

## **Post Harvest Technology / Post Harvest Management**

Post harvest technology is a very important branch of agriculture and its importance further increased in the field of horticulture as the crops are highly perishable in nature.

**Post harvest technology / post harvest management** may be defined as the branch of agriculture that deals with all the operations right from harvesting or even the preharvest stages till the commodity reaches the consumer, either in fresh (grains, apple, mango, tomato fruits) or processed form (flour, juice, nectar, ketchup) and utilization of the wastes (pomace, peel, seed, skin etc.) in a profitable manner (manufacture of fermented beverages, colour extraction, pectin extraction etc.)

What ever unit operations are done with the crops right from the harvesting stage till the product is consumed, all is dealt with in post harvest technology. Some times some specific preharvest operations i.e.-harvest sprays of calcium and boron on fruits that result in improving firmness (Post harvest quality) are also dealt with in post harvest technology as these are not the regular agronomic practices but are done to affect the pre harvest quality. Post harvest technology deals with 3 types of products.i.e.fresh produce, processed products, and handling and processing wastes.

**Importance of post harvest technology:** One of the most important considerations in the world today is to provide nutritious food to approximately six billion population of the planet. Fruits and vegetables, being a rich source of vital nutrients constitute an important component of human nutrition. The concerted efforts made in the horticulture sector have been amply rewarded with a tremendous increase in production of various fruits and vegetables, through out the world. In consistent with the global trend, India has emerged as the second largest producer of fruits and vegetables and 25-40% of this hard earned valuable produce goes waste due to inadequate post harvest infrastructure and poor utilization (1.8%) by processing industry. More over, there is little point in growing more if much of it is to be lost. Besides quantitative losses, the problem of quality and safety of produce is also significant to the consumers. The whole scenario thus, reflects a very gloomy picture. Unless *post harvest technology* gets its due recognition and proper growth, the horticulture industry cannot thrive.

World production of fruits and vegetables at present is 878 million metric tones (fruit production- 392 million metric tones and vegetable production- 486 million metric tones). Worldwide post harvest fruit and vegetables losses are as high as 30 to 40% and even much higher in some developing countries. Reducing post harvest losses is very important; ensuring that sufficient food, both in quantity and in quality is available to every inhabitant in our planet. The prospects are also that

the world population will grow from 5.7 billion inhabitants in 1995 to 8.3 billion in 2025. World production of vegetables amounted to 486 million ton, while that of fruits reached 392 million tonnes. Reduction of post-harvest losses reduces cost of production, trade and distribution, lowers the price for the consumer and increases the farmer's income.

Where as Indian production of fruits and vegetables are 112.52 million metric tones. It includes fruit production of 32 million metric tones which is about 8% of world production and second largest producer after Brazil in the world and vegetable production of 80.52 million metric tones which is about 15% of world production and second largest producer after China in the world. But India loses about 30-40% of the produce due to improper Post Harvest Management. A loss estimated at Rs. 40,000 crores per year. India wastes fruits and vegetables every year equivalent to the annual consumption of the United Kingdom.

Recently, *post harvest technology* of fruits and vegetables has engaged the attention of policy makers, planners and scientists in the developed countries. However, in the developing countries the situation is far from satisfactory, where even the recognition of the subject is a recent phenomenon. Development of *post harvest technology* could save a lot of produce from spoilage, become a new diversified source of food and a tool to fight malnutrition, prevailing in these countries. For this, sustained efforts for in-depth research, value addition and efficient strategy for technology and then only it could absorb new innovations which are a slow process.

The following points shall highlight the importance of Post harvest technology

- 1) **Reduction in post harvest losses:** Post harvest technology ensures reduction of losses in what has already been produced. So; reduction of post harvest losses is an alternative way of increasing production of agricultural and horticultural crops.
- 2) **Reduction of cost of production:** Post harvest technology reduces cost of production, packaging, storage, transportation, marketing and distribution, lowers the price for the consumer and increases the farmer's income.
- 3) **Reducing malnutrition:** Proper post harvest technology ensures availability of sufficient food to all thus reducing malnutrition and ensuring healthy growth of the nation. It also extends the season of availability of a particular commodity.
- 4) **Economic loss reduction:** Reduces economic losses at grower level, during marketing and at consumers end.
- 5) **Availability:** Had there been no knowledge of post harvest technology, apples would not have ever reached Kerala and Banana in H.P. or Kashmir today. Today we can get perishable commodities like Banana, tomato etc.throughout the year and in almost every place in the country. Apples can be made available through out the year although the cropping season is just

for 2-3 months. Thanks to the advancement made in the field of post harvest technology. The increasing exports of fruits and vegetables have become possible only by the interventions made in post harvest technology.

- 6) **Employment generation:** The food processing industry ranks first in terms of employment generation with approximately 15 lakhs persons employed. Employment potential in post harvest and value addition sector is considered to be very high. Every one crore rupee invested in fruit and vegetable processing in the organized sector generates 140 persons per year of employment as compared to just 1050 person days of employment per year in small scale investment (SSI) units. The SSI unit in food industry employs 4, 80,000 persons, contributing 13% of all SSI units employed.
- 7) **Export earnings:** Export of fresh and processed horticultural commodities also attracts valuable foreign exchange.
- 8) **Defense and astronaut's requirements:** Defense forces posted in remote border areas as well as astronauts who travel into space have special requirements of ready to eat and high energy low volume food. The requirements are fulfilled by processing industries.
- 9) **Infant and sports preparations:** To day special infant and sports drinks and other processed preparations are available for use especially by these people. These preparations are done especially to meet the specific nutritional requirements of their body.

**Causes of post harvest losses:** The causes of post harvest losses are many, but they can be classified into two main categories. The first of these is physical loss. Physical loss can arise from mechanical damage or pest or disease damage resulting in produce tissue being disrupted to a stage where it is not acceptable for presentation, fresh consumption or processing. Physical loss can also arise from evaporation of intercellular water, which leads to a direct loss in weight. The resulting economic loss is primarily due to the reduced mass of produce that remains available for marketing but can also be due to a whole batch of commodity being rejected because of a small proportion of wasted items in the batch.

Loss of quality is the second cause of post harvest loss, and this can be due to physiological and compositional changes that alter the appearance, taste, texture and make produce less aesthetically desirable to end users. The changes may arise from normal metabolism of produce (e.g. senescence) or abnormal events e.g. chilling injury) arising from the post harvest environment. Economic loss is incurred because such produce will fetch a lower price. In many markets there is no demand for second class produce, even at reduced price, which leads to total economic loss even though the goods may still be edible.

## **Maturity and maturity indices of fruits and vegetables**

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Fruits harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. Similarly; vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For example, small or immature vegetables possess better texture and quality than mature or over mature vegetables. Therefore harvesting of fruits and vegetables at proper stage of maturity is paramount importance for attaining desirable quality. The level of maturity actually helps in selection storage methods, estimation of shelf life, selection of processing operations for value addition etc.

Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage in the ontogeny of the plant organ, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit).

Maturity is the attainment of a particular size or stage after which ripening takes place is called maturity. It is also defined as the stage of development at which the produce has completed its natural growth and is ready for harvest. This stage would ensure proper completion of ripening process.

The term maturity is derived Latin word 'Maturus' which means ripen .It is that stage of fruit development, which ensures attainment of maximum edible quality at the completion of ripening process.

The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity.

