HORT 381 POST HARVEST MANAGEMENT AND VALUE ADDITION OF FRUITS AND VEGETABLES 2(1+1)

POST HARVEST MANAGEMENT

Course Overview:

This course deals with overall post harvest management of fruits and vegetables from farm to fork.

Learning objective:

The students are expected to gain knowledge on various management technologies on pre- harvest and post harvest of fruits and vegetables. Students are also expected to gain knowledge on conventional and modern packaging methods.

Outcome of the course

Students will acquire knowledge on post harvest management tools and novel paclkaging techniques.

Lecture schedule:

The Post Harvest Mangement portion is divided into following headings:

(i) The Importance of post harvest technology of horticultural crops

(ii) Maturity indices, harvesting and post harvest handling of fruits and vegetables

(iii) Maturity and ripening process – factors affecting ripening of fruits and vegetables- chemicals used for hastening and delaying ripening of fruits and vegetables.

(iv) Pre harvest factors affecting quality on post harvest life of fruits and vegetables – factors responsible for deterioration of harvested fruits and vegetables.

(v) Methods of storage-precooling, pre storage treatments, low temperature storage, controlled atmosphere storage, hypobaric storage, irradiation and low cost storage structures.

(vi) Various methods of packaging-packaging materials and transport – packaging technology for export. Fabrication of type of containers, cushioning material, vacuum packaging, poly shrink packaging, specific packaging for export of mango, banana, grapes, etc.,

Chapter 1: IMPORTANCE OF POST HARVEST TECHNOLOGY OF HORTICULTURAL CROPS

Horticulture plays a significant role in Indian Agriculture. It contributes 30% GDP from 11.73 % of its arable land area. India is the second largest producer of both fruits and vegetables in the world (52.85 Mt and 108.20 Mt respectively). Fruits and vegetables are of immense significance to man. In India, the fruits have been given a place of honour on being offered to God at every festival and have also been mentioned in our epics like Mahabharata, Ramayana and writings of Sushrutha and Charaka. Being rich source of carbohydrates, minerals, vitamins and dietary fibres these constitute an important part of our daily diet. The dietary fibres have several direct and indirect advantages. Not only this, fruits and vegetables provide a variety in taste, interest and aesthetic appeal. Their significance in human life is being recognised increasingly in Western societies with the objective of minimizing the occurrence of the diseases related with an affluent life style. Their lesser recognized benefits relate to their role in kidney functions, prevention of cancer and cardiac disorders through contribution of ascorbic acid, β-carotene and non-starch polysaccharides besides the biochemical constituents like phenols, flavonoids and alkaloids.

A considerable amount of fruits and vegetables produced in India is lost due to improper post-harvest operations; as a result there is a considerable gap between the gross production and net availability. Furthermore, only a small fraction of fruits and vegetables are utilized for processing (less than 1%) and exported (Fruits – 0.5% and Vegetables – 1.7%) compared to other countries.

Post harvest losses in fruits and vegetables are very high (20-40%). About 10-15% fresh fruits and vegetables shrivel and decay, lowering their market value and consumer acceptability. Minimizing these losses can increase their supply without bringing additional land under cultivation. Improper handling and storage cause physical damage due to tissue breakdown. Mechanical losses include bruising, cracking, cuts, microbial spoilage by fungi and bacteria, whereas physiological losses include changes in respiration, transpiration, pigments, organic acids and flavour.

NATURE AND CAUSES OF POST-HARVEST LOSSES

Losses occur after harvesting is known as post harvest losses. It starts first from the field, after harvest, in grading and packing areas, in storage, during transportation and in the wholesale and retail markets. Several losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers.

(a) Extend of post-harvest loss: It is evident that the estimation of post-harvest loss is essential to make available more food from the existing level of production.

A recent joint study conducted by the management consultancy firm, McKinsey and Co. and (The Confederation of Indian Industry (CII), at least 50% of the production of fruits and vegetab1es in the country is lost due to wastage and value destruction. The wastage cost is estimated to be Rs.23, 000 crores each year. Swaminathan Committee (1980) reported the post-harvest handling accounts for 20-30% of the losses at different stages of storage, grading, packing, transport and finally marketing as a fresh produce or in the processed form. According to Chadha (2009) India loses about 35-45% of the harvested fruits and vegetables during handling, storage, transportation etc. leading to the loss of Rs. 40,000 crores per year.

(b) Important sites of post-harvest losses: Important sites where post-harvest losses are noticed in India are —

- Farmer's field (15-20%)
- Packaging (15_2004)
- . Transportation (30-40%)
- Marketing (30-40%)

(c) Estimated loss of fruits

Crop	**Estimated loss (%)**
Papaya	40100%
Grapes	27%
Banana	20-28%
Citrus	20-95%
Avufado	43%
Apple	14%

Estimated loss of Vegetables

Onion	25-40%
Garlic	08-22%
Potato	30-40°
Tomato	5-347%
Cabbage & cauliflower	7.08-25.0%
Chlli	4-35,0%
Radish	3-5%
Carrot	5-9%

(d) Causes of post-harvest losses

Horticultural crops not only provide nutritional and healthy foods to human beings, but also generate a considerable cash income for growers. However, horticultural crops typically have high moisture content, tender texture and high perishability. If not handled properly, a high-value nutritious product can deteriorate and rot in a matter of days or hours. The causes of post-harvest losses can be divided into different categories:

1. Metabolic

All fresh horticultural crops are live organs. The natural process of respiration involves the breakdown of food reserves and the aging of these organs.

2. Mechanical

Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding and other forms of injury.

3. Developmental

These include sprouting, rooting, seed germination, which lead to deterioration in quality and nutritional value.

4. Parasitic diseases

High post-harvest losses are caused by the invasion of fungi, bacteria, insects and other organisms. Micro-organisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism and has plenty of nutrients and moisture to support microbial growth.

5. Physiological deterioration

Fruits and vegetable cells are still alive after harvest and continue their physiological activity. Physiological disorders may occur due to mineral deficiency, low or high temperature injury or undesirable atmospheric conditions, such as high humidity, physiological deterioration can also occur spontaneously by enzymatic action leading to over-ripeness and senescence, a simple aging phenomenon.

6. Lack of market demand

Poor planning pr inaccurate production and market information may lead to over production of certain fruits or vegetables which can't be sold in time. This situation occurs most frequently in areas where transportation and storage facilities are inadequate. Produce may lie rotting in production areas, if farmers are unable to transport it to people who need it in distant locations.

7. Consumption

These losses can be due to inadequate preservation methods at home, methods of cooking and preparation such as peeling, consumption styles etc.

8. Others

— Lack of clear concept of packing house operations.

— Lack of awareness among the growers, contractors and even the policy makers.

— Lack of infrastructure.

— Late realization of its importance,

— Inadequate technical support.

— Wide gap in technologies available and in vogue.

— Inadequate post-harvest quality control.

— Unorganized marketing.

— Absence of pre-cooling and cold storage.

— Inadequate market facilities, market intelligence and market information service (MIS)

— Poor storage facilities.

(e) Impact of post-harvest losses

Post harvest losses of horticultural crops affect both the nutritious status of the population and economy of the country.

Nutrition

Fruits and vegetables are rich source of vitamins and minerals essential for human nutrition. These are wasted in transit from harvest to consumer represent a loss in the quantity of a valuable food. This is important not only in quantitative terms, but also from the point of view of quality nutrition.

Economy

Careless harvesting and rough handling of perishable bruise and scar the skin, thus reducing quality and market price. Such damaged produce also fails to attract the international buyers, and bring the exporting country less profit and bad name. This ultimately results in huge economic losses to the country.

For improving the situation, it is essential to create awareness among growers, farm workers, manager's traders and exporters about the extent of losses being incurred and their economic consequences. These groups of people involved in the fruit industry also need to learn the basic principles of fruit handling and storage. In addition, the government needs to provide basic infra-structure like storage, handling, grading, packing, transport and marketing facilities and technical expertise. This could be carried out by the public and private sectors.

(f)Technologies for minimizing the losses

Fruits and vegetables are perishable in nature. Scientific harvesting and handling are the practical way to reduce the losses due to physical damage, spoilages, due to insect damages and microbial growth. Various protocols are standardized and available for adoption to get the best result, which will give economic benefits. Similarly, proper storage conditions, with suitable temperature and humidity are needed to lengthen the storage life and maintain quality once the crop has been cooled to the optimum storage tempera Lure. Greater emphasis need to be given on the training of farmers, creation of infrastructure for cold chain with common facilities for sorting, grading, packing and post harvest treatments in all major markets. Some technologies for extension of shelf life of fruits and vegetables are:

1. Waxing

It is used as protective coating for fruits and vegetables and help in reduction in loss in moisture and rate of respiration and ultimately results in prolonged storage life.

2. Evaporative cool storage

It is the best short-term storage of fruits and vegetables at farm level. It helps the farmers to get better returns for their produce. In this structure, horticultural crops reduce shriveling and extend their storage life.

3. Pre-packaging

This technology controls the rate of transpiration and respiration and hence keeps the commodity in fresh condition both at ambient and low temperature. It can able to bring revolutionary progress in our trade practice and also benefit the consumer and the producer because of its low cost and ready availability.

4. Cold storage

These structures are extensively used to store fruits and vegetables for a long period and employ the principle of maintaining a low temperature, which reduces the rate of respiration and thus delays ripening.

5. Modified atmosphere packaging (MAP)

These packaging modify the atmosphere composition inside the package by respiration. This technology is successful to extend the shelf life of (Cavendish banana, carrots capsicum, green chilli and tomatoes by 15, 14, 13, 8 and 15 clays as against 5, 7, 8, 4 and 7 days in control respectively, under ambient conditions. Storage of Papaya can be extended 4 weeks when stored at 10 -12 °C under modified atmosphere (MA) conditions by wrapping them in low density polyethylene (LDPE) bag. Using this technique, the fruit can be transported to different markets in refrigerated sea containers with Temperature Sea at 10-12 °C. Fruits ripen within 3-4 days after arrival when placed at ambient temperature. While using optimum low temperature, storage life of Cavendish banana, capsicum, green chili and tomato can be extended to 42,21,28 and 30 days in comparison to 21, 10,21 and 15 days respectively.

6. Controlled Atmosphere (CA) storage

It is based, on the principle of maintaining an artificial atmosphere in storage room, which has higher concentration of CO2 and lower concentration of 02 than normal atmosphere. This reduces the rate of respiration and thus delays aging. This method of storage is very effective when combined with low temperature storage.

7. Cold chain

Following cold chain handling system for fresh horticultural crops from (arm to consumer. It helps in reducing wastages and retention of quality of commodities.

8. Irradiation

It is the newer technologies that can be gainfully employed during storage to reduce post-harvest losses and extend storage life of fruits and vegetable. When fruits and vegetables expose to ionizing radiation (such as gamma-rays) at optimum dosage delays ripening minimizes insect infestation, retards microbial spoilages, control sprouting, and rotting of onion, garlic and potato during storage. It is also used as a disinfection treatment and controls fruit fly on citrus, mango seed weevil and papaya fruit fly.

9. Edible coatings

These are continuous matrices prepared from edible materials such as proteins, polysaccharides and lipids. They can be used as film wraps and when consumed with the food, become an ingredient of the food. They not only minimize the post harvest losses but also need for energy intensive operations and controlled atmosphere storage. They can control migration of gases, moisture, oil, fat, and solutes, as well as retain volatile flavouring compounds. An edible coating improves structural integrity and mechanical handling and carry product so that they help to maintain quality and inhibit microbial growth causing deterioration of the product.

10. Others

— Facilities/ services like grading, washing, cleaning, scientific harvesting and the like, in respect of perishables at the farm level.

— Cold storage facilities should be extended to tropical fruits and vegetables.

Handling protocols should be established for crops other than mango, citrus, grapes and capsicurn to improve the shelf life and export.

— The issue relating to increasing the shelf life of horticultural products needs to he addressed.

— Appropriate packaging material for export of fresh fruits, vegetables and for modified atmosphere packaging should be developed.

— Value addition needs to be viewed in a wider perspective than mere processing to ensure better return to the producer/ farmer, besides providing better quality product to the consumer.

- — Development of natural food columns, fiber, single cell protein and food grade enzymes from processing wastes will be useful.

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Lecture 2: MATURITY INDICES, HARVESTING AND POST HARVEST HANDLING OF FRUITS AND VEGETABLES

I. MATURITY

It is the stage of fully development of tissue of fruit and vegetables only after which it will ripen normally. During the process of maturation the fruit receives a regular supply of food material from the plant. When mature, the abscission or corky layer which forms at the stern end stops this inflow. Afterwards, the fruit depend on its own reserves, carbohydrates are dehydrated and sugars accumulate until the sugar acid ratio form. In addition to this, typical flavour and characteristic colour also develop. it has been determined that the stage of maturity at the time of picking influence the storage life and quality of fruit, when picked immature like mango develop white patches or air pockets during ripening and lacking in normal brix acid ratio or sugar acid ratio, taste and flavour on the other hand if the fruits are harvested over mature or full ripe they are easy susceptible to microbial and physiological spoilage and their storage life is considerably reduce. Such fruits persist numerous problems during handling, storage and transportation. Therefore, it is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.

Horticultural maturity

It is a developmental stage of the fruit on the tree, which will result in a satisfactory product after harvest.

Physiological maturity

It refers to the stage in the development of the fruits and vegetables when maximum growth and maturation has occurred. It is usually associated with full ripening in the fruits. The Physiological mature stage is followed by senescence.

Commercial maturity

It is the state of plant organ required by a market. It commonly bears little relation to Physiological maturity and may occur at any stage during development stage.

Harvest Maturity

It may be defined in terms of Physiological maturity and horticultural maturity, it is a stage, which will allow fruits / vegetables at its peak condition when it reaches to the consumers and develop acceptable flavour or appearance and having adequate shelf life.

Table 1: Criteria of maturity for harvesting fruits and vegetables

Fruit	Physical	Chemical
Mango	Olive green colour with clear lenticels, shoulder development size sp. gravity, days from fruit set.	Starch content, flesh colour
Banana	Skin colour, drying of leaves of the plant, brittleness of floral ends, angularity of the fruit, and days from emergence of inflorescence.	Pulp/peel ratio, starch content
Citrus	Colour break of the skin from green to orange, size	Sugar/acid ratio, TSS
Grapes	Peel colour, easy separation of berries, characteristic aroma	TSS 18-12 Thompson seedless, 12-14 for Bangalore Blue, 14-16 for Anab-e-shahi
Apple	Colour size	Firmness as measured by pressure tester
Papaya	Yellow patch or streaks.	Jelliness of the seed, seed colour

Vegetables are harvested at harvest maturity stage, which will allow it to be at its peak condition when it reaches the consumer, it should be at a maturity that allows the produce to develop an acceptable flavour or appearance, it should be at a size required by the market, and should have an adequate shelf life. Time taken from pollination to horticultural maturity under warm condition, skin colour, shape, size and flavour and abscission and firmness are used to assess the maturity of the produce.

Table 2: Time taken from pollination to horticultural maturity

S.No.	Vegetables	Time to harvest Maturity (days)
1.	Ridge gourd	5 -6
2.	Squash	7 - 8
3.	Brinjal	25 - 40

4.	Okra	4 - 6
5.	Pepper (green stage)	45 - 55
6.	Pepper (red stage)	60 -70
7.	Pumpkin (mature)	65 - 70
8.	Tomato (mature green)	35 - 45
9.	Tomato (red ripe stage)	45 - 60
10.	Peas	30 - 35

Skin colour

Loss of green colour in citrus and red colour in tomato.

Shape, size and flavour

Sweet corn is harvested at immature stage, smaller cobs marketed as baby corn. Okra and cow pea are harvested at mature stage (pre fiber stage). In chilli, bottle gourd, bitter gourd, cluster beans maturity is related to their size. Cabbage head and cauliflower curd are harvested before un pleasant flavour.

Abscission and firmness

Musk melon should be harvested at the formation of abscission layer. In cabbage and lettuce should be harvested at firmness stage.

Factors affecting maturity

1. Temperature: Higher temperature gives early maturity.

e.g. Gulabi (Pink) grapes mature in 100 days in Western India but only 82 days are enough in the warmer Northern India.

Lemon and guava takes less time to mature in summer than in winter. Sun-scorched portions of fruits are characterized by chlorophyll loss, yellowing, disappearance of starch and other alcohol insoluble material, increase in TSS content, decrease in acidity and softening.

2. Soil: Soil on which the fruit tree is grown affects the time of maturity.

e.g. Grapes are harvested earlier on light sandy soils than on heavy clays.

3. Size of planting material: This factor in propagated fruits affects fruit maturity.

e.g. In pineapple, the number of days taken from flowering to fruit maturity was more by planting large suckers and slips than by smaller ones.

4. Closer spacing: Close spacing of hill bananas hastened maturity.

5. Pruning intensity: It enhanced the maturity of Flordasun and sharbati Peaches.

6. Girdling: Process of constricting the periphery of a stem which blocks the downward translocation of CHO, hormones, etc. Beyond the constriction which rather accumulates above it. In Grape vines it hastens maturity, reduces the green berries in unevenly maturity cultivar and lowers the number of short berries. It is ineffective when done close to harvest. CPA has an additive effect with girdling

MATURITY INDEX

Maturity index

The factors for determining the harvesting of fruits, vegetables and plantation crops according to consumer's purpose, type of commodity, etc and can be judged by visual means (colour, size, shape), physical means (firmness, softness), chemical analysis (sugar content, acid content), computation (heat unit and bloom to harvest period), physiological method(respiration). These are indications by which the maturity is judged. Various index are as Follows;

1. Visual indices

It is most convenient index. Certain signals on the plant or on the fruit can be used as pointers. E.g. drying of top leaves in banana, yellowing of last leaf of Peduncle in jackfruit. Flow of sap from cut fruit stalk of mango slows down if the harvest is done after maturity but in immature fruits, exudation is more and comes with force in a jet form. in papaya, the latex becomes almost watery. The flow gets reduced on maturity in Sapota. In fruits like banana and Sapota, floral ends become more brittle and shed with a gentle touch or even on their own. In Sapota, the brown scurf on the fruit skin starts propping. In mango, lenticels become more prominent and the waxy bloom gradually disappears. Grapes develop translucent bloom. Other changes like angularity in banana, development of creamy wide space between custard apple segments and the flattening of the eyes in pineapple and tubercles in litchi serve as reliable maturity indices.

2. Seed development

It can also be used as an index of fruit maturity, e.g. endocarp hardening for stone and fiber development for dessert in mango.

3. Start of bud damage

Occasionally it can be used as an index of fruit maturity in mango.

4. Calendar date

For perennial fruit crops grown in seasonal climate which are more or less uniform from year to year, calendar date for harvest is a reliable guide to commercial maturity. This approach relies on a reproducible date for the time of the flowering and a relative constant growth period from flowering through to maturity. Time of flowering is largely dependent on temperature, and the variation in number of days from flowering to harvest can be calculated for some commodities by use of the degree- concept.

5. Heat units

Harvest date of newly introduced fruits in a widely varying climate can be predicted with the help of heat unit. For each cultivar the heat requirement for fruit growth and development can be calculated in terms of degree days: Maturity at higher temperature is faster as the heat requirement is met earlier. This heat unit helps in planning, planting, harvesting and factory programmes for crops such as corn, peas and tomato for processing.

MATURITY OF FRUITS AND VEGETABLES

Banana

The fruit is harvested when the ridges on the surface of skin change from angularity to round i.e. after the attainment of 3% full stages. Dwarf banana are ready for harvest within 11-14 months after planting while tall cultivars takes about 14-16 months to harvest. Peel colour change from dark green to light green the remaining style ends were dry, and brittle and fruits were less angular in shape.

Guava

TSS acid ratio, specific gravity and colour are determined the maturity in guava. For e.g.

Allahabad safeda	- 35.81
Apple colour guava	- 26.39
Chittidar guava	- 28.13
Lucknow	- 49 -34.25
Specific gravity	- Less than I
Colour	- Light green to yellow.

Ber

In ber maturity is judged by colour (yellow), specific gravity (less than 1) and TSS

Pomegranate

Sugar percentage should be 12-16% and acid percentage 1.5—2.5%, variety Ganesh harvest when seed colour becomes pink. In this stage TSS 12.5% and sugar acid ratio 19.5%.

Bael

It takes one year for fruiting after flowering. It is the fruit which ripen after one year of flowering. April start harvesting and may end it start in flowering.

Mango

This can be judged when one or two mangoes ripen on the tree are fall on the ground of their own accord. This process of fallen is known as tapaca specific gravity 1,01—1.02 and TSS 10-14%.

Table 3 Maturity indices of vegetable crops

Root, bulb and tuber crops	**Maturity indices**
Radish and carrot	Large enough and crispy
Potato, onion and garlic	Tops beginning to dry and topple clown
Yams, bean and ginger	Large enough
FRUIT VEGETABLES	
Cowpea, snap bean, sweet pea, winged bean	Well filled pods that snap readily
Lima bean and pigeon pea	Well filled pods that are beginning to lose their greenness.
Okra	Desirable size reached and the tips of which can be snapped readily
Snake gourd	Desirable size reached and thumbnail can still penetrate flesh readily
Egg plant, bitter gourd, slicing cucumber	Desirable size reached but still tender
Tomato	Seeds slipping when fruit is cut, or green colour turning pink
Muskmelon	Easily separated from vine with a slight twist leaving clean cavity (full slip stage).
Watermelon	Dull hollow sound when thumped
FLOWER VEGETABLES	
Cauliflower	Curd compact
Broccoli	Bud cluster compact

II. HARVESTING

The goals of harvesting are to gather a commodity from the field at the proper level of maturity with a minimum of damage and loss, as rapidly as possible and at a minimum cost. This is achieved through hand-harvesting in most fruit, vegetable and flower crops.

1. Hand Harvesting

Hand harvesting has a number of advantages over machine harvest. People can accurately determine product quality, allowing accurate selection of mature product. This is particularly important for crops that have a wide range of maturity and need to be harvested several times during the season. Properly trained workers can pick and handle the product with a minimum of damage. Many fresh-market products have a short shelf life if they are bruised or damaged during harvest and handling. The rate of harvest can easily be increased by hiring more workers. Hand- harvesting also requires a minimum of capital investment. The main problem with hand harvesting is labor management. Labor supply is a problem for growers who cannot offer a long employment season. Labor strikes during the harvest period can be costly. In spite of these problems, quality is so important to marketing fresh- market commodities successfully that hand harvesting remains the dominant method of harvest of most fruits and vegetables and for all cut flowers.

Effective use of hand labor requires careful management. New employees must be trained to harvest the product at the required quality and at an acceptable rate of productivity. Employees must know what level of performance and must be encouraged and trained to reach that level.

2. Mechanical Harvesting

Mechanical harvest is currently used for fresh-market crops that are roots, tubers, or rhizomes and for nut crops. Vegetables that are grown below ground (radishes, potatoes, garlic, carrots, beets and others) are always harvested only once and the soil can be used to cushion the product from machine caused mechanical injury. Tree nuts and peanuts are protected by a shell and easily withstand mechanical handling. A number of products destined for processing such as tomatoes, wine grapes, beans, peas, prunes, peachesand some leafy green vegetables are machine harvested because harvest damage does not significantly affect the quality of processed product. This is often because the product is processed quickly after harvest. These crops have also been amenable to new production techniques and breeding that allow the crop to be better suited to mechanical harvest.

The main advantage of mechanical harvest equipment is that machines can often harvest at high rates. Tree nut harvesters, for eg. attaching a shaking mechanism to the tree and remove most of the nuts in few seconds. The nuts are either caught on a fabric- covered frame or picked up from the ground by other machines. This allows an orchard to be harvested very quickly compared to handshaking with poles. Machine harvest also reduces management problems associated with workers. The commodity must be grown to accept mechanical harvest.

Demerits of Mechanical Harvesting

Machines are rarely capable of selective harvest. Mechanical harvesting will not be feasible until the crop or production techniques can be modified to allow one time harvest. Harvesting machines often causes excessive product perennial crops eg. Bark damage from a tree shaker. The harvesting machines are quite expensive.

III. POST HARVEST HANDLING

Being living organs, fruits and vegetables continue to respire even after harvesting when they have a limited source of food reserves. In addition to degradation of respiratory substrates, a number of changes in taste, colour, flavour, texture and appearance take place in the harvested commodities which make them unacceptable for consumption by the consumers if these are not handled properly. Post harvest technology starts immediately after the harvest of fruits and vegetables. The whole process of processing the commodities is categorized as Handling of fresh produce. Post harvest Technology of fresh fruits and vegetables combines the biological and environmental factors in the process of value addition of a commodity.

1. Precooling

Precooling (prompt cooling after harvest) is important for most of the fruits and vegetables because they may deteriorate as much in 1 hr at 32°C. In addition to removal of field heat from commodities, precooling also reduces bruise damage from vibration during transit. Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity and nature of crop.

There are many methods of precooling viz, cold air (room cooling, forced air cooling), cold water (hydrocooling), direct contact with ice (contact icing), evaporation of water from the produce (evaporative cooling, vacuum cooling) and combination of vacuum and hydrocooling (hydrovac cooling). Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydrocooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post harvest diseases.

2. Washing, Cleaning and Trimming

Before fresh fruits and vegetables are marketed various amounts of cleaning are necessary which typically involves the removal of soil dust, adhering debris, insects and spray residues. Chlorine in fresh water is often used as disinfectant to wash the commodity. Some fungicides like Diphenylamine (0.1 - 0.25%) or ethoxyquin (0.2 - 0.5%) may be used as post harvest dip to control the disorders. Eg. Apple superficial scald. For cleaning of some fruit type vegetables (melons, brinjals, tomatoes, cucumber) they should be wiped with damp cloth. Many vegetable need trimming, cutting and removal of unsightly leaves or other vegetative parts.

3. Sorting, Grading and Sizing

Sorting is done by hand to remove the fruits which are unsuitable to market or storage due to damage by insects, diseases or mechanical injuries. The remainder crop product is separated into two or more grades on the basis of the surface colour, shape or visible defects. For eg, in an apple packing house in India 3 grades viz. Extra Fancy, Fancy and standard may be packed for marketing. The fourth "cull" grade is meant for processing. After sorting and grading, sizing is done either by hand or machine. Machine sizers work on two basic principles: weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (Oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears or of non-uniform shape) commodities, respectively.

4. Curing

Curing is an effective operation to reduce the water loss during storage from hardy vegetables viz, onion, garlic, sweet potato and other tropical root vegetables. The curing methods employed for root crops are entirely different than that from the bulbous crops (onions and garlic). The curing of root and tuber crops develops periderms over cut, broken or skinned surfaces wound restoration. It helps in the healing of harvest injuries, reduces loss of water and prevents the infection by decay pathogens.

Onions and garlic are cured to dry the necks and outer scales. For the curing of onion and garlic, the bulbs are left in the field after harvesting under shade for a few days until the green tops, outer skins and roots are fully dried.

5. Waxing

Quality retention is a major consideration in modem fresh fruit marketing system. Waxes are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids. But coating applied to the surface of fruit is commonly called waxes whether or not any component is actually a wax. Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product but it can be a beneficial adjunct to good handling.

The advantages of wax application are:

- Improved appearances of fruit.
- Reduced moisture losses and retards wilting and shrivelling during storage of fruits.
- Less spoilage specially due to chilling injury and browning.
- Creates diffusion barrier as a result of which it reduces the availability of 02 to the tissues thereby reducing respiration rate.

- Protects fruits from micro-biological infection.

- Considered a cost effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.

- Wax coating are used as carriers for sprout inhibitors, growth regulators and preservatives.

The principal disadvantage of wax coating is the development of off- flavour if not applied properly. Adverse flavour changes have been attributed to inhibition of O_2 and CO_2 exchange thus, resulting in anaerobic respiration and elevated ethanol and acetaldehyde contents. Paraffm wax, Carnauba wax, Bee wax, Shellac, Wood resins and Polyethylene waxes used commercially.

6. Packaging

Proper or scientific packaging of fresh fruits and vegetables reduces the wastage of commodities by protecting them from mechanical damage, pilferage, dirt, moisture loss and other undesirable physiological changes and pathological deterioration during the course of storage, transportation and subsequent marketing. For providing, uniform quality to packed produce, the commodity should be carefully supervised and sorted prior to packaging. Packaging cannot improve the quality but it certainly helps in maintaining it as it protects produce against the hazards of journey. Striking developments have been in the field of packaging of horticultural produce and the gunny bags, grasses and stem leaves used so far for packaging are now being replaced by a variety of containers such as wooden boxes, baskets woven from bamboo or twigs, sack/jute bags and corrugated fibre board (CFB) boxes.

7. Storage

A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage and controlled atmosphere storage) are being used for fruits and vegetables depending upon the nature of the commodity and the storage period intended.

MATURITY AND RIPENING PROCESS

MATURITY

It is the stage of fully development of tissue of fruit and vegetables only after which it will ripen normally. During the process of maturation the fruit receives a regular supply of food material from the plant. When mature, the abscission or corky layer which forms at the stern end stops this inflow. Afterwards, the fruit depend on its own reserves, carbohydrates are dehydrated and sugars accumulate until the sugar acid ratio form. In addition to this, typical flavour and characteristic colour also develop. it has been determined that the stage of maturity at the time of picking influence the storage life and quality of fruit, when picked immature like mango develop white patches or air pockets during ripening and lacking in normal brix acid ratio or sugar acid ratio, taste and flavour on the other hand if the fruits are harvested over mature or full ripe they are easy susceptible to microbial and physiological spoilage and their storage life is considerably reduce. Such fruits persist numerous problems during handling, storage and transportation. Therefore, it is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.

FRUIT RIPENING

Fruit ripening is a genetically programmed stage of development overlapping with senescence. The fruit is said to be ripe when it attains its full flavour and aroma and other characteristics of the best fruit of that particular cultivar. The words “mature “and “ripe” are essentially synonymous when used to describe these fruits that ripe on the plants known as non-climacteric. However, in case of climacteric fruits a mature fruit require period before attaining a desirable stage of edibility.

Table 1. List of climacteric and non-climacteric fruits

Climacteric	Non-climacteric
Apple	Carambola
Apricot	Cherries
Avocado	Citrus
Banana	Grape
Ber	Litchi
Cherimoya	Loquat
Fig	Olive
Guava	Pineapple
Kiwifruit	Pomegranate

Mango Melons Pear Peach Plum Persimmon Papaya Tomato Sapota Passion fruit	Strawberry

Changes during Fruit Ripening

1. Cell Wall Changes

Cell wall consists of pectic substances and cellulose as the main components alongwith sma1amounts of hemicellulose and non-cellulosic polysaccharides. In cell wall, the changes particularly in the middle lamella which is rich in pectic polysaccharides are degraded and solubilised during ripening. During this softening, there is a loss of neutral sugars (galactose and arabinose-major components of neutral protein) and acidic pectin (rhamnogalacturonan) of all cell wall. The major enzymes implicated in the softening of fruits are pectine1asterase, polygalacturonase cellulase and β- galactosidase.

2. Starch

During fruit ripening sugar levels within fruit tend to increase due to either increased sugar importation from the plant or to the mobilization of starch reserves within the fruit, depending on the fruit type and whether it is ripened on or off the plant. With the advancement of maturity, the accumulated starch is hydrolysed into sugars (glucose, fructose or sugars) which are known as a characteristic event for fruit ripening. Further breakdown of sucrose into glucose and fructose is probably mediated by the action of invertase. In vegetables like potato and peas on the other hand, the higher sucrose content which remains high at fresh immature stage, converts into starch with the approach of maturity.

3. Organic Acids

With the onset of fruit ripening there is downward trend in the levels of organic acids. The decline in the content of organic acids during fruit ripening might be the result of an increase in membrane permeability which allows acids to be stored in the respiring cells, formation of salts of malic acid, reduction in the amounts of acid translocated from the leaves, reduced ability of fruits to synthesize organic acids with fruit maturity, translocation into sugars and dilution effect due to the increase in the volume of fruit.

