange Pippin)	Low-density polyethylene (LDPE)	3	3	4	5 weeks	Goulas 2008
Apple (cv. Fuji)	PP, polyvinyl Chloride (PVC)	5	4	10	7 months	Guan Wen et al. 2004
Mushroom (U3 Sylvan 381)	Plastic containers (26 L) with diffusion windows	5	10	4	12 days	Techavises and Hikida 2008
Mushroom	Non-perforated PVC	10.0–15	2.5	4	7 days	Simón et al. 2005
	PP1	20	2.5	4		
	PP2	<0.1	15	4	13 days	
Mushroom	PVC					Kim et al. 2006
	Polyolefins PD-941					
	polyolefins PD-961					
Litchi (cv. Mauritius)	Biorientated polypropylene-1 (BOPP-1)	11.47	12.07	2	34 days	Sivakumar and Korsten 2006
	Biorientated polypropylene-2 (BOPP-2)	6.53	19.07	2		
	Biorientated polypropylene-3 (BOPP-3)	17	6	2	34 days+2 days at 14 °C	
Litchi	Laminated polyethylene	15	5	1.5	4 weeks	Pesis et al. 2002
Litchi (cv. McLean's Red)	BOPP	16	6	2	18 days	Sivakumar et al. 2008
Tomatoes (cv. Calibra)	Pasive PP	11–13 kPa	5.5–6 kPa	0	14 days	Aguayo et al. 2004
		8–9.5 kPa	10.5–11.5 kPa	5		
	Active PP	7–10.5 kPa	7–9 kPa	0		
		7–10.5 kPa	7–9 kPa	5		

Modification of the pack atmosphere

Gas flushing

This method employs a continuous gas stream that flushes air out from the package prior to sealing. This method is less effective at flushing air out of the pack, and this results in residual oxygen levels of 2–5%. Gas flushing is therefore not suited for oxygen-sensitive food products.

Generally, gas flushing machines have a simple and rapid operation and therefore a high packing rate.

The effect of MAP on the nutritional quality of non-respiring food products

By using modified atmosphere packaging, the shelf-life of the packaged products can be extended by 50–200%, however, questions could arise regarding the nutritional consequences of MAP on the packaged food products. This section will discuss the effect of MAP on the nutritional quality of non-respiring food products while the effect of MAP on the nutritional value of respiring products, such as fresh fruits and vegetables, will be discussed in detail in the following sections. Very little information is available about the influence of MAP on the nutritional quality of non-respiring food products. In most cases, for packaging non-respiring food products, oxygen is excluded from the atmosphere and therefore one should expect a retardation of oxidative degradation reactions. Moreover, modified atmosphere packaged food products should be stored under refrigeration to allow CO2 to dissolve and perform its antimicrobial action. At these chilled conditions, chemical degradation reactions have only a limited importance. No information is available regarding the nutritional consequences of enriched oxygen concentrations in modified atmospheres which can be applied for packaging fresh meat and marine fish. Some oxidative reactions can occur with nutritionally important compounds such as vitamins and polyunsaturated fatty acids. However, no quantitative information is available about these degradation reactions in products packaged in O2 enriched atmospheres.

Quality assurance of MAP

Examples of instruments used in quality assurance of MAP are discussed in this section. These are provided by way of example and are not intended to be recommendations by the authors.

Packaging materials

Selection of the most appropriate packaging materials is essential to maintain the quality and safety of MAP foods. Flexible and semi-rigid plastics and plastic laminates are the most common materials used for MAP foods. Plastic materials account for approximately one-third of the total materials demand for food packaging applications, and their use is forecast to grow.

Relative ease of forming, light weight, good clarity, heat sealing and strength are some of the properties of plastics that make them suitable as food packaging materials. Advances in polymer processing have enabled the development of plastics that are better suited to particular food packaging applications. However, no single plastic possesses the properties that make it suited to all food packaging applications. Plastic packaging materials may consist of a monolayer formed from a single plastic, but most, if not all, MAP films are multilayer structures formed from several layers of different plastics. Using co extrusion, lamination or coating technologies, it is possible to combine different types of plastic to form films, sheets or rigid packs. By carefully selecting each component plastic, it is possible to design a material which possesses the key properties of packaging importance to best match the requirements of the product/package system. Plastics packaging for MAP applications is most commonly found in the form of flexible films for bags, pouches, pillow packs and top webs or as rigid and semi-rigid structures for base trays, dishes, cups and tubs. Commonly used plastic flexible laminates are produced from polyethylene (PE), polypropylene (PP), polyamide (nylons), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polyvinylidene chloride (PVdC) and ethylene vinyl alcohol (EVOH). Rigid and semi-rigid structures are commonly produced from PP, PET, unplasticised PVC and expanded polystyrene.

Application of MAP to Fruit and Vegetables

There are many advantages of MAP fruit and vegetables, but the most obvious one must be the extension of shelf-life. By decreasing the amount of available oxygen to the produce, the respiration rate and the rate of all metabolic processes are correspondingly decreased. This result in delayed ripening and senescence, which may be seen as chlorophyll retention, delayed softening and the prevention of discoloration. The extension of shelf -life is most noticeable with prepared products; this, combined with ease of use for the consumer, makes a MAP pack an attractive form of product presentation. Additionally, MAP packs reduce the quantity of water vapour lost from the produce. Although fresh fruit and vegetables have been removed from the parent plant and from their normal nutrient supplies, they will continue to respire. Under normal aerobic conditions, the rate of respiration of a product may be determined by either oxygen uptake rate or carbon dioxide production rate. A high respiration rate is usually associated with a short shelf -life. When the rate of packaging film transmission of oxygen and carbon dioxide equals the rate of respiration of the product, an equilibrium concentration of both gases is established.

The equilibrium values attained depend on:

a) The respiration rate of the product

b) Fill weight of product

c) The film surface area which is available for gas exchange

The respiration rate of the product is influenced by:

a) Storage temperature

b) Produce variety

c) Growing area and conditions

d) Injury to the produce

Chill temperatures are generally chosen for fresh produce because fruit and vegetables respire slowly at low temperatures, as do many micro-organisms, which are likely to spoil the product (Day, 1989). Some fruits and vegetables, most notably ones from tropical or sub-tropical areas, are susceptible to chilling injury.

Active packaging

Active packaging has been investigated for more than 40 years, or ever since passive packaging embracing oxygen and water vapour barriers became important to the protection of food and beverage products during distribution, that trek from the end of the production line to the consumer's tummy. The main purpose of food packaging is to protect the food from microbial and chemical contamination, oxygen, water vapour and light. The type of packaging used therefore has an important role in determining the shelf life of a food. 'Active' packaging does more than simply provide a barrier to outside influences. It can control, and even react to, events taking place inside the package.

Basic of Active packaging

Fresh foods just after harvest or slaughter are still active biological systems. The atmosphere inside a package constantly changes as gases and moisture are produced during metabolic processes. The type of packaging used will also influence the atmosphere around the food because some plastics have poor barrier properties to gases and moisture. The metabolism of fresh food continues to use up oxygen in the headspace of a package and increases the carbon dioxide concentration. At the same time water is produced and the humidity in the headspace of the package builds up. This encourages the growth of spoilage micro organisms and damages the fruit and vegetable tissue. Many food plants produce ethylene as part of their normal metabolic cycle. This simple organic compound triggers ripening and aging. This explains why fruit such as bananas and avocados ripen quickly when kept in the presence of ripe or damaged fruits in a container and broccoli turn yellow even when kept in the refrigerator. Extensive trials have shown that each fresh food has its own optimal gas composition and humidity level for maximizing its shelf life. Active packaging offers promise in this area; it is difficult with conventional packaging to optimise the composition of the headspace in a package. The atmosphere surrounding the food also influences the shelf life of processed foods. For some processed foods, a lowering of oxygen is beneficial, slowing down discoloration of cured meats and powdered milk and preventing rancidity in nuts and other high fat foods. High carbon dioxide and low oxygen levels can pose a problem in fresh produce leading to anaerobic metabolism and rapid rotting of the food. However, in fresh and processed meats, cheeses and baked goods, carbon dioxide may have a beneficial antimicrobial effect. Paper 30 – PAGE 1/5 3. Active Packaging Systems 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 (and may interact with the surface of the food) by removing gases from or adding gases to the headspace inside a package. Recent technological innovations for control of specific gases within a package involve the use of chemical scavengers to absorb a gas or alternatively other chemicals that may release a specific gas as required.