**1. Physiological maturity:** It is the stage at which a plant or plant part continues ontogeny (complete developmental history of an organism from egg/spore/ bud etc. to an adult individual) even if detached from the parent plant or the point of origin. It can also be defined as the stage at which a plant or plant part is capable of further development or ripening when it is harvested i.e. ready for eating or processing. Ex. A French bean pod or okra pod is at its physiological maturity when the seeds are fully developed and the pod is lignified which will dehisce with little pressure.

**2. Horticultural maturity / Harvest maturity:** It may be defined as the stage at which a plant or plant part possesses all the prerequisites for use by consumers for a particular purpose, i.e. local, distant, export market (**shipping** maturity) or exhibition or processing (processing maturity), culinary maturity, desert maturity etc. Ex. A pod vegetable is matured when it is tender with maximum size.

Horticultural maturity stage of tomato if harvested for long distance transportation would be the “turning stage of skin from green to red”, while the optimum stage of harvesting of the same crop for home use or local markets would be “when the fruits have attained full red colour”.

Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer. Generally a single maturity index is not considered to be reliable. In most of the crops more than one or two indices should be made use of while determining the exact stage of optimum maturity.

Fruits picked at the wrong stage of maturity may develop physiological disorders in storage and may exhibit poor defect quality. Fruit size is also sacrificed by harvesting too early. For selecting the harvest maturity of fruits or vegetables it should be kept in mind that harvested commodity has its peak acceptable quality (Non-toxic, size, appearance and flavour with adequate shelf life).

#### **Importance of maturity indices:-**

- Ensure sensory quality (flavour, Colour, aroma, texture) and nutritional quality.
- Ensure an adequate post harvest shelf life.
- Facilitate scheduling of harvest and packing operations
- Facilitate marketing over the phone or through internet.

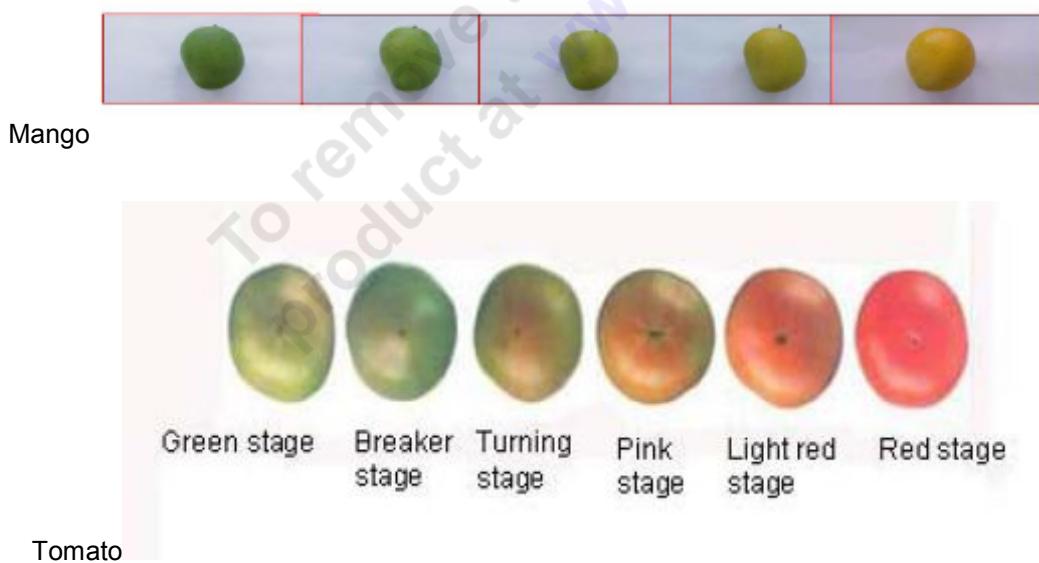
#### **Determination of harvest maturity can be done by different methods:**

- 1. Computation methods:** (1) calendar date, (2) Days From Full bloom to Harvest, (3) Mean heat units (4) T – stage.
- 2. Physical methods:** (1) Fruit retention strength,(2)Fruit size and surface morphology (3) Weight, (4) Specific gravity, (5) Colour, (6) Flesh firmness, (7) Total soluble solids (T S S), (8) Juice content and (9) oil content
- 3. Chemical methods:** (1) Titratable acidity (2) TSS/ acid ratio, (3) Sugar – Total and reducing), (4) Sugar/acid ratio, (5) Bio electrical conductance, (6) Starch- iodine test (7) Tannin content (8) Oil content, (8) Juice content.
- 4. Physiological methods :**(1)Respiration rate and (2)Ethylene evolution rate

**Determination of maturity:** Parameters which are considered for the determination of maturity indices are : Chronological age, size, shape ,surface characteristics, color, firmness, soluble solids, sugars, starch presence, sugar to acid ratio, oil content etc .In recent years much work has been done on developing non-destructive methods for the measurement of fruit and vegetable characteristics, using principles of NMR(nuclear magnetic resonance), X-rays, sonics and ultra sonic waves, delayed light emission and light reflectance. Maturity indices must be set for each region and variety.

No single method of maturity indices is satisfactory, a combination of the following may be better than relying upon any one.

**(1) Skin colour:** The loss of green colour of many fruits is a valuable guide to maturity .There is initially a gradual loss in intensity of colour from deep green to lighter green and with many commodities, a complete loss of green colour with the development of yellow, red or purple pigments. Some fruits exhibit no perceptible colour change during maturation. Assessment of harvest maturity by skin colour depends on the judgment of the harvester, but colour charts are available for cultivars, such as apples, tomatoes, peaches, chilli peppers, etc.Although human eye is used to evaluate colour but results can vary considerably due to human differences in colour perception. Therefore, an instrument is used to provide a specific colour value based on the amount of light reflected off the commodity surface or light transmitted through the commodity. This instrument can measure small differences in colour accurately and can be automated in the packing line. This instrument is popularly known as Colour Difference Meter. This instrument uses colorimetric method for colour measurement. This method is not entirely reliable as it is influenced by factors other than maturity.



Judging maturity of mango and tomato by colours

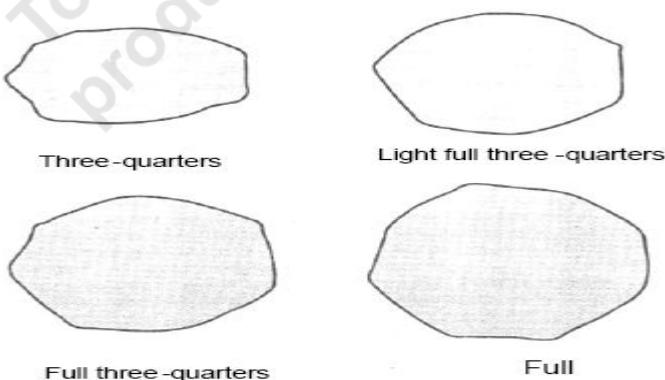
**(2) Shape:** The shape of fruit can change during maturation and can be used as a characteristic to determine harvest maturity. For instance, a banana becomes more rounded in cross-sections and less angular as it develops on the plant. Mangoes also change shape during maturation. As the mango matures on the tree the relationship between the shoulders of the fruit and the point at which the stalk is attached may change. The shoulders of immature mangoes slope away from the fruit stalk; however, on more mature mangoes the shoulders become level with the point of attachment, and with even more maturity the shoulders may be raised above this point.



Judging mango harvest by shape and shoulder

**(3) Size:** Changes in the size of a fruit / vegetable while growing are frequently used to determine the time of harvest. Size is generally of limited value as a maturity index in fruit, though it is widely used for many vegetables, especially those marketed early in their development. With these produce, size is often specified as a quality standard, with large size generally indicating commercial over maturity and under sized produce indicating an immature state. The assumption however, is not always a reliable guide for all purpose.