4. Colour

With the approach of maturation, the most obvious change which take place is the degradation of chlorophyll and is accompanied by the synthesis of other pigments usually either anthocyanins or carotenoids. They can give rise to a wide range of colours (from red to blue). The chloroplasts in green immature fruit generally lose chlorophyll on ripening and change into chromoplasts which contain carotenoid pigments. Carotenoids are normally synthesized in green plant tissue a major product being 3-carotene. However, in many fruits additional - carotene and lycopene is synthesized during ripening.

5. Flavouring Compounds

Although fruit flavour depends on the complex interaction of sugars, organic acids, phenolics and volatile compounds but the characteristic flavour of an individual fruit or vegetable is derived from the production of specific flavouring volatile. These compounds are mainly esters, alcohols, aldehydes, acids and ketones. At least 230 and 330 different compounds in apple and orange fruits have been indicated respectively.

6. Ascorbic Acid

L-ascorbic acid (Vitamin C) is the naturally occurring ascorbic acid in fruits. A reduced amount of ascorbic acid is noticed in pome, stone and berry fruits at the time of harvest. An increase in ascorbic acid content with the increase in fruit growth has been and the levels declined with the advancement of maturity and onset of fruit ripening in pear, sweet potatoes, potato, asparagus and okra during the course of post harvest handling.

7. Phenolics

The phenolic content of most fruits declines from high levels during early growth to low levels when the fruit is considered to be physiologically mature and thereafter susceptible to the induction of ripening.

8. Amino Acids and Proteins

Decrease in free amino acid which often reflects an increase in protein synthesis. During senescence the level of free amino acids increases reflecting a breakdown enzymes and decreased metabolic activity.

9. Ethylene Production and Respiration

Physiological events responsible to ripening process are as follows

(1) Ethylene production

(2) Rise in respiration

Ethylene production

In climacteric fruits such as mango, banana, ethylene production increase and causes:

- Rise in respiration
- Rise in temperature
- Rise in activity of hydrolytic enzymes.

Ethylene is produced from an essential amino acid — methionine. Following the steps as below:

SAM — Methionine S adenosyl methionine

(ACC synthase)

↓

Amino cyclo propane

(ACC oxidase)

↓

Carboxylic acid (ACC)

↓

Ethylene

↓

Perception by ethylene receptor

↓

Signal transduction

↓

Switching or ripening genes

Rise in respiration

Respiration is required for releasing energy and the substrate for synthesis of several organic compounds required in the ripening process. During ripening in climacteric fruits, there is rise in respiration called climacteric. The clirnacteric peak is obtained very fast when temperature is relatively high. Respiration is a most deteriorating process of the harvested fruits and vegetables which leads to the oxidative breakdown of the complex materials (carbohydrates or acids) of cell into simpler molecules (CO_2 and water) with the concurrent production of energy required by the cell for the completion of chemical reactions. In brief, the process of respiration can be summed up with the following reaction:

$$C_6H_{12}0_6 + 6O_2 \longrightarrow 6\ CO_2 + 6\ H_20 + \text{energy}$$

USE OF CHEMICALS FOR INCREASING SHELF LIFE OF FRUITS AND VEGETABLE

(A) Ethylene absorbent

Ethylene is responsible for decreasing shelf life. Putting $KMNO_4$ @ 100 ppm soaked filter paper can minimized ripening and increase shelf life. In Banana this method is very useful.

(B) Antifungal Agents

• SOPP: Sodium orthophenylphenate

• Diphenyl wraps protection against moulds, stem-end rot.

• Dibromoletrachloroethane and esters give better flavour.

(C) Use of Inhibitors

Treatment	Crop	Chemical	Concentration
Post-harvest	Mango	MH	1000-2000 ppm
After fruit formation	Apple	2-Dimethyl-hydrazide	10,000 ppm

(D) Use of Auxins

Also helpful to advance in ripening and may increase shelf life.

Chemical	Concentration	Crop	Stage
2,4-D	5 ppm	Grape	Pre-harvest
2,4,5-T	25 ppm	Fig	Pre-harvest
2,4,5-T	100 ppm	Mango	After harvesting

E) Vegetables can be preserved by lactic acid and may increase the shelf life.

F) Post harvest dipping of papaya fruits either in l00 ppm GA_3 or $CaCl_2$ al 2% extended shelf life up to 9 days without any decline in quality.

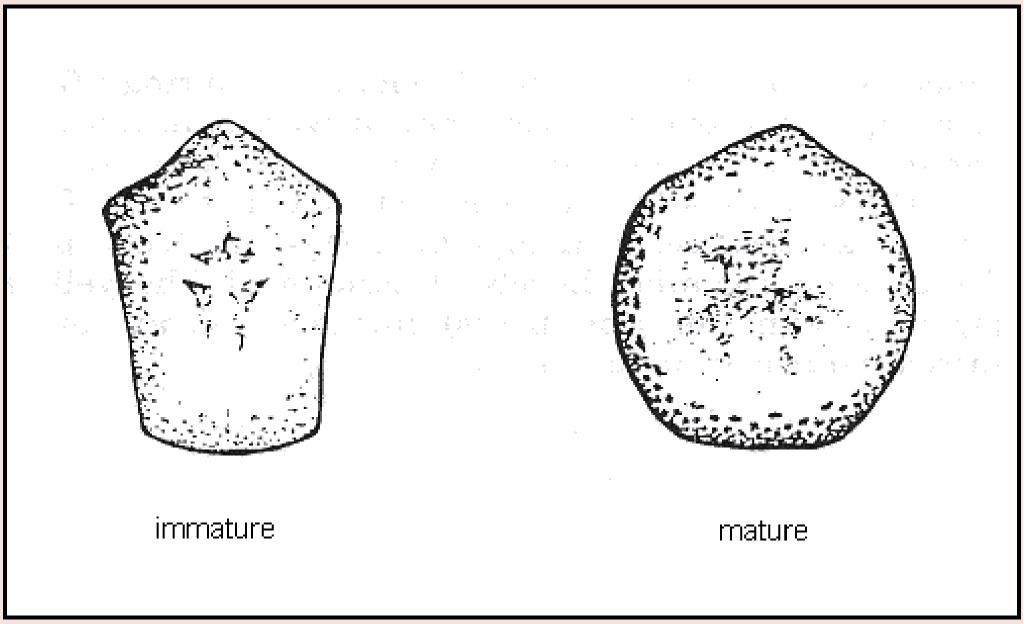
Lecture 4. Factors affecting ripening can be physiological, physical, or biotic.

Physiological factors relate to fruit maturity or environmental factors, which affect the metabolism of fruit and banana.

Physical factors include mechanical damage, or relate to dimensions of the fruit.

Biotic factors include attack from pests and diseases.

Fruit maturity. The more mature fruit is at harvest, the shorter the ripening period. Studies show that banana harvested 100 days after flowering ripened in 11 days. When the same cultivar was harvested 90 days after flowering, the ripening period increased to 15 days, and further increased to 22 days when the fruit was harvested at 80 days. Farmers have to match the date of harvest with the transportation time to the market. However, an early harvest reduces yield.



Cross-sections of immature and mature plantain/banana fruits.

As fruits mature, the cross-sectional diameter increases. Fruit angularity also changes during growth and maturation. As fruits approach full maturity, fruit angles become less acute Fruit angularity can be used to predict the optimum harvest date of banana.

Temperature. Physiological studies on bananas show that storage life decreases as external temperature increases over the range 15-35ºC. A 1ºC reduction increases storage period by 1-2 days.

The relationship between ripening period and temperature is due to fruit respiration. Fruit respiration depends on many enzymatic reactions, and the rate of these reactions increases exponentially with increase in temperature. Studies show that ripe fruits respire at approximately 4 times the rate of unripe fruits. Consequently, ripe fruits lose sugar resources at a higher rate than unripe fruits. This explains why ripe fruits deteriorate quickly.

The relationship between temperature and respiration is described mathematically by van't Hoff's temperature quotient (Q10). van't Hoff showed that the rate of respiration approximately doubles for each 10ºC rise in temperature.

Water loss and humidity. Where fruit is sold on a weight basis, loss of water means economic loss. Additionally, water loss reduces visual quality. Water loss causes fruit to lose its firmness, the peel becomes soft and shriveled, and ripening period reduces. Studies on fruits show a curvilinear or power relationship between fruit weight loss and ripening period. For a 2% change from 2% to 4% weight loss per day, ripening period reduced by 9 days or 50%. Therefore, at a low rate of weight loss, a small increase in weight loss has a critical effect on ripening.

The rate of water loss depends on the ambient relative humidity (RH). RH is the amount of water vapor present in the air, relative to the maximum amount of water vapor that can be held in the air, at a given temperature, saturated air being 100% RH. When a water-containing material such as fruit is placed in an enclosed space, for example, a sealed container, the water content of the air within the container increases or decreases until it is in equilibrium with the fruit.

The water equilibrium principle applies when fruit is stored. The rate of water loss depends on the ambient RH. At an ambient RH of 95-100%, fruit loses little or no moisture, and ripening period is unaffected. However, as humidity decreases, the rate of water loss increases, and ripening period reduces.

Excessive wetting can also be a problem. When fruit is stored in wet conditions, such as in moist coir (coconut fiber), the uptake of water from the coir to the fruit leads to peel splitting.

Sunlight. Exposure to direct sunlight reduces the ripening period of fruits. Sunlight increases fruit temperature above ambient temperature, which increases respiration, and possibly the rate of water loss. The solar radiation that falls upon foods held in direct sunlight increases the temperature above the ambient temperature. The amount of increase in temperature depends on the intensity of the radiation, the size and shape of the food' and the duration of exposure to the direct rays of the sun. The intensity of solar radiation depends upon latitude, altitude, season of the year, time of day, and degree of cloud cover.

Altitude. Within a given latitude the prevailing temperature is dependent upon the elevation when other factors are equal. There is on the average a drop in temperature of 6.5°C for each Km increase in elevation above sea level. Storing food at high altitudes will therefore tend to increase the storage life and decrease the losses in food provided it is kept out of the direct rays of the sun.

Atmosphere. The normal atmosphere contains by volume, approximately 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide' various amounts of water vapor and traces of inert gases. Modifying the atmosphere can improve the shelf life and reduce wastage of certain foods.

One type of controlled atmosphere storage (CA) is refrigerated storage in which the level of oxygen is reduced to about 3% with the carbon dioxide content being raised to 1 to 5%, depending on the commodity. This CA storage may double the storage life over that of regular cold storage for certain varieties of apples and pears by slowing down the natural rate of respiration.

Ethylene (C_2H_4) is a gaseous plant hormone which determines the time between harvest and senescence. The time from harvest to the climacteric respiratory response is called the 'green life' or preclimacteric period. Ethylene shortens the preclimacteric period; at high concentrations, ethylene causes rapid initiation of the climacteric respiratory response and accelerates ripening.

When nonclimacteric fruits are exposed to ethylene, fruits show an increased rate of respiration. However, respiration rate falls when ethylene is removed. A rise in respiration rate may occur more than once in nonclimacteric fruits. However, for climacteric fruits, the climacteric is autocatalytic, that is, once started, the process cannot be stopped until the fruit is ripe.

Poor storage methods allow a build up of ethylene, stimulate the climacteric response, and reduce the ripening period. For example, plastic sheets placed over stacks of fruit for shade increase the level of ethylene within the fruit stack and increase the rate of ripening. Therefore, store fruit in thatched or ventilated areas to prevent the build up of ethylene. Also, do not store unripe fruits with ripe fruits.

During the preclimacteric period, fruits are less susceptible to physical damage and pathological attack. This is the best time for handling, transportation, and marketing.

Mechanical damage. Mechanical damage is a physical factor affecting ripening. Fruit damage during handling generates ethylene. If ethylene production is sufficient to start the climacteric respiratory response, fruit immediately starts to ripen.

Damage can also reduce ripening period by causing moisture loss. The effect of damage can easily be measured by recording fruit weight loss over time. Cuts and abrasions on the surface membrane cause the most weight loss.

After harvest, fruits lose the ability to repair ruptured peel. Harvesting techniques which damage fruit reduce storability.

Studies show that an abrasion affecting 5-10% of the peel can reduce the ripening period by 40%. Damage can also lead to secondary infection, which increases the rate of water loss and further reduces quality.

Surface to volume ratio. The ratio between surface area and volume determines the rate of water loss. The greater the surface to volume ratio, the shorter the postharvest life. A leaf which has two large surfaces with little volume loses moisture faster than a fruit. Large fruits lose less water than small fruits.

Peel thickness. Fruits with thin peel lose more water. A higher peel permeability leads to a higher rate of water loss and a faster ripening rate. Also, fruits with thick peel, for example melons, withstand damage better than fruits with thin peel, such as tomatoes.

Stomatal density. A higher density of stomata may cause a higher rate of water loss, which accelerates ripening.

Biotic stress. Fungi, bacteria, viruses, and insects also account for a considerable proportion of total postharvest loss. Pests and diseases reduce both ripening period and overall quality. However, attack by pests and diseases is often secondary because a pest exploits a damaged area of the fruit. Careful fruit handling often prevents such attacks.

Chapter 5: PRE HARVEST FACTORS AFFECTING QUALITY ON POST HARVEST LIFE OF FRUITS AND VEGETABLES – FACTORS RESPONSIBLE FOR DETERIORATION OF HARVESTED FRUITS AND VEGETABLES

Quality of post harvest product

Post harvest quality represents market quality, edible quality, transport quality, table quality, nutritional quality, internal quality and appearance quality. Quality means a combination of characteristics, attributes and properties that gives the values to human and enjoyments. Consumers consider good quality in relation to colour, flavour and nutrition. Quality of the produce is the final manifestation of inter-relation between the commodity and its environment. The genetic characteristics and physiological status of the commodity determine the typical post-harvest behavior and quality of the produce and these two are the major bases for the interaction. Pre-harvest factors viz, environmental factors such as temperature, relative humidity, water potential, light, cultural practices and pest management techniques determined the inherent quality of the produce. However, the ultimate quality is the final manifestation of inter relation between the commodity and its environment.

Several pre-harvest and post-harvest factors affect the quality of horticultural crops. Some of these factors are related to plant, others are related to environment or to cultural practices.

A. Pre-harvest factors

a) Related to plants

- **Crops: Q**uality of the fruit and vegetables are varies from crop to crop e.g. jackfruit, bael, potato, onion, pumpkin, garlic etc. having good quality in relation to shelf life, while apple, mango, cherry, strawberry, tomato, capsicum, okra, brussels sprout, chinese cabbage, carrot, radish attract more to consumers due to their attractive appearance.
- **Cultivars:** The quality of seed or plant material is an important factor that controls the quality of the fruit and vegetable produced. Several parameters of quality are controlled genetically.

• **Cultural practices**: All cultural practices have direct effect on the final quality of the produce.

• **Planting period**: Many plants are very sensitive to environmental conditions, and thus quality will not be optimized when crop is produced under adverse conditions. Producing summer plants during the winter or vice-versa will not be appropriate, unless protection practices are implemented.

• **Planting density**: It affects both the quantity and quality of the produce. High density planting increases competition between plants, reduces light availability, and thus may decrease quantity. Low density planting lead to large size, better colored fruit or vegetable which may have shorter shelf life. Larger fruits are commonly more sensitive to physiological disorders.

• **Irrigation:** Irregular watering usually reduces fruit size, increases splitting, physiological disorders, reduces water content in the plant or plant part, etc.

• **Fertilization:** Poor management of fertilizers will increase physiological disorders due to deficiencies of some minerals or increase of other leading to toxicity. In both cases, quality will be negatively affected.

• **Pruning:** It reduces the load and increases the growth of fruit and chemical use after harvest.

• **Thinning:** This operation reduces the competition between fruits or plants and thus promotes a good balance between the vegetative and fruit parts and improves quality.

• **Protection:** Pathogens and insects have a very negative effect on quality. Poor management of plant protection programmes can lead to very poor quality and reduced yield.

b) Related to environments

Temperature is the most important environmental factor that affects quality, very low or very high temperature may injure sensitive crops. Adequate high intensity and quality is important for the formation of some colour. Wind and rain may cause negative effects on some crops.

c) Related to chemicals

Many hormones and growth regulators are used in agriculture and they can affect quality in different ways.

B) During harvest factor

• **Season:** Quality of produce are greatly influenced by season e.g. Winter season harvest having more shelf life as compared to other season, while off season fruits and vegetables give more remunerative price. Harvesting during or immediately after rains should not be carried out since it creates most favourable conditions for multiplication of micro-organisms. Citrus fruits become susceptible to damage if harvested during rains as their rind becomes turgid and prone to easy bruising, sun-scald etc.

• **Time:** Fruits and vegetables should always be harvested when temperature is mild. Because, higher temperature leads to faster respiration. Morning harvest of horticultural crop prefer for local market because they are fully fresh and turgid and having dew drop in this time. Evening harvesting is preferred for distant market due to higher accumulation of reserved carbohydrates and less amount of moisture which give the better quality of the produce to consumer. Leafy vegetables harvested in the latter part of the morning or late in the afternoon, the petioles of these vegetables break less easily and their leaves are more resistant to tearing, since they have lost water through transpiration and therefore are less brittle. Cucumber is harvested in the late morning when it to be transported under less than ideal condition because it is less prone to injury when it contains less water.

• **Method of harvesting**: Selection of suitable method for harvesting of the produce is necessary otherwise bruises or injuries during harvesting may later manifest as black or brown patches making them unattractive. Latex coming out of stem in mango should not be allowed to fall on fruits as it creates a black spot. Injury to peel may become an entry point for microorganisms, causing rotting. Some harvesting gadgets have been developed, e.g. mango harvester in Lucknow (CISH).

• **Stage of harvesting**: Fruits and vegetables must be harvested at right stage of maturity. A very common cause of poor product quality at harvest and rapid deterioration thereafter is harvesting immature vegetables. Vegetables harvested immature or over mature usually do not keep long. Fruit vegetables harvested too early lose water fast and are more susceptible to mechanical damage and microbial attack. An over mature vegetable is more susceptible to decay, has passed its best eating quality, and deteriorates fast.

• **Consumer demand**: Harvesting time and harvest maturity can be altered by the requirement of the consumer's demand which may affect the quality of the produce at some extent.

c) Post-harvest factors:

• **Curing:** Curing is done immediately after harvesting. It strengthens the skin. The process is induced at relatively higher temperature and humidity, involving suberization of outer tissues followed by the development of wound periderm which acts as an effective barrier against infection and water loss. It is favoured by high temperature and high humidity. Potato, sweet potato, colocasia, onion and garlic are cured prior to storage or marketing. Potato tubers are held at 18°C for 2 days and then at 7°—10°C for 10—12 days at 90% relative humidity. Curing also reduces the moisture content especially in onion and garlic. Drying of superficial leaves of onion bulbs protects them from microbial infection in storage.

• **Degreening**: It is the process of decomposing green pigment (Chlorophyll) in fruits usually applying ethylene or similar metabolic inducers to fruit. It is applicable to banana, citrus and tomato. Degreening is carried out in special treating rooms with controlled temperature and humidity in which low concentration of ethylene (20 ppm) is applied.

• **Pre-cooling:** High temperatures are detrimental to keeping quality of fruits and vegetables, especially when harvesting is done during hot days. Pre-cooling is a means of removing the field heat. It slows down the rate of respiration, minimizes susceptibility to attack of microorganisms, and reduces water loss. Peas and okra which deteriorate fast need prompt pre-cooling.

- **Washing and drying**: Most of the fruits and vegetables are washed after harvesting to improve their appearance, to prevent wilting and to remove primary inoculum load of microorganism. Hence, a fungicide/bactericide should be used in washing water. Washing, improves shelf life of bananas by delaying their ripening. After washing, excess of water should be removed which would otherwise encourage microbial spoilage.

• **Sorting and grading**: Fruits and vegetables require sorting and grading for uniform packing at field level. Sorting is done on the basis of size and colour while grading practice is performed as per the defect or on the basis of marketable and unmarketable produce.

• **Disinfection:** Papaya, mango, melon and other fruits are susceptible to fruit fly attack. Disinfection is done either by vapour heat treatment (VHT) at 43°C with saturated air with water vapour for 6-8 hr by Ethylene dibromide fumigation.

• **Waxing:** Fruits and vegetables have a natural layer on their outer surface which is partly removed by washing. An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency to prevent anaerobic condition within the fruits provides necessary protection against decay organism. Waxing also improves the appearance and glossiness, making them more acceptable.

• **Packing:** It means more than carrying multiples of an object. Packing not only protects the horticultural produce but also makes a favourable impression on the buyers and May able to fetch higher income.

• **Delivery:** Moving the harvest produce from the farm to the customer in good condition is important. All efforts upto delivery can be invalid if the fresh fruits and vegetables reach the destination in poor condition. Care should be taken to protect the produce and it becomes necessary when mixing load of fruits and vegetables to prevent violating the compatibility factors.

LECTURE 6. FACTORS RESPONSIBLE FOR DETERIORATION OF HARVESTED FRUITS AND VEGETABLES

A- Primary causes of loss: Those are directly affect the food

Enzymic changes

Enzymes which are endogenous to plant tissues can have undesirable or desirable consequences.

Examples involving enzymic changes include:

- the post-harvest spoilage of fruit and vegetables
- oxidation of phenolic substances in plant tissues by phenolase (leading to browning)
- sugar - starch conversion in plant tissues by amylases
- post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

The major factors useful in controlling enzyme activity are:

1. temperature
2. water activity
3. pH
4. chemicals which can inhibit enzyme action

Chemical changes

Sensory quality

The two major chemical changes which occur during the processing and storage of foods and lead to a deterioration in sensory quality are lipid oxidation and non-enzymatic browning. Chemical reactions are also responsible for changes in the colour and flavour of foods during processing and storage.

- Lipid oxidation rate and course of reaction is influenced by light, local oxygen concentration, high temperature, the presence of catalysts (generally transition metals such as iron and copper) and water activity. Control of these factors can significantly reduce the extent of lipid oxidation in foods.

Non-enzymic browning is one of the major causes of deterioration which occurs during storage of dried and concentrated foods.

Colour changes

Almost any type of food processing or storage causes some deterioration of the chlorophyll pigments. This reaction is accelerated by heat and is acid catalysed.

Flavour changes

In fruit and vegetables, enzymically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavors. In addition, these types of reactions can lead to significant off-flavors.

The permeability of packaging materials is of importance in retaining desirable volatile components within packages, or in permitting undesirable components to permeate through the package from the ambient atmosphere.

Nutritional quality

The four major factors which affect nutrient degradation and can be controlled to varying extents by packaging are

1. Light
2. oxygen concentration
3. temperature
4. water activity.

2.3- Physical changes

One major undesirable physical change in food is the absorption of moisture as a consequence of an inadequate barrier provided by the package; this results in caking. It can occur either as a result of a poor selection of packaging material in the first place, or failure of the package integrity during storage. In general, moisture absorption is associated with increased cohesiveness.

Biological changes

Microbiological

Micro-organisms can make both desirable and undesirable changes to the quality of foods depending on whether or not they are introduced as an essential part of the food preservation process or arise unintentionally and subsequently grow to produce food spoilage.

The two major groups of micro-organisms found in foods are bacteria and fungi, the latter consisting of yeasts and moulds. Bacteria are generally the fastest growing, so that in conditions favourable to both, bacteria will usually outgrow fungi.

Foods are frequently classified on the basis of their stability as non-perishable, semi-perishable and perishable.

The protection of packaged food from contamination or attack by micro-organisms depends on the mechanical integrity of the package (e.g. the absence of breaks and seal imperfections), and on the resistance of the package to penetration by micro-organisms.

Macrobiological

Insect Pests

Warm humid environments promote insect growth, although most insects will not breed if the temperature exceeds about 35 C° or falls below 10 C°. Also many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than about 11%.

Rodents

Rats and mice carry disease-producing organisms on their feet and/or in their intestinal tracts and are known to harbour salmonella of serotypes frequently associated with food-borne infections in humans.

B- Secondary causes of loss: Those lead to conditions that encourage a primary cause of loss such as:

1- Inadequate harvesting, packaging and handling skills.

2- Lack of adequate containers for the transport and handling of perishables.

3- Storage facilities inadequate to protect the food.

4- Transportation inadequate to move the food to market before it spoils.

5- Inadequate refrigerated storage.

6- Inadequate drying equipment or poor drying season.

7- traditional processing and marketing systems can be responsible for high losses.

8- Legal standards can affect the retention or rejection of food for human use.

10- Knowledge of management is essential for maintaining tool in good condition during marketing and storage.

11- Bumper crops can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage.

Sites of losses

Losses may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption. Losses can occur during one of the following processes:

1- Harvest. The separation of the commodity from the plant that produced it.

2- Preparation. The preliminary separation or extraction of the edible from the non- edible portion.

3- Preservation. The prevention of lose and spoilage of foods. For example, the sun-drying of fruit, the use of refrigeration and the use of fungicides to inhibit mold growth in fruits.

4- Processing. The conversion of edible food into another form more acceptable or more convenient to the consumer, for example, the manufacture of fruit juice and the canning of fruits and vegetables.

5- Storage. The holding of foods until consumption. Most storage is common storage (ambient temperature) but there are extensive storage capacities that can hold food under refrigerated or controlled atmosphere conditions.

6- Transportation. All forms of transportation are used to convey foods from the point of production to the ultimate point of consumption.

Lecture 7: Chemicals used in Ripening

Chemicals for hastening and delaying ripening of fruits and vegetables

Hastening ripening: These some times stimulate ripening of gathered fruits. It seems that the treatment is effective especially when the application is made very early soon after the picking. Stems of bananas immersed in solution containing 1000ppm sodium 2,4-D, 2,4,5 -T or Para- chloro- phenoxy acetic acid showed that ripening was accelerated.2, 4,5 -T and to some extent 2,4-D when sprayed in a wax emulsion delayed the development of yellow colour in the rind of lemons during storage increases the storage life..

Application of ethephon promotes degreening and early ripening in grape, tomato, coffee, pear, plum, peach and citrus. Smoking is commercially employed to hasten de-greening and ripening of banana and mango. Calcium carbide release acetylene which on hydrolysis hasten ripening process. ABA at 1ppm, thio- urea at 20%.CCC 4000ppm,ethrel 200-300ppm sprays one week before harvest hastens ripening.

Delaying ripening: Auxins may slow down (generally) or even sometimes accelerate ripening process. Ethylene formation is inhibited by auxin and therefore auxins have to be broken down by peroxidases (IAA Oxidases) to control fruit ripening. Ripening in accompanied by a rise in auxin degrading enzymes. Gibberellins also stop colour changes in fruits like banana. Accumulation of abscisic acid (ABA) is also associated with ripening. Chemials that delay ripening are (1) Kinetin, (2) GA, (3) Auxin, (4) Growth retardant (MH), (5) Alar, (6) CCC. (7)CIPC. (8)Metabolic Inducers-(a)Cycloheximide, Actinomycin-D(b)Vitamin-k,(c)Maleic acid, (d)Ethylene Oxide, (e)NA-DHA, (f)Carbon monoxide,(9) Ethylene absorbents-(a)KMno4(b)Fumigants like methyl bromide(c)Reactants

Volatiles: Non-ethylinic volatiles can stimulate ripening. Air purification with activated carbon, H2SO4 and NaOH slowed down the ripening of pre-climacteric apples in a recirculation system. Carbon (activated) reduces the effect in both the cases.

Growth regulators: These some times stimulate ripening of gathered fruits. It seems that the treatment is effective especially when the application is made very early soon after the picking. Stems of bananas immersed in solution containing 1000ppm sodium 2,4-D, 2,4,5 -T or Para- chloro- phenoxy acetic acid showed that ripening was accelerated.2, 4,5 -T and to some extent 2,4-D when sprayed in a wax emulsion delayed the development of yellow colour in the rind of lemons during storage. The storage life increases.

Application of ethephon promotes degreening and early ripening in grape, tomato, coffee, pear, plum, peach and citrus. Smoking is commercially employed to hasten de-greening and ripening of banana and mango. Calcium carbide release acetylene which on hydrolysis hasten ripening process. ABA at 1ppm, thio- urea at 20%.CCC 4000ppm,ethrel 200-300ppm sprays one week before harvest hastens ripening.

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The shelf life of fruits like apple, banana and others can be improved by storing the fruit in low oxygen tension (203%) or by absorbing ethylene with a suitable absorbent like alumina or silica gel impregnated with potassium permanganate. MH,GA(10-6M), IAA(10-6M) sprays one to two weeks before harvesting and post harvest dip of cycocel, Alar, GA(150ppm), Vit K3, KMNO4,Ca Cl2,Waxol delays ripening.

Chapter 8: METHODS OF STORAGE-PRECOOLING, PRE STORAGE TREATMENTS, LOW TEMPERATURE STORAGE, CONTROLLED ATMOSPHERE STORAGE, HYPOBARIC STORAGE, IRRADIATION AND LOW COST STORAGE STRUCTURES

Pre-cooling is the key component in the preservation of quality for perishable fresh produce in post-harvest systems. It is likely the most important of all the operations used in the maintenance of desirable, fresh and salable produce. Precooling is defined as the removal of field heat from freshly harvested produce in order to slow down metabolism and reduce deterioration prior to transport or storage. One of the most important factors affecting the postharvest life and quality of fruits and vegetables is temperature. Quality loss after harvest occurs as a result of physiological and biological processes, the rates of which are influenced primarily by product temperature. As the maintenance of market quality is of vital importance to the success of the horticultural industry, it is necessary not only to cool the product but to cool it as quickly as possible after harvest.

Pre-cooling rapidly lowers the temperature of freshly harvested produce and is done immediately following harvest to minimize spoilage. It is the first operation in the cold chain and is essential for produce (fruits and vegetables) as they are perishable in nature. Although produce may be pre-cooled in a cold storage facility, pre-cooling differs from cold storage. In cold storage, the temperature is simply maintained at a predetermined low temperature. If the cold storage facility is to double as a pre-cooling facility, higher refrigeration capacity is required as well as appropriate provisions for pre-cooling and handling of the produce. The main beneficiary of precooling is the grower as it allows him to sell the produce at the most appropriate time and at the competitive price. Consumers and general economy also benefit through adoption of proper post harvest handling procedures through improved shelf quality, lower real costs for fruits and vegetables through the reduction of losses and spoilage.

Proper pre-cooling preserves product quality by

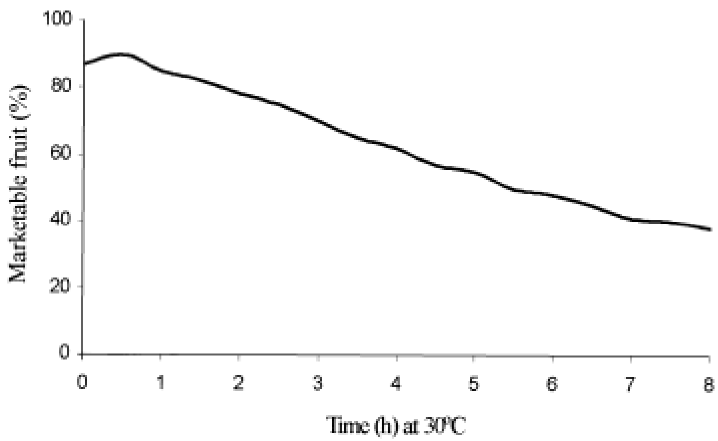
- inhibiting the growth of decay producing microorganisms
- restricting enzymatic and respiratory activity
- inhibiting water loss
- reducing ethylene production

The importance of precooling

(i) Importance of lag time between harvest and cooling

Field heat can cause rapid deterioration of some horticultural crops and therefore it is desirable to remove this heat as quickly as possible after harvesting. When it comes to produce quality, every minute counts and that precooling is among the most cost-effective and effcient quality preservation methods available to commercial crop produces. For example, strawberries experience increasing deterioration losses as delays between harvesting and cooling exceeds 1 h and the effects of the delay on cooling of strawberries is shown in Fig.1.

Fig.1. Effect of delay before cooling on the quality of Shasta strawberries



From this it can be seen that even after a short time of 2 h at 30^{0}C, only 80% of the strawberries are considered marketable fruit, which represents an apparent loss of approximately 10% by not cooling the produce immediately after picking. Furthermore, precooling slows down the deterioration and the rotting process by retarding the growth of decay organisms, and it reduces wilting since transpiration and evaporation occurs more slowly at low temperatures.