Ethylene Scavenging

A chemical reagent, incorporated into the packaging film, traps the ethylene produced by ripening fruit or vegetables. The reaction is irreversible and only small quantities of the scavenger are required to remove ethylene at the concentrations at which it is produced. A feature of this system is its pink colour, which can be used as an indicator of the extent of reaction and shows when the scavenger is used up. It is expected that the film will be produced in Australia and used as a valuable means of extending the export life of fruit, vegetables and flowers. Systems developed in other countries are already commercially available. These usually involve the inclusion in the package of a small sachet, which contains an appropriate scavenger. The sachet material itself is highly permeable to ethylene and diffusion through the sachet is not a serious limitation. The reacting chemical for ethylene is usually potassium permanganate, which oxidizes and inactivates it.

Oxygen Scavenging

The presence of oxygen in food packages accelerates the spoilage of many foods. Oxygen can cause off-flavour development, colour change, nutrient loss and microbial attack. Several different systems are being investigated to scavenge oxygen at appropriate rates for the requirements of different foods. One of the most promising applications of oxygen scavenging systems in food packages is to control meld growth. Most moulds require oxygen to grow and in standard packages it is frequently meld growth, which limits the shelf life of packaged baked goods such as cakes and crumpets and of packaged cheese. Laboratory trials have shown that meld growth on some baked products can be stopped for at least 30 days with active packaging and significant improvements in the free-free life of packaged cheese have also been obtained.

Another promising application is the use of active packaging to delay oxidation of and therefore rancidity development in vegetable oils. Again the use of discrete sachets containing oxygen absorbents has already found commercial application. In this instance the scavenging material is usually finely divided iron oxide. These sachets have been used in some countries to protect the colour of packaged cured meats from oxygen in the headspace and to slow down staling and meld growth on baked products, e.g. pizza crusts. This approach of inserting a sachet into the package is effective but meets with resistance among food packers. The active ingredients in most systems consist of a non-toxic brown/black powder or aggregate which is visually unappealing if the sachet is broken. A much more attractive approach would be the use of a transparent packaging plastic as the scavenging medium.

Moisture Control

Condensation or 'sweating' is a problem in many kinds of packaged fruit and vegetables. It is of particular concern in cartons of fresh flowers for which there is important export trade. Unless the relative humidity around flowers is kept at about 98 per cent, water will be lost from the bunches. Such high humidity levels mean there is a very real risk of condensation occurring during transport as the temperature of the flowers may fluctuate by several degrees. When one part of the package becomes cooler than another, water is likely to condense in the cooler areas. If the water can be kept away from the produce there may be little harm. However when the condensation wets the produce, nutrients leak into the water encouraging rapid meld growth. When the condensation inside packages is controlled, the food remains dry without drying out the product itself. Therefore sensitive products such as flowers and table grapes are protected from contact with water. This helps to reduce growth of meld.

Carbon Dioxide Release

High carbon dioxide levels are desirable in some food packages because they inhibit surface growth of micro organisms. Fresh meat, poultry, fish, cheeses and strawberries are foods, which can benefit from packaging in a high carbon dioxide atmosphere. However with the introduction of modified atmosphere packaging there is a need to generate varying concentrations of carbon dioxide to suit specific food requirements. Since carbon dioxide is more permeable through plastic films than is oxygen, carbon dioxide will need to be actively produced in some applications to maintain the desired atmosphere in the package. So far the problems associated with diffusion of gases, especially carbon dioxide, through the package, have not been resolved and this remains an important research topic.

Microbial Inhibitors

Ethanol

Antimicrobial activity of ethanol (or common alcohol) is well known and it is used in medical and pharmaceutical applications. Ethanol has been shown to increase the shelf life of bread and other baked products when sprayed onto product surfaces prior to packaging. A novel method of generating ethanol vapour, recently developed in Japan, is through the use of an ethanol releasing system enclosed in a small sachet which is included in a food package. Food grade ethanol is absorbed onto a fine inert powder which is enclosed in a sachet that is permeable to water vapour. Moisture is absorbed from the food by the inert powder and ethanol vapour is released and permeates the sachet into the food package headspace. This system is approved in Japan to extend the free-free shelf life of various cakes.

Sulfur Dioxide (SO_2)

Sulfur dioxide is primarily used to control meld growth in some fruits. Serious loss of table grapes can occur unless precautions are taken against meld growth. It is necessary to refrigerate grapes in combination with fumigation using low levels of sulfur dioxide. Fumigation can be conducted in the fruit cool stores as well as in the cartons. Carton fumigation consists of a combination of quick release and slow release systems, which emit small amounts of sulfur dioxide. When the temperature of the packed grapes rises due to inadequate temperature control, the slow release system fails releasing all its sulfur dioxide quickly. This can lead to illegal residues in the grapes and unsightly bleaching of the fruit. Considerable amount of work is done to develop systems, which gradually release sulfur dioxide and are less sensitive to high temperature and moisture than those presently used. These systems have potential use for fresh grapes and processed foods permitted to contain sulfur dioxide such as dried tree fruits and wine.

Other Developments

The examples given above are only some of the commercial and non-commercial applications of active packaging. This technology is the subject of research in many countries and rapid developments may be expected. Other systems of active packaging which are either already available or could soon be seen in the market place include:

• Sachets containing iron powder and calcium hydroxide, which scavenge both oxygen and carbon dioxide. These sachets are used to extend the shelf life of ground coffee.

• Film containing microbial inhibitors other than those noted above. Other inhibitors being investigated include metal ions and salts of propionic acid.

• Specially fabricated films to absorb flavours and doors or, conversely, to release them into the package.

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SECONDARY PROCESSING OF FRUITS AND VEGETABLES INTO VALUE ADDED PRODUCTS

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Introduction

India is the second largest producer of fruits and vegetables in the world after China with quantum post-harvest losses of around 25-30%. Roughly around 6% of the total fruit & vegetable production is processed into value added products in India. Secondary processing of fruit and vegetable into semi-finished products like pulps and juices is an important part to handle glut during the fruit harvesting season. During off-season these semi-finished products (raw pulp and juices) can be converted to finished products such as squashes, ready to serve drinks (RTS), nector, cordial etc. In this regard processing and preservation forms major pillars of food industry.

World trade of fruit and vegetable juice averaged nearly US$4,000 million during last decade (FAOSTAT, 2005). India exported 9.84 lakh tonnes of processed foods comprising of mango pulp, juices, concentrates, alcoholic and non-alcoholic beverages etc worth Rs 2,757.74 crores (MoFPI, 2010). Whereas during the year 2012-13, India exported processed food products worth Rs. 41,309.04 crores, which included major products like mango pulp (Rs.607.96 Crores), alcoholic and non-alcoholic beverages (Rs. 1932.73 Crores) and other processed products (MoFPI, 2013). The importing countries are USSR, Yemen, UK, UAE, Saudi Arabia, Kuwait, Germany, USA, Holland and Switzerland. Thus there is a good scope for processing of fruit and vegetables into different products to reduce wastage and earn foreign exchange.