For example, in bananas, the width of the individual fingers can be used to determine harvest maturity. Usually a finger placed midway along the bunch and its maximum width is measured with calipers.



Cross section of the middle banana fingers showing the changes in angularity as they mature on the plant

**(4) Optical methods:** Light transmission properties can be used to measure the degree of maturity of fruits. These methods are based on the chlorophyll content of the fruit, which is reduced during maturation. The fruit is exposed to a bright light, which is then switched off so that the fruit is in total darkness. Next, a sensor measures the amount of light emitted from the fruit, which is proportional to its chlorophyll content and thus its maturity.

**5) Heat Units / Degree days:** It is a measure of the time required for the development of the fruit to maturity after flowering can be made by measuring the degree days or heat units in a particular environment. It has been found that a characteristic number of heat unit or degree days is required to mature a crop under usually warm conditions, maturity will be advanced and under cooler conditions, maturity is delayed. The number of degree days to maturity is determined over a period of several years by obtaining the algebraic sum from the differences ,plus or minus ,between the daily mean temperatures and a fixed base temperature(commonly minimum temperature at which growth occurs).The average or characteristic number of degree days is then used to forecast the probable date of maturity for the current year and as maturity approaches, it can be checked by other means.

**(6) Aroma:** Most fruits synthesize volatile chemicals as they ripen. Such chemicals give fruit its characteristic odour and can be used to determine whether it is ripe or not. These odours may only be detectable by humans when a fruit is completely ripe, and therefore has limited use in commercial situations.

**(7) Leaf changes:** Leaf quality often determines when fruits and vegetables should be harvested. In root crops, the condition of the leaves can likewise indicate the condition of the crop below ground. For example, if potatoes are to be stored, then the optimum harvest time is soon after the leaves and stems have died. If harvested earlier, the skins will be less resistant to harvesting and handling damage and more prone to storage diseases. Apple leaves turns green to light green and to yellow at maturity.

**(8) Abscission:** As part of the natural development of a fruit an abscission layer is formed in the pedicel. For example, in cantaloupe melons, harvesting before the abscission layer is fully developed results in inferior flavoured fruit, compared to those left on the vine for the full period.

**(9) Firmness:** A fruit may change in texture during maturation, especially during ripening when it may become rapidly softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch, and the harvester may simply be able to gently squeeze the fruit and judge whether the crop can be harvested. Today sophisticated devices have been developed to

measure texture in fruits and vegetables, for example, texture analyzers and pressure testers; they are currently available for fruits and vegetables in various forms. A force is applied to the surface of the fruit, allowing the probe of the penetrometer or texturometer to penetrate the fruit flesh, which then gives a reading on firmness. Two commonly used pressure testers to measure the firmness of fruits and vegetables are the **Magness-Taylor** and **UC Fruit Firmness testers**.



Penetrometer

The Agricultural Code of California states that “Bartlett pears shall be considered mature if they comply with one of the following: (a) the average pressure test of not less than 10 representative pears for each commercial size in any lot does not exceed 23 lb (10.4 kg). (b) the soluble solids in a sample of juice from not less than 10 representative pears for each commercial size in any lot is not less than 13%”

**(10) Juice content:** The juice content of many fruits increases as the fruit matures on the tree. To measure the juice content of a fruit, a representative sample of fruit is taken and then the juice extracted in a standard and specified manner. The juice volume is related to the original mass of juice, which is proportional to its maturity. The minimum values for citrus juices are presented in the Table’

**Minimum juice values for mature citrus.**

Citrus fruit	Minimum juice content (%)
Naval oranges	30
Grapefruit	35
Lemons	25
Mandarins	33

**(11) Oil content and dry matter percentage:** Oil content can be used to determine the maturity of fruits, such as avocados. According to the Agricultural Code in California, avocados at the time of harvest and at any time thereafter,

shall not contain in weight less than 8% oil per avocado, excluding skin and seed. Thus, the oil content of an avocado is related to moisture content. The oil content is determined by weighing 5 -10 g of avocado pulp and then extracting the oil with a solvent (e.g., benzene or petroleum ether) in a distillation column. This method has been successful for cultivars naturally high in oil content.

**(12) Moisture content:** During the development of avocado fruit the oil content increases and moisture content rapidly decreases. The moisture levels required to obtain good acceptability of a variety of avocados cultivated in Chile are listed in the table given below.

Moisture content of certain varieties of avocado fruit cultivated in Chile.

Cultivar	Moisture content (%)
Bacon	77.5
Zutano	80.5
Fuerte	77.9
Edranol	78.1

**(13) Sugars:** In climacteric fruits, carbohydrates accumulate during maturation in the form of starch. As the fruit ripens, starch is broken down into sugar. In non-climacteric fruits, sugar tends to accumulate during maturation. A quick method to measure the amount of sugar present in fruits is with a brix hydrometer or a refractometer. A drop of fruit juice is placed in the sample holder of the refractometer and a reading taken; this is equivalent to the total amount of soluble solids or sugar content. This factor is used in many parts of the world to specify maturity.



**Refractometer**

**14) Starch content:** Measurement of starch content is a reliable technique used to determine maturity in pear cultivars. The method involves cutting the fruit in two and dipping the cut pieces into a solution containing 4% potassium iodide and 1% iodine. The cut surfaces stain to a blue-black colour in places where starch is present. Starch converts into sugar as harvest time approaches. Harvest begins when the samples show that 65-70% of the cut surfaces have turned blue-black.

**(15) Acidity:** In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree. Taking samples of such fruits, and extracting the juice and titrating it against a standard alkaline solution, gives a measure that can be related to optimum times of harvest. Normally, acidity is not taken as a measurement of fruit maturity by itself but in relation to soluble solids, giving what is termed the **brix: acid** ratio.

**(16) Specific gravity:** Specific gravity is the relative gravity, or weight of solids or liquids, compared to pure distilled water at 62°F (16.7°C), which is considered unity. Specific gravity is obtained by comparing the weights of equal bulk of other bodies with the weight of water. In practice, the fruit or vegetable is weighed in air, then in pure water. The weight in air divided by the weight in water gives the specific gravity. This will ensure a reliable measure of fruit maturity. As the fruit matures its specific gravity increases. This parameter is rarely used in practice to determine time of harvest, but could be used in cases where development of a suitable sampling technique is possible. It is used however to grade crops according to different maturities at post-harvest. This is done by placing the fruit in a tank of water, wherein those that float are less mature than those that sink.