(ii) Influence of precooling on the respiration rate

The rate of deterioration after harvest is closely related to the respiration rate of the harvested product, therefore the reduction of respiration rate is essential to preserving market quality. Since the rate of respiration is influenced by temperature , precooling to remove the field heat before storage will reduce the respiration rate and hence deterioration will decline accordingly. For example reduction in temperature of 9.5^{0}C in grapes halved the rate of respiration and doubled their keeping quality.

(iii) Influence on metabolism

The increase in the rate of deterioration is related to the metabolic processes of the crop. Within the plants temperature range, the rate of deterioration increases logarithmically with increasing temperature. Metabolic rates double for each 10^{0}C rise in temperature. From these reports, it can be seen that the quicker the temperature is reduced the less losses that can occur. Hence, precooling is essential in order to reduce metabolic changes such as enzyme activity, and to slow the maturation of perishable produce.

(iv) Effects of rapid cooing on ethylene

The reduction in temperature has the added advantage of reducing the production and sensitivity of the produce to ethylene that accelerates ripening and senescence. Therefore, the faster and more promptly the field heat and hence temperature is reduced after harvest, the quicker these deteriorative processes are retarded and hence the more of the initial quality can be maintained.

Methods for Precooling Produce

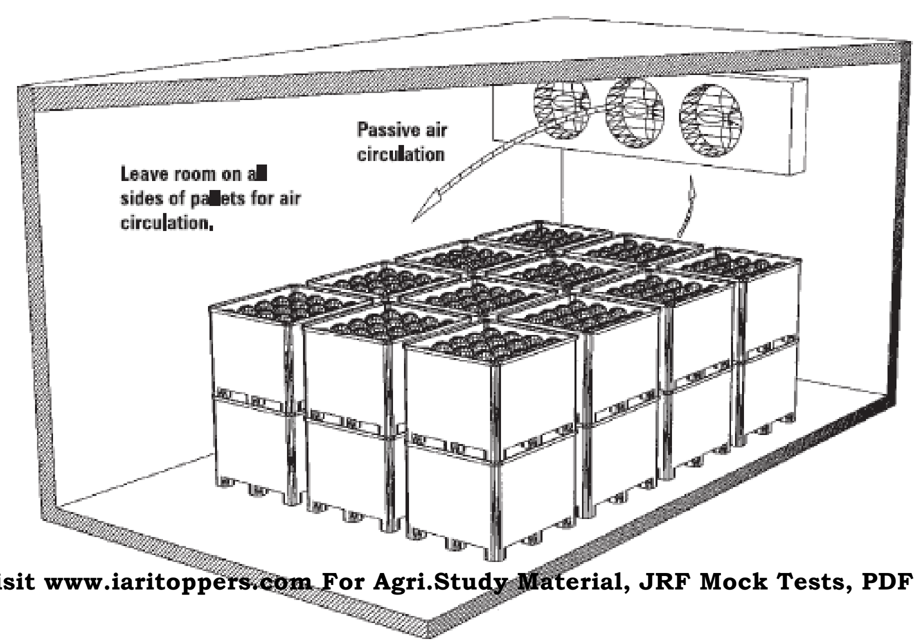
There are seven principal methods of pre-cooling fresh produce:

1) Room cooling
2) Forced-air cooling
3) Hydro-cooling
4) Ice cooling
5) Vacuum cooling
6) Cryogenic cooling
7) Evaporative cooling

Considerable loss in quality and shelf life can occur as a result of holding harvested produce in the field before pre-cooling. All methods require sufficient refrigeration capacity to reduce the temperature of the produce within the required time plus the ability to remove the normal heat gain in the facility.

1) Room cooling

Precooling produce in a cold-storage room or precooling room is an old well-established



practice . This widely used method involves the placing of produce in boxes (wooden, fiberboard or plastic), bulk containers or various other packages into a cold room, where they are exposed to cold air. It is used for produce sensitive to free moisture or surface moisture. Because this type of cooling is slow, room cooling is only appropriate for very small amounts of produce or produce that does not deteriorate rapidly.

Fig.2. Room cooling

Typically the cold air is discharged into the room near the ceiling, and sweeps past the produce containers to return to the heat exchangers. The cooled air is generally supplied by forced or induced draft coolers, consisting of framed, closely spaced and finned evaporator coils fitted with fans to circulate the air over the coils. Therefore, as to achieve fast and efficient cooling, care should be taken that the correct packaging (well vented) or containers and stacking patterns are used. Air velocities around the packages should be at least 60 m/min to provide the necessary turbulence to achieve heat removal and therefore attain adequate cooling. As much of the cooling is achieved by conduction, room cooling gives a slow and variable temperature reduction, therefore perishable produce used in this method must be tolerant of slow heat removal. A conventional cold store is unsuited for this operation because as much as three-quarters of the refrigerator capacity may be required simply to remove field heat and the cooling rates are frequently no better than 0.5^0C/h. The rooms commonly used for highly perishable fruit are designed to have an airflow rate of about 170 to 225 m^3/min for a room with a capacity of 15,000 kg and sufficient refrigeration so as to cool the fruit to 5^0C in approximately 12 h. Containers are stacked individually so that cold air from the ceiling blows over or around the produce to contact all surfaces of the containers.

Produce will dry out if a high relative humidity (90-95 percent) is not maintained. Containers should be well vented so as much air as possible can circulate through them. Spacing between the containers and walls must be from 6 to 12 inches, and between the boxes and ceiling, 18 to 24 inches. Room cooling is not recommended for bulk bins because they contain a much greater mass of produce than smaller containers. Proper design of the cooling room and refrigeration equipment is necessary for room cooling to work efficiently. The refrigeration equipment must be capable of cooling down fresh produce within 24 hours and of maintaining the storage temperature of the produce. Normally, much larger refrigeration equipment is needed to cool down the produce than to maintain the produce at a cool temperature. Room cooling has become increasingly difficult as more commodities are being handled in larger quantities and are packaged immediately after harvest due to better mechanization. These difficulties coupled with its slow and variable cooling extend the cold chain and therefore reduce the product life in subsequent storage.

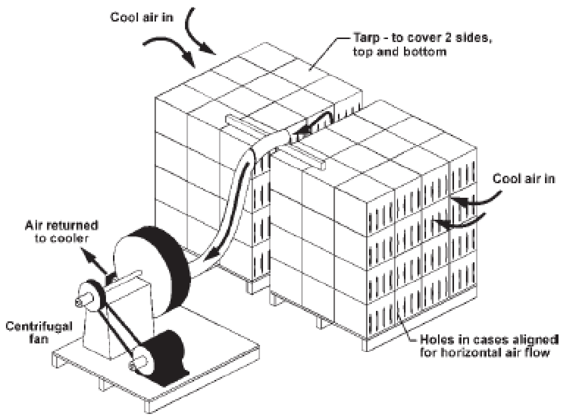
2) Forced air cooling

Forced air cooling was developed to accommodate products requiring relatively rapid removal of field heat immediately after harvest. Forced air or pressure cooling is a modification of room cooling and is accomplished by exposing packages of produce to higher air pressure on one side than on the other. This technique involves definite stacking patterns and the baffling of stacks so that the cooling air is forced through (rather than around) the individual containers. For successful forced air cooling operations, it is required that containers with vent holes be placed in the direction of the moving air and packaging materials that would interfere with free movement of air through the containers should be minimized. A relatively small pressure difference between the two sides of the containers exists, resulting in good air movement and excellent heat transfer and hence faster cooling.

Produce can be cooled by a variety of different forced air cooling arrangements. These include (a) air circulated at high velocity in refrigerated rooms, (b) by forcing air through the voids in bulk products as it moves through a cooling tunnel on continuous conveyors, and (c) by encouraging forced airflow through packed produce by the pressure differential technique. Each of these methods is used commercially, and each is suited for certain commodities when properly applied. The product cooling rate is affected by numerous variables and, therefore, the overall cost of the forced air cooling will vary. These variables include product size and shape; thermal properties; product configuration (bulk or packaged); carton vent area; depth of product load during cooling; initial product temperature; final desired product temperature and airflow rate, temperature, and relative humidity.

The cooling rate in a given system depends primarily on the velocity of the cold air flowing through it, and this is the only controlling factor, since no change can be made in certain fixed factors such as size, shape and thermal properties of the produce. In addition, the temperature of the cold air cannot be reduced below a certain safe point to avoid chilling injury. In general, the cool air necessary for this type of cooling can be generated from (a) direct expansion refrigeration system, (b) ice bank cooling system and (c) water cascade. Forced air coolers utilise centrifugal (commonly known as squirrel cage) or axial fans which push the cold air around the system. Fans are selected based on the criteria of required airflow and static pres-sure. These requirements are influenced by the type of produce and quantity being cooled, the arrangement of the produce (bulk, boxes or stacking) and the cooling rate required.

Differential pressures in use are approximately 0.6 to 7.5 mbar with air flows ranging from 0.001 to 0.003 m^3/s kg product.



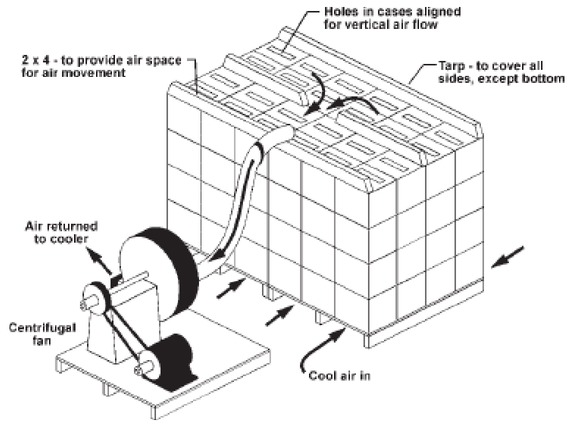


Fig.3. Forced horizontal air flow **Fig.4. Forced vertical air flow**

The air can be channeled to flow either horizontally or vertically. In a horizontal flow system, the air is forced to flow horizontally from one side of the pallet load to the other through holes in the sides of the pallet bin or containers. Only two sides that are opposite can be open in the pallet bin or containers. In stacking containers, the side holes must line up for the air to pass from one side of the stack to the other. In this system, the top and bottom of the pallet or containers must be sealed to prevent air from by passing the produce.

In a vertical flow system, the air is forced to flow vertically from the bottom to the top of the pallet through holes in the bottom of the pallet, and containers if used, then out the top. In this system, the sides must be sealed to prevent the air from bypassing the produce. Also, if containers are used, the holes in the tops and bottoms of the containers must line up, so the air can travel vertically from one container to the next. This method is faster than room cooling because a flow of chilled air is in direct contact with the produce. In these systems, condensation on the produce can be minimized by a simple cover placed on top of the stack of containers, which prevents the entry of ambient air during handling.

The key to forced-air cooling is moving the cold air through the container and its contents. Important factors in container ventilation are location of container vents, stacking of containers, and size of the vents. Container vents should be aligned whether the containers are straight-stacked or crossstacked, to maximize air flow through the containers. If vents are too small or too few, air flow is slowed. If there are too many, the container may collapse. In this method, containers are stacked close together (tight). Five percent vent-hole space per side and/or end is best. Liners, bags, wrappers, or dividers can slow the flow of air through the container, so precooling produce is usually recommended prior to additional packing. The following are forced-air cooling alternatives.

Cold Wall

A permanent false wall or air plenum contains an exhaust fan that draws air from the room and directs it over the cooling surface. The wall is at the same end of the cold room as the cooling surface. The wall is built with a damper system that only opens when containers with openings are placed in front of it. The fan pulls cold room air through the container and contents, cooling the produce.

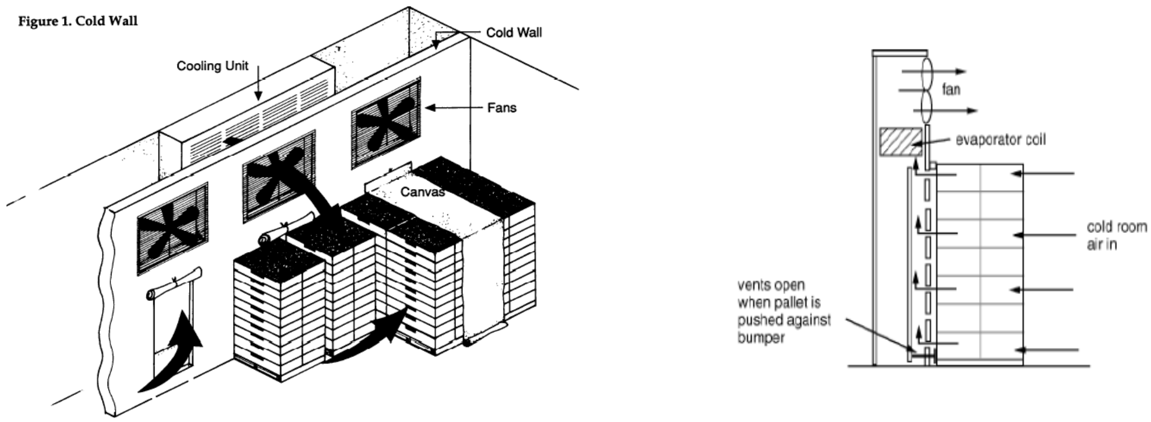


Fig.5. Cold Wall

Forced-air Tunnel

An exhaust fan is placed at the end of the aisle of two rows of containers or bins on pallets. The aisle top and ends are covered with plastic or canvas, creating a tunnel. An exhaust fan draws cool room air through the container vents and top . The exhaust fan may be portable, creating a single forced-air tunnel where needed, or it may be part of a stationary wall adjacent to the cooling surface, with several fans that create several tunnels.

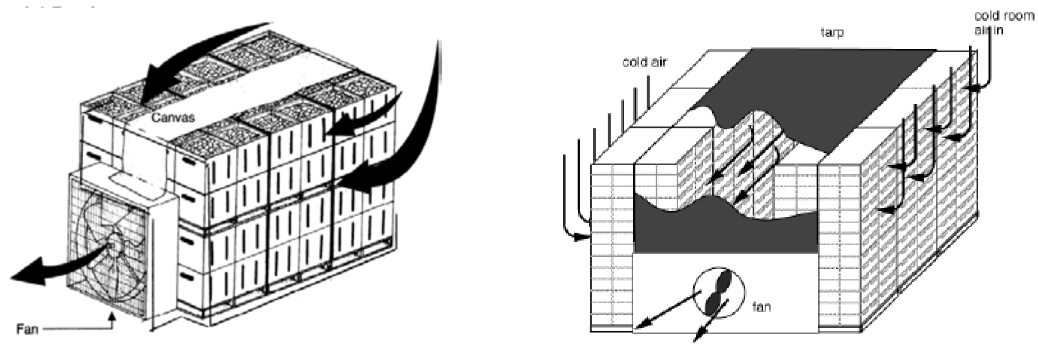


Fig.6. Forced-air Tunnel

Serpentine Cooling

A serpentine system is designed for bulk bin cooling. It is a modification of the cold-wall method. Bulk bins have vented bottoms with or without side ventilation. Bins are stacked several high and several deep with the fork lift openings against the cold wall. Every other forklift opening—sealed with canvas—in the stack matches a cold wall opening. The alternate unsealed forklift opening allows cold air to circulate through the produce. Cold room air is drawn through the produce via the alternate unsealed openings in the stack and the top of the bin.

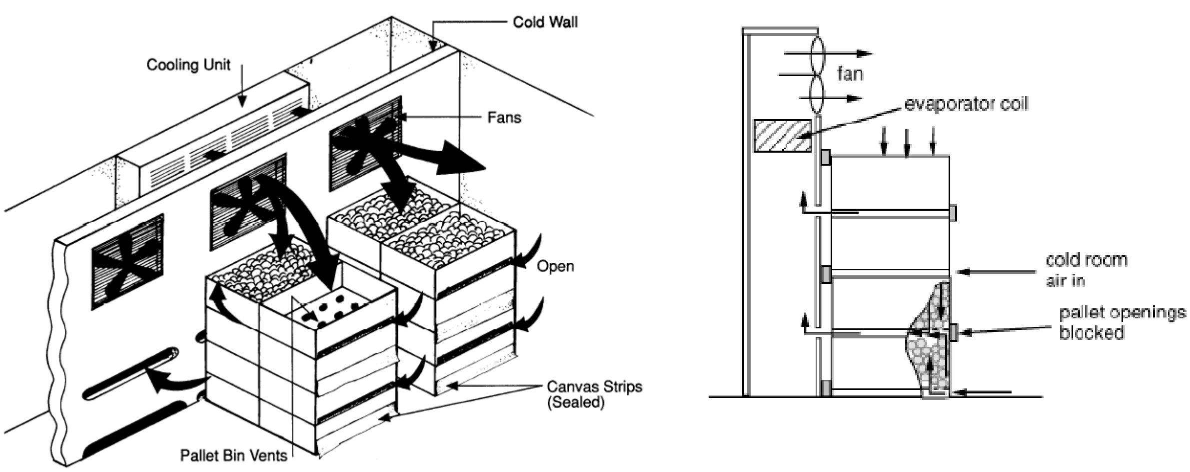


Fig.7. Serpentine Cooling

Because the cooling air comes in direct contact with the product being cooled, cooling is much faster than with conventional room cooling. Cooling by the forced air method was usually

4 to 10 times faster than room cooling but that hydrocooling and vacuum cooling was 2 to 23 times faster than forced air cooling. Another aspect of forced air cooling is that converting existing facilities is often simple and inexpensive, provided that sufficient refrigeration capacity and cooling surfaces are available. When very rapid cooling is required forced air cooling is more costly than other precooling methods, and therefore this may limit its application to some produce which needs to be cooled extremely quickly. Another drawback of forced air cooling is that it requires a definite stacking pattern hence this technique requires skilled operators so as to achieve the required loading pattern to ensure satisfactory cooling rates.

3) Hydrocooling

Hydrocooling essentially is the utilization of chilled or cold water for lowering the temperature of a product in bulk or smaller containers before further packing. Hydrocooling is achieved by flooding, spraying, or immersing the product in/with chilled water. There are several different hydrocooler designs in operation commercially. Hydrocooling methods differ in their cooling rates and overall process efficiencies. Differences between the individual techniques are evident by the method of cooling and by the way that produce is moved or placed in the cooler. Various types of hydrocooler are available, some of which include conventional (flood) type, immersion type, and batch type. The flood type hydrocooler cools the packaged product by flooding as it is conveyed through a cooling tunnel. With the batch system, chilled water is sprayed over the product for a certain length of time, depending on the season and the incoming product temperature. These hydrocoolers have a smaller capacity than conventional hydrocoolers and are therefore less expensive. A frequent complaint about both conventional and batch type hydrocoolers is that cooling by these techniques is not uniformly and hence may leave `hot spots' throughout the load. For hydrocooling to be effective, contact between the water and the product surface must be uniform. This may not be achieved by these design of hydrocoolers as the chilled water may not be evenly distributed throughout the load, resulting in undercooling of some parts. The bulk or immersion type cooler uses a combination of immersion and flood cooling. Loose produce is immersed in cold water, and remains immersed until an inclined conveyor gradually lifts the products out of the water and moves it through an overhead shower. The most rapid hydrocooling is obtained by this cooling technique. It is nearly twice as rapid as conventional hydrocooling methods, due to the fact that moving chilled water completely surrounds the exterior surface of the produce and hence facilitates quicker temperature reduction. The bulk type cooler has the added benefit over the flood type cooler of allowing greater packaging flexibility, i.e. packaging after cooling, and therefore it may be more suitable to a wide range of growers.

In general products hydrocooled should tolerate being wetted and not be damaged by falling water or disinfectants that it may contain, hence hydrocooling is recommended for produce for which washing is part of their market preparation. A risk associated with most hydrocoolers is the decay hazard associated with recirculated water, which leads to the possibility of decay producing organisms accumulating in the system, resulting in the contamination of the cooled produce. To prevent this from occurring, mild disinfectant such as chlorine at concentrations of 100 ppm (measured as hypochlorus acid) or approved phenol compounds are used and therefore produce cooled by this technique must not be affected by the use of these chemicals. One of the chief benefits of hydrocooling is that it is seen to prevent loss of moisture during the cooling process. Another advantage of this technique is that it is very rapid in contrast to other pre-cooling techniques available. Field heat can be removed in 20-30 min using hydrocooling instead of several hours normally needed for forced air-cooling. Hydro-air cooling is an important and specialized area of hydrocooling in which a mixture of refrigerated air and water in a fine mist spray is circulated around and through stacks of the produce. The advantage of hydro-air cooling is the reduced water requirements and the potential for improved sanitation. In hydro-air cooling the ratio of air-water influences the heat transfer capability of the cooling system and the applicability of certain products to this technique.

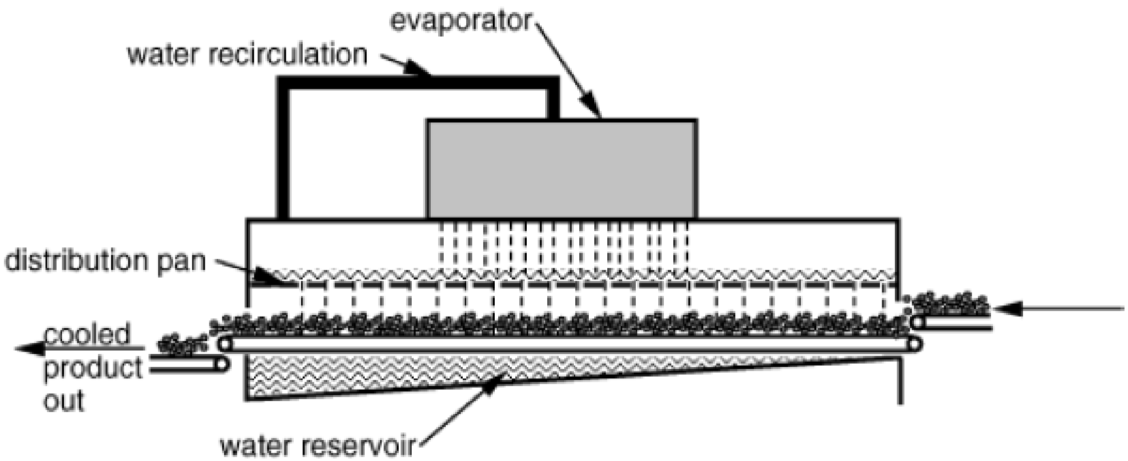


Fig.8. Cut-away side view of a continuous-flow shower-type hydrocooler

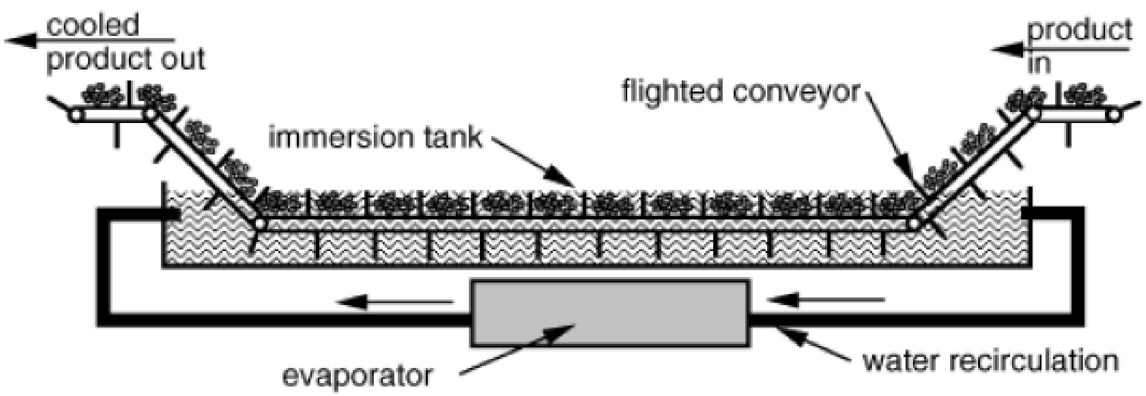


Fig.9. Cut-away side view of a continuous-flow immersion hydrocooler

Shower coolers distribute water using a perforated metal pan that is flooded with cold water from the refrigeration evaporator. Shower type coolers can be built with a moving conveyor for continuous flow operation or they can be operated in a batch mode. Immersion coolers are suited for product that sinks in water. They usually cool slower than shower coolers because water flows at slower rates past the product.

Water is a better heat-transfer medium than air and, consequently, hydrocoolers cool produce much faster than forced-air coolers. In well-designed shower coolers, small diameter produce, like cherries, cool in less than 10 min. Large diameter products like melons cool in 45 to 60 min. Immersion coolers usually have longer cooling times than

shower coolers because water speed past produce is slower. Packages for hydro-cooled produce must allow vertical water flow and must tolerate water contact. Plastic or wood containers work well in hydrocoolers. Corrugated fiberboard must be wax-dipped to withstand water contact. Hydro-coolers cause no moisture loss in cooling. In fact, they can rehydrate slightly wilted product.

4) Ice cooling

In ice cooling, crushed or fine granular ice is used to cool the produce. The ice is either packed around produce in cartons or sacks, or it is made into a slurry with water and injected into waxed cartons packed with produce. The ice then fills the voids around the produce. Before the advent of comparatively modern precooling techniques, contact or package icing was used extensively for precooling produce and maintaining temperature during transit. Although, unlike other cooling methods ice not only removes heat rapidly when first applied, it continues to absorb heat as it melts. There are a variety of different methods in which ice is applied to the produce so as to achieve the desired cooling effect.

Package icing involves direct placement of slush, flaked, or crushed ice over the product in shipment containers. This method is sufficient where it is used; however, it can result in uneven cooling because the ice generally remains where it was placed until it has melted. In liquid icing, ice slurry is used instead of plain crushed ice as it can sustain cooling requirements better. Liquid icing may be considered a hybrid of package icing and hydrocooling. The simplest form of liquid icing is where a mixture of water and finely crushed ice is pumped into open containers travelling along a conveyor under an injection nozzle. If produce has been packed and palletised in the field, the liquid ice can be injected into the packages through vents or hand openings. Liquid-icing distributes the ice throughout the commodity, i.e. placed in each individual package better, thus achieving improved ice/produce contact and hence better and more uniform cooling. Another method of icing is top icing, or placing ice on top of packed containers. This is only used occasionally to supplement another cooling method. Because corrugated containers have largely replaced wooden crates, the use of top icing has decreased. Wax-impregnated corrugated containers have allowed the use of icing of products after packaging to continue; however, it is being replaced by hydrocooling and vacuum cooling.

The major advantage of icing is that produce does not dry as it is cooled. Another advantage is that in addition to removing field heat, package icing can maintain low product temperature during transit and therefore refrigerated transportation may not be necessary for short transport duration. Although icing requires relatively small outlays of special equipment, a large weight of ice must be shipped, thus increasing costs, and also water-proof containers which are more expensive than normal are required for this cooling technique. Another ambiguity of icing is that icing wets the produce and thus the surface of warm wet produce provides an excellent site for post-harvest diseases and soft rots. Therefore, it is essential that produce be not allowed to rewarm once it is iced. Another drawback of this method of pre-cooling is that after the ice has melted, the package is left only partly full. Ice cooling is faster than hydrocooling because contact with the produce is good, and ice has a higher heat removal capacity than water. As in hydro-cooling, ice cooling requires particular attention to water quality and sanitation.

5) Vacuum cooling

Rapid cooling of horticultural produce can be carried out with vacuum cooling. Vacuum cooling is achieved by the evaporation of moisture from the produce. The evaporation is encouraged and made more efficient by reducing the pressure to the point where boiling of water takes place at a low temperature.

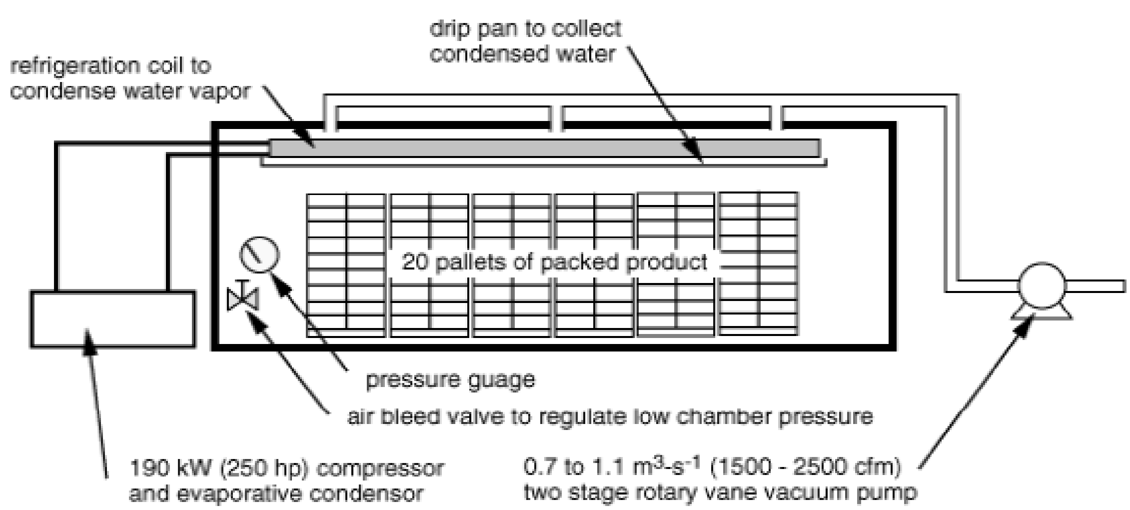
The basic principles of the vacuum cooling process are described as follows:

1. At atmospheric pressure (1013 mbar), the boiling temperature of water is 100^0C. This boiling point changes as a function of saturation pressure therefore at 23.37 mbar the water boiling temperature will be 20^0C and at 6.09 mbar, it will be 0^0C.

2. To change from the liquid to vapour state, the latent heat of vaporization must be provided by the surrounding medium, so that the sensible heat of the product is reduced.

3. The water vapour given off by the product must be removed.

Key components of a 20-pallet capacity vacuum cooler



In the vacuum cooling process the pressure in the vacuum chamber is reduced from atmospheric to about 20 mbar and, during this time, evaporation is slow and relatively little cooling takes place, i.e. temperature of the produce remains constant until saturation pressure at this temperature is reached. At approximately this pressure the `flash point' occurs; this is the point where the water in the produce begins to vapourise, i.e. produce begins to lose moisture and cool rapidly . For example, if the produce had an ambient field heat of 20$^0$C then the `flash point' would occur at 24 mbar. At this point the wet bulb temperature sharply increases as the air in the tank is evacuated and is replaced by the evaporated water vapour. This vapour has to be removed quickly in order to keep the overall cooling cycle to a reasonably length, and this is accomplished by the use of a condenser in the chamber. The pressure is further reduced and cooling continues until a pressure corresponding to the desired final saturation temperature is reached. In practice, most operators do not reduce the pressure below 6.09 mbar (saturation pressure corresponding to a temperature 0^{0}C because of the extra work involved and because of the freezing potential at reduced pressures.

The heat required to vaporize this water is removed from the product surface, hence the cooling rate is limited by heat and mass transfer , i.e. evaporation rate of water from the products surface and inner tissues. Therefore the rate of cooling depends primarily upon the ratio of surface area of the product to its weight or volume, the ease with which water is given up from the product tissues , the rate of vacuum drawn in the flash chamber and the temperature of the load at the start . Many investigations agree that vacuum cooling of fresh produce by the rapid evaporation of water from the product works best with products having a high ratio of surface to volume. Since water is seen as the primary refrigerant, it is a safe assumption that the quantity of heat removed from the product is directly related to the amount of water evaporated off the products surface.