Table1. Profile of fruit and vegetable products developed in India

Horticultural produce	Product
Tomato	Pulp, Puree, Sauce/Ketchup
Apple	Juice/Concentrate
Citrus fruits	Squash/cordial
Fleshy fruits	Pulp, Juice, Nectar
Guava	Jelly
Onion	Powder/Paste
Potato	Chips
Garlic	Powder/Paste
Ginger/Turmeric	Powder
Mango	Powder (amchur)
Mango/Jackfruit/Guava	Fruit leather
Apple	Chips
Papaya/Pumpkin	Candy
Mango, citrus fruits, vegetables like carrots, Jackfruit, Cauliflower etc.	Pickles
Cabbage	Sauerkraut (by lactic acid fermentation)

Source: Maini and Anand (2006)

Processing of fruits and vegetables

Food processing covers all the processes that food items go through from the farm till it reaches to the consumer's plate. Generally processing of fruit and vegetable is carried out in following three different forms:

1. **Primary processing:**

Simple primary processing operations like sorting, trimming, grading, washing, surface drying and packaging can be used to prepare fruit and vegetables for immediate marketing. The purpose of primary processing is to clean the contaminant from the raw material by removing skin breaks, bruises, spots, rots, decay, other deterioration and making the raw material suitable for processing by grading in different lots or conversion of raw material into the form suitable for secondary processing. The available equipment and technologies for various unit operations of primary processing include farm level fruit and vegetable washing machine, basket centrifuge, shrink packaging of fruit and vegetable and hydro cooler-cum-washer for fruits and vegetables, vegetable dryer, tamarind dehuller and deseeder, pomegranate aril remover cumin cleaner-cum-grader, turmeric washing and polishing machine *etc*.

2. Secondary processing

It is generally referred to processing of primary processed raw material into product which is suitable for uses as food or consumption after drying, dehydration, cooking etc.

i) Drying: Drying is the oldest and cheapest method of preservation of horticultural produce. Significant information is available on the use of solar drier for drying of fruits, vegetables, plantation crops and spices. However, medicinal and aromatic plants can be dried in solar drier, poly tunnel solar drier or mechanical drier.

ii) Osmotic dehydration: Osmotic dehydration consisting of partial removal of water by dipping in sugar syrup prior to washing in a mechanical dehydrator is now a standard accepted practice for preparation of intermediate moisture products with acceptable sensory qualities. Some fruits not otherwise fit for drying owing to inherent high acid and astringent taste can also be dried by using this technique.

iii) Processing of lesser utilized fruits: Large quantities of lesser utilized horticultural crops like bael, aonla, jack fruit, aloe vera *etc* cannot be consumed in fresh form without processing. They are known for many therapeutic/medicinal and nutritive properties. Processing of such crops can play an important role in satisfying the demand for nutritious, delicately flavoured and attractive natural foods of high therapeutic value.

- Bael fruit having hard shell and mucilaginous texture is popularly consumed as a dessert fruit in India. Bael products like ripe bael drink, squash, RTS drink, jam, bael dry powder.
- Kokum and hill lemon are not acceptable in the fresh form owing to their high acidity, while fresh aonla has a strong astringent taste.
- Aonla preserve, candy, shreds, *chayawanprash*, squash, dehydrated powder, aonla beverages, toffees etc.

iv) *Value addition*: The fruit and vegetables which cannot be sold in the fresh market can be utilized for preparation of different value added products. The value added products include juice, concentrate, fruit based carbonated juices, canning, pulp extraction, pickling, chutney and sauce, preserves and candies, beverages like squashes, RTS drinks and appetizer *etc* from different fruits and vegetables.

v) *Fermented products*: Production of alcoholic drinks like cider, wine, vermouth, vinegar *etc* is now an accepted practice for utilization of different fruits.

- Manufacture of champagne (sparkling wine), still wine and brandy from grapes is commercially practiced in the country.
- Other fermented beverages include cider, wine and vermouth from apple, plum, apricot, wild apricot, peach, strawberry, banana *etc*.

vi) *By-product waste utilization*: Fruit processing plants generate large volume of by-products in the form of pomace, seeds, stones/pits skin, peel which is thrown as a waste. Though such left over produce still contain good proportion of nutrients which can be utilized to prepare large number of value added products for industrial uses.

- Pomace can be used for extraction of pectin, dietary fibre and industrial alcohol.
- Oil extracted from fruit stones/seed left after processing of stone fruits pulp can be used for cooking of foods, pharmaceutical and cosmetic purposes.

3. Tertiary processing

It is the conversion of secondary processed material into ready to eat form.

Fruit juice and pulp

Fruit juice and beverages generally comprise of naturally extracted juices, RTS drinks, nectars, squashes, cordials and appetizers *etc*. These products are highly refreshing, thirst quenching, appetizing and nutritionally superior to many synthetic and aerated drinks. Fruit juice is the natural liquid expressed by pressure or other mechanical means from the edible portion of the fruit. Certain vegetable juices are also consumed in fresh form eg. tomato juice is the most commonly consumed vegetable juice in processed form either canned or bottled. Whereas pulp is defined as the inner edible part of a fruit or vegetable. The composition of juice and pulp is unaltered during preparation and preservation while for fruit beverages like drinks, squashes, cordial etc. the fruit juice or pulp, sugar, acid, color, flavor etc. are mixed in appropriate proportions to a desirable taste.

Method of preparation of fruit and vegetable Pulps

The fruit is washed thoroughly to remove any adhering dust and dirt. The fruit is then subjected to preliminary treatments which vary with the type of fruit such as strawberries are crushed between rollers; raspberries are steamed, crushed and passed through sieves to remove the hard cores. Plums, peach and apricots are heated with a small quantity of water until they become soft and are then passed through a wide mesh sieve to separate the stones. Fruit after softening by boiling with small quantity of water can be passed through the pulper to extract the pulp. Pears are peeled, cored and cut into small pieces. Mangoes are peeled, stones separated and then the slices are passed through a pulper. Pineapples are peeled, sliced and the cores punched. The slices are then cut into smaller pieces and passed through a screw type crusher to get a fairly coarse pulp which is suitable for making the jam.

Vegetable juices: Generally fruit juices are consumed either fresh or processed. Certain vegetable juices are also consumed in fresh form but for mostly medicinal purpose for eg. bitter gourd juice is mainly used by diabetic patients. Tomato juice is consumed in processed form either canned or bottled. Tomato is also used as soup, a warm beverage prior to meal.

Tomato and tomato products

Fresh tomatoes are highly refreshing and appetizing. They are rich source of vitamins particularly vitamin C. Commercial products from tomatoes include juice, puree, paste, ketchup, soup canned and dehydrated tomatoes. As a semi-finished product, tomato puree is prepared on a small scale while at large scale tomato paste has gained commercial significance. Both puree and paste are used for preparation of different finished products like ketchup, juice, soup etc.

Tomato juice/pulp

Plant ripened and fully red tomatoes are used for juice making. All green, blemished and over-ripe fruits should be removed. The yields, colour and flavour of the juice depend on the degree of ripeness of the tomatoes and the variety. Tomatoes pulp/juice is the basic ingredient for preparation of different tomato products such as tomato puree, paste, ketchup etc.

Method for Preparing Tomato juice/pulp

Plant ripened and fully red tomatoes are used for juice making and green, blemished and over-ripe fruits should be removed. Tomatoes are washed thoroughly with water, crushed (fluted wooden roller-crushers or fruit grater) and pulped (hot pulping or cold pulping).