### Maturity indices of some fruits and vegetables

Maturity Index	Commodities
Peel Colour	Citrus, Papaya, pineapple, tomato (breaker stage), grapes, mango, straw berry and peas
Pulp Colour	Tomato, mango and apple
Size	Asparagus, cucumber, citrus, apple and pears.
Shape	Banana (fullness of fingers, disappearance of angularity), mango (fullness of cheeks), pineapple (flattening of eyes with slight hollowness at the centre) and litchi (flattening of tubercles)
Drying of plant parts	Onion, garlic, banana, potato and ginger
Surface characteristics	Grape, tomato, melon and mango
Ease of separation from plant	Musk melon, grape and mango
Ease of snapping	Beans, okra and peas
Juiciness (Milk exudation)	Sweet corn
Tapping	Watermelon and jackfruit
Solidity	Cabbage
Netting	Musk melon

Aroma	Jack fruit
Specific gravity	Mango 1.0-1.02 for Alphonso less than 1.0 for dashehari, potato, pineapple (0.98-1.02) & guava (1.00).
Firmness	Melons, apples and pears
Sugars	Melons and grapes
TSS	Grape ( $14-16^{\circ}$ brix for Anab-e-shahi, $18-22^{\circ}$ Brix for Thompson seedless, $12-14^{\circ}$ brix for Bangalore blue), mandarin $12-14^{\circ}$ brix, sweet orange- $12^{\circ}$ brix papaya 11.5) brix, pineapple $12-14^{\circ}$ brix.
Acidity	Citrus (Mandarin-0.4%, sweet orange 0.3%), mango & pineapple (0.5-0.6%)
Starch index	Apple, pear and banana
Juice content	Citrus (35-50%)
Heat units	Pea,mango,grape,apple and pear
Days from anthesis	Melons and pineapple
Days from full bloom	Mango, citrus apple and pear
Days from fruit set	Banana (90 days) for dwarf Cavendish, mango (110-125 days for Alphonso and Pari).

### Harvesting of Fruits and Vegetables

**Harvesting:** It is detaching a commodity from the point of origin. This point of origin may be an above ground plant part i.e. shoot e.g. apple, tomato etc.or an under ground plant part eg.potato, carrot etc.

It involves removing the product from the parent plant either by hand or by some device or machine. Manual harvesting is essential for the picking of fragile, highly perishable

products. Harvesting by machine involves mechanically removing the product from the parent plant.

**Preparing to harvest:** A poor harvesting operation would result in poor quality produce and a low selling price. The grower should plan the harvesting operation with great care ,especially when the enterprise is on a commercial scale. Labour, equipment and transportation should be pre arranged.Labour should be trained to pick the produce at the right stage (market harvest) and the proper manner (e.g., plucking, cutting, and digging) with out bruising the produce. Mechanical injury is reduced by training workers to use the appropriate containers in the best shape (not rough edged or lining), to avoid rough handling (throwing, dropping) and to pack properly. Harvesting equipment should be cleared and readied for the operation.

When the crop is ready for harvesting, the decision as to when to start harvesting will depend largely on;

- Weather conditions
- The taste of the market
- The flexibility of marketing date .It depends on the crops. Some such as root crops can be harvested and sold over a long period or stored on the farm to await favorable prices. Others such as soft berries must be marketed as soon as they are ready or they will spoil.

When the decision to harvest has been made, the best time of day must be considered.

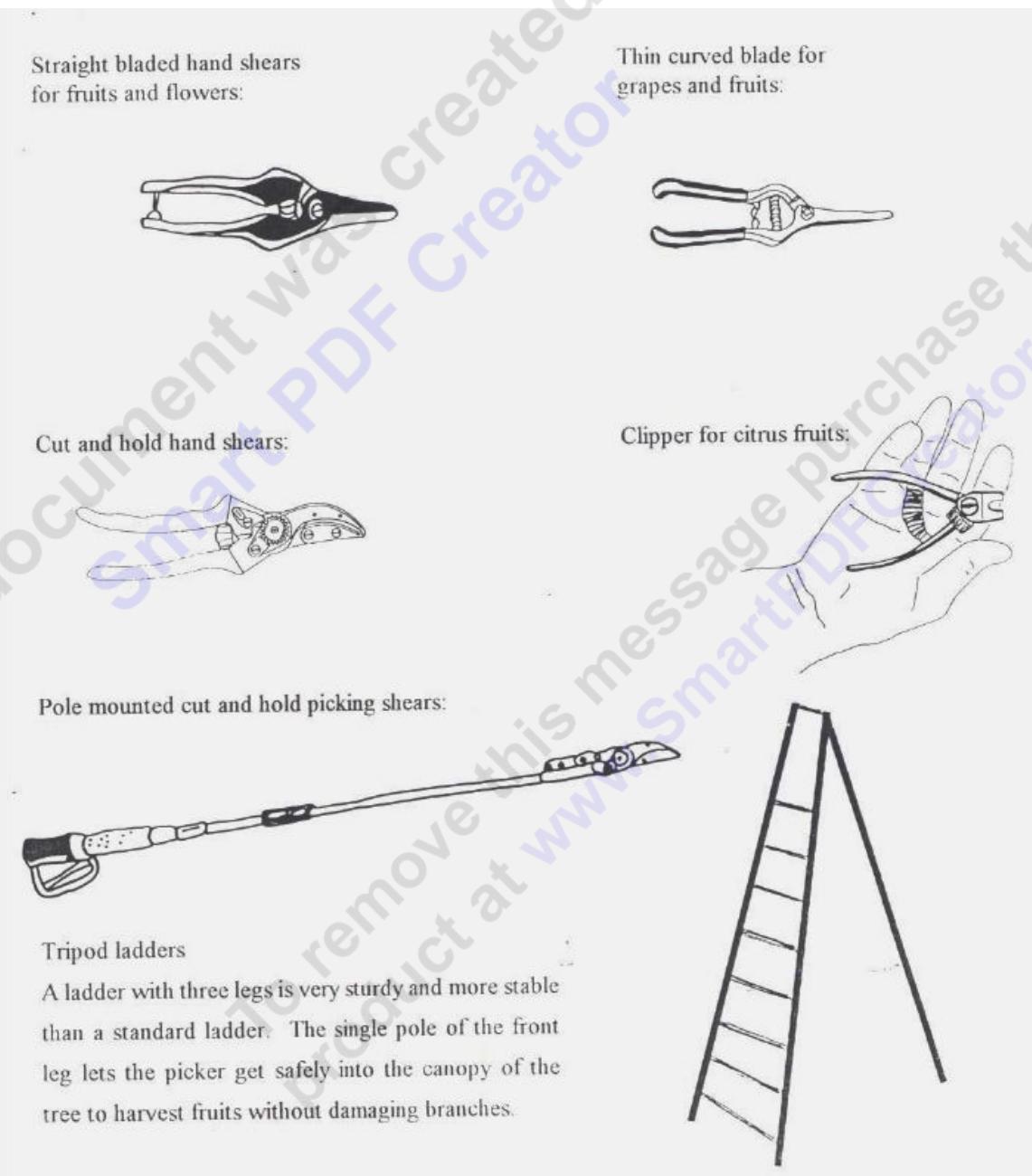
The aim is to dispatch the produce to the market in best possible condition that is as cool as possible, properly packed and free from damage.

#### **Devices for harvesting of fruits:**

In order to avoid any injury to the fruits, the use of the following devices is advised.