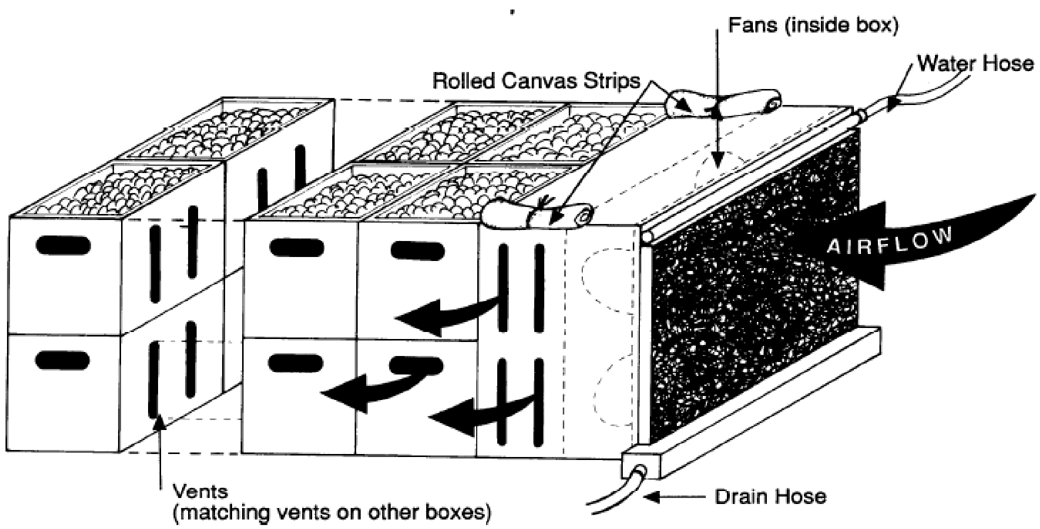
Vacuum cooling is greatly influenced by the surface area to mass ratio and the ease with which water is released from the products tissues. Large temperature gradients develop in products with a low surface area to mass ratio. In order to prevent surface freezing before the product is cooled to the required temperature, a ``bouncing'' procedure is practised. This is accomplished by switching the vacuum pump off and on to keep the saturation temperature above freezing. One disadvantage of vacuum cooling is that it causes weight loss in the produce being cooled due to the removal of moisture. Temperature reductions average 5 to 5.5^{0}C for each 1% of weight loss, regardless of the product cooled. This small loss in weight is usually acceptable in the products that are cooled by this technique. A way of reducing this loss is by spraying free water on to the product before it is placed into the cooling chamber. Special vacuum cooler `hydrovac' have been developed, which have a built-in water spray activated towards the end of the cooling operation and thus minimizes weight loss. The rapid cooling achievable by the use of vacuum cooling makes it more appealable and gives it a distinct advantage over other cooling techniques. Examples of its speed of removing heat are given previously. Another advantage is that vacuum cooling can achieve uniform cooling throughout a package or lot of produce, provided the package or box is not hermetically sealed to allow free evaporation.

6) Cryogenic cooling

The use of the latent heat of evaporation of liquid nitrogen or solid CO_2 (dry ice) can produce `boiling' temperatures of -196 and -78^{0}C, respectively. This is the basis of cryogenic precooling. In cryogenic cooling, the produce is cooled by conveying it through a tunnel in which the liquid nitrogen or solid CO_2 evaporates. However, at the above temperatures the produce will freeze and thus be ruined as a fresh market product. This problem is prevented by careful control of the evaporation rate and conveyor speed. Cryogenic cooling is relatively cheap to install but expensive to run. Its main application is in cooling crops such as soft fruits, which have a seasonal production period. Hence, by using cryogenic cooling the grower would not incur the high capital costs associated with alternative cooling techniques over such period of use. The high cost of liquid nitrogen, dry ice and other suitable non-toxic refrigerants make this process most suitable for relatively expensive products.

7) Evaporative Cooling

Evaporative cooling is an inexpensive and effective method of lowering produce temperature. It is most effective in areas where humidity is low. Dry air is drawn through moist padding or a fine mist of water, then through vented containers of produce. As water changes from liquid to vapor, it absorbs heat from the air, thereby lowering the produce temperature. The incoming air should be less than 65 percent relative humidity for effective evaporative cooling. It will only reduce temperature, 10-15°F. This method would be suitable for warm-season crops requiring warmer storage temperatures (45-55°F), such as tomatoes, peppers, cucumbers or eggplant.



Evaporative Cooling

Table Recommended Precooling Methods and Storage conditions for Fruits and Vegetables

Fruits and vegetables	Temperature F	% Relative humidity	Precooling method	Storage life Days	Ethylene sensitive
Apples	30-40	90-95	R, F, H	90-240	**Y**
Apricots	32	90-95	R, H	7-14	**Y**
Asparagus	32-35	95-100	H, I	14-21	**Y**
Avocados	40-55	85-90		14-28	**Y**
Bananas	56-58	90-95		7-28	**Y**
Beans, snap	40-45	95	R, F, H	10-14	**Y**
Beans, lima	37-41	95		7-10	
Beets, roots	32	98-100	R	90-150	
Blackberries	31-32	90-95	R, F	2-3	
Blueberries	31-32	90-95	R, F	10-18	
Broccoli	32	95-100	I, F, H	10-14	**Y**
Brussel sprouts	32	95-100	H, V, I	21-35	**Y**
Cabbage	32	98-100	R, F	90-180	**Y**
Cantaloupe	36-41	95	H, F	10-14	**Y**
Carrots, topped	32	98-100	I, R	28-180	**Y**

Cauliflower	32	90-98	H, V	20-30	
Celery	32	98-100	I	14-28	**Y**
Cherries, sweet	30-31	90-95	H, F	14-21	
Corn, sweet	32	95-98	H, I, V	4-6	
Cranberries	36-40	90-95		60-120	
Cucumbers	50-55	95	F, H	10-14	**Y**
Eggplant	46-54	90-95	R, F	10-14	**Y**
Endive	32	90-95	H, I	14-21	**Y**
Garlic	32-34	65-75	N	90-210	
Grapefruit	50-60	85-90		28-42	
Grapes	32	85	F	56-180	
Kiwifruit	32	95-100		28-84	**Y**
Leeks	32	95-100	H, I	60-90	**Y**
Lemons	50-55	85-90		30-180	
Lettuce	32	85-90	H, I	14-21	**Y**
Limes	48-50	85-90		21-35	
Mushrooms	32	95		12-17	
Nectarines	31-32	95	F, H	14-18	**Y**
Okra	45-50	90-95		7-14	**Y**
Onions, bulb	32	65-70	N	30-180	
Onions, green	32	95-100	H, I	7-10	
Oranges	32-48	85-90		21-56	
Peaches	31-32	90-95	F, H	14-28	**Y**
Pears	32	90-95	F, R, H	60-90	**Y**
Peas, in pods	32	95-98	F, H, I	7-10	**Y**
Peppers, bell	45-55	90-95	R, F	12-18	**Y**
Peppers, hot	45-50	60-70	R, F	14-21	**Y**
Pineapple	45-55	85-90		14-36	
Plums	32	90-95	F, H	14-28	**Y**
Potatoes, early	50-60	90	R, F	56-140	
Potatoes, late	40-50	90	R, F	56-140	**Y**
Pumpkins	50-60	50-75	N	84-160	
Radishes	32	95-100	I	21-28	

Raspberries	32	90-95	R, F	2-3	**Y**
Rutabagas	32	98-100	R	120-180	
Spinach	32	95-100	H, I	10-14	**Y**
Squash, summer	41-50	95	R, F	7-14	**Y**
Squash, winter	50-55	50-70	N	84-150	
Strawberries	32	90-95	R, F	5-10	
Sweet potatoes	55-60	85-90	N	120-210	**Y**
Tangerines	40	90-95		14-28	
Tomatoes	62-68	90-95	R, F	7-28	**Y**
Turnips	32	95	R, H, V, I	120-150	
Watermelon	50-60	90	N	14-21	

F = forced-air cooling, H = hydrocooling, I = package icing, R = room cooling, V = vacuum cooling, N = no precooling needed. Sources: USDA Agricultural Marketing Service, Kansas State University Cooperative Extension Service.

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Chapter 9: VARIOUS METHODS OF PACKAGING- PACKAGING MATERIALS AND TRANSPORT

Packaging fresh fruits and vegetables is one of the more important steps in the long and complicated journey from grower to consumer. Bags, crates, hampers, baskets, cartons, bulk bins, and palletized containers are convenient containers for handling, transporting, and marketing fresh produce. More than 1,500 different types of packages are used for produce in the U.S. and the number continues to increase as the industry introduces new packaging materials and concepts. Although the industry generally agrees that container standardization is one way to reduce cost, the trend in recent years has moved toward a wider range of package sizes to accommodate the diverse needs of wholesalers, consumers, food service buyers, and processing operations.

Packing and packaging materials contribute a significant cost to the produce industry; therefore it is important that packers, shippers, buyers, and consumers have a clear understanding of the wide range of packaging options available. This fact sheet describes some of the many types of packaging, including their functions, uses, and limitations. Also included is a listing, by commodity, of the common produce containers standard to the industry.

The Function of Packaging or Why package Produce?

A significant percentage of produce buyer and consumer complaints may be traced to container failure because of poor design or inappropriate selection and use. A properly designed produce container should contain, protect, and identify the produce, satisfying everyone from grower to consumer.

PACKAGING POINTS

Recyclability/Biodegradability

A growing number of U.S. markets and many export markets have waste disposal restrictions for packaging materials. In the near future, almost all produce packaging will be recyclable or biodegradable, or both. Many of the largest buyers of fresh produce are also those most concerned about environmental issues.

Variety

The trend is toward greater use of bulk packages for processors and wholesale buyers and smaller packages for consumers. There are now more than 1,500 different sizes and styles of produce packages.

Sales Appeal

High quality graphics are increasingly being used to boost sales appeal. Multi-color printing, distinctive lettering, and logos are now common.

Shelf Life

Modern produce packaging can be custom engineered for each commodity to extend shelf life and reduce waste.

Containment

The container must enclose the produce in convenient units for handling and distribution. The produce should fit well inside the container, with little wasted space. Small produce items that are spherical or oblong (such as potatoes, onions, and apples) may be packaged efficiently utilizing a variety of different package shapes and sizes. However, many produce items such as asparagus, berries, or soft fruit may require containers specially designed for that item. packages of produce commonly handled by hand are usually limited to 50 pounds. Bulk packages moved by fork lifts may weigh as much as 1,200 pounds.

Protection

The package must protect the produce from mechanical damage and poor environmental conditions during handling and distribution. To produce buyers, torn, dented, or collapsed produce packages usually indicate lack of care in handling the contents. Produce containers must be sturdy enough to resist damage during packaging, storage, and transportation to market. Because almost all produce packages are palletized, produce containers should have sufficient stacking strength to resist crushing in a low temperature, high humidity environment. Although the cost of packaging materials has escalated sharply in recent years, poor quality, lightweight containers that are easily damaged by handling or moisture are no longer tolerated by packers or buyers. Produce destined for export markets requires that containers to be extra sturdy. Air-freighted produce may require special packing, package sizes, and insulation. Marketers who export fresh produce should consult with freight companies about any special packaging requirements. Additionally, the USDA and various state export agencies may be able to provide specific packaging information.

Damage resulting from poor environmental control during handling and transit is one of the leading causes of rejected produce and low buyer and consumer satisfaction. Each fresh fruit and vegetable commodity has its own requirements for temperature, humidity, and environmental gas composition. Produce containers should be produce friendly - helping to maintain an optimum environment for the longest shelf life. This may include special materials to slow the loss of water from the produce, insulation materials to keep out the heat, or engineered plastic liners that maintain a favorable mix of oxygen and carbon dioxide.

Identification

The package must identify and provide useful information about the produce. It is customary (and may be required in some cases) to provide information such as the produce name, brand, size, grade, variety, net weight, count, grower, shipper, and country of origin. It is also becoming more common to find included on the package, nutritional information, recipes, and other useful information directed specifically at the consumer. In consumer marketing, package appearance has also become an important part of point of sale displays.

Universal Product Codes (UPC or bar codes) may be included as part of the labeling. The UPCs used in the food industry consist of a ten-digit machine readable code. The first five digits are a number assigned to the specific producer (packer or shipper) and the second five digits represent specific product information such as type of produce and size of package. Although no price information is included, UPCs are used more and more by packers, shippers, buyers, and Example of a UPC retailers as a fast and convenient method of inventory control and cost accounting. Efficient use of UPCs requires coordination with everyone who handles the package.

Types of Packaging Materials

Wood

Pallets literally form the base on which most fresh produce is delivered to the consumer. Pallets were first used during World War II as an efficient way to move goods. The produce industry uses approximately 190 of the 700 million pallets produced per year in the U.S.. About 40 percent of these are single-use pallets. Because many are of a non-standard size, the pallets are built as inexpensively as possible and discarded after a single use. Although standardization efforts have been slowly under way for many years, the efforts have been accelerated by pressure from environmental groups, in addition to the rising cost of pallets and landfill tipping fees.

Over the years, the 40-inch wide, by 48-inch long pallet has evolved as the unofficial standard size. Standardization encourages re-use, which has many benefits. Besides reducing cost because they may be used many times, most pallet racks and automated pallet handling equipment are designed for standard-size pallets. Standard size pallets make efficient use of truck and van space and can accommodate heavier loads and more stress than lighter single-use pallets. Additionally, the use of a single pallet size could substantially reduce pallet inventory and warehousing costs along with pallet repair and disposal costs. The adoption of a pallet standard throughout the produce industry would also aid efforts toward standardization of produce containers.

In the early 1950s, an alternative to the pallet was introduced. It is a pallet-size sheet (slipsheet) of corrugated fiberboard or plastic (or a combination of these materials) with a narrow lip along one or more sides. packages of produce are stacked directly on this sheet as if it were a pallet. Once the packages are in place, they are moved by a specially equipped fork lift equipped with a thin metal sheet instead of forks.

Slipsheets are considerably less expensive than pallets to buy, store, and maintain; they may be re-used many times; and they reduce the tare weight of the load. However, they require the use of a special fork-lift attachment at each handling point from packer to retailer.

Depending on the size of produce package, a single pallet may carry from 20 to over 100 individual packages. Because these packages are often loosely stacked to allow for air circulation, or are bulging and difficult to stack evenly, they must be secured (unitized) to prevent shifting during handling and transit. Although widely used, plastic straps and tapes may not have completely satisfactory results. Plastic or paper corner tabs should always be used to prevent the straps from crushing the corners of packages.

Plastic stretch film is also widely used to secure produce packages. A good film must stretch, retain its elasticity, and cling to the packages. Plastic film may conform easily to various size loads. It helps protect the packages from loss of moisture, makes the pallet more secure against pilferage, and can be applied using partial automation. However, plastic film severely restricts proper ventilation. A common alternative to stretch film is plastic netting, which is much better for stabilizing some pallet loads, such as those that require forced-air cooling. Used stretch film and plastic netting may be difficult to properly handle and recycle.

A very low-cost and almost fully automated method of pallet stabilization is the application of a small amount of special glue to the top of each package. As the packages are stacked, the glue secures all cartons together. This glue has a low tensile strength so cartons may be easily separated or repositioned, but a high shear strength so they will not slide. The glue does not present disposal or recycling problems.

Pallet Bins

Substantial wooden pallet bins of milled lumber or.plywood are primarily used to move produce from the field or orchard to the packing house. Depending on the application, capacities may range from 12 to more than 50 bushels. Although the height may vary, the length and width is generally the same as a standard pallet (48 inches by 40 inches). More efficient double-wide pallet bins (48 inches by 80 inches) are becoming more common in some produce operations.

Most pallet bins are locally made; therefore it is very important that they be consistent from lot to lot in materials, construction, and especially size. For example, small differences in overall dimensions Pallet bin can add up to big problems when several hundred are stacked together for cooling, ventilation, or storage. It is also important that stress points be adequately reinforced. The average life of a hardwood pallet bin that is stored outside is approximately five years. When properly protected from the weather, pallets bins may have a useful life of 10 years or more.

Uniform voluntary standards for wood pallets and other wood containers are administered by the National Wooden Pallet and Container Association, Washington, DC. Additionally, the American Society of Agricultural Engineers, St. Joseph, Michigan, publishes standards for agricultural pallet bins (ASAE S337.1).

Wire-Bound Crates

Although alternatives are available, wooden wire-bound crates are used extensively for snap beans, sweet corn and several other commodities that require hydrocooling. Wire-bound crates are sturdy, rigid and have very high stacking strength that is essentially unaffected by water. Wire-bound crates come in many different sizes from half- bushel to pallet-bin size and have a great deal of open space to facilitate cooling and ventilation. Although few are re-used, wire-bound crates may be dissembled after use and shipped back to the packer (flat). In some areas, used containers may pose a significant disposal problem. Wirebound crates are not generally acceptable for consumer packaging because of the difficulty in affixing suitable labels.

Wooden Crates and Lugs

Wooden crates, once extensively used for apples, stone fruit, and potatoes have been almost totally replaced by other types of containers. The relative expense of the container, a greater concern for tare weight, and advances in material handling have reduced their use to a few specialty items, such as expensive tropical fruit. The 15-, 20-, and 25-pound wooden lugs still used for bunch grapes and some specialty crops are being gradually replaced with less costly alternatives.

Wooden Baskets and Hampers

Wire-reinforced wood veneer baskets and hampers of different sizes were once used for a wide variety of crops from strawberries to sweet potatoes. They are durable and may be nested for efficient transport when empty. However, cost, disposal problems, and difficulty in efficient palletization have severely limited their use to mostly local grower markets where they may be re-used many times.

Corrugated Fiberboard

Corrugated fiberboard (often mistakenly called cardboard or pasteboard) is manufactured in many different styles and weights. Because of its relativity low cost and versatility, it is the dominant produce container material and will probably remain so in the near future. The strength and serviceability of corrugated fiberboard have been improving in recent years.

Most corrugated fiberboard is made from three or more layers of paperboard manufactured by the kraft process. To be considered paperboard, the paper must be thicker than 0.008 inches. The grades of paperboard are differentiated by their weight (in pounds per 1,000 square feet) and their thickness. Kraft paper made from unbleached pulp has a characteristic brown color and is exceptionally strong. In addition to virgin wood fibers, Kraft paper may have some portion of synthetic fibers for additional strength, sizing (starch), and other materials to give it wet strength and printability. Most fiberboard contains some recycled fibers. Minimum amounts of recycled materials may be specified by law and the percentage is expected to increase in the future. Tests have shown that cartons of fully recycled pulp have about 75 percent of the stacking strength of virgin fiber containers. The use of recycled fibers will inevitably lead to the use of thicker walled containers.

Double-faced corrugated fiberboard is the predominant form used for produce containers. It is produced by sandwiching a layer of corrugated paperboard between an inner and outer liner (facing) of paper-board. The inner and outer liner may be identical, or the outer layer may be preprinted or coated to better accept printing. The inner layer may be given a special coating to resist moisture. Heavy-duty shipping containers, such as corrugated bulk bins that are required to have high stacking strength, may have double- or even triple-wall construction. Corrugated fiberboard manufacturers print box certificates on the bottom of containers to certify certain strength characteristics and limitations. There are two types of certification. The first certifies the minimum combined weight of both the inner and outer facings and that the corrugated fiberboard material is of a minimum bursting strength. The second certifies minimum edge crush test (ETC) strength. Edge crush strength is a much better predictor of stacking strength than is bursting strength. For this reason, users of corrugated fiberboard containers should insist on ECT certification to compare the stackability of various containers. Both certificates give a maximum size limit for the container (sum of length, width, and height) and the maximum gross weight of the contents.

Both cold temperatures and high humidities reduce the strength of fiberboard containers. Unless the container is specially treated, moisture absorbed from the surrounding air and the contents can reduce the strength of the container by as much as 75 percent. New anti-moisture coatings (both wax and plastic) are now available to substantially reduce the effects of moisture.

Waxed fiberboard cartons (the wax is about 20 percent of fiber weight) are used for many produce items that must be either hydrocooled or iced. The main objection to wax cartons is disposal after use— wax cartons cannot be recycled and are increasingly being refused at landfills. Several states and municipalities have recently taxed wax cartons or have instituted rigid back haul regulations. Industry sources suggest that wax cartons will eventually be replaced by plastic or, more likely, the use of ice and hydrocooling will be replaced by highly controlled forced-air cooling and rigid temperature and humidity maintenance on many commodities.

In many applications for corrugated fiberboard containers, the stacking strength of the container is a minor consideration. For example, canned goods carry the majority of their own weight when stacked. Fresh produce usually cannot carry much of the vertical load without some damage. Therefore, one of the primarily desired characteristics of corrugated fiberboard containers is stacking strength to protect the produce from crushing. Because of their geometry, most of the stacking strength of corrugated containers is carried by the corners. For this reason, hand holes and ventilation slots should never be positioned near the corners of produce containers and be limited to no more than 5 to 7 percent of the side area.

Interlocking the packages (cross stacking) is universally practiced to stabilize pallets. Cross stacking places the corner of one produce package at the middle of the one below it, thus reducing its stacking strength. To reduce the possibility of collapse, the first several layers of each pallet should be column stacked (one package directly above the other). The upper layers of packages may be cross stacked as usual with very little loss of pallet stability.

There are numerous styles of corrugated fiberboard containers. The two most used in the produce industry are the one piece, regular slotted container (RSC) and the two piece, full telescoping container (FTC). The RSC is the most popular because it is simple and economical. However, the RSC has relatively low stacking strength and therefore must be used with produce, such as potatoes, that can carry some of the stacking load. The FTC, actually one container inside another, is used when greater stack- ing strength and resistance to bulging is required. A third type of container is the Bliss box, which is — constructed from three separate pieces of corrugated fiberboard. The Bliss box was developed to be used when maximum stacking strength is required. The bottoms and tops of all three types of containers may be closed by glue, staples, or interlocking slots.

Almost all corrugated fiberboard containers are shipped to the packer flat and assembled at the packing house. To conserve space, assembly is usually performed just before use. Assembly may be by hand, machine, or a combination of both. Ease of assembly should be carefully investigated when considering a particular style of package.

In recent years, large double-wall or even triple- wall corrugated fiberboard containers have increasingly been used as one-way pallet bins to ship bulk produce to processors and retailers. Cabbage, melons, potatoes, pumpkins, and citrus have all been shipped successfully in these containers. The container cost per pound of produce is as little as one fourth of traditional size containers. Some bulk containers may be collapsed and re-used.

For many years, labels were printed on heavy paper and glued or stapled to the produce package. The high cost of materials and labor has all but eliminated this practice. The ability to print the brand, size, and grade information directly on the container is one of the greatest benefits of corrugated fiberboard containers. There are basically two methods used to print corrugated fiberboard containers:

Post Printed

When the liner is printed after the corrugated fiberboard has been formed, the process is known as post printing. Post printing is the most widely used printing method for corrugated fiberboard containers because it is economical and may be used for small press runs. However, postprinting produces graphics with less detail and is usually limited to one or two colors.

Preprinted

High quality, full-color graphics may be obtained by preprinting the linerboard before it is attached to the corrugated paperboard. Whereas the cost is about 15 percent more than standard two color containers, the eye catching quality of the graphics makes it very useful for many situations. The visual quality of the package influences the perception of the product because the buyer's first impression is of the outside of the package. Produce managers especially like high quality graphics that they can use in super market floor displays.

Preprinted cartons are usually reserved for the introduction of new products or new brands. Market research has shown that exporters may benefit from sophisticated graphics. The increased cost usually does not justify use for mature products in a stable market, but this may change as the cost of these containers becomes more competitive.

Pulp Containers

Containers made from recycled paper pulp and a starch binder are mainly used for small consumer packages of fresh produce. Pulp containers are available in a large variety of shapes and sizes and are relatively inexpensive in standard sizes. Pulp containers can absorb surface moisture from the product, which is a benefit for small fruit and berries that are easily harmed by water. Pulp containers are also biodegradable, made from recycled materials, and recyclable.

Paper and Mesh Bags

Consumer packs of potatoes and onions are about the only produce items now packed in paper bags. The more sturdy mesh bag has much wider use. In addition to potatoes and onions, cabbage, turnips, citrus, and some specialty items are packed in mesh bags. Sweet corn may still be packaged in mesh bags in some markets. In addition to its low cost, mesh has the advantage of uninhibited air flow. Good ventilation is particularly beneficial to onions. Supermarket produce managers like small mesh bags because they make attractive displays that stimulate purchases.

However, bags of any type have several serious disadvantages. Large bags do not palletize well and small bags do not efficiently fill the space inside corrugated fiberboard containers. Bags do not offer protection from rough handling. Mesh bags provide little protection from light or contaminants. In addition, produce packed in bags is correctly perceived by the consumer to be less than the best grade. Few consumers are willing to pay premium price for bagged produce.

Plastic Bags

Plastic bags (polyethylene film) are the predominant material for fruit and vegetable consumer packaging. Besides the very low material costs, automated bagging machines further reduce packing costs. Film bags are clear, allowing for easy inspection of the contents, and readily accept high quality graphics. Plastic films are available in a wide range of thicknesses and grades and may be engineered to control the environmental gases inside the bag. The film material "breathes" at a rate necessary to maintain the correct mix of oxygen, carbon dioxide, and water vapor inside the bag. Since each produce item has its own unique requirement for environmental gases, modified atmosphere packaging material must be specially engineered for each item. Research has shown that the shelf life of fresh produce is extended considerably by this packaging. The explosive growth of precut produce is due in part to the availability of modified atmosphere packaging.

In addition to engineered plastic films, various patches and valves have been developed that affix to low-cost ordinary plastic film bags. These devices respond to temperature and control the mix of environmental gases.

Shrink Wrap

One of the newest trends in produce packaging is the shrink wrapping of individual produce items. Shrink wrapping has been used successfully to package potatoes, sweet potatoes, apples, onions, sweet corn, cucumbers and a variety of tropical fruit. Shrink wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels.

Rigid Plastic Packages

Packages with a top and bottom that are heat formed from one or two pieces of plastic are known as clamshells. Clamshells are gaining in popularity because they are inexpensive, versatile, provide excellent protection to the produce, and present a very pleasing consumer package. Clamshells are most often used with consumer packs of high value produce items like small fruit, berries, mushrooms, etc., or items that are easily damaged by crushing. Clamshells are used extensively with precut produce and prepared salads. Molded polystyrene and corrugated polystyrene containers have been test marketed as a substitute for waxed corrugated fiberboard. At present they are not generally cost competitive, but as environmental pressures grow, they may be more common. Heavy-molded polystyrene pallet bins have been adopted by a number of growers as a substitute for wooden pallet bins. Although at present their cost is over double that of wooden bins, they have a longer service life, are easier to clean, are recyclable, do not decay when wet, do not harbor disease, and may be nested and made collapsible.

As environmental pressures continue to grow, the disposal and recyclability of packaging material of all kinds will become a very important issue. Common polyethylene may take from 200 to 400 years to breakdown in a landfill. The addition of 6 percent starch will reduce the time to 20 years or less. packaging material companies are developing starch-based polyethylene substitutes that will break down in a landfill as fast as ordinary paper.

The move to biodegradable or recyclable plastic packaging materials may be driven by cost in the long term, but by legislation in the near term. Some authorities have proposed a total ban on plastics. In this case, the supermarket of the early 21st century may resemble the grocery markets of the early 20th century.

Standardization of Packaging

Produce package standardization is interpreted differently by different groups. The wide variety of package sizes and material combinations is a result of the market responding to demands from many different segments of the produce industry. For example, many of the large-volume buyers of fresh produce are those most concerned with the environment. They demand less packaging and the use of more recyclable and biodegradable materials, yet would also like to have many different sizes of packages for convenience. packers want to limit the variety of packages they must carry in stock, yet they have driven the trend toward preprinted, individualized containers. Shippers and trucking companies want to standardize sizes so the packages may be better palletized and handled.

Produce buyers are not a homogeneous group. Buyers for grocery chains have different needs than buyers for food service. For grocery items normally sold in bulk, processors want largest size packages that they can handle efficiently - to minimize unpacking time and reduce the cost of handling or disposing of the used containers. Produce managers, on the other hand, want individualized, high quality graphics to entice retail buyers with in-store displays.

Selecting the right container for fresh produce is seldom a matter of personal choice for the packer. For each commodity, the market has unofficial, but nevertheless rigid standards for packaging; therefore it is very risky to use a nonstandard package. Packaging technology, market acceptability, and disposal regulations are constantly changing. When choosing a package for fresh fruits and vegetables, packers must consult the market, and in some markets, standard packages may be required by law

Packaging materials in use

A great variety of materials are used for the packing of perishable commodities. They include wood, bamboo, rigid and foam plastic, solid cardboard and corrugated fibre board. The kind of material or structure adopted depends on the method of perforation, the distance to its destination, the value of the product and the requirement of the market.

1. CFB Boxes

Corrugated fiberboard is the most widely used material for fruit & vegetable packages because of the following characteristics:

- Light in weight
- Reasonably strong
- Flexibility of shape and size
- Easy to store and use
- Good pointing capability
- Economical

2. Wooden Boxes

Materials used for manufacture of wooden boxes include natural wood and industrially manufactured, wood based sheet materials.

3. Sacks

Sacks are traditionally made of jute fibre or similar natural materials. Most jute sacks are provided in a plain weave. For one tonne transportation of vegetables, materials of 250 grams per square meter or less are used. Natural fibre sacks have in many cases been replaced by sacks made of synthetic materials and paper due to cost factors, appearance, mechanical properties and risk of infestation and spreading of insects. Sacks made of polypropylene of type plain weave are extensively used for root vegetables. The most common fabric weight is 70-80 grams per square meter.

Palletisation

Pallets are widely used for the transport of fruit & vegetable packages, in all developed countries. The advantages of handling packages on pallets are:

- Labour cost in handling is greatly reduced.
- Transport cost may be reduced.
- Goods are protected and damage reduced.
- Mechanized handling can be very rapid.
- Through high stacking, storage space can be more efficiently used.
- Pallets encourage the introduction of standard package sizes.

In designing export packages, their handling on pallets for shipping or for transport and storage within the importing country, is an important factor. The most common pallet size is 1200 mmx1100 mm.

Ventilation of Packages

Reduction of moisture loss from the product is a principal requirement of limited permeability packaging materials. A solution to moisture loss problems from produce appeared with the development and wide distribution of semi permeable plastic films. Airflow through the ventilation holes allows hot fruit or vegetable to slowly cool and avoid the buildup of heat produced by the commodity in respiration. Holes are also important in cooling the fruit when the packages are placed in a cold storage, especially with forced air-cooling. Ventilation holes improve the dispersal of ethylene produced.

Cushioning Materials

The function of cushioning materials is to fix the commodities inside the packages and prevent them from mixing about in relation to each other and the package itself, when there is a vibration or impact. Some cushioning materials can also provide packages with additional stacking strength. The cushioning materials used vary with the commodity and may be made of wrapping papers, Fibreboard (single or double wall), Moulded paper pulp trays, Moulded foam polystyrene trays, Moulded plastic trays, Foam plastic sheet, Plastic bubble pads, Fine shredded wood, Plastic film liners or bags.

Controlled and Modified Atmospheric Packaging (CAP and MAP)

The normal composition of air is 78% Nitrogen, 21% Oxygen, 0.03% Carbon dioxide and trees of the noble gases. Modified atmosphere packaging is the method for extending the shelf-life of perishable and semi-perishable food products by altering the relative proportions of atmospheric gases that surround the produce. Although the terms controlled atmosphere (CA) and modified atmosphere (MA) are often used interchangeably a precise difference exists between these two terms.

Controlled atmosphere (CA)

This refers to a storage atmosphere that is different from the normal atmosphere in its composition, wherein the component gases are precisely adjusted to specific concentrations and maintained throughout the storage and distribution of the perishable foods. Controlled atmosphere relies on the continuous measurement of the composition of the storage atmosphere and injection of the appropriate gases or gas mixtures into it, if and when needed. Hence, the system requires sophisticated instruments to monitor the gas levels and is therefore practical only for refrigerated bulk storage or shipment of commodities in large containers.

If the composition of atmosphere in CA system is not closely controlled or if the storage atmosphere is accidentally modified, potential benefit can turn into actual disaster. The degree of susceptibility to injury and the specific symptoms vary, not only between cultivars, but even between growing areas for the same cultivars and between years for a given location. With tomatoes, excessively low O_2 or high CO_2 prevents proper ripening even after removal of the fruit to air, and CA enhances the danger of chilling injury.