1. Pulping

Tomato pulp can be extracted either by passing through the pulper after crushing without heating (cold pulping) or after boiling the crushed or whole tomatoes till softening followed by extraction of pulp in a pulper (hot pulping). During pulping, the fine juice and pulp passing through the sieves of pulper are collected while skin and seeds are separated through another end.

a) Cold pulping: It is commonly referred to as cold break process in which the tomatoes after washing are sliced or crushed in a fruit grater and immediately passed through a pulper to extract the pulp.

b) Hot pulping: It is also known as hot break process. The tomatoes after slicing or crushing in a fruit grater are boiled in pressure cooker/steam jacketed stainless steel kettle or aluminum pans till softening to facilitate pulp extraction in pulper. Hot pulping destroys the inherent enzymes (pectinase) which otherwise hydrolyze the pectin, to make the extracted juice thin in consistency.

Equipment's for juice/pulp extraction: Tomato juice/pulp is extracted either by passing the crushed tomatoes through a continuous spiral press or pulper.

a) **Continuous spiral press**: It consists of a long spiral screw which presses the tomatoes against a tapered screen of fine mesh. The juice passes through the screen while seeds and peel are removed from the lower end of the sieve.

2. **Pulper**: The pulper consists of a horizontal cylinder made of fine stainless steel. The heavy paddles inside the cylinder rotates rapidly, forcing the fine pulp to pass through the screen/sieves which is collected separately while the pieces of skin, seeds, fibre etc pass out through another end of the machine.

3. **Finishing and homogenization:** For commercial production, the juice is homogenized for separation of liquid from the pulp and to impart a thick consistency and uniform appearance. For homogenization, the juice is heated to 66ºC and forced under high pressure (70 kg/cm ^{2}).

4. **Filling:** The finished juice is heated to 82-88ºC and filled hot in pre-sterilized glass bottles or cans (plain or lacquered). The bottles are then hermetically sealed using crown corks and sterilized in boiling water (100ºC) for about 25-30 minutes. The cans are double seamed and processed in boiling water depending upon the can size.

5. Labeling and storage: After sterilization, the cans are cooled and stored in a cool dry place. Glass bottles are allowed to air cool.

Preservation by sugar

Sugar acts as a preservative by osmosis. It absorbs most of the available water and restricts the availability of water/moisture required for growth of micro-organism. The concentration of 68-70% sugar is used for preparation of jam and jellies. Sugar adds value to these products as it imparts sweetness as well as body to these products. When sugar is boiled with acid and fruits it is hydrolyzed into dextrose and fructose, the degree of inversion depending on the pH and duration of boiling. Because of inversion of sucrose, a mixture of sucrose, glucose and fructose are found in jams and jellies. Apple jam, pineapple jam, strawberry jam and mixed fruit jam prepared by using pulp of two or more fruits are quite common. Similarly, guava jelly is also examples of such products.

FRUIT JAM: Jam is prepared by boiling the fruit pulp with a sufficient quantity of sugar to a thick consistency, firm enough to hold fruit tissues in position. The method for preparation of jam and jelly is the same except that pulp and pieces of fruit are used in jam while, for jelly making clear fruit extract is used. According to FPO specifications, minimum soluble solids in the final product shall not be less than 68 percent (w/w).

FRUIT JELLY: Jelly is prepared by boiling the fruit with or without addition of water, straining the extract and mixing the clear extract with sugar and boiling the mixture to a stage at which it will set to a clear gel. The jelly should be transparent, well set, but not too stiff and having original flavour of the fruit. It should be of attractive colour and should keep its shape with a clean cut surface. In the preparation of jellies, pectin is the most essential constituent. Pectin is present in the cell wall of fruits. In order to get a good quality jelly fruits rich in pectin, but deficient in acid should be preferred.

Method for Preparation of Fruit Jelly

Selection of fruits: The fruits should be sufficiently ripe, but not over ripe and they should have good flavour. Slightly under-ripe fruit yields more pectin than over-ripe fruit; as during ripening the pectin present is decomposed into pectic acid, which does not form a jelly with acid and sugar.

Pectin requirement: Usually 0.5 to 1% of pectin in the extract is sufficient to produce a good jelly. If the pectin content is in excess, a firm and tough jelly is formed and if it is less, the jelly may fail to set. Pectin, sugar, acid and water are the four essential constituents of a jelly and must be present approximately in the following proportions: Pectin 1%, Sugar 60 to 65%, Fruit acid 1%, Water 33 to 38%.

Determination of end-point: The end-point in jelly can be judged by using following methods:

Cold plate test: A drop of the boiling liquid from the pan is taken and placed on a plate and allowed to cool quickly. If the jelly is about to set, the mixture on the plate will crinkle when pushed with a finger. The main drawback in this method is that while the drop on the plate is cooling, the jelly mixture continues to boil in the pan and there is a risk of over-cooking the product or of missing the correct setting point.

Sheet or flake test: This test is more reliable than the plate test. A small portion of jelly is taken with a large spoon or wooden ladle, cooled slightly and then allowed to drop off. If the jelly drops like syrup, it requires further concentration. Falling of the drop in the form of flakes or sheet indicates the end point.

PICKLES

The preservation of fruit and vegetables in salt and vinegar is called pickling. Pickles may be prepared without fermentation or with partial or complete fermentation. Spices, edible oil, sugar/jaggery etc. are added to improve taste and palatability of the product. Thus, pickles are good appetizer and help in digestion by stimulating the flow of gastric juices. The nutritive value of pickle varies with the kind of raw material used and method of preparation such as with or without fermentation. Mango, cauliflower, turnip, carrot (mixed vegetable), aonla, lime/lemon pickle etc. are the commercial pickles available commercially.

Pickling process

Pickling is the process of fermentation by lactic acid forming bacteria, present on the surface of the raw material. Lactic acid bacteria (active at 30ºC) convert fermentable sugar in fruit or vegetable to lactic and other volatile acids. The acid and brine acts upon vegetable tissues to produce characteristic taste and aroma of pickle. The salt and lactic acid formed preserve the pickle by preventing the growth of putrefactive bacteria provided oxygen is excluded. Fermented cucumber and olive pickles are quite common. Pickle is prepared by using either of following processes followed by finishing and packing:

a. Dry salting with curing or fermentation

b. Fermentation in brine

c. Salting without fermentation

Dry salting: The dry salt added to the prepared vegetables, extracts the juice from the vegetables and forms the brine. The brine is then fermented by lactic acid forming bacteria which serves the purpose of pickling. The method is known as dry salting.

Procedure for dry salting

1. Vegetables are washed, sliced and placed in barrel in layers to which salt is sprinkled followed by placing another vegetable layer and sprinkled with salt. Generally, 3 kg dry salt is added to each 100 kg of prepared vegetable. The salt is added in layers till the barrel is ¾ full.
2. The barrel is placed in warm and dry place to allow the fermentation to proceed within short period. Once brine is formed, fermentation and bubbles of CO_2 begin to rise from the liquid. The fermentation temperature is 27-32ºC and completes in 8-10 days.
3. When the gas bubbles cease to form, the fermentation is considered as complete. The pickle is then pressured and packed by excluding the air. Removal of air is important to avoid mould yeast (scum).

Fermentation in Brine

Immersing vegetable or unripe fruits in salt solution of known concentration for a certain length of time is called brining**.** Brining is generally used those vegetables which do not contain sufficient juice to form brine with dry salt. For example, cucumber, olives, raw mangoes etc.

Salting without fermentation

In this method raw material is packed with a large quantity of salt to inhibit fermentation. Generally, 25 kg salt is mixed with 100 kg of prepared vegetable. The cured vegetables are drained and excess salt is removed by soaking in water. After removal of salt, the vegetables are placed in vinegar 10% (100 grain) strength to reduce the vegetable to shrivel when packed in sweetened and spiced vinegar and also helps in absorption.