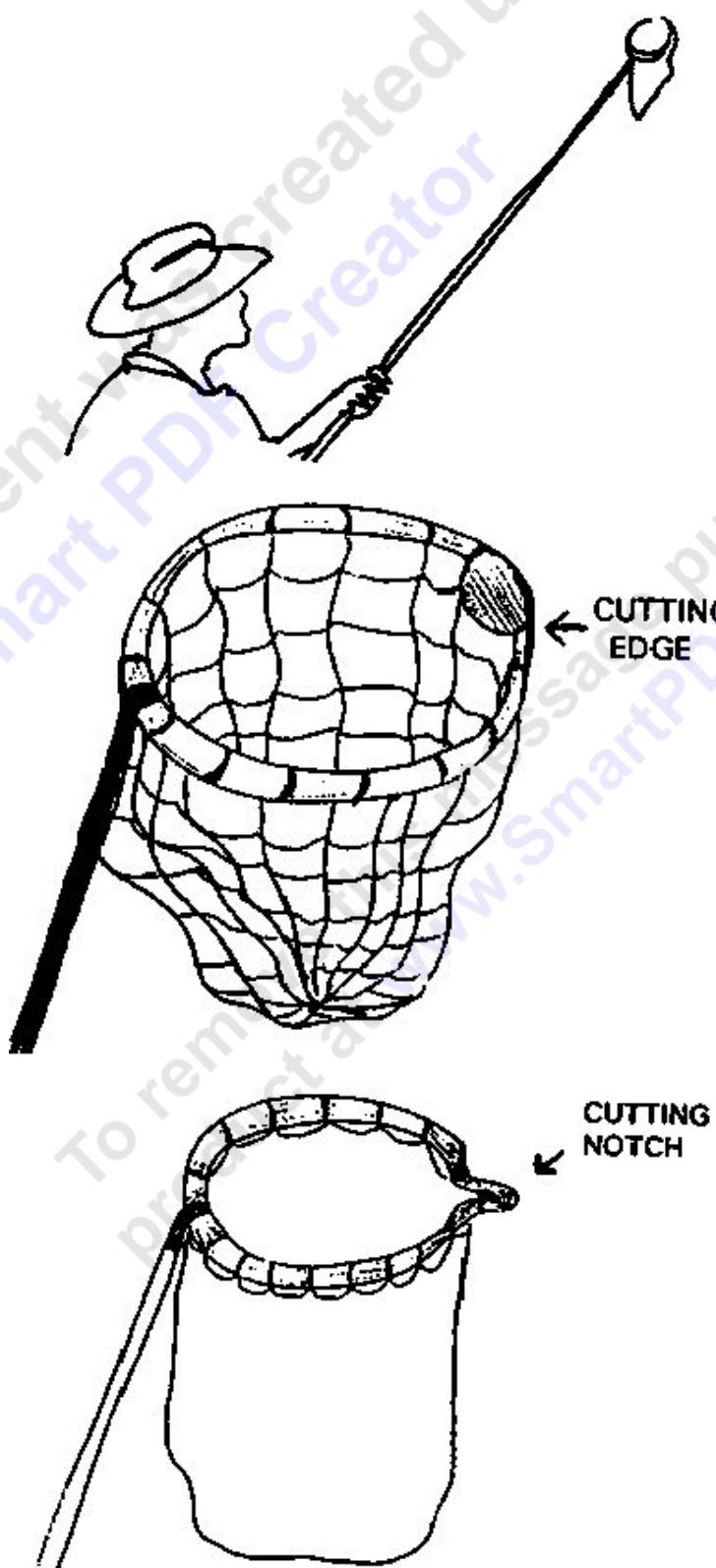
- ❖ Stepladders are to be used to avoid getting up the tree.

- ❖ Clippers may be used to avoid pulling off the fruit from the stock.
- ❖ Scissors are to be used for harvesting grape bunches.
- ❖ Hooks may be used for harvesting for fruits like acid lime, sweet oranges, mango, guava, sapota etc.
- ❖ Special picker bags may be used to hold the harvested fruit.
- ❖ Some harvesting gadgets have been developed e.g.mango harvester in CISH (Lucknow), IIHR (Bangalore) and KKV (Ratnagiri).





Nut Wizzard for collecting drooped nuts



The basic rules to observe for harvesting are:

- Fruits should not be pulled but clipped.
- Fruits should not be thrown to the ground but should be brought carefully to the ground in pickers bags.
- Fruits should not be picked during rains or in the morning when the dew is settled on them, as this moisture develops brown spots on the rinds. Wet produce will over heat if not well ventilated, and it will be more likely to decay. Some produce may be more subject to damage when wet.e.g.oil spotting and rind breakdown in some citrus fruits.
- Fruits should not be piled in direct sun after harvesting but should be placed under shade.
- Fruits should not be heaped, but spread evenly.
- All the damaged, cut and diseased fruits should be promptly removed and should not be mixed with healthy fruits.
- Harvest during the coolest part of the day-early morning or late afternoon.
- Protect harvested produce in the field by putting it under open sided shade when transport is not immediately available. Produce exposed to direct sunlight will get very hot. For example, aubergine and potatoes left exposed to tropical sunlight for four hours can reach temperatures of almost 50°C.
- Produce for local markets can be harvested early in the morning .For more distant markets it may be advantage –if suitable transport can be arranged-to harvest in the late afternoon and transport to market at night or early in the next morning.
- Harvesting with improper methods results in damage of crop by bruising which can be caused by compression (due to overfilling of boxes or in bulky stores), impact (due to dropping of crop or from some thing hitting the crop) or vibration (due to loose packing during transportation).So, during harvesting factors like delicacy of crop, maturity criteria, time, method of harvesting, mode of packaging and transportation, the importance of speed during and directly after

harvesting, economy of operations, and need for the harvesting method to fill the requirement should be taken into consideration.

- Some fruits i.e. citrus fruits (Malta, lemon, orange etc.) and temperate stone fruits (plum etc.) are reported to have longer shelf life and lesser rotting during storage when harvested along with attached pedicel. So, such fruits should carefully be harvested with attached pedicel.
- In addition to harvesting methods, the stage of harvest plays crucial role in maintaining the best quality of crop during the course of post harvest handling and storage. For the determination of harvest maturity, a, number of methods have been evolved which vary from crop to crop.

Many fruits and vegetables are harvested unripe for their safe handling, transportation and marketing but they must be matured when harvested so that they can ripen later on normally and develop good eating quality.

### **Methods of harvesting**

There are two methods of harvesting. They are (1) Hand harvesting and (2) Mechanical harvesting. Several factors are considered in deciding on the appropriate method of harvesting a crop. Some crops offer no choice since machines have not yet been developed for harvesting them. In other cases ,the product is so delicate that mechanical harvesting becomes a great challenge and is not cost effective. Where human labour is plentiful and inexpensive ,hand picking may be economical.

**Hand harvesting:** Harvesting by hand is being practiced in all the horticultural crops since time immemorial. Some of the crops eg.flowers even to day are harvested by hands. But in India hand harvesting is still the most common method used in horticultural commodities. Due to inadequate mechanization, small land holdings and diversity of crops being grown by a small farmer. In developing countries, most produce for internal rural and urban markets is harvested by hand.

### **Advantages of hand harvesting:**

- 1) Hand harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time.
- 2) Accurate selection of maturity
- 3) Accurate grading (discarding the damaged, diseased fruits at the time of harvesting only)
- 4) Less expensive
- 5) Minimum damage to the commodity
- 6) Rate of harvesting can be increased by employing more number of persons
- 7) Minimum of capital investment
- 8) Some labour can be used for harvesting different types of crops eg.apple and gladiolus can be harvested by same person but can not be harvested by same machine.
- 9) Immature or small sized fruits could be left on the plant for next harvest eg.pea, capsicum where 3-4 harvests are taken from the same plant.

#### **Disadvantages of hand harvesting:**

- 1) More time consuming
- 2) Dependent on availability of labour. Labour is very costly in some countries like Japan. Strike of labour during the time of harvesting may result in crop losses.

**Mechanical harvesting:** Harvesting by use of machines. It is very useful for rapid harvesting of a particular crop and at low cost. Special harvesting machines are designed for specific crops. In developed countries mechanical harvesting is common for most of the crops, but in India still it is uncommon. Larger commercial producers may find a degree of an advantage, but the use of sophisticated harvesting will be limited for production of cash crops for processing or export or both. Machine harvesting is usually viable only when an entire crop is harvested at one time.