Modified atmospheric packaging (MAP)

Unlike CAPs, there is no means to control precisely the atmospheric components at a specific concentration in MAP once a package has been hermetically sealed. Modified atmosphere conditions are created inside the packages by the commodity itself and / or by active modification. Commodity – generated or passive MA is evolved as a consequence of the commodity's respiration. Active modification involves creating a slight vacuum inside the package and replacing it with a desired mixture of gases, so as to establish desired EMA quickly composed to a passively generated EMA.

Another active modification technique is the use of carbon dioxide or ethyl absorbers (scavengers) within the package to prevent the build-up of the particular gas within the package. This method is called active packaging. Compounds like hydrated lime, activated charcoal, magnesium oxide are known to absorb carbon dioxide while iron powder is known to absorb carbon dioxide. Potassium permanganate, squakna and phenyl methyl silicone can be used to absorb ethylene within the packages. These scavengers can be held in small sachets within the packages or impregnated in the wrappers or into porous materials like vermiculite. With activity respiring commodities like fruits and vegetables, the package atmosphere should contain oxygen and carbon dioxide at levels optimum to the particular commodity. In general, MA containing between 2-5% Oxygen and 3.8% carbon dioxide have been shown to extend the shelf life of a wide variety of fruits and vegetables.

If the shelf life of a commodity at 20-25°C is 1, by employing MAP, it will be doubled, whereas refrigeration can extend the shelf life to 3, and refrigeration combined with MAP can increase it to 4. Few types of films are routinely used for MAP, the important ones are polyvinyl chloride, (PVC), polystyrene, (PS), polyethylene (PE) and polypropylene (PP). The recent developments in co-extrusion technology have made it possible to manufacture films with designed transmission rates of oxygen.

Vacuum packaging

Vacuum packaging offers an extensive barrier against corrosion, oxidation, moisture, drying out, dirt, attraction of dust by electric charge, ultra violet rays and mechanical damages, fungus growth or perishability etc. This technology has commendable relevance for tropical countries with high atmosphere humidity.

In vacuum packaging the product to be packed is put in a vacuum bag (made of special, hermetic fills) that is then evacuated in a vacuum chamber and then sealed hermetically in order to provide a total barrier against air and moisture. If some of the product cannot bear the atmosphere pressure due to vacuum inside the package then the packages are flushed with inert gases like Nitrogen and CO_2 after evacuation.

Edible packaging

An edible film or coating is simply defined as a thin continuous layer of edible material formed on, placed on, or between the foods or food components. The package is an integral part of the food, which can be eaten as a part of the whole food product. Selection of material for use in edible packaging is based on its properties to act as barrier to moisture and gases, mechanical strength, physical properties, and resistance to microbial growth. The types of materials used for edible packaging include lipids, proteins and polysaccharides or a combination of any two or all of these. Many lipid compounds, such as animal and vegetable fats, acetoglycerides have been used in the formulation of edible packaging for fresh produces because of their excellent moisture barrier properties. Lipid coatings on fresh fruits and vegetables reduce weight losses due to dehydration during storage by 40-70 per cent. Research and development effort is required to develop edible films and coatings that have good packaging performance besides being economical.

Conclusion

Improved packaging will become more essential in India as International trade expands. Standardized packaging of sized and graded produce that will protect the quality during marketing can greatly aid transactions between sellers and buyers. Better packaging should be of immediate value in reducing waste. Much background research on packaging of perishable products and flowers is needed simulating the actual handling conditions expected during marketing.

Recommended Controlled Atmosphere Conditions during transport/storage of vegetables

Commodity	Storage temp °C	Optimum Oxygen %	Optimum carbon dioxide %	Approximate storage life
Asparagus	1-5	21	5-10	21 d
Beans, snap	5-10	8-10	5-10	7-10 d
Beets	0-5	None	None	8 m
Brinjal	8-12	-	-	1-2 wks
Cabbage	0-5	3-5	5-7	6-12 m
Carrot	0-5	None	None	405 m
Cauliflower	0-5	2-3	3-4	2-3 m
Cucumber	8-12	3-5	0	14-21 d
Mushrooms	0-5	Air	10-15	3-4 d
Okra	8-12	3-5	0	7-10 d
Onions bulb	0-5	1-2	0	8 m
Pea (green)	0-1	5-10	5	5-10 d
Pepper, bell	8-12	3-5	0	2-3 wks
Pepper, chilli	8-12	3-5	0.5%	
Pumpkin	7-10	-	-	2-4 m
Radish	0-5	None	None	3-4 wks
Spinach	0-5	Air	10-20	2-3 wks
Tomatoes	5-13	3-5	2-3	2 wks
D – days Wks – weeks M - months				

Beneficial effects of controlled atmosphere on some vegetables

Commodity	Application	Benefits
Asparagus	Storage	Retention of sugars, organic acids and soluble proteins: retardation of toughening and discase
anana, green	Transport	Extension of shelf life
Beans, green	Transport	Extension of storage life, retention of chlorophyll
Broccoli	Storage	Retardation of yellowing
Brussels sprouts	Storage	Extension of storage life.
Cabbage whole	Storage	Retention of green colour and fresh flavour
Sheredded	Storage	Retardation of browning and off-odour development
Cauliflower	Storage	White colour of the curls preserved retention of leaf chlophyll
Lerruce shredded	Storage	Delayed browning
Onion, green	Transport	Retention of chlorophyll in tops
Peas, green	Storage	Extension of storage life, retention of chlorophyll

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LECTURE 10. PACKAGING TECHNOLOGY

The increasing demand for fresh and quality packaged food, consumer convenience and manufacturers concern for longer shelf life of the food products is driving the market for Global active and smart packaging technology for food Markets. Being perishable, fruits and vegetables require to be preserved until they are sold and used by consumers. This offers challenges in food preservation. The package must not only act as an inert barrier to the external environment but also resist respiration issues. Demands on package performance continue to increase as a result of market and social changes. Active packaging reduces the need for additional preservatives in perishable food stuffs. Thus the shelf-life is extended and the food stuffs maintain freshness longer and are mildly preserved. Research work in this area brings out newer methods and technologies for improving the active packaging. Some of the new developments:

Ethylene scavenger:

Ethylene (produced by all plants) is a plant growth hormone and has a detrimental impact even at low concentrations on the quality and shelf-life of many fruits and vegetables during storage and distribution. Ethylene induces fruit ripening and accelerates fruit softening and ageing. There are several methods used by the horticultural industry to minimize the impact of ethylene during storage and distribution. The two major methods are:

1. Low temperatures of storage: reduces the production of ethylene by lowering respiration and metabolic rates of the produce.
2. Controlled atmospheric storage with low oxygen and high level of carbon dioxide: suppresses respiration rates and renders the produce less sensitive to the effects of ethylene. 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.

Packaging technologies with an aim to scavenge or absorb ethylene from the surrounding environment of packaged produce have also been developed. The most widely used ethylene-scavenging packaging technology is based on a sachet that contains either potassium permanganate or activated carbon with a metal catalyst. Several ethylene-removing plastic film-based products consisting of PE impregnated with finely dispersed minerals like clays, zeolites and carbon have been developed. Oxygen scavengers can be incorporated in the packaging system itself rather than being added as sachets or labels as seen above. The oxygen scavenger can be incorporated into crowns, cans and a variety of metal and plastic closures. A novel plastic-based ethylene-scavenging technology developed by Food Science Australia is based on irreversible and specific reaction between diene (Tetrazine) and ethylene. Tetrazine is colored while its product with ethylene is colorless. This feature can provide the indication of the residual ethylene scavenging activity. The disadvantage however is that Tetrazine is sensitive to moisture. Another alternative approach is to use of ethylene inhibitors such as 1-methylcylcopropene (1-MCP). 1-MCP binds to the ethylene receptors in plant tissue and, as a result prevents the hormonal action of ethylene. However, it requires a dedicated fumigation chamber. 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.

Oxygen Scavenger:

The presence of oxygen in food packages accelerates the spoilage of many foods. Oxygen can cause off-flavour, colour change and nutrient loss, among other degradation. One of the most promising applications of oxygen scavenging systems in food packages is to control mould growth. Most moulds require oxygen to grow and in standard packages it is frequently mould growth which limits the shelf life. This also delays oxidation of and therefore rancidity development. Sachets containing oxygen absorbents, where the scavenging material is usually finely divided iron oxide.

Antimicrobial Packaging: Extends shelf-life and promotes safety by reducing the rate of growth of specifc microorganisms by allowing direct contact of the package with the surface of solid foods. The packaging could be self-sterilizing or sanitizing to greatly reduce the potential for recontamination of processed products and simplify the treatment of materials to eliminate product contamination. Antimicrobial systems can be constructed by using antimicrobial packaging materials, antimicrobial inserts (such as sachets) to generate antimicrobial atmosphere conditions inside packages, or antimicrobial edible food ingredients in the formulation of food. Since antimicrobial packaging systems are designed to control the growth of micro-organisms in packaged foods, the systems essentially consist of packaging materials, the in-package atmosphere, target micro-organisms, and antimicrobial agents. These elements are related to one another and to the final system design features. Antimicrobial packaging technologies have been developed considerably. Technologies that release volatile or gaseous microbial control agents are preferred due to the typically limited contact of the produce with the package surfaces.

Controlled Release of Sulfur Dioxide: Sulfur dioxide (SO_2) is an effective gaseous microbial agent, in use for over 80 years. SO_2 is traditionally used as antioxidant and preservative in fruit and vegetable products, dried fruits, snack products and wine. The main advantage of SO_2 is the combination of antioxidative activity with its ability to inhibit polyphenol oxidase, which is catalysing browning of food products. Furthermore, sulphur dioxide acts as food preservative preventing microbial growth. However, SO_2 and sulphites strongly reduce vitamin B1 uptake. Reduced uptake of this vitamin can lead to several health problems such as chronic headache and disturbance of the memory. Food is the main source for the uptake of sulphur dioxide. A special risk group is the group of asthma patients, as sulphites promote attacks of asthma. High levels of sulfur dioxide can result in undesirable bleaching of the fruit, making them unacceptable for sale. Furthermore, in 1989, a residue tolerance level of 10 ppm for sulfur dioxide was introduced by the US. Environmental Protection Agency (EPA) because it can cause adverse effect on people suffering from asthma. Several approaches to developing a plastic-based packaging film for the controlled release of sulfur dioxide have been used. Some methods that show potential are:

• Multi layer plastic film with external surface containing calcium sulfite that will release sulfur dioxide with inside layer of organic acid like citric acid. Moisture from produce gets absorbed by inner layer. This causes migration of hydrogen ion from acid compound to outer layer. Reaction of acid with calcium sulfite triggers liberation of sulfur dioxide.

• Sodium metabisulfite can be blended into the polymer having different water vapour transmission rates. A film based on this modified polymer can release sulfur dioxide in controlled manner depending upon its water transmission rate.

• A plastic film that has been incorporated by sodium chloride in the form of encapsulation can release chlorine dioxide, a general biocide in controlled rates.

• Laminating a sulfite-containing film to a film containing a food grade organic acid such as citric or succinic acid.

Three approaches are followed to finally replace SO_2 and sulphites in food:

a. Reduction of oxygen contact of the food products by modified atmosphere packaging or by edible coatings for fruits and vegetables

b. Use of plant metabolites as antioxidants and antimicrobial agents

c. Inhibition of polyphenol oxidase, which is responsible for enzymatic browning in fruit and vegetable products

Modified Atmosphere Packaging (MAP): A technique used for prolonging the shelf-life period of fresh or minimally processed foods. In this preservation technique, the air surrounding the food in the package is changed to another composition. This way the initial fresh state of the product may be prolonged. Shelf-life is prolonged with MAP since it slows the natural deterioration of the product. MAP is used with various types of products, where the mixture of gases in the package depends on the type of product, packaging materials and storage temperature. Meat and fish need very low gas permeability films so for non-respiring products (meat, fish, cheese etc.) high barrier films are used. Fruits and vegetables are respiring products where the interaction of the packaging material with the product is important. If the permeability (for O_2 and CO_2) of the packaging film is adapted to the products respiration, an equilibrium modified atmosphere will establish in the package and the shelf-life of the product will increase. Instead of preserving foods through the extremes of heat (sterilization) or cold (freezing), MAP utilizes "minimal processing" - preserving food with the absolute least amount of damage to quality, texture, taste and nutrition. MAP has been in existence for the last several decades. Several technologies have been developed with an aim to replace the existing headspace gas mixture with the ideal ratio of oxygen and carbon dioxide to preserve the produce until it is consumed by the user. Some of the most common MAP systems are:

- Micro perforation of PE packaging film
- Incorporation of inorganic particles along with micro perforated PE film

Humidity and condensation control

Water loss from fresh produce or minimally processed foods as a result of normal respiration, microbiological activity, or physical activity can occur as a result of evaporation from the product followed by permeation through the package material, when the package material does not provide an adequate water-vapor barrier. Condensation or “sweating” is a problem in many kinds of packaged foods, particularly fresh fruit and vegetables. When one part of the package becomes cooler than another, water vapor condenses as liquid droplets in the cooler areas. If the liquid water is kept away from the product, it harms package appearance and consumer appeal, both of which are important. When condensation moistens the product’s surface, soluble nutrients leak into the water, encouraging rapid growth of mold spores and leading to loss of nutrients. The use of humidity-control technology reduces condensation inside packages of respiring and other high-water-content foods and eliminates water films on the food without further drying the food. Therefore, moisture-sensitive humidity of the tray is controlled by :

- The presence of sodium chloride;
- Overwrap material claimed to be capable of controlling the relative humidity within a package that consists of a duplex of two sheets: the external sheet is a water-vapor barrier and the inner sheet is a water-vapor-permeable (but not water-permeable) film;
- A sandwich package composed of two sheets of polyvinyl alcohol (PVA) film

sealed along the edge. Between the two sheets is a layer of propylene glycol humidifying agent.

• The PVA film is very permeable to water-vapor but is a barrier to the propylene glycol;

• A sheet made of aluminum metallized film with nonwoven fabric on the reverse side, to absorb meat and fish exudations.

• Multilayer package containing a layer of PVOH or cellulosic fiber like paper sandwiched between PE films.

Although active packaging may provide many benefits to shelf life extension, there are several issues to consider before implementing such a packaging system. The regulatory status of the active packaging system, cost-to-benefit ratio, production capability, commercial viability, consumer acceptance, and sensory effects on the food. Generally, the shelf life has clearly been extended through implementation of active packaging. Combinations of systems along with new technologies to be further developed will continue to improve the quality and safety of food.

IMPORTANCE AND SCOPE OF FRUIT AND VEGETABLE PRESERVATION IN INDIA

Fruits and vegetables are an important supplement to the human diet as they provide the essential minerals, vitamins and fibre required for maintaining health. In India, the total fruits and vegetable production is about 137 million tonnes per year i.e. 46 MT fruits and 92 MT vegetables. The varied agro climatic conditions available in our country make it possible for us to produce several types of tropical, subtropical and temperate fruits and vegetables. It has been variously estimated that 20 to 30% of the horticultural produce is lost before consumption which accounts for Rs. 5000 crores because of poor harvesting, handling, storage, transportation and marketing practices. The fruits and vegetables are highly perishable commodities and the ambient high temperature obtained in the tropical country like ours makes them more susceptible for rapid development of senescence, decay and rotting. Both respiratory and transpiratory rates are proportional to temperature, increases and so that the produce quickly dries, wilts and spoils unless properly preserved.

Two approaches are possible for solving this problem. One is the creation / expansion of cold storage facilities in the fruit and vegetable producing regions themselves, as also in the major urban consumption centres, to ensure supply of fresh fruits and vegetables throughout the year. Another approach is to process the fruits and vegetables into various products which could be preserved for a long time and add to the value of the product. With increasing urbanization rise in middle class purchasing power, change in food habits and the dyeing out of the practice of making preserves in individual homes, there is increasing demands for factory made jams, jellies, fruit beverages, dehydrated foods, pickles etc. in the domestic market. Moreover, there is considerable demand for some of these products in foreign markets e.g. mangoes both fresh and canned, fruit juices, salted cashew are good foreign exchange earners.

The production of fruit and vegetable products in India are canned, bottled fruits and vegetables, jams, jellies, marmalades, fruit juices, fruit pulps, squashes, crashes, cordials, fruit syrups, fruit nectars, RTS fruit beverages, fruit juice concentrates, chutneys, pickles, mango slices in brine preserves, candied and crystallized fruits and peels, dehydrated fruits and vegetables, frozen fruits and vegetables, tomato products, sauces, soups etc.

In India there are 4000 processing industries are functioning. But a marginal quantity of 1.0 to 2.0 % of the produce is processed and packaged in contrast with developed and developing countries i.e., 70 to 80%. The total annual consumption of processed fruits and vegetable products in the country is rockened at only 50,000 tonnes of which defence and star hotels account for 15,000 tonnes and the remaining 35,000 tonnes to the public, i.e. a percapita consumption of 40 gms / year. Thus we can see on enormous scope and potential for the expansion of fruits and vegetable industries in India in the future.

Export of fruits and vegetables from India

In terms of global trade, India's share in agricultural export is insignificant. While India contributes 8.56% and 13.5% respectively to world's fruits and vegetables production, its share in global exports of these products is less than 1.0%. Delhi, Bombay and Trivandrum are the three main parts for air freighting of fruits and vegetables. These are mainly exported to Kuwait, Dubai and Saudi Arbia. Grapes are exported in large quantities from Bombay during January to March, while mango is exported during April to June. West Asia, the Far East and West Europe are the main export markets for Indian fruits and vegetables. Fruits juices, fruit pulp and pickles are mainly imported by the USSR, Yemen, Arab Republic. The other markets for processed fruits are UK, UAE, Saudi Arabia, Kuwait, Germany, USA, Holland and Switzerland. Nearly half of India's processed fruit exports are mango based fruit juice, canned and bottled fruits.

Fresh onions and mangoes are the main commodities entering in export trade. The other important fruits exported are melon, sweet melon, grapes, pomegranate, sapota, custard apple, orange, papaya, pineapple. Among other vegetables the principal items are tomato, ladies finger bitter gourd, chillies, fresh beans, cabbage, brinjal etc.

PRINCIPLES OF PRESERVATION BY HEAT, LOW TEMPERATURE, CHEMICALS AND FERMENTATION

PRINCIPLES OF FOOD PRESERVATION BY HEAT

Application of heat to the foods leads to the destruction of microorganisms. The specific treatment varies with:

i) The organisms that has to be killed.

ii) The nature of the food to be preserved and

iii) Other means of preservation that may be used in addition to high temperature.

High temperatures used for preservation are usually: (1) Pasteurization temperature – below 100°C (2) Heating at about 100°C and (3) Sterilization temperature above 100°C.

a. Pasteurization–below 100°C

Pasteurization is a heat treatment that kills part but not all the microorganisms present and the temperature applied is below 100°C. The heating may be by means of steam, hot H_2O, dry heat or electric currents and the products are cooled promptly after the heat treatments. The surviving microorganisms are inhibited by low temperature (or) some other preservative method if spoilage is to be prevented.

Preservative methods used to supplement pasteurization include (i) refrigeration e.g. of milk (2) keeping out microorganisms usually by packaging the product in a sealed container (3) maintenance of anaerobic conditions as in evacuated, sealed containers (4) addition of high concentration of sugar, as in sweetened condensed milk and (5) presence (or) addition of chemical preservatives e.g. the organic acids on pickles.

Methods of pasteurization

HTST method - High temperature and short time (above 70°C)

LTH method - Low temperature and higher time (or) Holding method (60-70°C)

b. Heating at about 100°C

A temperature of approximately 100°C is obtained by boiling a liquid food, by immersion of the container of food in boiling water or by exposure to flowing steam. Some very acid foods, e.g., sauerkraut may be preheated to a temperature somewhat below 100°C, packaged hot, and not further heat processed. Blanching fresh vegetables before freezing or drying involves heating briefly at about 100°C.

c. Sterilization-above 100°C

By this method all microorganisms are completely destroyed due to high temperature. The time and temperature, necessary for sterilization vary with the type of food. Temperatures above 100^{o}C can only be obtained by using steam pressure sterilizers such as pressure cookers and autoclaves.

Fruits and tomato products should be noted at 100^{o}C for 30 min. so that the spore-forming bacteria which are sensitive to high acidity may be completely killed. Vegetables like green peas, okra, beans, etc. being non acidic and containing more starch than sugar, require higher temperature to kill the spore forming organisms. Continuous heating for 30-90 min. at 116^{o}C is essential for their sterilization. Before using, empty cans and bottles should also be sterilized for about 30 min. by placing them in boiling water.

Difference between pasteurization and sterilization

Pasteurization	Sterilization
1. Partial destruction of microorganism	Complete destruction of microorganism
2. Temperature below 100^{o}C	Temperature 100^{o}C and above
3. Normally used for fruits	Normally used for vegetables

Aseptic canning

It 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.

Hot Pack (or) Hot fill

Filling of previously pasteurized or sterilized foods, while still hot, into clean but not necessarily sterile containers, under clean but not necessarily aseptic conditions.

PRESERVATION BY LOW TEMPERATURE

Microbial growth and enzyme reactions are retarded in foods stored at low temperature. The lower the temperature, the greater the retardation. Low temperature can be produced by

(a) Cellar storage (about 15^{o}C)

The temperature in cellar (underground rooms) where surplus food is stored in many villages is usually not much below that of the outside air and is seldom lower than 15^{o}C. It is not enough to prevent the action of many spoilage organisms or of plant enzymes. Root crops, potatoes, cabbage, apples, onions and similar foods can be stored for limited periods during the winter months.

(b) Refrigerated (or) chilling (0 to 5^{o}C)

Chilling temperature are obtained and maintained by means of ice or mechanical refrigeration. It may be used as the main preservative method for foods or for temporary preservation until some other preservative process is applied. Most perishable foods, including eggs, dairy products, meats, sea foods, vegetables and fruits, may be held in chilling storage for a limited time with little change from their original condition. Enzymatic and microbial changes in the foods are not prevented but are slowed considerably.

Factors to be considered in connection with chilling storage include the temperature of chilling, the relative humidity, air velocity and composition of the atmosphere in the store room, and the possible use of ultra violet rays or other radiations.

PRESERVATION BY CHEMICALS

A preservative is defined as only substance which is capable of inhibiting, retarding or arresting the growth of microorganisms.

Microbial spoilage of food products is also controlled by using chemical preservatives. The inhibitory action of preservatives is due to their interfering with the mechanism of cell division, permeability of cell membrane and activity of enzymes.

Pasteurized squashes, cordials and crushes have a cooked flavour. After the container is opened, they ferment and spoil within a short period, particularly in a tropical climate. To avoid this, it is necessary to use chemical preservatives. Chemically preserved squashes and crushes can be kept for a fairly long time even after opening the seal of the bottle. It is however, essential that the use of chemicals is properly controlled, as their indiscriminate use is likely to be harmful. The preservative used should not be injurious to health and should be non-irritant. It should be easy to detect and estimate.

Two important chemical preservatives are permitted to beverages according to the FPO (1955).

1. Sulphur dioxide and
2. Benzoic acid

Sulphur dioxide

It is widely used throughout the world in the preservation of juice, pulp, nectar, squash, crush, cordial and other products. It has good preserving action against bacteria and moulds and inhibits enzymes, etc. In addition, it acts as an antioxidant and bleaching agent. These properties help in the retention of ascorbic acid, carotene and other oxidizable compounds. It also retards the development of nonenzymatic browning or discolouration of the product. It is generally used in the form of its salts such as sulphite, bisulphate and metabisulphite.

Potassium metabisulphite (K_2O 2So2 (or) $K_2S_2O_5$) is commonly used as a stable source of So2. Being a solid, it is easier to use than liquid (or) gaseous So2.It is fairly stable in neutral (or) alkaline media but decomposed by weak acids like carbonic, citric, tartaric acid and malic acids. When added to fruit juice (or) squash it reacts with the acid in the juice forming the potassium salt and So2, which is liberated and forms sulphurous acid with the water of the juice. The reactions involved are as follows

Potassium meta bisulphate + Citric acid $\longrightarrow$ Potassium Citrate + Sulphur dioxide + H_2O

$$SO2 + H_2O \longrightarrow H_2SO_3 \text{ (Sulphurous acid)}$$

SO2 has a better preservative action than sodium benzoate against bacteria and moulds. It also retards the development of yeasts in juice, but cannot arrest their multiplication, once their number has reached a high value.

It is well known that fruit juices with high acidity do not undergo fermentation readily. The preservative action of the fruit acid its due to is hydrogen ion concentration. The pH for the growth of moulds ranges from 1.5 to 8.5, that of yeasts from 2.5-8.0, and of bacteria from 4.0 to 7.5.As fruit beverage like citrus squashes and cordials have generally a pH of 2.5 to 3.5, the growth of moulds and yeasts in them cannot be prevented by acidity alone. Bacteria, however, cannot grow. The pH is therefore, of great importance in the preservation of food product and by regulating it, one or more kinds of microorganisms in the beverage can be eliminated.

The concentration of So2 required to prevent the growth of mirgroorganism at different pH levels are as under.

pH	**S.ellipsoideus (yeasts)**	**Mucor (mold)**	**Penicillium (mold)**	**Mixed bacteria**
2.5	200	200	300	100
3.5	800	600	600	300
7.0	Above 5000	Above 5000	Above 5000	Above 1000

The toxicity of So2 increases at high temperature. Hence its effectiveness depends on the acidity, pH, temperature and substances present in fruit juice.

According to FPO, the maximum amount of So2 allowed in fruit juice is 700 ppm, in squash, crush and cordial 350 ppm and in RTS and nectar 100 ppm. The advantages of using So2 are a) It has a better preserving action than sodium benzoate against bacterial fermentation b) it helps to retain the colour of the beverage for a longer time than sodium benzoate (c) being a gas, it helps in preserving the surface layer of juices also (d) being highly soluble in juices and squashes, it ensures better mixing and hence their preservation and (e) any excess of So2 present can be removed either by heating the juice to about 71^{o}C or by passing air through it or by subjecting the juice to vacuum. This causes some loss of the flavouring materials due to volatilization, which can be compensated by adding flavours.

Disadvantages (or) limitations

a. It cannot be used in the case of some naturally coloured juices like those of jamun, pomegranate, strawberry, coloured grapes, plum etc. on account of its bleaching action.

b. It cannot also be used for juices which are to be packed in tin containers because it not only corrodes the tin causing pinholes, but also forms H_2S which has a disagreeable smell and reacts with the iron of the tin container to form a black compound, both of which are highly undesirable and

c. So2 gives a slight taste and colour to freshly prepared beverages but these are not serious defects if the beverage is diluted before drinking.

II. Benzoic acid

It is only partially soluble in H_2O hence its salt, sodium benzoate is used. One part of sodium benzoate is soluble in 1.8 parts of water at ordinary temperature, whereas only 0.34 parts of benzoic acid is soluble in 100 parts of water. Sodium benzoate is thus nearly 170 times as soluble as benzoic acid, pure sodium benzoate is tasteless and odourless.

The antibacterial action of benzoic acid is increased in the presence of Co_2 and acid e.g. *Bacillus subtilis* cannot survive in benzoic acid solution in the presence of Co_2. Benzoic acid is more effective against yeasts than against moulds. It does not stop lactic acid and acetic acid fermentation.

The quantity of benzoic acid required depends on the nature of the product to be preserved, particularly its acidity. In case of juices having a pH of 3.5-4.0, which is the range of a majority of fruit juices, addition of 0.06 to 0.10% of sodium benzoate has been found to be sufficient. In case of less acid juices such as grape juice atleast 0.3% is necessary. The action of benzoic acid is reduced considerably at pH 5.0. Sodium benzoate is excess of 0.1% may produce a disagreeable burning taste. According to FPO its permitted level in RTS and nectar is 100 ppm and in squash, crush and cordial 600 ppm.

In the long run benzoic acid may darken the product. It is, therefore, mostly used in coloured products of tomato, jamun, pomegranate, plum, watermelon, strawberry, coloured grapes etc.

Preservation by fermentation

Decomposition of carbohydrates of 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. 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% acetic acid prevents spoilage in many products.

UNIT LAYOUT-SELECTION OF SITE AND PRECAUTIONS FOR HYGIENIC CONDITIONS OF THE UNIT

Availability of raw materials

Raw material is of primary importance. It should be of very high quality. The price of the raw material is one of the main factors which affect the cost of the finished products. In India, the price of fruits and vegetables is quite high in the beginning of the season but there is a glut when plenty o0f raw material of excellent quality can be purchased at low cost.

Site and building

The site of the plant dealing with fruits and vegetables should be near the growing area to ensure the ready availability of freshly picked raw materials and to minimize the time taken for its transport.

The site should have adequate water supply and enough space should be available so that there is no congestion and there is scope for further expansion of the plant. Sites having factories nearby which emits fumes that contaminate the air are not suitable.

After selecting the site the question of the type of building is to be considered. Existing old buildings are not suitable. The building should be designed for Indian conditions. Single-storied structures based o0n the requirement of working space, cost of the land, etc., are preferable as all equipments heavy machinery can be erected without difficulty and can be shifted easily whenever necessary. Ventilation and lighting are also better in single –storied buildings. Generally fruit and vegetable processing units are single-storied. The division of space should be done according to the steps of the process.

Receiving and storage section

The area will depend on the nature of the raw materials. The receiving area should be as near to rail and road as possible specially where perishable products are concerned.

Preparation section

The preparation section of fruit and vegetable processing plant requires a greater area. It should be well sanitated so that the risk of spoilage is reduced. The section should be fitted with water and steam lines such that the spreading of hoses while washing is avoided. As far as possible floors should be (a) resistant to chemicals, (b) resistant to wear (c) slip-proof, and d) have proper slope with clean and well-placed drains. The area can also be subdivided into different compartments for washing, peeling or shelling, extraction of juice, etc.

Filling, exhausting, sealing and processing section: care should be taken to control the humidity in this section where process like exhausting and sterilizing operations are mainly carried out. The floor should be quite sturdy to withstand heavy wear and tear.

Finishing section

This section where incubation, lacquering, labeling and packing are done should be scrupulously clean, cool and dry with good ventilation.

Laboratory

Although a laboratory is expensive to set-up it is a very important unit in a fruit and vegetable processing plant. Its functions are: (a) examination of raw materials (b) control of processes (c) quality control of finished products (d) introduction of new processes and better products and (e) development of new techniques.

Apart from these sections, there should be suitable arrangement for storing, keeping machinery and other equipment and disposal of waste.

Water supply

Water plays an important role in the food industry. It is used in substantial quantities for (a) cleaning of equipment, floors, walls, etc., (b) washing and preparation of raw materials, (c) preparation of brine, syrups, etc., (d) blanching, (e) cooling of processed cans, and (f) steam generation, etc.

The water should be free from contamination. If necessary, it should be chlorinated.

Disposal of waste

A large quantity of waste is produced by a cannery, containing a high percentage of solid matter, such as skins, peels and colloidal starchy material. Hence the cannery should be situated at such a place where waste could also be profitably utilized to make by-products.

Transport facilities

It is essential that the cannery should be situated near a road which connects it important towns in that area.

SANITARY REQUIREMENTS OF A FACTORY OF FRUIT PRODUCTS

- The Premises - adequately lighted, ventilated & cleaned by white washing/color washing or oil painting.
- Windows & all openings shall be well screened with wire-mesh & the doors fitted with automatic closing springs, roof shall be permanent, floor cemented.
- The equipments and the factory l not be used for manufacture of repugnant products like fish, meat, eggs etc.
- The premises - located in a sanitary place with open surroundings, preferably in industrial area/estates. Communicated not directly with residence.

- Adequate arrangements for cleaning equipments, machinery, containers tables and raw materials shall be provided. Copper, brass or iron equipments, containers or vessels are not permitted.
- The water used shall be potable.
- Adequate drainage system and provisions for disposal of refuse shall be made.
- Sufficient number of latrine & urinals shall be provided for workers.
- Wherever cooking is done on open fire, proper outlets for smoke/steam etc. like chimney, exhaust fan etc. shall be provided.
- The workers engaged in the factory shall be healthy and shall be medically examined, inoculated and vaccinated whenever required.
- The workers shall be provided with aprons, head-wears gloves etc. and shall be personally neat and tidy.