Types of pickles

Pickles are generally categorized into fermented pickle and partial or non- fermented pickles. Cucumber and olive pickles are examples of fermented pickles. While non-fermented pickles are of four general types depending upon the covering medium used. They are salt pickles (lime and mango), Oil pickles (Lemon, cauliflower, aonla), Vinegar pickles (garlic, green chilli), Pickle in mixture of salt, oil, spices and vinegar (cauliflower, carrot).

A. Fermented pickles: Cucumber pickle, dill pickle and olive pickle.

B. Pickles preserved with salt: Lime and mango pickle

C. Pickles in oil: Mango, chilli, mushroom, lime etc.

D. Pickle in vinegar (acetic acid*):* Garlic, green chilli, papaya etc.

E. Pickle in mixture of salt, oil, spices and vinegar: turnip, cauliflower, jackfruit, mixed vegetable pickle, etc.

Vegetable fermentation

Fermentation is one of the oldest processing techniques to extend the shelf life of perishable food and was particularly important before refrigeration. Some of the Lactic acid producing microbial strains, possessing possess protective and functional properties are mostly used as starter culture(s) for controlled and optimized production of fermented vegetable products. Fermentation of vegetables plays an important role in preservation, production of wholesome nutritious foods in a wide variety of flavors, aromas, and textures which enrich the human diet and remove anti-nutritional factors to make the food safe to eat. Various vegetables such as Chinese cabbage, cabbage, tomato, carrot and spinach are most suitable for fermentation due to presence of more fermentable saccharides. However, the most reported fermented vegetables for preparation of fermented products are categorized as follows.

(i) ***Root vegetables***: carrots, turnips, beetroot, radishes, celeriac, and sweet potato.

(ii) ***Vegetable fruits***: cucumbers, olives, tomatoes, peppers, okra, and green peas.

(iii) ***Vegetables juices:*** carrot, turnips, tomato pulp, onion, sweet potato and horseradish.

Health Benefits of fermented vegetable/foods

Processing of vegetables through fermentation approaches preserves and utilizes the vegetables. Beside this, it also leads production of beneficial enzymes, b-vitamins, Omega-3 fatty acids, and various strains of probiotics in various fermented foods. The eating of fermented food offers numerous health benefits such as prevention of cancer, obesity, constipation and health promotion. Fermented foods also have cholesterol reduction activity, fibrolytic effect, antioxidative and antiaging properties, brain health promotion, immune promotion, and skin health promotion activity.

Table. 3 Example of some vegetables used for production of fermented products worldwide.

Sr. No.	Vegetables used for fermentation	Fermented vegetable products	Country
1	Cabbage	Sauerkraut	International
2	Carrots	Kanji	India
3	Green onion	Kimchi	Korea
4	Cucumber	Jiang-gua, Khalpi, Paocai	Taiwan Nepal, India China
5	Cauliflower	Gundruk	India
6	Raddish	Kimchi Paocai Sinki	Korea China India
7	Broccoli	Yan-tsai-shin	Taiwan
8	Eggplant	Ca muoi	Vietnam
9	Bamboo	Soidon	India

Conclusion

Thus, fruit and vegetables can be utilized for preparation of variety of value added products including pulp, juice, pickles, jelly etc. Pickles acts as appetizers and add other value added products add variety to the diet. Processing industries meant for manufacture of value added products can be established in the production catchments which shall help in handling of gluts during the season and also cause savings in transportation costs besides ensuring quality raw material for processing.

MACHINE VISION APPLICATION FOR QUALITY DETECTION OF FRUITS AND VEGETABLE

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Introduction

In India, the annual production of horticultural commodity has crossed over 290 million tons for the year 2016-17. This much huge quantity makes the quality inspection and evaluation process complicated. Since its heterogeneous nature, quality evaluation is very much labour intensive, tedious and it needs of skilled & trained personnel. Machine vision is being used for non-agricultural commodities more than a decade at commercial level, since its suitability for process automation. Machine vision systems not only recognize size, shape, color, and texture of objects, but also provide numerical attributes of the objects or scene being imaged. Many applications using machine vision technology have been developed in agricultural sectors, such as land-based and aerial-based remote sensing for natural resources assessments, precision farming, postharvest product quality and safety detection, classification and sorting, and process automation. At the same time, application of machine vision in agricultural and allied sector is still in immature stage due to lack of awareness and R&D.

Quality of horticultural refers both external (shape, size, external defects and damage) characteristics and internal (firmness, sugar content, acid content and internal defects). But commercially all agricultural produce especially fruits are being graded based on the external quality factors like size, shape and visible damage. More over most of the grading is carried out manually. Manual sorting continues to be the most prevalent method used in India. Problems inherent in this system include high labor costs, worker fatigue, inconsistency, variability, and scarcity of trained labor. The paucity of available labor and increasing employment costs during the peak harvesting seasons have been identified as the important factors driving the demand for automation of the industry.

In spite of the many possibilities offered by new technologies to accurately measure the intrinsic quality characteristics of agricultural products, human beings are more flexible and adaptable to evaluate and to appreciate quality factors than machines (Paulus et al., 1997). Human visual inspection is still valuable in some agricultural product sorting operations.

Mechanical on-line grading systems are available for few commodities and all those systems are based on the external quality factors. Grading based on the internal quality parameters are promising and has gained interest from producer, processor and consumer in the recent years. A machine vision based system could replace the manual system for grading based on the internal quality parameters.

Machine Vision system

The machine vision systems works in the visible (VIS) color region as well as human invisible range such as ultraviolet (UV), near-infrared (NIR), infrared (IR) and X rays. The visible (VIS) color region may be useful to inspect the external quality, besides the invisible range may be useful to inspect the internal quality factor. Some of the advantages of machine vision technology are that it can be fairly accurate, nondestructive, and yields consistent results. Applications of machine vision technology will improve industry's productivity, thereby reducing costs and making agricultural operations and processing safer for farmers and processing-line workers. It will also help to provide better quality and safe foods to consumers. The automated inspection of produce using machine vision not only results in labour savings, but can also improve quality inspection. (Kanali et al.)

Components of Machine Vision system

A typical machine vision system consists of three principle components viz. illumination (light source), image capturing device (camera) and image analysis and decision making system. Proper illumination is very essential for a machine vision system. With a well-chosen lighting system, tedious image processing procedures can be avoided thus make the process easy to identify region of interest (ROI) from an image or scene to be recognized or analyzed. The typical example of lighting configuration is shown in Fig. which is best suitable for stationary batch imaging process. The lighting unit selection and its configuration in a machine vision system depend on the application. For imaging in the invisible range, UV light, NIR and X rays are used as illumination.

In the visible range imaging, area scan or line scan cameras are being used depend upon the process. Monochrome or RGB colour images can be captured in both type of cameras. CCD or CMOS are the two main sensors used in the monochrome as well as RGB colour image capturing.

In recent years, multispectral imaging and hyperspectral imaging are gaining much interest in R&D field, both consists of a set of several images, each acquired at a narrow band of wavelengths. Multispectral images can be obtained by capturing a series of spectral images (Kim et al., 2001). while hyperspectral imaging combines the features of imaging and spectroscopy to acquire both spatial and spectral information from an object. The technique yields much more useful information than other imaging techniques, because each pixel on the image surface possesses a spectral signature of the object at that pixel.