#### **Advantages of mechanical harvesting:**

- 1) Rapid harvesting thus saving time
- 2) Less dependency on labour.No risk of labour strikes and labour management related problems
- 3) Improve working conditions for workers

#### **Dis-advantages of mechanical harvesting:**

- 1) Required skilled manpower for use of machine, therefore dependence on trained labour.
- 2) Improper machine usage may result in huge economic losses
- 3) Machine require regular maintenance
- 4) May cause damage to perennial crops(bark of the branches of the trees)
- 5) Social impact of low labour requirements and employment

- 6) Inadequate facilities for handling and processing large quantity of harvested produce.

**Harvesting machines:** Mechanical harvesting devices that employ direct contact methods such as combing, cutting, pulling, snapping, twisting, stripping and compacting.

**1. Shake-catch and collect system:** This was designed for the harvesting of deciduous tree fruits, grapes and blue berries. The system consists of vibrator to shake the fruit from the plant and the falling fruit is caught in an underlying frame and collected in to boxes.

**(2) Pick and collect system:** This picks up fruit from the surface of the land and it was designed for harvesting of walnuts, almonds, pecans, filberts and tung. Fruit, which naturally falls to the ground or that which is harvested by shaking, are collected by this system. This is a labour saving device.

**(3) Once-over harvesters:** These were designed for the harvesting of vegetable crops grown for canning and picking, such as peas, snap beans, tomatoes and cucumbers. All the fruits present on the plant are harvested in one operation. The type of machine used varies with the crop. With peas, the vines are cut at the base and the pods are separated in a machine called "viner". With snap beans, rotary tines or fingers attached to a reel or chain work downwards from the top to the bottom of the plants as the machine moves forward. The finger like tines strips the pods from the plants and places them on a moving conveyor belt, which carries them to the boxes. With tomatoes and cucumbers the basal stems are cut and the tops are carried to a compartment of the machine, which shakes the fruit from the vines. All over ripe and other undesirable fruits are removed by hand.



Coffee Mechanical harvester



Carrot harvester



Sweet Pepper Harvester

### Pre-harvest factors affecting the quality of fruits and vegetables

The factors affecting the quality of fruits and vegetables can be grouped into environmental and cultural.

#### 1. Environmental factors

Sl.No.	Factors	Quality affected
1	Temperature	Maturity, colour, sugar, acidity etc. High temperature reduces the quality, e.g., citrus, radish, spinach, cauliflower, etc., and increased the quality in grapes, melons tomato, etc. Low temperature cause chilling and freezing injury.
2	Light	Essential for anthocyanin formation. Exposed fruit to sun light develop the <b>lighter weight, thinner peel, lower juice and acids and higher TSS</b> than shaded fruits, e.g., citrus, mango, etc. Exposure of potato to light causes <b>Greening</b> (solanine formation) which has toxic properties. High sun light intensity causes <b>Sunscald</b> in citrus and tomatoes and reduces the <b>pure white colour</b> of cauliflower.

		Low light intensity causes <b>thin and large leaves</b> in leafy vegetables.
<b>3</b>	<b>Rains</b>	Causes <b>cracking</b> in grapes, dates, litchi, limes, lemon, tomato, sweet potato, etc. It reduces <b>appearance</b> and <b>sweetness</b> .
<b>4</b>	<b>Wind</b>	Causes <b>brushing, scratching</b> and <b>corky scar</b> (citrus fruits) on the fruit and damage leafy vegetables.
<b>5</b>	<b>Humidity</b>	High humidity reduces the <b>colour</b> and <b>TSS</b> and <b>increases acidity</b> in citrus, grapes, tomato, etc., but on other hand it is needed for <b>better quality</b> of banana, litchi and pineapple.

## 2. Cultural factors

Sl.No.	Factors	Quality affected
<b>I. Mineral nutrition</b>		
1.	Nitrogen	High nitrogen <b>reduces the ascorbic acid content, TSS/acid ratio and keeping quality</b> but increases <b>thiamine, riboflavin, carotene</b> , e.g., Citrus and Spinach. Its deficiency reduces <b>size of fruits</b> .
2.	Phosphorous	High phosphorous <b>decreases size, weight, vitamin C</b> e.g., Citrus. Its deficiency causes <b>poor appearance of fruit</b> .
3.	Potassium	Increase <b>size, weight and vitamin C</b> , e.g., Citrus. Its deficiency causes uneven ripening.
4.	Calcium	Increases <b>firmness</b> of many fruits, e.g., Apple, Mango, Guava, Tomato, etc.
5.	Magnesium	Increases <b>size, weight and vitamin C</b> , e.g., Citrus fruits
6.	Zinc	Increases <b>size, weight and vitamin C</b> , e.g., Citrus. Deficiency causes straggled cluster in Grape.
7.	Boron	Deficiency causes <b>flesh browning in fruits</b> , e.g., Anola and <b>gummy discolouration of albedo</b> in citrus. Fruits and vegetables become <b>hard and misshapen</b> . Cabbage, Turnip and cauliflower are sensitive to boron deficiency.
8.	Copper	Deficiency causes <b>irregular blotch on citrus fruits</b> and <b>spoils the appearance</b> .
<b>II Growth Regulators</b>		
1.	Auxins	Increases <b>fruit size</b> in loquat (2, 4, 5-TP), mandarins (NAA) and <b>TSS</b> in mango (2, 4,-D).
2.	Gibberlic acid	Increases size and weight of grape berries, apricot, and strawberry and causes <b>parthenocarpic fruits</b> in fig, guava, grape, tomatoes etc. It reduces <b>disorder of fruits</b> , e.g., water spot and corky spot in citrus

3.	Cytokinin	Maintain <b>green colour</b> of leafy vegetables and causes <b>parthenocarpic fruits</b> in fig.
4.	Ethylene	Ethephon increases <b>anthocyanin</b> (coloured grape, plum, apple, chillies, brinjal), carotenoides (mango, guava, papaya, citrus, tomato etc), <b>ascorbic acid and TSS</b> and reduces <b>tannin</b> (grapes, dates, etc) and acidity (grape, mango, tomato, etc.)
5.	Growth retardant	Alar ( $B_9$ ) increases <b>colour</b> in fruits, e.g., apple, cherry, apricot, etc. <b>Maleic hydrazide</b> (MH) inhibits <b>sprouting</b> in onion bulbs.
III	Root stock	In citrus Troyer and Carizzo (Citranges) rootstock produce the fruit of <b>excellent quality</b> of oranges, mandarins and lemons. In guava <i>P.pumilum</i> root stock <b>increases sugar</b> and <i>P.cujavillii</i> <b>ascorbic acid</b> content of fruits.
IV	Irrigation	Excess irrigation causes <b>high acidity</b> and deficiency of moisture reduces <b>fruit size, juice content</b> and increases <b>thickness of peel</b> .
V	Pruning	It affects the <b>size, colour, acidity and sugar content</b> of grape, phalsa, ber, peach, apple etc.
VI	Thinning	Thinning in grapes, dates, peaches, plum, etc., increases <b>size, colour, acidity and sugar</b> content of fruits.
VII	Girdling	In grapes, it increases <b>size, colour and sugar</b> content of the berries.
VIII	Variety	Varieties differ in <b>size, shape, colour and chemical composition</b> . <b>High yield, bright appearance</b> and good <b>shipping qualities</b> are most important characters of the varieties.
IX	Diseases and pests	Both are harmful to fruits and vegetables.
X	Pesticide	Pesticide spray residues may give rise to flavor taints in the processed product. Excessive use of pesticides may even produce harmful metabolites and toxicity not necessarily destroyed during processing.
XI	Maturity	In general vegetables with exception of potato and onion are of higher quality when less mature because they are more tender, succulent, less fibrous or starchy. On the other hand fruits when ripe are of higher quality on account of full size, bright colour, sweetness and less acidic.
XII	Mechanical injury	Fruits and vegetables should be in no case injured or damaged otherwise injury, such as skin abrasion and tissue bruising will reduce appearance and may be source

		of infection.
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### **Factors responsible for deterioration of harvested fruits and vegetables**

The major factors responsible for deterioration of fruits and vegetables during their post harvest life are:

**Four factors:** 1. Respiration 2. Transpiration 3. Ethylene 4.Mechanical damage to the harvested produce.

**I. RESPIRATION:** It is the most deteriorating biological process of the harvested fruits and vegetables which leads to oxidative breakdown of complex material (CHO/acids) into simpler molecules (CO<sub>2</sub>, H<sub>2</sub>O) with production of energy. Since the products are still alive after harvest, their living cells respire to secure energy. The equation for respiration is as follows.