Satisfactory hygienic conditions are also maintained during processing, in order to protect the product from bacterial contamination. For the routine bacteriological control of the plant or factory, counts on utensils, equipment, working surfaces, walls and floors are regularly carried out and the results tabulated or recorded on charts to give an immediate indication of any change. The counts are used as a check on the sanitary conditions of the plant. If the sanitary conditions of manufacture are to be passed as being “good”, the general bacterial counts must be low. In addition, periodic inspection of the plant is made by a trained inspector to make sure that adequate hygiene standards are maintained.

PRESERVATION THROUGH CANNING, BOTTLING, FREEZING, DEHYDRATION, DRYING, ULTRAVIOLET AND IONIZING RADIATIONS

PRESERVATION THROUGH CANNING

The process of sealing food stuffs hermetically in containers and sterilizing them by heat for long storage is known as canning.

In 1804, Appert in France invented a process of sealing foods hermetically in containers and sterilizing them by heat. In honour of the inventor, canning is also known as appertizing. Saddington in England was the first to describe a method of canning of foods in 1807. In 1810, Peter Durand, another Englishman, obtained the first British Patent on canning of foods in tin containers. In 1817, William Underwood introduced canning of fruits on a commercial scale in U.S.A.

Fruits and vegetables are canned in the season when the raw material is available in plenty. The canned products are sold in the off-season and give better returns to the grower.

Principles and Process of Canning

Principle

Destruction of spoilage organisms within the sealed container by means of heat.

Process

Selection of fruits/vegetables ⟶ Grading ⟶ Washing ⟶
Cooling ⟶ Blanching ⟶ Cutting ⟶ Peeling ⟶
Filling and Syruping or Brining ⟶ Exhausting ⟶ Storage ⟶
Cooling ⟶ Processing ⟶ Sealing

(1) Selection of fruits and vegetables

- Fruits and vegetables should be absolutely fresh.
- Fruits should be ripe, but firm, and uniformly mature. Over-ripe fruits should be rejected
- because they are infected with microorganisms and give a poor quality product. Unripe
- fruits should be rejected because they generally shrivel and toughen on canning.
- All vegetables except tomatoes should be tender.
- Tomatoes should be firm, fully ripe and of deep red colour.
- Fruits and vegetables should be free from dirt.
- They should be free from blemishes, insect damage or mechanical injury.

(2) Grading

The selected fruits and vegetables are graded according to size and colour to obtain uniform quality. This is done by hand or by machines such as screw grader and roller grader. Fruits like berries, plums and cherries are graded whole, while peaches, pears, apricots, mangoes, pineapple, etc., are generally graded after cutting into pieces or slices.

(3) Washing

It is important to remove pesticide spray residue and dust from fruits and vegetables. One gram of soil contains 10^{12} spores of microorganisms. Therefore, removal of microorganisms by washing with water is essential. Fruits and vegetables can be washed in different ways. Root crops that loosen in soil are washed by soaking in water containing 25 to 50 ppm chlorine (as detergent). Other methods of washing are spray washing, steam washing, etc.

(4) Peeling

The objective of peeling is to remove the outer layer. Peeling may be done in various ways.

Hand peeling

It is done mostly in case of fruits of irregular shape, e.g., mango and papaya, where mechanical peeling is not possible.

Steam peeling

Free-stone and clingstone peaches are steam peeled in different ways. The former are cut and steam washed. Potatoes and tomatoes are peeled by steam or boiling water.

Mechanical peeling

This is done in case of apples, peaches, pineapples and cherries and also for root vegetables like carrots, turnips and potatoes.

Lye peeling

Fruits like peaches, apricots, sweet oranges, mandarin oranges and vegetables like carrots and sweet potatoes are peeled by dipping them in 1 to 2 per cent boiling caustic soda solution (lye) for 30 seconds to 2 minutes depending on their nature and maturity. Hot lye loosens the skin from the flesh by dissolving the pectin. The peel is then removed easily by hand. Any trace of alkali is removed by washing the fruit or vegetable thoroughly in running cold water or dipping it for a few seconds in 0.5 per cent citric acid solution. This is a quick method where by cost and wastage in peeling is reduced.

Flame peeling

It is used only for garlic and onion which have a papery outer covering. This is just burnt off. Vegetables like peas are shelled, carrots are scarped, and beans are snipped or trimmed.

(5) Cutting

Pieces of the size required for canning are cut. Seed, stone and core are removed. Some fruits like plum from which the seeds cannot be taken out easily are canned whole.

(6) Blanching

It is also known as scalding, parboiling or precooking. It is usually done in case of vegetables by exposing them to boiling water or steam for 2 to 5 minutes, followed by cooling. The extent of blanching varies with the food. Generally fruits are not blanched. This brief heat treatment accomplishes the following:

- Inactivates most of the plant enzymes which cause toughness, discolouration (polyphenol oxidase), mustiness, off-flavour (peroxidase), softening and loss of nutritive value.
- Reduces the area of leafy vegetables such as spinach by shrinkage or wilting, making their packing easier.
- Removes tissue gases which reduce sulphides.
- Reduces the number of microorganisms by as much as 99%.
- Enhances the green colour of vegetables such as peas, broccoli and spinach.
- Removes saponin in peas.
- Removes undesirable acids and astringent taste of the peel, and thus improves flavour.
- Removes the skin of vegetable such as beetroot and tomatoes which helps in their peeling.

Disadvantages

- Water-soluble materials like sugar and anthocyanin pigments are leached by boiling water.
- Fruits lose their colour, flavour and sugar.

(7) Cooling

After blanching, the vegetables are dipped in cold water for better handling and keeping them in good condition.

(8) Filling

Before filling, cans are washed with hot water and sterilized but in developing countries these are subjected to a jet of steam to remove dust and foreign material. Automatic, large can-filling machines are used in advanced countries but choice grades of fruits are normally filled by hand to prevent bruising. In India, hand filling is the common practice. After filling, covering with syrup or brine is done and this process is called syruping or brining.

A 1-b butter size can should hold 230 285 g of fruit slices and a A 2 ½ size can 510 to 565 g.

The blanched vegetables are packed in sterilized cans which should hold the drained weight of vegetables as specified below:

1 lb butter size can	-	269-283 g
A 2 ½ size can	-	538-566 g
Pint size glass jar	-	283-311 g

(i) Syruping

A solution of sugar in water is called a syrup. Normally sucrose syrup is used in canning. Syrup is added to improve the flavour and to serve as a heat transfer medium for facilitating processing. Syruping is done only for fruits.

Strained, hot syrup of concentration 20 to 55^{o} Brix is poured on the fruit. Fruits rich in acid require a more concentrated syrup than less acid ones. The syrup should be filled at about 79 to 82^{o}C, leaving a head space of 0.3 to 0.5 cm. Sometimes citric acid and ascorbic acid are also mixed with the syrup to improve flavour and nutritional value, respectively.

(ii) Brining

A solution of salt in water is called brine. The objective of brining is similar to that of syruping. Only vegetables are brined. Common salt of good quality free from iron should be used. Hot brine of 1 to 3 per cent concentration is used for covering vegetables and is filled at 79 to 82^{o}C, leaving a head space of 0.3 to 0.5 cm. The brine should be filtered through a thick cloth before filling.

After syruping or brining the cans are loosely covered with lids and exhausted. Lidding has certain disadvantages such as spilling of the contents and toppling of the lids. Hence lidding has now been modernized by ‘clinching’ process in which the lid is partially seamed. The lid remains sufficiently loose to permit the escape of dissolved as well as free air from the can and also the vapour formed during the exhausting process.

(9) Exhausting

The process of removal of air from cans is known as exhausting. After filling and lidding or clinching, exhausting is essential. The major advantages of exhausting are as under:

a) Corrosion of the tinplate and pinholing during storage is avoided.
b) Minimizes discolouration by preventing oxidation.
c) Helps in better retention of vitamins particularly vitamin C.

d) Prevents bulging of cans when stored in a hot climate or at high altitude.

e) Reduces chemical reaction between the container and the contents.

f) Prevents development of excessive pressure and strain during sterilization.

Containers are exhausted either by heating or mechanically. The heat treatment method is generally used. The cans are passed through a tank of hot water at 82 to 87°C or move on a belt through a covered steam box. In the water exhaust box, the cans are placed in such a manner that the level of water is 4-5 cm below their tops. The exhaust box is heated till the temperature of water reaches 82 to 100°C and the centre of the can shows a temperature of about 79°C. The time of exhausting varies from 6 to 10 minutes, depending on the nature of the product. In the case of glass jars or bottles, vacuum closing machines are generally used. The bottles or jars are placed in a closed chamber in which a high vacuum is maintained.

It is preferable to exhaust the cans at a lower temperature for a longer period to ensure uniform heating of the contents without softening them into pulp. Exhausting at high temperature should be avoided because the higher the temperature, the more is the volume of water vapour formed, and consequently the greater the vacuum produced in the can.

(10) Sealing

Immediately after exhausting the cans are sealed airtight by means of a can sealer. In case of glass jars a rubber ring should be placed between the mouth of the jar and the lid, so that it can be sealed airtight. During sealing the temperature should not fall below 74°C.

(11) Processing

Heating of foods for preserving is known as processing, however, in canning technology processing means heating or cooling of canned foods to inactivate bacteria. Many bacterial spores can be killed by either high or every low temperature. Such drastic treatment, however affects the quality of food. Processing time and temperature should be adequate to eliminate all bacterial growth. Moreover, over-cooking should be avoided as it spoils the flavour as well as the appearance of the product.

Almost all fruits and acid vegetables can be processed satisfactorily at a temperature of 100°C, i.e., in boiling water. The presence of acid retards the growth of bacteria and their spores. Further, they do not thrive in heavy sugar syrup which is normally used for canning of fruits. Vegetables (except the more acid ones like tomato and rhubarb) which are non-acid in nature, have a hard texture, and proximity to soil which many infect them with spore-bearing organisms processed at higher temperatures of 115 to 121°C.

The sourness of fruits and vegetables is due to their acid content (measured in pH) which has a great influence upon the destruction of microorganisms. The lower the pH the greater is the ease with which a product can be processed or sterilized. Fruits and vegetables can be classified into the following four groups according to their pH value.

Class	pH	Product
Low acid (called non-acid)	Above 5.0	Vegetables such as peas, lima bean, asparagus, cauliflower, potato, spinach, beet, corn, french bean
Medium acid	4.5-5.0	Turnip, carrot, okra, cabbage, pumpkin, beet, green bean, etc., and products like soups and sauces
Acid	3.7-4.5	Tomato, pear, banana, mango, jackfruit, pineapple, sweet cherry, peach, apple and other fruits
High acid	Below 3.7	Citrus juice, rhubarb, prune, sauerkraut, pickle, chutney, etc.

Bacterial spores can be more easily destroyed at pH 3.0 (fruits) than at pH 5.0 to 6.0 (vegetables, except tomato and rhubarb). Bacterial spores do not grow or germinate below pH 4.5. Thus, a canned product having pH less than 4.5 can be processed in boiling water but a product with pH above 4.5 requires processing at 115 to 121^{o}C under a pressure of 0.70 to 1.05 kg/cm^{2} (10 to 15 lb/sq inch). It is essential that the centre of the can should attain these high temperatures.

The temperature and time of processing vary with the size of the can and the nature of the food: the larger the can, the greater is the processing time. Fruits and acid vegetables are generally processed in open type cooker, continuous non-agitating cookers, while vegetables (non-acid) are processed under steam pressure in closed retorts known as automatic pressure cookers and continuous agitating cookers. In India, small vertical stationary retorts (frontispiece) are generally used for canned vegetable processing. The sealed cans are placed in the cookers, keeping the level of water 2.5 to 5.0 cm above the top of the cans. The cover of the cooker is then screwed down tightly and the cooker heated to the desired temperature. The period of sterilization (process) should be counted from the time the water starts boiling. After heating for the required period the cooker is removed from the fire and the petcock is opened. When the pressure comes down to zero the cover is removed and the cans are taken out.

(12) Cooling

After processing, the cans are cooled rapidly to about 39°C to stop the cooking process and to prevent stack-burning. Cooling is done by the following methods.

(i) Dipping or immersing the hot cans in tanks containing cold water.

(ii) Letting cold water into the pressure cooker specially in case of vegetables.

(iii) Spraying cans with jets of cold water; and

(iv) Exposing the cans to air.

Generally the first method, i.e. dipping the cans in cold water, is used. If canned products are not cooled immediately after processing, peaches and pears becomes dark in colour, tomatoes turn brownish and bitter in taste, peas become pulpy with cooked taste and many vegetables develop flat sour (become sour).

(13) Storage

After labelling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place. The outer surface of the cans should be dry as even small traces of moisture sometimes induce rusting. Storage of cans at high temperature should be avoided, as it shortens the shelf-life of the product and often leads to the formation of hydrogen swell.

The marketable life of canned products varies according to the type of raw materials used. Canned peach, grapefruit, pineapple, beans, spinach, pea, celery, etc. can be stored for about two years, while pear, apricot, carrot, beetroot, tomato, etc. can be stored for a comparatively long period.

PRESERVATION BY BOTTLING

Bottles have proved to be very good containers for home preservation of fruits. Although their initial cost is high, they can be used several times and last for many years if carefully handled.The fruits look attractive through glass and do not develop metallic flavour. Bottling does not need a sealing machine.

There are many types of glass containers of different shapes and sizes and with various types of hermetic seals. The products remain in a very hygienic condition and do not come into contact with rubber or metal.

Filling and syruping

The bottles are thoroughly washed and sterilized. The fruit slices are filled leaving about 3cm space at the top of the Jar or bottle. The sugar syrup recommended for different fruits is filled boiling hot leaving ahead space of 1-1.5cm.

Exhausting and sterilization

Separate exhausting of bottles is not required and it is done simultaneously with sterilization by putting a pad of cloth under the bottles. The bottles should not be abruptly immersed in hot water, otherwise they may break because of sudden rise in temperature. The temperature of the water should about the same as that of the same as that of the contents and should be raised gradually and the bottles kept i9n the boiling water for the required time. At the start of sterilization the lids are left loose and the level of boiling water should come up to the neck of the bottle, but when sterilization is over the mouths of bottles and jars should be immediately closed or corked tightly.

Cooling and storage

These are done as for canning of fruits and vegetables.

PRESERVATION BY FREEZING

At temperature below the freezing point of H_2O, growth of microorganisms and enzyme activity are reduced to minimum. Most perishable foods can be preserved for several months. Fruits, vegetables, juices and fleshy foods (meat poultry fish and sea foods) can be preserved in this method.

Cold storage we generally means storage at temperature above freezing, and this covers a range of about 16^{o}C (60^{o}F) down to –2.2 ^{o}C (28^{o}F). Commercial and household refrigerators are usually run at 4.4^{o} – 7.2 ^{o}C (40-45 ^{o}F). While pure water will freeze at 0^{o}C (32 ^{o}F)), most foods will not begin to freeze until about –2.2 ^{o}C) (28^{o}F) or lower is reached.

Frozen storage (Freezing) as the name implies refers to storage at temperatures where the food is maintained in frozen condition. Good frozen storage generally means – 18^{o}C (0 ^{o}F) or below.

Refrigerated or cold storage generally will preserve perishable foods for days or weeks depending upon the food. Frozen storage will preserve perishable foods for months or even years. Further distinctions between refrigeration and freezing temperatures are related to microorganisms activity. Most food spoilage microorganisms grow rapidly at temperatures above 10^{o}C (50^{o}F) .Some food poisoning organisms grow slowly down to 3.3^{o}C (38 ^{o}F) psychrotropic organisms will grow slowly within the range of 4.4 ^{o}C to – 9.4 ^{o}C (40 ^{o}F to 15 ^{o}F), provided the food is not solidly frozen. These will not produce food poisoning or disease but even below – 3.9^{o}C (25 ^{o}F) will cause the food to deteriorate. Below – 9.4^{o}C (15 ^{o}F) there is no significant growth of microorganisms in food; instead there is a gradual decrease in the numbers of living organisms. But the destruction of microorganisms by cold is not complete when the food is thawed there can be rapid microorganisms multiplication and spoilage.

Characteristics of food systems being frozen

It is a basic property of aqueous solutions that increasing their concentrations of dissolved solids will lower their freezing points. Thus the more salt, sugar, minerals, or proteins in a solution the lower the freezing point and the longer it will take to freeze when put into a freezing chamber. If water and juice are placed in a freezer the water will freeze first. Further, unless the temperature is considerably below the freezing point of pure water the juice will never freeze completely but rather will become icy and slushy. What really is happening here is that the water component of the juice freezes first and leaves the dissolved solids in a more concentrated solution which requires a still lower temperature to freeze it.

Since different foods have quite different compositions with respect to their levels of water and the kinds and amounts of solids dissolved in the water, it is to be expected that these will have different freezing points and under a given freezing condition will require different times to reach a solidly frozen state.

Methods of freezing

There are various methods of freezing

1. Sharp Freezing (Slow freezing)

This technique, first used in 1861, involves freezing by circulation of air, either naturally or with the aid of fans. The temperature may vary from –15 to –29°C and freezing may take from 3 to 72 hours. The ice crystals formed one large and rupture the cells. The thawed tissue cannot regain its original water content. The first products to be sharp frozen were meat and butter. Now-a-days freezer rooms are maintained at –23 to –29°C or even lower, in contrast to the earlier temperature of –18°C.

2. Quick freezing

In this process the food attains the temperature of maximum ice crystal formation (0 to –4°C) in 30 min or less. Such a speed results in formation of very small ice crystals and hence minimum disturbance of cell structure. Most foods are quick frozen by one of the following three methods:

a) By direct immersion

Since liquids are good heat conductors food can be frozen rapidly by direct immersion in a liquid such as brine or sugar solution at low temperature. Berries in sugar solution packed fruit juices and concentrates are frozen in this manner. The refrigeration medium must be edible and capable of remaining unfrozen at –18°C and slightly below. Direct immersion equipments such as ottenson Brine freezer, Zarotschenzeff 'Fog' freezer, T.V.A. freezer, Bartlett freezer etc. of commercial importance earlier are not used today.

Advantages

- There is perfect contact between the refrigerating medium and the product, hence the rate of heat transfer is very high.
- Fruits are frozen with a coating of syrup which preserves the colour and flavor during storage.
- The frozen product is not a solid block because each piece is separate.

Disadvantages

- Brine is a good refrigerating medium but it cannot be used for fruits.
- It is difficult to make a syrup that will not become viscous at low temperature.
- The refrigeration temperature must be carefully controlled, as at high temperature the medium will enter the product by osmosis and at low temperature the medium may freeze solid.
- It is very difficult to maintain the medium at a definite concentration and also to keep it free from dirt and contamination.

b) By indirect contact with refrigerant

Indirect freeing may be defined as freezing by contact of the product with a metal surface which is itself cooled by freezing brine or other refrigerating media. This is an old method of freezing in which the food or package is kept in contact with the passage through the refrigerant at –18 to -46°C flows. Knowles Automatic Package feezer, Patterson continuous plate freezer, FMC continuous can freezer and Birds eye freezers are based on this principle.

c) By air blast

In this method, refrigerated air at –18 to –34°C is blown across the material to be frozen. The advantages claimed for quick freezing over slow freezing (sharp freezing) are (1) smaller (size) ice crystals are formed, hence there is less mechanical destruction of intact cells of the food (2) period for ice formation is shorter, therefore, there is less time for diffusion of soluble material and for separation of ice (3) more rapid preservation of microbial growth and (4) more rapid slowing down of enzyme action.

3) Cryogenic freezing

Although most foods retain their quality when quick frozen by the above methods, a few require ultrafast freezing. Such materials are subjected to cryogenic freezing which is defined as freezing at very low temperature (below –60°C). The refrigerant used at present in cryogenic freeing are liquid nitrogen and liquid CO_2. In the former case, freezing may be achieved by immersion in the liquid, spraying of liquid or circulation of its vapour over the product to be frozen.

4. Dehydro-freezing

This is a process where freezing is proceded by partial dehydration. In case of some fruits and vegetables about 50% of the moisture is removed by dehydration prior to freezing. This has been found to improve the quality of the food. Dehydration does not cause deterioration and dehydro frozen foods are relatively more stable.

5. Freeze drying

In this process food is first frozen at $-18^{o}C$ on trays in the lower chamber of a freeze drier and the frozen material dried (initially at $30^{o}C$ for 24 hrs and then at $20^{o}C$). Under high vacuum (0.1 mm Hg) in the upper chamber. Direct sublimation of the ice takes place without passing through the intermediate liquid stage. The product is highly hygroscopic, excellent in taste and flavour and can be reconstituted readily. Mango pulp, orange juice concentrate, passion fruit juice and guava pulp are dehyderated by this method.

Changes during freezing and storage of frozen products

Quick freezing rapidly slow down chemical and enzymatic reactions in foods and stops microbial growth. A similar effect is produced by sharp freezing, but less rapidly. The physical effects of freezing are of great importance. This is an expansion in volume of the frozen food and ice crystals form and grow in size. These crystals are larger in slow freezing than in quick freezing and more ice accumulates between tissue cells and may crash the cells. Water is drawn from the cells to form ice. It is claimed that ice crystals rapture fruit and vegetable tissue cells and even microorganism. The increased concentration of solutes in the cells hastens their salting out, dehydration and denaturation of proteins and causes irreversible changes in colloidal systems, such as the syneresis of hydrophilic colloids. Further, freezing is considered to be responsible for killing microorganisms. The vegetative cells of yeasts and moulds and many gram negative bacteria are susceptible, while gram – positive bacteria including staphyloeocci and enterococci are moderately resistant, while spores bacilli and clostridia are insensitive to freezing.

During storage of food in the frozen condition, chemical and enzymatic reactions proceed slowly. Unfrozen concentrated solution of sugars, salts etc. May ooze out from fruits or concentrates during storage as a viscous material called 'metacryotic liquid'. Fluctuation in storage temperature results in an increase in the size of ice crystals resulting in physical damage to the food. Desiccation of the food at its surface is likely to take place during storage. When ice crystals evaporate from the surface of fruit, "freezer burn" is produced which usually appears as dry, grainy and brownish spots where the chemical changes mentioned above takes place and the tissues become dry and tough. There is slow but continuous decrease in the number of viable microorganisms on storage.

Freezing – 18 to –40°C

Freezing process of fruits, vegetables and juices

Suitable vegetables: Beans, cauliflower, peas, carrot etc.

Suitable fruits: Pineapple slices, mango slices or pulp, guava slices and orange. segments etc.

I. Beans

Beans (mature) → Removal of strings (fibre) → Cutting into 2 cm pieces → Blanching for 5 min (Direct immersion, no cloth bag) ☐ Cooling in

→Arranging in carotene → Freezing by plate frozen (takes about 2 hrs to reach -1 to -5°C when product is considered to be frozen) → Storage at - 18°C.

II. Carrot

Carrot → Washing → Peeling of skin → Cutting into 2 cm pieces → Blanching for 3 min (no cloth bag) → Cooling → Packing in polythene bags → Sealing → Arranging in cartons → Freezing at –1 to –5°C → Storage → 18°C.

III. Peas

Peas → Washing → Removal of shell → Washing → Blanching for 4 min → Cooling → Preliminary grading by density gradient using 10% brine (Flaters → immature peas, sinkers → mature peas) → Further grading of mature peas, using 9%, 13% and 15% brine → Packing in polythene bags. Floaters 9% - A grade, 13% - B grade, 15% - C grade, → Sealing → Arranging in cartons → Freezing at – 1°C to – 5°C → Storage at – 18°C.

IV. Cauliflower

Cauliflower (mature) → Cutting into bits – Blanching for 2 min → Cooling → Dipping in 0.05% KMS solution for 5 min → Draining → Packing in polythene bags → Sealing → Arranging in cartons → Freezing at –1 to –5°C → Storage at –18°C.

V. Guava

Guava → Washing - Placing in 2% boiling lye till skin becomes black → Removing and washing with H_2O → Dipping in 0.5% citric acid solution → Cutting into 4 pieces → Scooping out seeds → Packing pieces in polythene bags and covering with 25% sugar syrup containing 100 mg ascorbic acid → Sealing → Arranging in cartons → Freezing at –1 to –5°C → storage at –18°C.

VI. Orange

Orange → Peeling → Separating segments → Treatment with hot 1% lye →Washing with water → Dipping in 1% citric acid solution → Removing seeds → Packing in polythene bags and covering with 25% sugar syrup containing 100 mg of ascorbic acid → Sealing → Arranging in cartons → Freezing at –1 to –5^{o}C – Storage at – 18^{o}C.

PRESERVATION BY DEHYDRATION /DRYING

The practice of drying of food stuffs, specially fruits and vegetables, for preserving them is very old. The term 'drying' and 'dehydration' means the removal of water. The former term is generally used for drying under the influence of non-conventional energy sources like sun and wind. If fruits (or) vegetables are to be sun dried, they (or) their pieces should be evenly spread in single layer (on) trays or boards and exposed to the sun. In sun drying there is no possibility of temperature and humidity control. The hottest days in summer are, therefore, chosen so that the foods dry very fast, thus preventing them from getting spoiled due to souring. Souring (or) turning acidic is usually due to growth of microorganisms which convert the carbohydrates in the food to acid. Quick removal of moisture prevents the growth of the microorganisms.

Dehydration means the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow. In this process a single layer of fruits (or) vegetables, whole or cut into pieces (or) slices are spread on trays which are placed inside the dehydrator. The initial temperature of the dehydrator is usually 43^{o}C which is gradually increased to 60-66^{o}C in the case of vegetables and 50-71 ^{o}C for fruits.

Advantages of dried / dehydrated foods

- Dried foods are in more concentrated form than foods preserved in other ways. They are less costly to produce than canned or preserved food, because of lower labour costs and because of no sugar is required.
- Due to reduction in bulk of the product, it requires less storage space.
- The weight of a product is reduced to 1/4th to 1/9th its original (or) fresh weight and thus the cost of its transport is reduced.

Sundrying

Sundrying of fruits and vegetables is practiced widely in tropical and subtropical regions where there is plenty of sun shine and practically little or no rain during the drying season. Sundrying in direct (or) diffused sunlight (shade drying), one of the earliest method of food preservation, is still used for the production of dried fruits, and also for drying nuts. It was originally limited to fruits high in sugar content, which when harvested, would dry naturally without hazard of loss from fermentation and molding.

Process for drying of fruits

Fruits (mature and free from insects and disease→ Washing → Peeling / removal of outer skin → Preparation → Pretreatments → Spreading on flat wooden trays → Sulphuring → Drying →

Sweating → Packaging in air tight tin containers (or) polythene bags → Storage (at ambient temperature).

Pretreatments

Lye peeling

Dipping the fruits (grapes and dates) in 0.5% to 2.5% boiling caustic soda solution for 0.5 to 2.0 minutes depending on their nature and maturity. Hot lye loosens the skin from the flesh by dissolving the pectin. The peel is then removed easily by hand. Any trace of alkali is removed by washing the fruit thoroughly in running cold water (or) dipping it for a few seconds in 0.5% citric acid solution.

Sulphuring

Sulphuring is done only for fruits and not vegetables. So_2 fumes act as a disinfectant and prevent the oxidation and darkening of fruits on exposure and thus improves their colour. This phenomenon is generally seen in sliced fruits which darken due to oxidation of the colouring matter. Sulphur fumes also act as a preservative, check the growth of molds etc. and prevent cut fruit pieces from fermenting while drying in the sun. Vitamins in sulphured fruits are protected but not in unsulphured ones.

The whole fruits, slices (or) pieces are exposed to the fumes of burning sulphur inside a closed chamber known as sulphur box for 30-60 min. or in small airtight rooms.

Sulphur box is a closed airtight chamber of galvanized iron sheet. It is fitted in a wooden frame work having runways on both sides to hold the trays. For small scale sulphuring, a box of size of 90 x 60 x 90 cm which can hold 11 trays, each of 80 x 60 x 5 cm size is suitable. A box holding 10 trays will require burning of about 3 g of sulphur in one charge.

Sweating

Keeping dried products in boxes or bins to equalize moisture content.

Sundrying of fruits

1. Banana

Dried ripe banana is known as 'banana fig'. The fruit is peeled, sliced lengthwise, sulphured and dried in the sun. Unripe bananas are peeled after blanching in boiling water and cut into discs for drying. The dried slices are either cooked or fried. They can also be converted into banana flour which can be used as such or in combination with cereal flours.

2. Date

In the hard dried dates, sucrose sugar predominates, whereas in the soft dried dates, invert sugars predominates. Dates are picked in the dung stage, that is when the tip of the fruit has turned a translucent brown. They are spread on mats for 5 to 8 days for curing. This is rather expensive as several pickings have to be made as the date attain other proper stage of ripening. Scientists have found that dates could be picked 3 to 4 days before the "dung" stage and then dipped for ½ to 2 min in 0.5-2.5 % caustic soda solution before placing them for drying in order to get a good dried product.

3. Fig

The fruits are allowed to ripen on the tree and gathered when they drop. They are then spread thinly on the drying yard for 3 to 4 days for drying. After drying they are sorted and packed. Figs are treated with salt and lime (1 kg of each per 1000 litrs of water) to remove the hair from the skin and also to soften the flesh. They are then dried without sulphuring, till there is exudation of juice on pressing the dried fig between the fingers.

4. Grapes

Large quantities of seedless grapes known as kishmish grapes are imported into India from Afghanistan. Ripe bunches of grapes are hung inside dark rooms known as kishmish khanas till the berries acquire a greenish or light amber tint. These shade dried grapes are considered to be a far superior to the ordinary sundried (or) dehydrated grapes. The other important dried grape called 'Monucca' (or) Rasisin is prepared from the large seeded Haitha grapes which are lye dipped prior to the sun drying.

For efficient drying, grapes should have a high sugar content of 20 to 24 degree brix. From this point of view, some of the varieties of grapes are not suitable for drying. The higher sugar content grapes are dried without any sulphuring till there is no exudation of juice on pressing dried grape between the fingers. The yield and quality of the final dried product depend on the brix of the fresh grape taken for drying.

In California, the Sultanina (or) Thompson seedless varieties of grapes are dried. The grapes are sometimes dipped for 3-6 seconds in caustic soda and sodium bicarbonate, covering the surface of a solution with a thin layer of olive oil. This treatment removes only the wax and the bloom on the grapes without cracking the skin. The dried product has a glossy appearance. Lye dipped grapes are sometimes treated with sulphur fumes, for 3-5 hrs for bleaching them, because certain markets prefer such glossy product.

In Australia, potassium carbonate solution with a layer of olive oil (or) sometimes grape seed oil itself, is used for dipping the grapes. The drying is carried out on wire net racks arranged inside a shed. In this way, the grapes are dried without direct exposure to the sun. Drying takes 10-20 days depending upon the variety of grape. The dried product is generally of high quality.

5. Jack fruit

Jack fruit bulbs of ripe fruit are sliced and the seeds removed. The slices are dried with (or) without sulphuring. The bulbs can also be made into a fine pulp, which can be dried in the form of sheets or slabs.

6. Mango

Unripe, green mangoes are peeled, sliced and dried in the sun. The dried product is used for the preparation of mango powder which is added as a relish in various food preparations. Ripe mangoes are taken and the juicy pulp squeezed by hand. The pulp is spread on Bamboo mats and a small quantity of sugar sprinkled over it. Whet the first layer has dried, another layer of pulp is spread over it for drying. This process is repeated until the dried slab is 1.2 to 2.5 cm thick. The dried product has a light yellow amber colour and possess a delicious taste.

Other fruits

Pomegranate seeds are dried, and the dried product known as anardana is sued as a savoury and acidulant like tamarind in cooking. Apple rings are threaded and dried by hanging them out to dry in the sun.

The cereals, pulses and oilseeds are usually sundried in most of the areas after harvesting from the crop. Sundried vegetables results poor quality in physical and chemical characteristics during storage.