The captured image is analysis and decision making is performed with a computer or microprocessor or a PLC system. Image analysis may consist of image enhancement, feature extraction, and feature classification. Image enhancement procedures includes morphological operations, filters, and pixel-to-pixel operations are generally used to correct inconsistencies in the acquired images. Image feature extraction is a statistical procedures starting from mean, standard deviation to more complex measurement such as principle component analysis. Once image features are identified, then image feature classification is done by numerical techniques such as neural networks and fuzzy inference systems. The decision making system is working effectively with the help of these neural networks and fuzzy inference systems.

Application of Machine vision on Horticultural commodities

Agricultural produce and products are graded based on two inspection types namely; agricultural external grading systems and agricultural product grading based on internal quality assessment which has gained untold prominence in the recent past. In a machine vision system, both factors can be used either separately or together.

In quality inspection, the need for automation is higher and suitability would be more for horticultural produce when compare to other agriculture and allied products using machine vision techniques. The fresh produce as well as processed products has to be analysed for its quality. The fruits mainly apples and mangos are being exported as a fresh produce and it fosters foreign currency reserve considerably. Machine vision may be best adopted for classification and grading fresh produce where manual visual inspection may not be easy. Many researcher (Table.1) reported about the adoptability of machine vision for horticultural produce like apples, oranges and other high commercial value products. So the manufacturers and exporter fresh produce and process products can make more profit with the help of machine vision.

Table. 1: Reported researches of machine vision on agriculture and allied products

S.I No.	Commodity	Application	Methodology	References
1	Apple	Classification	Morphological operations	Stajnko and Emelik (2005), Stajnko et al.(2004), Kleynen et al.(2005), Throop et al.(2005), Bennedsen et al.(2005), Unay and Gosselin (2006).
		Defects detection	Mahalanobis distances comparition of pixel by pixel	Leemans (1998)
2	Chilli	Sorting based on width	photodiode scanner with laser line generator	Federico Hahn (2005)
3	Citrus fruits	Visual Inspection and grading	Morphological operations	Blasco et al.(2004), Go´mez et al.(2007)
4	Kiwifruits	fruit shape clasification	quantitative classification	Majid Rashidi et al.(2007),
5	Mushrooms	Disease detection	Colour Intensity Normalization	Vı´zha´nyo´ and Tillett (2009)
6	Oil Palm Fruits	Ripening classification	RGB colour intensity differences	Meftah Sallem M et. al.(2008),

		Quality Evaluation	Colour comparision	Kondo, N (1996)
7	Oranges	Classification	Thinning process	Ruiz, L.A.(1996)
8	Peaches and Pears	Maturity	Colour analysis	Miller and Delwiche (1989)
9	Pomegranate Arils	Sorting	Linear Discriminant Analysis (LDA) in RGB space	Blasco et al.(2004)
10	Potatoes	Grading	Fourier analysis based shape separation	Tao et al.(1995)
11	Tamarind	Grading	Morphological operations	Jarimopas and Jaisin (2000)
12	Tomatoes	Seedling quality	Adoptive thresholding technique	
		Grading	Chromatic and textural classification	Lino et al.(2008)

Benefits and bottlenecks

The machine vision technology is precise, quick responsive, this would be more accurate than manual inspection. The manual inspection is susceptible to human error, high variability and highly depend upon the inspecting person. In contrast the machine vision inspection of food products may be consistent, efficient and cost effective. Quality control in combination with the increasing automation is possible in all fields from maturity detection and harvesting to packaging defects and control. Another benefit of machine vision systems is the nondestructive in which information is attained

Besides of these advantages, the machine vision has some of the bottlenecks too. While dealing with the agricultural and allied products, due to its biological versatility and heterogeneous in nature, object identification and quality evaluation is considerably more difficult. Most of the machine vision methods are developed and evaluated under controlled conditions, but this may not be suitable and practically feasible in all cases. To overcome these bottle necks effective and efficient system may be developed which suits at commercial level.

Conclusion

Several techniques of machine vision have been studied, considering the wide scope of activities related to the agriculture and food segment, from the cultivation on the fields to the manufactured food products, encompassing the use of several aspects of vision through the computer in a wide variety of conditions for the acquisition of data and processing. Machine vision systems would be rapid, hygienic, and economically viable for agriculture and allied sectors. However, difficulties still exist, evident from the relatively slow commercial uptake of computer vision technology in all sectors. Besides, the main problems related to the techniques of computational vision have been clearly identified, demonstrating that there is still much work to the done, in order to obtain more reliable results (Juliana F.S.G and R L Fabiana., 2012). Except few, most of the study were limited within the image processing or batch type/lab scale inspection system.in order to develop improved system which suits to commercial level, more emphasis to be given on instrumentation and controls with the machine vision system.

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PLASTICULTURE TECHNOLOGIES BASED ON RENEWABLE ENERGY FOR COLD STORAGE DEVELOPMENT

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Introduction

The renewable potential in India is estimated to be more than 245 GW with over 100 GW of solar energy potential. Various forms of renewable energies contribute to this massive potential. Many sectors including food storage/cold chain can strive for energy security by adopting renewable energy. India's electricity sector is amongst the world's most active players in renewable energy utilization As of March 2013, India had an installed capacity of about 32.7 GW of new and renewable technologies based electricity. In the last year wind sector achieved an important milestone as it completed 20 GW of installations. Solar PV has been expanding exponentially in the last few years and achieved an installation of 2.6 GW. Solar has the benefit of ease of implementation, irrespective of the location as compared to wind and hence it is seen as an alternative to grid electricity or even diesel. Renewable energy is now becoming technologically and economically sound alternative to grid power and can be deployed in far remote places at competitive price and to the scale required. Globally, investments in renewable energy sector are being done at par with traditional energy generation. In the last year in RE sector alone global investments have been 254 billion dollars investment in India standing at 6.5 billion dollar . In new capacity addition, India stands at 6th place globally . Entrepreneur in cold chain sector can evaluate the options available for powering through RE for reliability and profitability by reducing wastage. Options available are detailed in next section.The Government of India has set a target of 175 GW renewable power installed capacity by the end of 2022. This includes 60 GW from wind power, 100 GW from solar power, 10 GW from biomass power and 5 GW from small hydro power.61% of the renewable power came from wind, while solar contributed nearly 19% (MNRE, 2016). India being a country where agriculture sector is one of the key contributors in the National GDP, hence the storage and processing of the harvest is very critical. The cooling of majority of fruits and vegetables needs to be done even before it is transported so as to maintain the freshness and prevent from immediate deterioration. India is the largest producer of fruits and milk, second largest producer of vegetables, and third largest producer in the fishing sector in the world. Post-harvest losses mainly on account of lack of proper storage and transit facility, account for about 25-30% losses, besides deterioration in quality. Perishable nature of produce requires a cold chain arrangement to maintain quality and extend the shelf life if consumption is not meant immediately after the harvest. The cold storage facilities for India's agricultural produce are short by more than 10 million tons. Due to unreliable grid power supply, most of the current cold storages use grid power hybridized with DG sets. Additionally the energy expenses account for 28% of costs in cold storages. A report commissioned by the Planning Commission of India to study the reasons for post-harvest losses in the key agricultural states like UP and Bihar points to lack of reliable power supply in these states. Cold storage facilities at the farms does not exist or it is in very bad shape as most of the agricultural sector is in the rural areas and hence do not have continuous access to good quality grid power; the fact remains that a majority of India's villages are un-electrified and most of the electrified villages receive very little power supply during off-peak hours