The rate of respiration is again influenced by no of factors during storage. These factors are divided into two groups.(A) Plant factors ( B) Environmental factors.

**Plant Factors:**

- 1) **Soluble Sugars:** Soluble sugars particularly glucose are chief sugars used in respiration. Hence, the greater the conc of soluble sugars within the living tissues, the greater is the rate of respiration.
- 2) **Proportion of living cells:** Living cells require constant supply of energy. Respiration liberation the necessary energy. So the rate of respiration will be directly proportional to the number of living cells.
- 3) **Water content of the product:** The rate of respiration varies directly with water content of the product. Generally succulent products respire more rapidly than non-succulent products. Thus lettuce heads respire (detegrate) more rapidly than potatoes or sweetpotatoes or even peppers.

#### A) Environmental factors:

- a) **Concentration of O<sub>2</sub> + CO<sub>2</sub>:** More O<sub>2</sub> concentration more will be the respiration rate and vice versa.
- b) **Temperature:** Higher the temperature greater will be the respiration rate.

**II. TRANSPERSION:** It is the main cause of deterioration because it results in not only direct quantitative losses (loss of salable weight) but also in loss in appearance (wilting and shriveling), textural quality loss (softening loss of crispness) and loss in nutritional quality. Transpiration is also influenced by both plant factors as well as environmental factors.

#### A) Plant factors

1) **Differentiation of tissues:** Plant products differ in the degree of differentiation of their tissues and hence they differ in the rate of transpiration under the same conditions. In general, non-differentiated very succulent tissues contain more water than highly differentiated, non-succulent tissues. Under the same conditions tissues with high water content lose water more rapidly than tissues with low water content.

**Ex: Highly succulent** –Asparagus spears, spinach leaves highly differentiated products– mature cabbage heads, onions, celery etc.

**A) Outer cover:** Two kinds of tissues constitute the outer cover of plant products. These are epidermis and periderm. The epidermis consists of a single layer of living cells on the outer walls a layer of wax on epidermis retards transpiration, plant products with cutinized epidermis will shrink less rapidly in storage than those with non-cutinized epidermis.

The plant products with a well developed and non-injured periderm lose water less rapidly and keep longer in storage than those products with a poorly developed (or) badly injured or bruised periderm. Plant products which possess a periderm as the outer cover are apples, pears, citrus fruits, root crop vegetables, potatoes and sweet potatoes.

## B) Environmental factors:

- 1) **Temperature:** High storage temperature induces a greater rate of transpiration and greater shrinkage than comparatively low temperature.
- 2) **Relative humidity:** The rate of transpiration is inversely proportional to the relative humidity. In other words low relative humidity induces a high rate of transpiration and high RH induces low rate of transpiration.

**III. ETHYLENE:** All the living cells are capable of producing ethylene. Moreover, ripening fruits are rich source of ethylene production. The cuticle on fruit surface acts as a resistant barrier through which it is dissipated. This is one of the reasons, due to which internal concentration of ethylene within the fruit is greater than the external concentration in atmosphere.

Ethylene causes degreening in oranges and banana, it bleaches green colour of leafy vegetables, celery, cabbage, broccoli etc. In fruits and vegetables degreening related to ripening process.

The most obvious and studies effect of ethylene is an initiator of fruit ripening or, as contributor to ripening.

**IV. MECHANICAL DAMAGE:** The various mechanical injuries that can occur to a product are:-

**Roller bruising:** Fruits can severely damage by vibration or transit bruising some times called 'roller bruising'. Usually the damage occur on the fruit surface as a result of rubbing (or) vibration against another surface during handling transportation.

**Impact bruising:** It is as another injury that can affect fresh produce. This happens when the product drops onto a hard surface during filling of the package or from dropping of individual packages or even pallet loads of produce. The impact bruising may not be seen at the product surface, since the symptoms appear as internal damage.

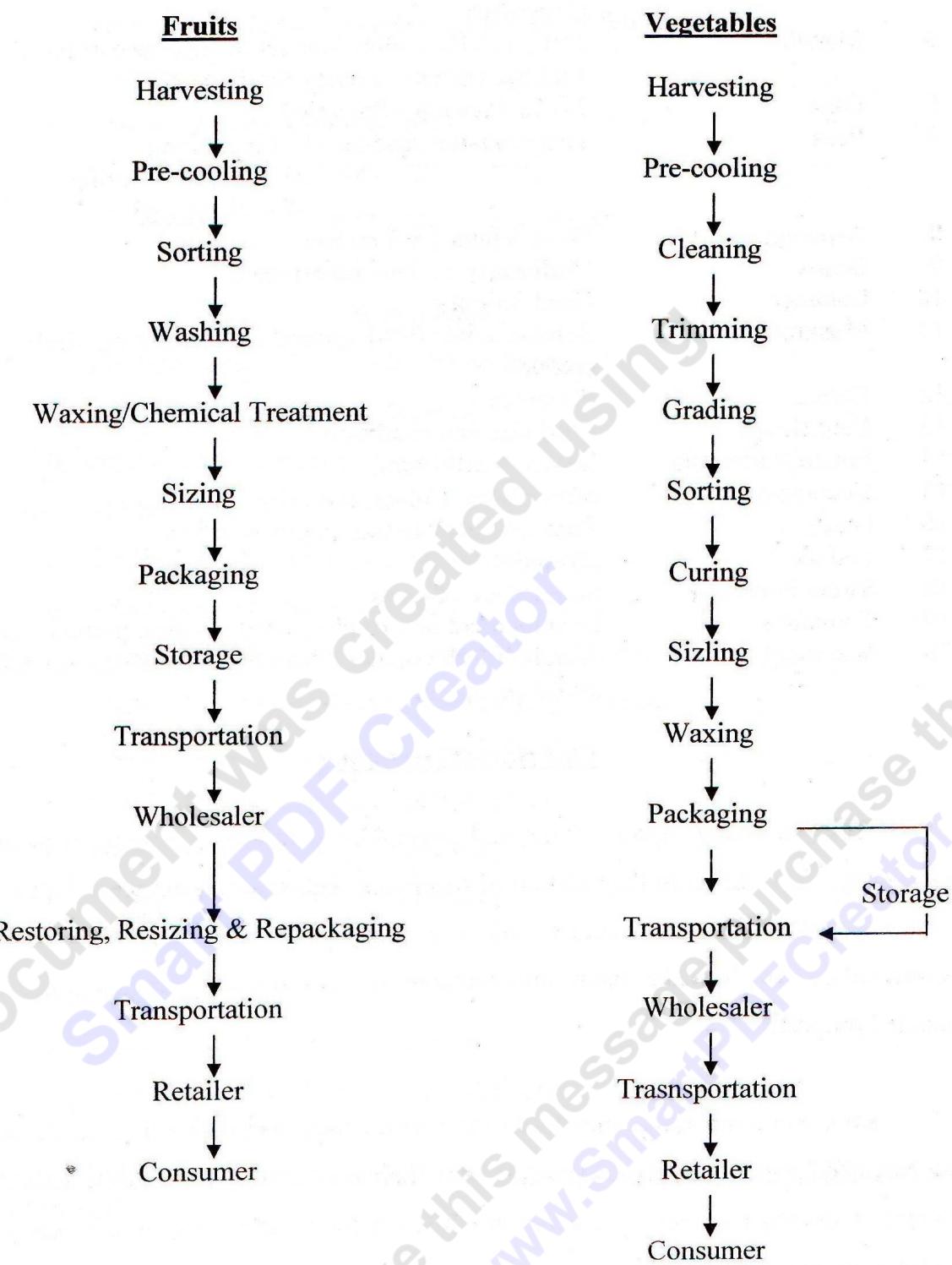
**Compression bruising:** It also causes losses and deterioration of fresh commodities. It occurs from simply 'squeezing' the product into too small a space.