Types of drier

	Drier type	**Usual food type**
I.	**Air convection driers**	
1.	Kiln drier	Pieces
2.	Cabinet, tray or pan drier	Pieces, purees, liquids
3.	Tunnel drier	Pieces
4.	Continuous conveyor belt drier	Purees, liquids
5.	Belt trough drier	Pieces
6.	Air lift drier	Pieces, granules
7.	Fluidized bed drier	Small pieces, granules
8.	Spray drier	Liquids, purees
II.	**Drum (or) Roller drier**	
1.	Atmospheric driers	Purees, liquids
2.	Vacuum driers	Purees, liquids
III.	**Vacuum driers**	
1.	Vacuum shelf	Pieces, purees, liquids

2.	Vacuum belt	Purees, liquids
3.	Freeze driers	Pieces, liquids

Methods of drying

I. Air convection driers

All air convection driers have some sort of insulated enclosures, a means of circulating air through the enclosure and a means of heating this air. They also will have various means of product support, special devices for dried product collection, some will have air driers to lower drying air humidity.

Movement of air generally will be controlled by fans, blowers and baffles. Air volume and velocity will affect drying rate, but its static pressure also is important since products being dried become very light and can be blown off trays or belts.

The air may be heated by direct or indirect methods. In direct heating the air is in direct contact with flame (or) combustion gases. In indirect heating the air is in contact with a hot surface, such as being blown across pipes heated by steam, flame or electricity. The important point is that indirect heating leaves the air uncontaminated. On the other hand in direct heating the fuel is seldom completely oxidized to CO_2 and water. Incomplete combustion leaves gases and traces of soot and this is picked up by the air and can be transferred to the food product. Direct heating of air also contributes small amounts of moisture to the air since moisture is a product of combustion but this is usually insignificant except with very hygroscopic foods. These disadvantages are balanced by the generally lower cost of direct heating of air compared to indirect heating, and both methods are widely used in food dehydration.

1. Kiln drier

Kiln driers of early design were generally two storey constructions. A furnace or burner on the lower floor generated heat, and warm air would rise through a slotted floor to the upper story. Foods such as apple slices would be spread out on the slotted floor and turned over periodically. This kind of drier generally will not reduce moisture to below about ten per cent. It is still in use for apple slices.

2. Cabinet, Tray and Pan driers

Food may be loaded on trays or pans in comparatively thin layers upto a few centimeters. Fresh air enters the cabinet is drawn by the fan through the heated coil and is then blown across the food trays to exhaust. In this case the air is being heated by the indirect method. Screens filter out any dust that may be in the air. The air passes across and between the trays in this design. The air is exhausted to the atmosphere after one pass rather than being recirculated within the system. The moisture laden air, after evaporating water from the food, would have to be dried before being recirculated, or else it would soon become saturated and further drying of the food would stop.

Cabinet, tray and pan driers are usually for small scale operations. They are comparatively inexpensive and easy to set in terms of drying conditions. They may run upto 25 trays high, and will operate with air temperatures of about 93^{o}C dry bulb and air velocities of about 2.5 to 5.0 M/5 across the trays. The commonly are used to dry fruit and vegetable pieces, and depending upon the food and the desired final moisture, drying time may be of the order or 10 of even 20 hr.

3. Tunnel and continuous belt drier

For larger operations we elongate the cabinet, place the trays on carts. If drying time to the desired moisture is 10 hr then each wheeled cart of trays will take 10 hr to pass through the tunnel. When a dry cart emerges it makes room to load another wet crat into the opposite end of the tunnel. Such an operation becomes semi continuous.

A main construction feature by which tunnel driers differ has to do with the direction of air flow relative to tray movement. The wet food carts move from left to right. The drying air moves across the trays from right to left. This is the counter flow or countercurrent principle. Its significance is that the air, when it is hottest and driest, contacts the nearly dry product, whereas the initial drying of entering carts gets cooler, moisture air that has cooled and picked upto moisture going through the tunnel. This means that the initial product temperature and moisture gradients will not be as great and the product is less likely to undergo case hardening or other surface shrinkage leaving wet centers. Further, lower final moistures can be reached since the driest product encounters the dried air. In contrast, there also are concurrent flow tunnels with the incoming hottest, driest and travelling in the same direction. In this case rapid initial drying air slow final drying can cause case hardening and internal splits and porosity as centers finally dry, which sometimes is desirable in special products.

Just as carts of trays can be moved through a heated tunnel, so a continuous belt may be driven through a tunnel or oven enclosure. Then we have a continuous belt or conveyor drier and a great number of designs are possible.

4. Belt trough drier

A special kind of air convection belt drier is the belt trough drier in which the belt forms a trough. The belt is usually of metal mesh and heated air is blown up through the mesh. The belt moves continuously, keeping the food pieces in the trough in constant motion to continuously expose new surface. This speeds drying and with air of about 135^{o}C, vegetable pieces may be dried to 7-5% moisture in about 1 hr.

But not all products may be dried this way since certain sizes and shapes do not readily tumble. Fragile apple wedges may break. Onion slices tend to separate and become entangled. Fruit pieces that exude sugar on drying tend to stick together clump with the tumbling motion. These are but a few additional factors that must be considered in selecting a drier for a particular food.

5. Air lift drier

Several types of pneumatic conveyor driers go a step beyond tumbling to expose more surface area of food particles. These generally are used to finish dry materials that have been partially dried by other methods, usually to about 25% moisture, or at least sufficiently low so that the material becomes granular rather than having a tendency to clump and mat.

6. Fluidized bed drier

Another type of pneumatic conveyor drier is the fluidized bed drier. In fluidized bed drying, heated air is blown up through the food particles with just enough force to suspend the particles in a gentle boiling motion. Semidry particles such as potato granules enter at the left and gradually migrate to the right, where they are discharged dry. Heated air is introduced through a porous plate that supports the bed of granules. The moist air is exhausted at the top. The process is continuous and the length of time particles remain in the drier can be regulated by the depth of the bed and other means. This type of drying can be used to dehydrate grains, peas and other particulates.

7. Spray driers

The most important kind of air convection drier is the spray drier. Spray driers turn out a greater tonnage of dehydrated food products than all other kinds of driers combined, and there are various types of spray driers designed for specific food products.

Spray driers are limited to foods that can be atomized, such as liquids and low viscosity pastes or purees. Atomization into minute droplets results in drying in a matter of seconds with common inset air temperatures of about 200^{o}C. Since evaporative cooling seldom permits particles to reach above about 80^{o}C (180^{o}C) and properly designed systems quickly remove the dried particles from heated zones, this method of dehydration can produce exceptimally high quality with many highly heat sensitive materials, including milk, eggs and coffee.

In typical spray drying we introduce the liquid food as a fine spray or mist into a tower or chamber along with heated air. As the small droplets make intimate contact with the heated air they flash off their moisture, become small particles and drop to the bottom of the tower from where they are removed. The heated air which has now become most is withdrawn from the tower by a blown or fan. The process is continuous in that liquid food continues to the pumped into the chamber and atomized, along with dry heated air to replace the moist air that is withdrawn, and the dried product is removed from the chamber as it descends.

Milk and coffee powder is usually dried in the spray drier. Thermoplastic materials / substances viz., fruit juices are spray dried in a specially developed BIRS spray drier.

II. Drum (or) Roller driers

In drum (or) roller drying, liquid foods, purees pastes and mashes are applied in a thin layer onto the surface of a revolving heated drum. The drum generally is heated from within by steam. Drier may have a single drum or a pair of drums. The food may be applied between the nip where two drums come together, and then the clearance between the drums determines the thickness of the applied food layer, or the food can be applied to other areas of the drum. Food is applied continuously and the thin layer loses moisture. At a point on the drum or drums a scraper blade is positioned to peel the thin dried layer of food from the drums. The speed of the drum is so regulated that the layer of food will be dry when it reaches the scraper blade, which also is referred to as a doctor blade. The layer of food is dried in one revolution of the drum and is scrapped from the drum before that position of the drum returns to the point where more wet food is applied. Using steam under pressure in the drum, the temperature of the drum surface may be well above 100^{o}C, and is often held at about 150^{o}C. With a food layer thickness commonly less than 2 mm, drying can be completed in 1 min or less, depending on the food material. Other features of drum driers include hoods above drums to withdraw moisture vapor and conveyers in troughs to receive and move dried product.

Typical products dried on drums include milk, potato mash, heat tolerant purees such as tomato paste, and animal feeds. But drum drying has some inherent limitations that restrict the kinds of foods to which it is applicable. To achieve rapid drying, drum surface temperature must be high, usually above 120^{o}C. This gives products a more cooked flavour and colour than when they are dried at a lower temperature. Drying temperature can, of course, be lowered by constructing the drums within a vacuum chamber but this increases equipment and operating costs over atmospheric drum or spray drying.

A second limitation is the difficulty of providing zoned temperature control needed to vary to drying temperature profile. This is particularly important with thermoplastic food materials. Whereas dried milk and dried potato are easily scraped from the hot drum in brittle sheet form, this is not possible with many dried fruits, juices and other products which tend to be sticky and semimolten when hot. Such products tend to crimp, roll up, and otherwise accumulate and stick to the doctor blade in a taffy like mass.

This condition can be substantially improved by a cold zone to make the tacky material brittle just prior to the doctor blade. But zone controlled chilling is not as easy to accomplish on a drum of limited diameter and therefore limited arc, as it would be in perhaps 6 m of length of a horizontal drying belt 45 m long. One means of chilling is by directing a stream of cool air onto a segment of the product on the drum prior to the doctor blade.

For relatively heat resistant food products, drum drying is one of the least expensive dehydration methods. Drum dried foods generally have a somewhat more cooked character than the same materials spray dried; thus drum dried milk is not up to beverage quality but is satisfactory as an ingredient in less deligately flavoured manufactured foods. More gentle vacuum drum drying or zone-controlled drum drying increases dehydration costs.

III. Vacuum driers

Vacuum dehydration methods are capable of producing the highest quality dried products, but costs of vacuum drying generally also are higher than other methods which do not employ vacuum. In vacuum drying, the temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and the intensity of heat input. Heat transfer to the food is largely by conduction and radiation.

All vacuum drying systems have four essential elements. These include a vacuum chamber of heavy construction to withstand outside air pressures, that may exceed internal pressures by as much as 9800 kg/cm^2; means to supply heat; a device for producing and maintaining the vacuum; and components to collect water vapour as it is evaporated from the food.

The vacuum chamber generally will contain shelves or other supports to hold the food and these shelves may be heated electrically or by circulating a heated fluid through them. The heated shelves are called platens. The platens convey heat to the food in contact with them by conduction, but where several platens are one above another they also radiate heat to the food on the platen below. In addition, special radiant heat sources such as infrared elements can be focussed onto the food to supplement the heat conducted from platen contact.

The device for producing and maintaining vacuum will be outside the vacuum chamber and may be a mechanical vacuum pump or a steam ejector. A steam ejector is a kind of aspiration in which high velocity steam jetting past an opening draws air and water vapour from the vacuum chamber by the same principle that makes an insect spray gun draw fluid from the can.

The means of collecting water vapour may be a cold wall condenser. It may be inside to vacuum chamber or outside the chamber but most come ahead of the vacuum pump so as to prevent water vapour from entering and fouling the pump. When a steam ejector can condense water vapour as it is drawn along the air from the vacuum chamber and so a cold wall vapour condeser may not be needed except where a very high degree of efficiency is required.

Degree of vacuum

Atmospheric pressure at sea level is approximately 15 psi, or sufficient pressure to support a 30 inch column of mercury. This is equivalent to 760 mm of Hg or 1 in Hg is approximately 25 mm. At 1 atm or 30 in., or 760 mm of Hg, pure water boils at 100^{o}C. At 10 in or 250 mm of Hg pure water boils at 72^{o}C. At 2 in. or 50 mm of mercury pure water boils at 38^{o}C. High vacuum dehydration operates at still lower pressures such as fractions of mm of Hg. Freeze drying generally will operate in the range of 23 mm down to about 0.1 mm of Hg.

There are two kinds of vacuum drier.

1. Vacuum shelf driers

Batch type

If liquids such as concentrated fruit juices are dried above about 55 mm Hg, the juice boils and splatters, but in the range of about 3 mm Hg, and below, the concentrated juice puffs as it loses water vapour. The dehydrated juice then retains the puffed spongy structure. Since temperature well below 40^{o}C can be used, in addition to quick solubility there is minimum flavour change or other kinds of heat damage. A vacuum shelf drier is also suitable for the dehydration of food pieces. In this case, the rigidity of the solid food prevents major puffing, although there also is a tendency to minimize shrinkage.

2. Continuous vacuum belt drier

Continuous type drier

This drier is used commercially to dehyderate high quality citrus juice crystals, instant tea and other delicate liquid foods.

The drier consists of a horizontal tank like chamber connected to a vacuum producing, moisture condensing system. The chamber is about 17 m long and 3.7 m in diameter. Within the chamber are mounted two revolving hollow drums. Around the drum is connected a stainless steel belt which moves in a counter clock wise direction. This drum on the right is heated with steam confined within it. This drum heats the belt passing over it by conduction. As the belt moves, it is further heated by infrared radiant elements. The drum to the left is cooled with cold H_2O circulated within it and cools the belt passing over it. The liquid food in the form of a concentrate is pumped into a feed pan under the lower belt strand. An applicator roller dipping into the liquid continuously applies a thin coating of the food onto the lower surface of a moving belt. As the belt moves over the heating drum and past the radiant heaters, the food rapidly dries in the vacuum equivalent to about 2 mm Hg. When the food reaches the cooling drum, it is down to about 2% moisture. At the bottom of the cooling drum is a doctor blade which scrapes the cooled, embrittled product into the collection vessel. The belt scrapped free of product receives additional liquid food as it passes the applicator roller and the process repeats in continuous fashion.

Products dried with this equipment have a slightly puffed structure. If designed, a greater degree of puffing can be achieved. This has been done in the case of milk by pumping nitrogen gas under pressure into the milk prior to drying. Some of the gas goes into solution in the milk. Upon entering the vacuum chamber this gas comes out of solution violently and further puffs the milk as it is being dried.

3. Freeze drying

Freeze drying can be used to dehydrate sensitive high value liquid foods such as coffee and juices, but it is especially suited to dry solid foods of high value such as straw berries, whole shrimp, chicken dice, mushroom slices and sometimes food pieces as large as steaks and chops. These types of foods, in addition to having delicate flavours and colors, have textural and appearance attributes which cannot be well preserved by any current drying method except freeze drying. Any conventional drying method that employs heat would cause considerable shrinkage distortion and loss of natural strawberry structure (texture), upon reconstitution such as dried strawberry would not have the natural colour, flavour or turgor and would be more like a strawberry preserve or jam. This can be largely prevented by drying from the solidly frozen state, so that in addition to low temperature, the frozen food has no chance to shrink or distort while giving up its moisture.

The principle behind freeze drying is that under certain conditions of low vapor pressure, water can evaporate from ice without the ice melting. When a material can exist as a solid, a liquid and a gas but goes directly from a solid to a gas without passing through the liquid phase. The material is said to sublime. Dry ice sublimes at atmospheric pressure and room temperature. Frozen water will sublime if the temperature is $0^{o}C$ or below and the frozen H_2O is placed in a vacuum chamber at a pressure of 4.7 mm (or) less. Under such conditions the H_2O will remain frozen and water molecules will leave the ice block at a faster rate than water molecules from the surrounding atmosphere reenter the frozen block.

Within the vacuum chamber heat is applied to the frozen food to speed sublimation and if the vacuum is maintained sufficiently high usually within a range of about 0.1 to 2 mm g and the heat is controlled just short of melting the ice, moisture vapour will sublime at a near maximum rate. Sublimation takes place from the surface of the ice, and so as it continues the ice front recedes towards the center of the food piece; i,e. the food dries from the surface inward. Finally, the last of the ice sublimed and the food is below 5% moisture. Since the frozen food remains rigid during sublimation, escaping H_2O molecules leave voids behind them, resulting in porous sponge like dried structure. Thus freeze dried foods reconstitute rapidly but also must be protected from ready absorption of atmospheric moisture and O_2 by proper packaging.

A heating plate is positioned above and below the food to increase heat transfer rate but an open space is left with expanded metal so as not to seal off escape of sublimed H_2O molecules. Nevertheless, as drying progresses and the ice front recedes, drying rate drops off for several reasons. Thus the porous dried layer ahead of the reducing ice layer acts as an effective insulator against further heat transfer and the porous layer slows down the rate of escape of H_2O molecules subliming from the ice surface.

4. Foam mat drying

The foam is deposited on a perforated tray or belt support as a uniform layer approximately 3 mm thick. Just before the perforated support enters the heated oven it is given a mild air blast from below. This forms small craters in the stiff foam which further expands foam surface and increases drying rate. At oven temperatures of about 82^oC foam layers of many foods can be dried to about 2 to 3% moisture in approximately 12 min.

Preservation by Irradiation

Sterilization of food by ionizing radiations is a recently developed method of preservation which has not yet gained general acceptance. The unacceptable flavour of some irradiated foods and the fear that radioactivity might be induced in such food has come in the way of its greater use.

When gamma rays (or) electron beams pass through foods there are collisions between the ionizing radiation and food particles at atomic and molecular levels, resulting in the production of ion pairs and free radicals. The reactions of these products among themselves and with other molecules results in physical and chemical phenomena which inactivate microorganism in the food. Thus irradiation of food can be considered to be a method of ‘Cold sterilization’ i.e. food is free of microorganism without high temperature treatment. Radiation dose of upto 1 Mrad is not hazardous.

Ionizing radiations can be used for sterilization of foods in hermetically sealed packs, reduction of the spoilage organisms in the perishable foods, delays ripening of fruits, inhibits sprouting of root vegetables and controls infestation (insects) in stored cereals.

PREPARATION OF JAMS, JELLIES, MARMALADES, CANDIES, CRYSTALLIZED AND GLAZED FRUITS, PRESERVES, CHUTNEYS, PICKLES, KETCHUP, SAUCE, PUREE, SYRUPS, JUICES, SQUASHES AND CORDIALS

PREPARATION OF JAMS

Jam is a product made by boiling fruit pulp with sufficient quantity of sugar to a reasonably thick consistency, firm enough to hold the fruit tissues in position. Apply, sapota, papaya, plums, mango, grapes, jack, pineapple, banana, guava and pears are used for preparation of jam. It can be prepared from one kind of fruit or from two or more kinds.In its preparation about 45% of fruit pulp should be used for every 55% of sugar.The FPO specification of jam is 68.5% TSS, 45% of fruit pulp and 0.5-0.6% of acid (citric acid) per 100 gm of the prepared product.

a) Selection and preparation of fruit

Select good quality ripe fruits. Wash the fruits well in cold water. Peel the fruits and remove the stones and corers present. Cut the peeled fruit into small pieces with a stainless steel knife. If the fruit is hard, it should be cut into very small pieces. Pulp the fruits by using pulper.

b) Addition of sugar and acid

c) Cooking

Cook the mixture slowly with occasional stirring.The fruit pulp should be crushed with a laddle during cooking. Continue cooking till the temperature of the mass reaches 105.5°C.

Sheet (or) Flake Test

A small portion of jam is taken out during boiling in a spoon or wooden laddle and cooled slightly. It is then allowed to drop. If the product falls off in the form of a sheet (or) flakes instead of flowing in a continuous stream (or) syrup, it means that the end point has been reached and the product is ready. Otherwise boiling is continued till the sheet test is positive.

d) Packaging

Fill the hot jam into clean dry sterilized jars. Allow the jam to cool and fix the sterilized lid to the jar. Store in a cool place.

Process

Ripe firm fruits → Washing → Peeling →Pulping (Remove seed and core) → Addition of sugar and acid → Boiling (with continuous stirring) → Judging of end point by further cooking upto 105°C (or) 68% TSS (or) by sheet test → Filling hot into sterilized bottles → cooling → Sterilized bootles → cooling → Waxing → Capping → Storage (at ambient temperature).

PREPARATION OF JELLY

A jelly is a semi solid product prepared by boiling a clear, strained solution of pectin containing fruit extract, free from pulp, after the addition of sugar and acid. A perfect jelly should be transparent, well set but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape when removed from the mould. It should be firm enough to retain a sharp edge but tender enough when it is pressed. It should not be gummy, sticky or syrupy or have crystallized sugar.The product should be free from dullness with little (or) no syneresis (weeping) and neither tough nor rubbery. The FPO specification for jelly is the final product should have 65% solids, 45% fruit extract and 0.5-0.75% acid.

Guava, sour apple, plum, karonda, wood apple, papaya and jack fruit are rich in pectin and generally used for preparation of jelly. Pineapple, strawberry grapes etc. can be used but only after addition of pectin powder, because these fruits have low pectin content. Preparation of jelly is similar to that of jam.

Process

Fruit (Firm, not over ripe) → Washing → Cutting into thin slices → Boiling with water (1 ½ times the weight of fruits for about 20-30 min) → Addition of citric acid during boiling (2 g per kg of fruit) → Straining of extract → Pectin test (for addition of sugar) → Addition of sugar → Boiling → Judging of end point (sheet / drop / temp test) → Removal of scum (or) foam (one teaspoonful of edible oil added for 45 kg sugar) → Addition of colour and remaining citric acid → Filling hot into clean sterilized bottles → Waxing (paraffin wax) → Capping → Storage at ambient temperature.

Important considerations in jelly making

Pectin, acid, sugar (65%) and water are the four essential ingredients. Pectin test and determination of end point of jelly formation are very important for the quality of jelly.

PREPARATION OF MARMALADE

This is a fruit jelly in which slices of the fruit (or) its peel are suspended. The term is generally used for products made from citrus fruits like oranges and lemons in which shredded peel is used as the suspended material. Citrus marmalades are classified into (1) jelly marmalade (2) jam marmalade. The FPO specifications for marmalade are TSS- 65% and fruit juice - 45% of the prepared product.

Ingredients

Pectin extract	-	1 litre
Sugar	-	750 gm
Shredded peel	-	62 gm

Jelly marmalade

It prepared from the clarified pectin extract.

Process

Ripe fruits → Washing → Peeling outer yellow portion (Flavedo) thinly → Cutting yellow portion into fine shreds (1.9 - 2.5 cm long and 0.8 – 0.12 cm thick) □ Cutting of 0.3 -0.45 cm thick slices of peeled fruit (or) crushing into pulp in a greater → Boiling (in 2-3 times its weight of H_2O for 40-60 min.) Straining the extract □ Testing for pectin conten t) → Addition of sugar (as required) □ Cooking to 103-105°C (Continuous stirring) □ Addition of shreds (shredded peel boiled for 10 to 15 min. in several changes of water for softening and removing bitterness and added @ about 62 g per kg of extract) □ Boiling till (continuous stirring) □ Testing for end p -88°C with continuous stirring) □ Flavouring Storage at ambient temperature.

Jam Marmalade

The method of preparation is practically the same as that for jelly marmalade. In this case the pectin extract of fruit is not clarified and the whole pulp is used. Sugar is added according to the weight of fruit, generally in the proportion of 11. The pulp – sugar mixture is cooked till the TSS content reaches 65%.

PREPARATION OF CANDIED FRUITS / VEGETABLES

A fruit /vegetable impregnated with cane sugar (or) glucose syrup and subsequently drained free of syrup and dried is known as candied fruit / vegetable. The most suitable fruits for candying are amla, kranda, pineapple, cherry, papaya, apple, peels of orange, lemon, grape fruit and ginger etc. The FPO specifications for candied fruits are TSS -75%, total sugar-70% and reducing sugar-25%.

The process for making candied fruit is practically similar to that for preserves.The only difference is that the fruit impregnated with syrup having a higher percentage of sugar – 75°bx.The syrup left over from the candying process can be used for candying another batch of the same kind of fruit after suitable dilution, for sweetening chutneys, sauces and pickles and vinegar making.

PREPARATION OF CRYSTALLIZED FRUITS /VEGETABLES

Candied fruits /vegetables coated with crystals of sugar, either by rolling in finely powdered sugar or by allowing sugar crystals from dense syrup to deposit on them are called crystallized fruit / vegetable.

The candied fruits are placed on a wire mesh tray which is placed in a deep vessel. Cooled syrup (70% TSS) is gently poured over the fruit so as to cover it entirely. The whole mass is left undisturbed for 12-18 hrs during which a thin coating of crystallized sugar is formed. The tray is then taken out carefully from the vessel and the surplus syrup dried off. The fruits are then placed in a single layer on wire mesh trays and drained at room temperature or at about 49°C in driers.

PREPARATION OF GLAZED FRUITS /VEGETABLES

Covering of candied fruits / vegetables with a thin transparent coating of sugar, which imparts them a glossy appearance is known as glazing.

Cane sugar and water (21 by weight) are boiled in a steam pan at 113-114°C and the scum is removed as it comes up. Thereafter the syrup is cooled to 93°C and rubbed with a wooden laddle on the side of the pan when granulated sugar is obtained. Dried candied fruits are passed through this granulated portion of the sugar solution, one by one, by means of fork and then placed on trays in a warm dry room. They may also be dried in a drier at 49°C fir 2-3 hrs when they become crisp, they are packed in airtight containers for storage.

Preparation of Preserves

A mature fruit / vegetable (or) its pieces impregnated with heavy sugar syrup till it becomes tender and transparent is known as preserve. Aonla, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, carrot etc. can be used for making preserves. FPO specifications for preserve is TSS 68°bx and fruit pulp - 55%.

General considerations

Cooking of fruit directly in syrup causes shrinking of fruit and reduces absorption of sugar. Therefore, the fruit should be blanched first to make it soft enough to absorb water, before steeping in syrup. However, highly juicy fruits may be cooked directly.

Fruits may be cooked in syrup by three processes as given below

i. Rapid process

Fruits are cooked in low sugar syrup. Boiling is continued with gentle heating until the syrup becomes sufficiently thick. Soft fruits such as strawberries, grapes which require very little boiling for softening. Unlike hard fruits like apples, pears and peaches, which require prolonged heating. Rapid boiling should, however be avoided as it makes the fruit tough, especially when heating is done in a large shallow pan with only a small quantity of syrup. The final concentration of sugar should not be less than 68% which corresponds to a boiling point of 106°C. This is a simple and cheap process but the flavour and colour of the product are lost considerably during boiling.

ii. Slow process

The fruit is blanched until it becomes soft. Sugar, equal to the weight of fruit, is then added to the fruit in alternate layers and the mixture allowed to stand for 24 hrs. During this period, the fruit gives out water and the sugar goes into solution, resulting in a syrup containing 37-38% TSS. Next day, the syrup is boiled after removal of fruits to raise its strength to about 60% TSS. A small quantity of citric acid (1 to 1.5 g/kg sugar) is also added to invert a portion of the cane sugar and thus prevent crystallization. The whole mass is then boiled for 4-5 min. and kept for 24 hrs. On the third day, the strength of syrup is raised to about 65% TSS by boiling. The fruit is then left in the syrup for a day. Finally, the strength of the syrup is raised to 70% TSS and the fruits are left in it for a week. The preserve is now ready and is packed in containers. This method is usually practiced.

3. Vacuum process

The fruit is first softened by boiling and then placed in the syrup which should have 30-35% TSS. The fruit-syrup blend is then transferred to a vacuum pan and concentrate under reduced pressure to 70% TSS. Preserves made by this process retain the flavour and colour of the fruit better than by the other two methods.

In all these processes, the fruit is kept covered with syrup during cooking as well as afterwards otherwise it will dry up and the quality of the product would be affected.

The product should be cooled quickly after the final boiling to prevent discolouration during storage.

The fruits are drained free of syrup and filled in dry containers or glass jars. Freshly prepared boiling syrup containing 68% TSS is then poured into the jars / containers which are then sealed airtight. In the commercial scale production, however, it is better to strerilize the cans to eliminate any possibility of spoilage of product during storage.

Process

Mature fruits → Washing → Preparation of fruit for sugar treatment → Keeping fruit and sugar in alternate layers (1.0 kg Fruit: 1 kg Sugar) (or) steeping fruit in syrup of 40% TSS for a day → Removal of fruit → Increasing consistency of syrup to 60% TSS by boiling □ Steeping of fruit for a day →Repeating the process and raising strength of syrup by 5% TSS to 70% on alternate days – Steeping in 70% TSS for a week → Preserve – Draining – Filling in jar (or) container → Covering fruit with freshly prepared sugar syrup of 68% TSS □ Sealing (airtight) – Storage.

PREPARATION OF CHUTNEYS

A good quality chutney should be palatable and appetizing. Mango chutney is an important food product exported from India to many countries. Apple and apricot chutneys are also very popular in the country.

The method of preparation of chutney is similar to that for jam except that spices, vinegar and salt are added. The fruits / vegetables are peeled, sliced or grated or cut into small pieces and cooked in water until they become sufficiently soft. The quality of chutney depends to a large extent on its cooking which should be done for a long time at a temperature below the boiling point. To ensure proper thickening, cooking is done without a lid even though this results in some loss of volatile oils from the spices. Chopped onion and garlic are added at the start to mellow their strong flavours. Spices are coarsely powdered before adding. Vinegar extract of spices may be used instead of whole spices. Spices and vinegar are added just before the final stage of cooking, because prolonged boiling causes loss of some of the essential oils of spices and of vinegar by volatilization. In mango and apricot sweet chutneys, where vinegar is used in large quantity, the amount of sugar added may be reduced, because vinegar itself acts as a preservative. These chutneys are cooked to the consistency of jam to avoid fermentation.

Sweet mango chutney

Recipe

Mango slices (or) shreds – 1.0 kg, sugar (or) gur – 1.0 kg, salt – 45 g, onions (chopped) – 50 g, garlic (chopped)-15 g , ginger (chopped) – 15 g, red chilli powder – 10 g, black pepper, cardamom, cinnamon, cumin – 10 g each, cloves – 5 nos. and vinegar – 170 ml.

Process

Mature mangoes → washing → Peeling →Grating (or) slicing → cooking with a little water to make highly soft → Mixing with sugar and salt and leaving for an hour → Keeping all ingredients (except vinegar) in cloth bag, tied loosely, putting in mixture and cooking on low flame →During cooking, spice bag pressed occasionally □ Cooking to consistency of jam (upto 105^{o}C) with stirring occasionally → Removal of spice bag after squeezing → Addition of vinegar → Cooking for 2-5 min. → Filling hot into bottles → Sealing (airtight) → Storage at ambient temperature.

PREPARATION OF PICKLES

The preservation of food in common salt (or) in vinegar is known as pickling. It is one of the most ancient methods of preserving fruits and vegetables. Pickles are good appetizers and add to the palatability of a meal. They stimulate the flow of gastric juice and thus helps in digestion.

Preservation by salt ($NaCl_2$)

Sodium chloride is an indispensable component of food. At lower concentrations it contributes significantly to the flavour. At higher concentrations it exhibits an important bacteriostatic action. Salt is easily available and not expensive.

Pickling process

Pickling is done in two stages (1) By curing (or) fermentation with dry salting (or) fermentation in brine (or) salting without fermentation (2) By finishing and packing.

Pickling is the result of fermentation by lactic acid forming bacterial which are generally present in large numbers on the surface of fresh vegetables and fruits. Theses bacteria can grow in acid medium and in the presence of 8-10% salt solution whereas the growth of a majority of undesirable organisms is inhibited. Lactic acid bacteria are most active at 30^{o}C, so this temperature must be maintained as far as possible in the early stage of pickle making. When vegetables are placed in brine, it penetrates into the tissues of the farmers and soluble material present in them diffuses into the brine by osmosis. The soluble material includes fermentable sugars and minerals. The sugars serve as food for lactic acid bacteria which convert them into lactic acid and other acids. The acid brine thus formed acts upon vegetables tissues to produce the characteristics taste and aroma of pickle. There are two methods for pickling

1. Dry salting method

Alternate layers of vegetables and salt (20-30 gm of dry salt/kg vegetables) are kept in a vessel which is covered with a cloth and a wooden board and allowed to stand for about 24 hrs. During this period, due to osmosis, sufficient juice comes out from the vegetables to form brine.