India is the second largest producer of horticultural commodities in the world wherein 93.707 million metric tonnes of fruits and 176.177 million metric tonnes of vegetables were produced during the year 2016–17 (National Horticulture board). India supports nearly 16% of world's population with 2.4% land resource and 4% water resource and lately the dwindling quality and the vagaries of the availability of these resources are raising serious questions on the sustainability of the agricultural practice. To counter the problem, efforts need to be redirected to improve the productivity of the land, efficiency of the supply chain while reducing the carbon footprint, by efficient usage of fertilizers, as a result of agricultural practice. Plasticulture, which is use of plastic in agricultural practice, is an answer to this rallying cry. Plasticulture is a scientific way of carrying out agriculture, which not only improves the productivity, but optimizes the input resources as well, thereby reducing the cost. Plasticulture can play a key role in energy conservation. It essentially stresses on the use of plastics in agriculture, horticulture, water management, food grains storage and related areas. A multitude of plastic materials may be employed in plasticulture applications such as water conservation, irrigation efficiency, crop protection, including farm output practices like crop storage and transportation. Growing population and decreasing size of arable lands has necessitated the need to employ clean, green and sustainable practices to save resources and enhance productivity. Usage of plastics in agriculture can lead to: Yield improvement upto 50-60%, Water savings upto 60-70% , Prevention of weeds growth, Soil conservation , Protection against adverse climatic conditions, Fertilizer savings upto 30-40%, Reduction in post-harvest losses, Conversion – cold desert/wasteland for productive use

Cold storage: renewable integration

The cold chain sector is sizable (6,000 nos /30,000 metric ton) and fast growing with many key industry critically dependent on it. However sector faces several constraint in its growth, which not only limits its potential but also results in wastage and loss of value in the industry that depend on it. One of constraints, unavailability of grid power/harnessing renewable energy in OFF grid mode at the point of farm produce and solution thereof is attempted in the paper. In the cold chain we can include renewable energy interventions at various stages to support the development of a self-sustainable model of Green Cold Chain which require little or does not require grid power to drive it, also there can be a technological intervention wherein the renewable infrastructure supporting the Cold Storage facility can also feed electricity to the nearby habitat. This shall safeguard the farmers from unwanted losses due to pilferages, mismanagement of stock and lack of grid supported cold chain infrastructure, also at the same time it can supply electricity to the villages. The renewable energy technologies can be integrated in the existing system or developed in isolation based on three key factors such as:

Stage in the Cold Chain

Fig. 1: Green Cold Chain Highlighting Potential Stages for Renewable Intervention Green technologies can be easily integrated in almost all the stages of the cold chain as indicated in Fig. starting from the very initial level of pre-cooling, transportation and then cold storages.

Type of Stock to be Processed

The need of temperature range for various food and produces varies from sub zero degree to 10 degree Celsius and hence the renewable energy technology shall also vary accordingly to attain the temperature range. Temperature range of various agricultural produce can be seen below at Table 1.

Table 1: Temperature Range For Various Produces [5]

Sl. No.	Fruits/Vegetables	Temperature range (°C)
1	Apples	-1 – 4
2	Bean/Carrots/Cauliflower	0
3	Lychees/ Orange	4 – 7
4	Onions	0 – 2
5	Strawberries	0
6	Sprouts	0 – 2
7	Potatoes	7 – 10

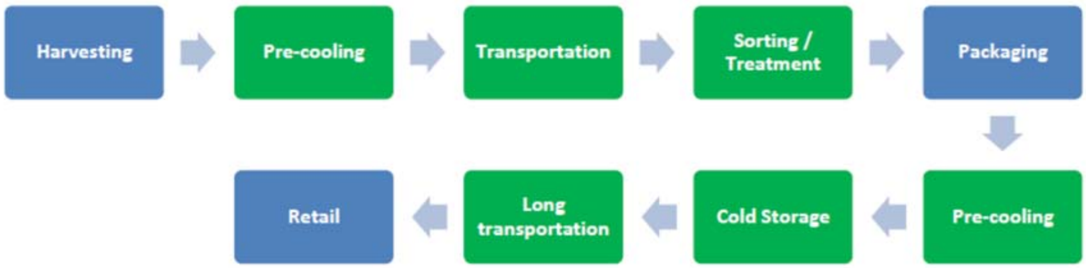
2.3. Load Requirement for the Desired Infrastructure

The electrical load requirement for various units as mentioned in Table 2 varies and the load can vary from 3 kW to 125 kW. The renewable energy technology can be used in standalone mode or to supplement the electricity loads of the existing projects.

Table 2: Cold Storage Load Requirement

		Technical Parameters		
Capacity (MT)		Dimensions (m^3)	Temp (°C)	Electrical load
Small units	2 – 3	3.8x2.2x2.44	0 to 15	3 kW(with pre-cooling)[6]
	10	6x4.6x2.43	0 to 15	15 kW(with pre-cooling)[6]
Large units	5,000	4x(21x16x13.70)	-4 to + 4	125 kW(without pre-cooling)[7]

There can be multiple solutions like mobile solar powered vans/solar cooled containers for transporting the stock to nearby cold storage, large cold storages driven by solar thermal/solar PV technology. Solar refrigeration engages a system where solar power is used for cooling purposes . Also renewable energy interventions can be integrated in the existing plants such as Biomass-Gasifier can be coupled with the diesel.



Green Cold Chain Highlighting Potential Stages for Renewable Intervention

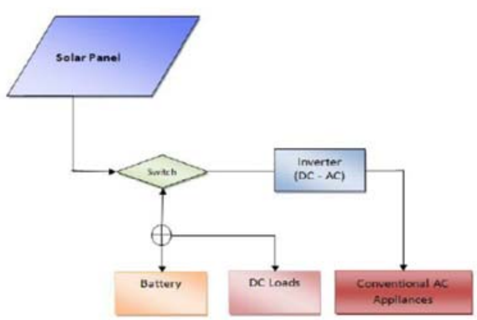
The electrical load requirement for various units varies and the load can vary from 3 kW to 125 kW. The renewable energy technology can be used in standalone mode or to supplement the electricity loads of the existing projects.

Switch to Solar: Save on Electricity Bills

Sl. No.	Electricity Source	Cost of Power	% Annual Increase in Cost
1	Grid Electricity	6 – 12	5 – 8 %
2	Battery Storage	11 – 13	
3	Diesel Generator	15 – 23	
4	Solar PV	6 – 7	NIL

Solar Energy Technological options for cold storage

Solar Photovoltaic Power Pack (upto 60% energy cost - diesel saving)



Solar Photovoltaic Power Pack model

- Power Pack systems are used to generate electricity for locations where grid is unreachable or the access is expensive.
- It is a PV based solar energy system, where solar energy is converted into electrical energy and used for refrigeration much like conventional methods.
- These Solar Power Pack Systems can also be used in combination with existing grid for uninterrupted supply of electricity.

Plasticulture in post-harvest management

Total food grains production in the country is estimated as 252.22 million tonnes in 2016-17 which is marginally higher by 0.20 million tonnes than the previous year's foodgrains production of 252.02 million tonnes. India is a country with a large population with huge food requirements. Unfortunately, about 20-30% of the fruits and vegetables produced in the country are lost due to mismanagement, wastage and value destruction. So, a sizable chunk of the harvested product is lost before reaching its end-consumer. There is a huge potential to save this sizable fraction and improve the system. Lack of sorting facilities, inappropriate packaging, slow transport systems and inadequate storage facilities are some of the key factors behind this loss of perishable goods. Effective post-harvest management includes good quality storage infrastructure, bulk handling tools and creating the necessary infrastructure across the value chain. Plastics are used to make crates, seals, etc. which make the handling and packaging of the harvest easy. Advantages of plastics are: easy to handle, cheap, durable for long period and inert with most items, all of which make plastics a sustainable choice over its substitutes such as paper, cloth, etc. Plastics have the potential to play a significant role in preservation of quality and longevity of harvested produce. Application The value chain of the post harvesting process for both perishables and durables are described in the table below. To harness or untap the potential of plastics in agriculture ICAR has started All India Coordinated Research Project on Plasticulture Engineering and Technologies (PET) become operational in 1988 during VII Plan period (known as AICRP on Application of Plastic in Agriculture). AICRP on PET takes research and extension activity pertaining to water management, protected farming, post-harvest produce management etc. Post harvest management of farm produce including grains, cereals, fruits and vegetables is one of the theme area of the AICRP on Plasticulture engineering and technology

1. Safe Storage of agriculture products in plastic derived bags, containers etc
2. Drying of produce in solar poly tunnel/ Polyhouse dryer
3. Packaging of products for transportation and containment

Novel Plasticulture technology developed under AICRP on PET for cold storage

Description of adsorption cooling cycle

This system was fabricated to develop a farm level cold store at ICAR-CIPHET Abohar. System was tested with different sequences of valves. Appropriate sequence with better performance was found as adsorber – check valve – condenser – receiver – float valve – needle valve – check valve – adsorber. This system was found suitable in lowering the temperature of cooling coil by 18°C (reduced the temperature from 38 to 20°C). Efforts are being made to increase the number of cycles per day. Cold chamber is to be fabricated and storage study is to be conducted.

Adsorption, alias physisorption, is the process by which molecules of a fluid (methanol) are fixed on the walls/surface of a solid material (activated charcoal). The adsorbed molecules undergo no chemical reaction; they simply lose energy when being fixed. Adsorption, the phase change from fluid to adsorbate (adsorbed phase) is reversible exothermic reaction. The adsorption cooling cycle is completed in following four steps.

Step 1: Isosteric heating which involves increase in adsorber temperature and pressure due to the solar irradiance.

Step 2: Desorption + condensation which involves desorption of the methanol vapours contained in the activated charcoal; condensation of the vapours in the condenser; drainage of methanol in the evaporator through the receiver and float valve.

Step 3: Isosteric cooling which involves decrease of the period of sunshine; cooling of the adsorber; decrease of the pressure and the temperature in the system.

Step 4: Adsorption + evaporation which involves evaporation of methanol contained in the evaporator; cooling of the evaporator; production of cooling effect in the evaporator; re-adsorption of methanol vapours by the activated charcoal.

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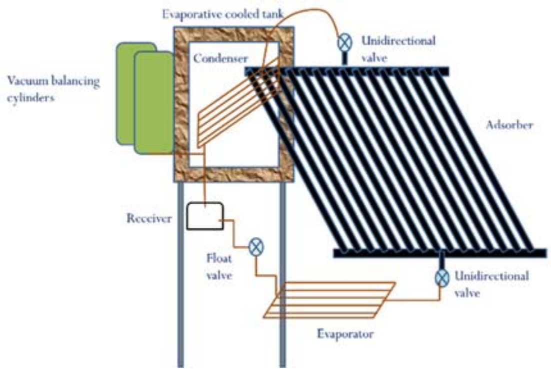

Sketch/ layout of system
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solar energy based vapor adsorption cooling system
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Some of the popular Plasticulture technologies based on renewable energy in post-harvest management

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Portable polytunnel dryer
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Types of dryer developed under AICRP on PET for drying of fruits, vegetables and fish products.

Conclusion

India is at a crucial juncture when it needs to tackle the issue of food security by optimizing the use of resources, which traditionally has been taken for granted. Plasticulture is a viable solution for India, to launch 2nd Green revolution. Application of plastics or plasticulture technologies played an important role in post-harvest sector. Post-harvest losses can be minimized by intervention of plasticulture technologies. The renewable energy applications as discussed theoretically can only be implemented and adapted in commercial space if the project is both technologically proven and financially viable. The financial viability in any renewable energy projects can easily be calculated by monetary savings and payback period

henceforth. There are various renewable energy technologies which can be integrated within the cold chain. GOI also provides incentives for integrating RE in this sector through various schemes of MNRE, MoFPI, MoA etcs. Adopting RE serves the purpose of . Energy security and sustainable energy in case of non-availability of grid or fault in grid. Strengthening the agriculture sector and the farmers by reducing wastage and help achieve food security. Further it also helps in creation of job at rural level and elevating the financial status of farmers.

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Dr. R.K. Gupta has obtained his bachelor degree in Agricultural Engineering from Allahabad University and M. Tech. Degree in Post Harvest Engineering from Indian Institute of Technology, Kharagpur. Further, Dr. Gupta had also obtained Post Graduate Diploma in Food Processing Management from International Institute of Management, Masstricht, The Netherlands and Ph.D. from IIT Kharagpur in the area of Agricultural and Food Engineering (Post Harvest Engineering). More than 31 years, he is engaged in research and development and training in the area of post harvest processing and value addition of Food Crops. His areas of expertise are horticultural crop processing, oilseeds processing, coarse cereals including minor millets processing and value addition, novel products development. Dr. Gupta has published around 100 research papers in referred journals in mostly in Food Engineering &Technology stream. He is also a Fellow of Indian Society of Agricultural Engineers, Institutions of Engineers (India), Bioved Research Society, Hi-Tech Horticultural Society and having other awards of professional societies. He member of many National as well as International committee/ forums. Dr. Gupta is presently holding the post of Director of ICAR-Central Institute of Post-Harvest Engineering and Technology (CIPHET) located at Ludhiana.

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Dr. Ranjeet Singh born in 3rd Dec 1973 at Ludhiana, Punjab, India. He has completed his schooling at KV Jamalpur, Bihar in 1991 and joined in undergraduate at RAU Pusa, Bihar. He graduated in B. Tech (Agricultural Engineering) in 1995. He joined in M. Tech (Agricultural Process Engineering) with ICAR-JRF Merit Scholarship at Punjab Agricultural University, Ludhiana and completed in 1999. After post-graduation, Dr. Ranjeet Singh joined as Scientist (AS&PE) in 2001 at ICAR-CIAE, Bhopal and developed numerous food processing technologies and machinery. He obtained Ph.D in the field of Processing and Food Engineering at Punjab Agricultural University, Ludhiana in 2011. After that he joined ICAR-CIPHET Ludhiana. Till date he is serving as Sr. Scientist at ICAR-CIPHET, Ludhiana. During his tenure, he has developed 10 technologies and published more than 60 research publications in national and International referred journals, 02books along with 100 popular articles/book chapters/ seminars/ conferences abstracts etc. and bagged 05 national awards to his credit.

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Dr.Eyarkai Nambi.V, born in 3rd June 1984 at Madurai, Tamil Nadu, India. He has completed his schooling at Madurai in 2001 and Joined in undergraduate at Tamil Nadu Agricultural University, Coimbatore. He graduated in B.Tech (Food Process Engineering) in 2005 with university 2nd rank holding. He joined in M.Tech (Agricultural Process Engineering) with Periyar Endowment Merit Scholarship at Tamil Nadu Agricultural University and completed in 2007. After post-graduation, Dr.V.E.Nambi joined as lecturer in SRM University Chennai and worked till April 2009. During his teaching period, he has guided 8 UG Students and handled courses related to Unit operations in food Engineering, Meat and poultry processing, Food microbiology, Management in food industries, Food plant layout *etc.* In 2009, He joined as Scientist in ICAR-CIPHET through ARS examinations. Till date he is serving as scientist at ICAR-CIPHET, Ludhiana. In 2015, He obtained Ph.D in the field of Food Engineering and Agricultural Processing at Tamil Nadu Agricultural University, Coimbatore. He has received **Jawaharlal Nehru Award for Outstanding Ph.D thesis in the field of Agricultural Engineering** for the year 2016. During his tenure, he has developed 6 technologies and filed 4 Patents. He has published more than 28 research publications in International refereed journals and 35 seminar/conferences abstracts.