The amount of brine required is usually equal to half the volume of vegetables. Brining is the most important step in pickling. The growth of a majority of spoilage organisms is inhibited by brine containing 15% salt. Lactic acid bacteria, which are salt tolerant can thrive in brine of 8-10% strength though fermentation takes place fairly well even in 5% brine. In a brine containing 10% salt, fermentation proceeds somewhat slowly. Fermentation takes place to some extent upto 15% but stops at 20% strength. It is therefore, advisable to place the vegetables in 10% salt solution for vigorous lactic acid fermentation.

As soon as the brine is formed, the fermentation process starts and Co_2 begins to evolve. The salt content is now increased gradually, so that by the time the pickle is ready, salt concentration reaches 15%. When fermentation is over, gas formation ceases.

Under favourable conditions fermentation is completed in7-10 days. When sufficient lactic acid has been formed, lactic acid bacteria cease to grow and no further change takes place in the vegetables. However, precautions should be taken against spoilage by aerobic microorganisms, because in the presence of air, pickle sum is formed which brings about putrefaction and destroys the lactic acid. Properly brined vegetables keep well in vinegar for a long time.

II. Fermentation in brine

Steeping of the vegetable in a salt solution of pre-determined concentration for a certain length of time is called brining. This type of treatment is adopted in the case of cucumbers and similar vegetables which do not contain sufficient juice to form brine with dry salt. Brine can be prepared by dissolving in common salt in water and filtering it through the cloth to remove insoluble impurities. The remaining process is similar to that of dry salting method.

Raw materials used in pickling

1. Salt: Free from impurities, and salts such as lime (CaO), iron (blackening), magnesium (results bitter taste) and carbonates (makes the pickle soft in texture).

2. Vinegar: Vinegar of good quality should contain atleast 4% acetic acid. Synthetic vinegar (or) low quality vinegar are not suitable for pickle preparations. Usually malt (or) cider vinegar is used. In order to ensure good keeping quality pickle, the final concentration of acetic acid in the pickle should not be less than 2%. Acetic acid (commercial) is also used because it is highly concentrated.

3. Sugar: Used in the preparation of sweet pickles should be of high quality.

4. Spices: Spices are added practically to all pickles, the quantity added depending upon the kind of fruit (or) vegetable taken and the kind of flavour desired. The spices generally used are bay leaves, cardamom, chillies, cinnamon, clove, coriander, dill herb, ginger, mace, mustard,black pepper, cumin, turmeric, garlic, mint, fenugreek, asafoetida etc.

5. Water: Only potable water should be used for the preparation of brine. Hard water contains salts of Ca, Na, Mg etc., which interfere with the normal salt curing of the vegetable. If hard water is to be used, a small quantity of vinegar should also be added to the brine the neutralize its alkalinity. Iron should not be present in the water in any appreciable quantity as it causes the blackening of the pickle.

6. Cooking utensils: Metallic vessels should be non-corrodiable. Vessels made of iron (or) copper are not suitable. Glass -lined vessels, and stainless steel vessels are preferred. The laddles, spoons and measuring vessels should also be masde on non-corrodible materials. At present, pickles are prepared with salt, vinegar, oil (or) with a mixture of salt, oil, spices and vinegar. These methods are discussed below

I. Preservation with salt

Salt improves the taste and flavour and hardens the tissues of vegetables and controls fermentation. Vegetables do not ferment when they are packed with a large quantity of salt. Spoilage is prevented by adding sufficient common salt, bringing its final concentration in the material from 15-20%. At this high salt concentration, mould and even lactic acid forming bacteria do not grow. This method of preservation is applicable only to vegetables which contain very little sugar because sufficient lactic acid cannot be formed by fermentation to act as preservative. Some fruits like lime, mango, etc. are also preserved with salt.

Example

1. Lime pickle: Lime – 1 kg, salt – 200 g red chilli powder –15 g, cinnamon, cumin, cardamom and black pepper (powdered) each –10 g cloves – 5 Nos.

Process

Limes → Washing →Cutting into 4 pieces → Squeezing out juice from ¼ amount of fruit → Mixing spices and salt with juice → Mixing with lime pieces → Filling in jars → Covering with lid → Keeping in sun for 4-6 days (shaking jar atleast twice a day) → Storage at ambient temperature.

II. Preservation with vinegar

In vinegar pickles, vinegar acts as a preservation. The final concentration of acid as acetic acid in the finished pickle should not be less than 2%. To avoid dilution of vinegar below this strength by the H_2O liberated from the tissues, the vegetables (or) fruits are generally placed in strong vinegar of about 10% acidity for several days before final packing. This treatment helps to expel the gases present in the intercellular spaces of vegetable tissues. Papaya, pears, onion, garlic, chillies, mango and cucumber pickles are prepared in this method.

Example

Cucumber pickle

Cucumber – 1.0 kg, salt – 200 g red chilli powder – 15 g, cardamom (large), cumin, black pepper (powdered) each – 10 g, cloves – 6 Nos., vinegar – 750 ml.

Process

Cucumbers → Washing → Peeling → Cutting into 5 cm round pieces → Mixing with salt → Filling in jar → Standing for 6-8 hrs → Draining off H_2O → Adding spices and vinegar → Keeping in sun for a week → Storage.

III. Preservation with oil

The fruit (or) vegetable should be completely immersed in the edible oil. Cauliflower, lime, mango, amla, karonda, bittergourd, brinjal, turnip pickles are prepared from this method.

Example

Green chilli pickle: Green chillies – 1 kg, salt – 150 gm, mustard (ground) – 100 gm lime juice – 200 ml (or) amchur – 200 gm, fenugreek cardamom (large), turmeric, cumin (powdered) each – 15 gm, mustard oil – 400 ml.

Process

Green chillies → Washing →Drying → Making incision → Mixing all spices in a little lime juice → Mixing with chillies → Filling into jar → Adding lime juice and oil → Keeping in sun for a week – Storage.

IV. Preparation with mixture of salt, oil, spices and vinegar

Example

Tomato pickle: Tomatoes – 1 kg, salt 75 g, garlic (chopped) – 10 g, ginger (chopped)- 50 g, red chilli powder, cumin, cardamom (large), cinnamom, turmeric, fenugreek – each – 10 g, cloves – 50 nos, asafoetida (powdered) – 2g, vinegar – 250 ml, oil – 300 ml.

Process

Tomatoes (ripe, firm and pulpy) → Washing → Blanching for 5 min → Cooling immediately in water → Peeling → Cutting into 4-6 pieces (or) mashing → Frying all ingredients in a little oil except vinegar → Mixing with pieces → Heating for 2 min → Cooling → Addition of vinegar and remaining oil → Filling in jar → Storage.

PREPARATION OF SAUCES / KETCHUPS

There is no essential difference between sauce and ketchup. However, sauces are generally thinner and contain more total solids than ketchups. Tomato, apple, papaya, walnut, soybean etc. are used for making sauces. The FPO specifications of sauces are TSS – 25% and acidity – 1%.

Sauces are of two kinds (i) thin sauces of low viscosity consistency mainly of vinegar extract of flavouring materials like herbs and spices and (ii) thick sauces that are highly viscous.

Sauces / ketchups are prepared from more or less the same ingredients and in the same manner as chutney, except that the fruit or vegetable pulp or juice used in sieved after cooking to remove the skin, seeds and stalks of fruits. Vegetables and spices and to give a smooth consistency to the final product. However, cooking takes longer because fine pulp (or) juice is used.

Some sauces develop a characteristic flavour and aroma on storing in wooden barrels. Freshly prepared products often have a raw and harsh taste and have, therefore, to be matured by storage. High quality sauces, are prepared by maceration of spices herbs, fruits and vegetables in cold vinegar or by boiling them in vinegar. Thickening agents are also added to the sauce to prevent sedimentation of solid particles. Apple pulp is commonly used for this purpose in India but starch from potato, maize, arrow root (cassava) and sago are also used.

A fruit sauce should be cooked to such a consistency that it can be freely poured without the fruit tissues separating out in the bottle. The colour of the sauce should be bright. Sauces usually thicken slightly on cooling. By using a funnel hot ketchup is filled in bottles leaving a 2 cm head space at the top and the bottles are sealed or corked at once. The necks of the bottles when cold, are dipped in paraffin wax for airtight sealing.

Apple sauce

Recipe : Apple – 1.0 kg, sugar – 250 g, salt – 10 g, onion (chopped) – 200 g, ginger (chopped) – 100 g, garlic (chopped) - 50 g, red chillipowder – 10 g, cloves – 5 Nos. cinnamon, cardamom – 15 g (each), vinegar – 50 ml, sodium benzoate – 0.7 g/kg of finished product.

Process

Apples → Washing → Peeling → Removal of core and seeds → Making into fine pulp → Straining of pulp → Cooking pulp with one third quantity of sugar → Putting spice bag in pulp and processing occasionally → Cooking to one - third of original volume of pulp → Removal of spice bag (after squeezing in pulp) →Adding remaining sugar and salt → Cooking to one – third its original volume → Addition of vinegar and preservative → Filling hot into bottles → Crown corking → Pasteurization at 85-90^{o}C for 30 min. → Cooling → Storage at ambient temperature.

PREPARATION OF PUREE AND PASTE

Tomato pulp without skin or seeds, with or without added salt, and containing not less than 9.0% of salt free tomato solids, is known as medium tomato puree'. It can be concentrated further to heavy tomato puree which contains not less than 12.0% solids. If this is further concentrated so that it contains not less than 25% tomato solids, it is known as tomato paste, on further concentration to 33% or more of solids it is called concentrated tomato paste.

Tomato pulp is prepared from ripe tomatoes in the same manner as tomato juice. Cooking for concentration of the pulp can be done either in an open cooker or a vacuum pan. In the former most of the vitamins are destroyed and the product become brown. On the other hand, use of vacuum pans, which are extensive, help to preserve the nutrients, and also reduce the browning to a great extent. In vacuum pans the juice is boiled at about 71^{o}C only. While cooking in an open cooker, a little butter or edible oil is added to prevent foaming, burning and sticking.

After cooking, the total solids content of the juice is higher than required, more juice is added to lower it, if it is lower, cooking is continued till the desired concentration is reached. The endpoint of cooking puree and paste can be determined either with a hand refractometer or by measuring the volume.

Process

Tomato juice (strained) → Cooking to desired consistency (open cooker / vacuum pan) → Judging of endpoint for puree (or) paste → Filling hot into bottles or cans (82-88^{o}C) → Sterilization in boiling water for 20 min. →Cooling → Storage at ambient temperature.

PREPARATION OF SYRUP

This type of fruit beverage contains 25% fruit juice (or) pulp, 65% TSS, 1.3 to 1.5% acidity and 350 ppm of So_2 or 600 ppm of KMS. It is diluted before serving, Fruits like aonla, jamun, pomegrante, grape, lemon, orange and sometimes ginger can be used for the preparation of syrup. It is also prepared from extracts of rose, sandal almond etc.

Synthetic syrups

Heavy sugar syrup of 70-75 per cent strength is used as the base of all synthetic syrups and they are flavoured and coloured with artificial essence/flavours and colours. They never contain fruit pulp/juice. A large proportion of these syrups can, however, be replaced by real fruit juices, squashes and syrups which are more nutritious.

Large quantities of synthetic syrups (orange, lemon, pineapple, strawberry) are manufactured and sold in varius countries. These can be prepared by using 1.5 kg of sugar, 500 ml of H_2O and 15 g of citric acid. Different colours and flavours are added as required. Among colours, orange red, lemon yellow, green, raspberry red etc. are mostly used, while artificial essence/flavours of rose, orange, pineapple, strawberry, lemon etc. are added as flavouring substances.

PREPARATION OF FRUIT JUICES

i. Selection of fruit:

All fruits are not suitable because of difficulties in extracting the juice or because the juice is of poor quality. The variety and maturity of the fruit and locality of cultivation influence the flavour and keeping quality of its juice. Only fully ripe fruits are selected. Over ripe and green fruits, if used, adversely affect the quality of the juice.

ii. Sorting and washing

Diseased, damaged (or) decayed fruits are rejected or trimmed. Dirt and spray residues of arsenic, lead etc., are removed by washing with water or dilute hydrochloric acid (1 part acid 20 parts water).

iii. Juice extraction

Generally juice is extracted from fresh fruit by crushing and pressing them. Screw type juice extractors, basket presses or fruit pulpers are mostly used.

The method of extraction differs from fruit to fruit because of differences in their structure and composition. Before pressing, most fruits are crushed to facilitate the extraction. Some require heat processing for breaking up the juice – containing tissues. In case of citrus fruits, the fruit is cut into halves, and the juice extracted by light pressure in a juice extractor or by pressing the halves in a small wooden juice extraction. Care should be taken to remove the rind of citrus fruits completely otherwise it makes the juice bitter. Finally, the juice is strained through a thick cloth or a sieve to remove seeds. All equipments used in the preparation of fruit juices and squashes should be rust and acid proof. Copper and iron vessels should be strictly avoided as these metals react with fruit acids and cause blackening of the product. Machines and equipments made of aluminium, stainless steel etc. can be used. Extracted juices should not be unnecessarily exposed to air as it will spoil the colour, taste and aroma and also reduce the vitamin content.

IV. Deaeration

Fruit juices contain some air, most of which is present on the surface of the juice and some is dissolved in it. Most of the air as well as other gases are removed by subjecting the fresh juice to a high vacuum. This process is called deaeration and the equipment used for the purpose is called a deaerator. Being a very expensive method, it is not used in India at present.

V. Straining (or) Filtration

Fruit juices always contain varying amounts of suspended matter consisting of broken fruit tissue, seed, skin, gums, pectic substances and protein in colloidal suspension. Seeds and pieces of pulp and skin which adversely affect the quality of juice, are removed by straining through a thick cloth or sieve. Removal of all suspended matter improves the appearance but often results in disappearance of fruity character and flavour. The present practice is to let fruit juices and beverages retain a cloudy or pulpy appearance to some extent. In case of grape juice, apple juice and lime juice cordial however, a brilliantly clear appearance is preferred.

VI. Clarification

Complete removal of all suspended material from juice, as inlime juice cordial, is known as clarification which is closely related to the quality, appearance and flavour of the juice. The following methods of clarification are used (a) Settling (b) filtration (c) freezing (D) cold storage (e) high temperature (f) chemicals such as gelatin, albumen, casein, mixture of tannin and gelatin (g) enzymes such as pectinol and filtragol.

VII. Addition of sugar

All juices are sweetened by adding sugar, except those of grape and apple. Sugar also acts as preservative for the flavour and colour and prolongs the keeping quality. Sugar based products can be divided into 3 groups on the basis of sugar content.

a. Low sugar – 30 per cent sugar or below
b. Medium sugar – sugar above 30 and below 50%
c. High sugar – 50% sugar and above

Sugar can be added directly to the juice or as a syrup made by dissolving it in hot water, clarifying by addition of a small quantity of citric acid or a few drops of lime juice and filtering.

VIII. Fortification

Juices, squashes, syrups etc. are sometimes fortified with vitamins to enhance their nutritive value, to improve taste, texture or colour and to replace nutrients lost in processing. Usually ascorbic acid and Beta-carotene (water – soluble form) are added at the rate of 250-500 mg and 7-10 mg per litre, respectively. Ascorbic acid acts as an antioxidant and beta-carotene imparts an attractive orange colour. For a balanced taste some acids are added. Citric acid is often used for all types of beverages and phosphoric acid for cola type of drinks.

IX. Preservation

Fruit juices, RTS and nectars are preserved by pasteurization but sometimes chemical preservatives are used. Squashes, crushes and cordials are preserved only by adding chemicals. In the case of syrup, the sugar concentration is sufficient to prevent spoilage. Fruit juice concentrates are preserved by heating, freezing or adding chemicals.

X. Preservation by Bottling

Bottles are thoroughly washed with hot water and filled leaving 1.5-2.5 cm headspace. They are then sealed either with crown corks (by crown corking machine) or with caps (by capping machine).

Individual Beverages

1. Juices

Juices are of two types

a. Natural juice (pure juice): It is the juice, as extracted from ripe fruits, and contains only natural sugars.

b. Sweetened juice: It is a liquid product which contains at least 85% juice and 10% TSS.

Pure fruit juices such as apple juice and orange juice are commercially manufactured. Apple juice is generally bottled while other juices are canned.

Example Apple juice

Apples → Washing with 1.5% Hcl – Grating (apple grater)→ Crushing for juice extraction → Straining → Clarification (By enzyme (or) gelatin) → Filtration→ Heating at 82-85^{o}C → Filling hot into cans →Sealing → Processing at 100^{o}C for 15 min. → Cooling → Storage.

Citrus juice

Mandarin and sweet oranges → Washing → Peeling (By hand) → Separation and cleaning of segments → Juice extraction (Screw type extractor) → Straining → Heating at 80^{o}C – Bottling (or) canning (Baby food cans) → Crown corking (or) can sealing →Pasteurization → Cooling → Storage.

Example for sweetened juice

Mango juice

Mangoes (ripe) → washing → peeling □ stone removal →straining of pulp – addition of water (1 lit pulp 0.5 lit H_2O) → mixing with syrup → Homogenization → Heating at 85^{o}C → Filling hot into cans → sealing → Processing at 100^{o}C for 20 min → cooling → storage.

2. Ready-to-serve (RTS)

This is a type of fruit beverage which contains atleast 10% fruit juice and 10% total soluble solids besides about 0.3 per cent acid. It is not diluted before serving hence it is known as ready to serve.

Commercially RTS beverages (with 13% TSS and 0.3 % acid) can be prepared by using SO2 -70 ppm or benzoic acid 120 ppm.

For example: Papaya RTS

Ripe fruits → Washing → Peeling → Cutting into halves → Seed removal → Passing through pulper → Pulp → Mixing with strained syrup solution (Sugar + Water acid, heated just to dissolve) Homogenisation → Bottling → crown corking → Crown corking → Pasteurization (about 90^{o}C for 25 min) – Cooling → Storage.

PREPARATION OF SQUASH

This is a type of fruit beverage containing atleast 25 per cent fruit juice (or) pulp, 45% TSS, 1.0% acidity and 350 ppm of So_2 (or) 600 ppm of sodium benzoate. It is diluted before serving (13). Lime, mango, orange and pineapple are used for making squash commercially using KMS as preservative or fruits viz. jamun, passion fruit, raspberry, strawberry, grape fruit etc. with sodium benzoate as preservative.

PREPARATION OF CORDIAL

It is a sparkling, clear, sweetened fruit juice from which pulp and other insoluble substances have been completely removed. It contains atleast 25% juice, 30% TSS, 1.5% acid and 350 ppm of SO_2.This is very suitable for blending with wines. Lime and lemon are suitable for making cordial.

Process

Fruits → Washing → Cutting into halves →Juice extraction → Straining →Addition of preservative (kms/gm/litre juice) → Storing in glass container for 10-15 days for clarification (suspended material settles down) → Syphoning off the suspernatant clear juice → Straining and measuring → Preparation of Syrup → Straining → Mixing of juice with syrup → Addition of preservative → (KMS 0.6 g / lit product) → Bottling → Capping → Storing in cool and dry place.

SPOILAGE OF CANNED PRODUCTS - BIOCHEMICAL, ENZYMATIC AND MICROBIAL SPOILAGE

SPOILAGE OF CANNED PRODUCTS

Enzymatic spoilage

Many reactions in plant and animal tissues are activated by enzymes. The changes in foods during storage can be produced both by enzymes present in the food or by enzymes from microorganisms that contaminate the food. A good example of the former is the ripening of banana due to the enzymes present which hasten the ripening process. After some time the fruit become too soft and unfit to eat. If there is a bruised spot on the fruit, yeasts can grow and produce enzymes which spoil the fruit.

Enzymes convert starch into sugars, protein into amino acids, and pectin into pectic acids and thus change the constituents of food. Some fruits and vegetables turn brown when damaged or when their cut surfaces are exposed to air due to the presence of the enzymes phenolase, peroxidase and polyphenol oxidase. Their actions can be easily controlled by regulating the temperature and excluding moisture and air. Enzyme can act between zero and 60^{o}C. the optimum temperature of reaction is usually 37^{o}C, the rate varying directly with temperature. All enzymes are inactivated at 80^{o}C.

Microbial spoilage

Bacteria, yeasts and moulds may infect food after harvesting, during its handling, processing and storage. But not all microorganisms cause spoilage, e.g., lactic acid bacteria are used in the making of cheese and other fermented dairy products, yeasts for the production of wine and beer and *Acetobacter* bacteria for vinegar production. Spoilage organisms are present everywhere- in soil, air, water and even in the raw and processed food.

(i) Bacteria

These are unicellular microorganisms that are classed as plants though they do not contain chlorophyll. A bacterial cell is about I □m in length

Bacteria are classified according to their shape. Cocci are spherical, bacilli are cylindrical and spirilla and vibrios are spiral. Bacterial spores are more resistant than yeast or mould spores to most processing conditions. Bacteria, with a few exceptions, cannot grow in acid media in which yeasts and moulds thrive. They multiply by ‘fission’ or division of cells. When a bacterium becomes mature it divides into two, these two become four and so on. The growth of bacteria is very rapid and depends upon the nature of the food material, moisture, temperature and air. Some bacteria do not grow in air but temperature plays a major role in their growth, the optimum being generally 37^{o}C.

Some bacteria produce spores which can be destroyed by heating at 121°C for 30-40 minutes. Bacteria are very sensitive to acids and are destroyed in their presence even at the temperature of boiling water. Hence, most fruits being acidic can be easily sterilized at 100°C whereas vegetables being non-acidic require a higher temperature of 116°C. The important groups of bacteria are:

(a) Bacillus: rod-shaped;

(b) Coccus: spherical;

(c) Coccobacillus: oval-shaped;

(d) Aerobes :require atmospheric oxygen for growth, e.g., *Acetobacter aceti;*

(e) Facultative anaerobes: can grow with or without atmospheric oxygen;

(f) Obligate anaerobes: do not grow in atmospheric oxygen;

(g) Mesophiles: require a temperature below 38°C for growth;

(h) Obligate thermophiles: grow between 38 and 82°C;

(i) Facultative thermophiles: grow over the whole range of temperature covered by mesophiles and obligate thermophiles and below; and

(j) Psychrotrophs: grow fairly well at refrigeration temperatures and some can even grow slowly at temperature below freezing.

Important Food Spoilage Bacteria

Group	**Genus**
Acetics	**Acetobacter and Gluconobacter**
Lactics	*Lactobacillus, Leuconostoc, Pediococcus, Streptococcus*
Butyrics	*Clostridium*
Propionics	*Propionobacterium*
Proteol Gytics	*Bacillus, Pseudomonas, Clostridium, Proteus* etc.

Some useful bacteria

The following bacteria are of great importance in the food processing industry.

Acetobacter sp.

These bacteria, also known as "Vinegar bacteria", cause significant spoilage in the wine industry but are necessary for vinegar production. The important species are *Acetobacter aceti,* A. *orleansis* and A. *Schutzenbachi.* They are very small, usually non-motile and generally do not form spores. These bacteria are aerobes and in the presence of oxygen convert ethyl alcohol to acetic acid. They are of two types-one type forms a tough shiny film on the surface of wine and the growth is known as "vinegar mother", while the other grows throughout the wine without forming "vinegar mother". These bacteria can be easily destroyed by heating to 65°C.

Lactobacillus sp.

Different organisms of this group, also known as "lactic acid bacteria", have different properties but all of them produce lactic acid from carbohydrates. Those which are used in distilling and brewing industries are facultative thermophiles (heat-tolerants) which grow abundantly at 50 to 55^{o}C and produce much lactic acid. Mesophiles are used in the preparation of pickles. *Lactobacillus plantarum* is generally found in pickles and olives. The other important species are *Pediococcus cerevisiae, Leuconostoc mesenteroides, Streptococcus faecalis* and *Lactobacillus brevis.* These bacteria cause "lactic souring" and spoil wines, which can be easily prevented by maintaining a sulphur dioxide concentration of 0.007 per cent in wine.

(ii) Yeasts

Yeasts are unicellular fungi which are widely distributed in nature. They are somewhat larger than bacteria. The cell length is about 10 □m and the c

Most yeasts are spherical or ellipsoidal. Yeasts that multiply by means of 'budding' are known as 'true yeasts'. The bud when it becomes mature separates from the mother cell and functions like an independent organism. Yeasts grow luxuriantly at a moderate temperature in a solution of sugar in plenty of water. Under suitable conditions the sugar is converted into alcohol and carbon dioxide gas is evolved.

Yeast + Sugar $\longrightarrow$ Alcohol + Carbon dioxide

This is the reason that carbon dioxide is evolved from food materials spoiled by yeasts and pushes out corks from bottles with great force. Active fermentation can be easily recognized by the formation of carbon dioxide foams or bubbles. Yeasts prefer a low concentration of sugar for their growth. Most of them do not develop in media containing more than 66% sugar or 0.5% acetic acid. Boiling destroys the yeast cells and spores completely. Some of the yeasts which grow on fruits are *Saccharomyces, Candida* and *Brettanomyces.*

Pseudo-yeasts

These are like true yeasts but do not form spores. All the members of this group are particularly unsuitable for fermentation purposes as they produce off-flavours and cloudiness.

Yeasts causing food spoilage

Yeast	**Product spoiled**
Saccharomyces	Low-sugar products
Candida	High-acid foods, salty foods, butter
Brettanomyces	Beers, wines
Zygosaccharomyces (osmophilic)	Honey, syrups, molasses, wines, soy sauce

Pichia	Wines
Hansenula	Beers
Debaryomyces	Meat brine, cheese, sausages, etc.
Hanseniospora	Fruit juices
Torulopsis	Milk products, fruit juices, acid foods
Rhodotorula	Meat, sauerkraut
Trichosporon	Chilled beer

(iii) Moulds

Moulds are multicellular, filamentous fungi belonging to the division Thallophyta but are devoid of chlorophyll. They are larger than yeasts. They are strict aerobes and require oxygen for growth and multiplication and tend to grow more slowly than bacteria.

The principal parts of a mould are a web-like structure known as mycelium and the spore. The mycelium is often white and cottony and penetrates into the attacked foodstuff. After fixing itself the mould produces viable spores which resist the unfavourable conditions after dispersal and germinate when they get favourable conditions. They thrive best in closed, damp and dark situations with an adequate supply of warm, moist air but require less free moisture than yeasts and bacteria. They prefer sugar-containing substances and may spoil jams, jellies, preserves and other sugar-based products. Acid medium favours their growth and, therefore, they grow well in pickles, juices, etc. This is the main reason that fruits and fruit products are attacked by moulds which not only consume nutrients present in the food thereby lowering its food value but also spoil the flavour, texture and appearance of the product. They may grow even on moist leather but do not thrive in an alkaline medium. Moulds are sensitive to heat; boiling quickly destroys both moulds and their spores. The most important moulds are;

a) *Penicillium* sp. (Blue moulds),
b) *Aspergillus* sp. (Black moulds),
c) *Mucor* sp. (Gray moulds), and
d) *Byssochlamys fulva*

a. Penicillium sp.

These are also known as blue moulds. In the initial stage of growth they have a cottony appearance but later when the spores or conidia are formed, their appearance becomes powdery and the colour becomes blue, brown or pink according to age. The spoiled materials have a 'mouldy' odour and flavour.

b. Aspergillus sp.

In the initial stages of growth it is white and cottony like *Penicillium* but later with the formation of spores, it becomes black and is hence known as "black mould". Unlike *Penicillium* it does not produce off-odour and flavour. They generally attacks grapes and bael.

(c) Mucor sp.

It is gray in colour and hence is known as 'gray mould'. It is also known as 'pin mould' or bread mould' because if frequently grows on moist bread. Although *Mucor* attacks fruits, in the preservation of fruits and vegetables it does not pose a serious problem like blue and black moulds.

(d) Byssochlamys fulva

This mould causes spoilage of canned fruits. The infected fruits disintegrate and sometimes carbon dioxide gas is also produced. It can grow under reduced oxygen tension and the ascospores posses high resistance to heat. For destroying spores heating of the cans at 88 to 90^{o}C is essential.

Although the organism is not as resistant as some of the thermophiles, its control in canned foods is difficult. Canned products which cannot withstand prolonged heating without deterioration are ultimately spoiled. Association of this mould with fruit in the field has been observed. Hence the emphasis should be on eliminating the organism from the raw material itself instead of processing to destroy it in the can.

A small number of moulds produce toxic substances, known as mycotoxins, in food. *Aspergillus flavus* produces aflatoxins in harvested crops, such as groundnut, which are stored in the field without drying properly.

PRESERVATIVES, COLOURS PERMITTED AND PROHIBITED IN INDIA

PRESERVATIVES

Any substance which is capable of inhibiting, retarding or arresting the growth of microorganisms is known as a preservative.

- It may be a chemical or a natural substance (sugar, salt, acid).
- The term preservative includes fumigants, e.g., ethylene oxide and ethyl formate, used to control microorganisms on spices, nut and dried fruits.

Classification of preservatives

- Class I
  - Common salt, Sugar ,Dextrose, Glucose ,Wood smoke, Spices, Vinegar, Honey
- Class II
  - Benzoic acid, sulphurous acid
  - Nitrates / nitrites of sodium/ potassium in respect of foods like ham, pickled meat.
  - Sorbic acid- sodium, potassium & calcium salts
  - Nisin
  - Sodium and calcium propionate

Permissible limits of Class II preservatives in food products (FPO)

Sulphurdioxide

1.	Fruit pulp	-	2000-3000 ppm SO_2
2.	Fruit juice concentrate	-	1500 ppm SO_2
3.	Dried fruits viz., apples, peaches pears and other fruits	-	2000 ppm SO_2
4.	Raisins	-	750 ppm SO_2
5.	Squashes, cordials, crushes, fruit syrups and fruit juices	-	700 ppm of KMS
6.	Jam, marmalade, preserve	-	40 ppm SO_2
7.	Crystallized and glazed fruits	-	150 ppm SO_2
8.	RTS	-	70 ppm
9.	Pickles and chutneys	-	100 ppm SO_2
10.	Dehydrated vegetables	-	2000 ppm SO_2
11.	Syrups and sherbets	-	350 ppm SO_2
12.	Wines	-	450 ppm SO_2

Benzoic acid

1. Squashes, crushes fruit, syrups, cordials - 600 ppm
2. Jam, jelly, marmalade - 200 ppm
3. Pickles and chutneys - 250 ppm
4. Tomato and other sauces - 750 ppm
5. Tomato puree and pasta - 250 ppm

COLOURS

Permitted Natural Food Colours (FPO-1995)

These are isolated from the natural sources/synthesized.

» Cochineal
» Carotene
» Chlorophyll
» Lactoflavin
» Caramel
» Annatto
» Ratanjot
» Saffron
» Curcumin

Synthetic colours

Permitted synthetic food colours (FPO-1995)

- Dye should be pure & free from all harmful impurities.
- Should be in high solubility.
- Acid dyes generally more stable than alkaline ones.
- Sunlight, oxidation, reduction by metals & microorganisms affect dyes.
- Degrade by thermal processing.
- Colour should not contain more than

Copper	- 10 ppm
Chromium	- 20 ppm
Arsenic	- 1 ppm
Lead	- 10 ppm

- Available in the form of powder / ready-to-use solutions.
- Prevent sedimentation – glycerine is added to the solution to increase density.
- Permitted level in fruit products – 0.2 /kg
- Synthetic colour preserved by addition of

- Alcohol - 10%
- Glyerine - 25%
- Citric acid - 12.1%
- Tartaric acid - 15.6 %

Approved coal tar dyes			
Colour	**Common name**	**Colour index**	**Chemical class**
Red	Ponceau 4R Carmoisine Fast Red	16255 14720 16045	Azo Azo Azo
Yellow	Tartrazine Sunset yellow FCF	19140 15985	Pyrazolone Azo
Blue	Indico carmine Brilliant blue FCF	73015 42090	Indigoid Triphenylmethane
greem	Fast green Green FCFs	44090 42053	Triphenylmethane Triphenylmethane

Banned colours (Public Health Regulations, 1925)

Metallic colours

Antimony, arsenic, cadmium, chromium, copper, mercury, lead & zinc.

Vegetable colouring matter

Gamboge.

Coal tar colours

Picric acid, victoria yellow, manchester yellow, aurantia & aurine.

Other colour

Magetna-II & blue V.R.S, red 6B, Red FB & brilliant black.