**Pests and diseases--**Fruits and vegetables are attacked by a variety of insect pests which render them unfit for human consumption (or) reduce their market value. In all cases, infestation starts in the field. In most cases, damage is visible in the field itself and such fruits and vegetables are discarded during harvesting. However, in many cases the infestation is internal and not visible at the time of harvesting. It is only during post harvest storage/handling that the infestation becomes visible.

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**Flow Chart for Post Harvest Handling of Fruits and Vegetables**



## POST HARVEST HANDLING OF FRUITS AND VEGETABLES

Post harvest handling is the name given to all the processes through which the fruits and vegetables pass from the time of harvest till they are delivered to the consumer.

**(1) 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 field heat. It slows down the respiration of the produce, minimizes susceptibility to attack of micro-organisms, reduces water loss and eases the load on cooling system of storage or transport.

Currently used pre-cooling methods include room cooling, forced air cooling, water cooling, vacuum cooling and package icing.

a) **Room cooling:** It is relatively a simple method which needs only a refrigerated room with adequate cooling capacity. The produce is packed in containers which are loosely stacked in the cooling room, leaving enough space between containers for each one to be exposed to circulating cold air. The rate of cooling is rather slow compared to other methods of cooling, because the heat inside each container needs to be transferred to the surface of the container by means of conduction before being carried out by the refrigerated air. It may take hours or even days to cool the product depending upon what kind of product it is, the size and nature of container and the temperature and velocity of the circulating air.

All fruits and vegetables like banana ,beans, cabbage, coconut, garlic ,ginger,lemon,onion,orange, lime cucumber, pineapple, potato, pumpkin, radish, sweet potato, tomato watermelon are pre cooled by this method.

b) **Forced air cooling:** It is a more rapid way of air to cool the produce. Cold air is forced to flow through the inside of each container, so that it carries away heat directly from the surface of the produce rather than from the surface of the container. The air flow is produced by creating a pressure difference between the two perforated sides of each container. The containers are stacked inside covered tunnel with an exhaust fan at one end. Highly perishable and high value products such as grapes, strawberries and raspberries may be cooled in less than an hour using this method.

Fruits and fruit type vegetables like banana, berries, Brussels sprouts ,cucumber, egg plant, fig, ginger, grape, guava ,litchi, mango, kiwi fruit, okra, oranges, papaya, passion fruit, bell pepper, pineapple, pomegranate, sapota, straw berry, tomato, tubers, cauliflower etc are pre cooled by this method.

c) **Water cooling (Hydro cooling):** It is also known as hydro cooling. It is rapid and less expensive method. Produce is exposed to cold water by

means of showering or dipping. The required cooling time is often a matter of minutes. However not all kinds of products tolerate hydro cooling. Hydrocooled products inevitably have a wet surface which may encourage decay in some kinds of produce.

Some leafy vegetables, fruits like artichoke, asparagus beet, broccoli, Brussels sprouts, cantaloupe, carrot, cauliflower, celery, Chinese cabbage, cucumber, brinjal, green onion, kiwifruit, leek ,knoll-khol ,orange, parsley, parsnip, peas, pomegranate, radish, spinach, rhubarb, swiss chard, summer squash etc. are pre cooled by this method.

d) **Vacuum cooling:** It is the most efficient method for cooling leafy vegetables, particularly headed ones such as lettuce, cabbage and Chinese cabbage. The produce is placed inside a vacuum tube in which air pressure is reduced. When the pressure is reduced to 4.6mm Hg, water boils of at  $0^{\circ}\text{C}$  from all over the leaf surface. The boiling effect draws heat for vaporization and hence cools the produce. The cooling time is usually in the order of 20-30 minutes. The equipment needed for vacuum cooling is very expensive, and may not be good choice for small scale

Some stem, leafy and flower type vegetables like endive, Brussels sprouts, carrot, cauliflower, Chinese cabbage, celery, leek, lima bean, spinach, sweet corn, swiss chard etc. are pre-cooled by this method.

e) **Package-icing or top icing:** It is the simplest way of cooling. Adding crushed ice, flake ice or slurry of ice in containers can cool the produce. However this method is not suitable for produce which is very sensitive to ice cold temperatures .Cooling by ice is also inevitably wets both the produce and the container and generates water which needs to be drained. Roots, stems, flower type vegetables like endive ,broccoli, Brussels sprouts, carrot, spring, onions ,Chinese cabbage, leek, parsley, snow peace, spinach, swiss chard, sweet corn etc. are pre-cooled by this method.

(2) **Curing:** It is done immediately after harvesting. It strengthens the skin. The process is induced at a relatively higher temperature and humidity involving sterilization 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, garlic are cured prior to storage or marketing.

In Sweet potato this condition is most rapid at  $33^{\circ}\text{C}$  and relative humidity of 95%. Potato tubers are held at  $18^{\circ}\text{C}$  for 2 days and then at  $7^{\circ}\text{C}-10^{\circ}\text{C}$  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. Maximum safe temperature for onion curing at field is  $37.8^{\circ}\text{C}$  for 3-5 days. Artificial curing of onions in crates at  $40^{\circ}\text{C}$  for 16 hours reduces rot losses in storage.

**(3) De-greening:** It is the process of decomposing green pigments in fruits usually by applying ethylene or other similar metabolic inducers to give a fruit its characteristic colour as preferred by the consumer. It is applicable to banana, mango, citrus and tomato. The time required to degreen a fruit depends upon the degree of natural colour break at maturity. The higher the green colour and more mature a fruit is, the less time is required to reduce the chlorophyll to a desired level. De-greening is carried out in special treating rooms with controlled temperature and humidity in which low concentrations ethylene (20ppm) is applied to keep the CO<sub>2</sub> level below 1 % (Low colouring). The ethylene should be supplied from a gas cylinder. These rooms are thoroughly ventilated to keep the carbon-dioxide level below 1%, which does not allow higher colouring. Ethylene accelerates decomposition of chlorophyll without significantly affecting the synthesis of carotenoid pigments. The best degreening temperature is 27°C. Higher temperature delay degreening. The Relative humidity should be 85-90%. Higher humidity levels cause condensation during degreening and are associated with slow degreening and increase in decay. Low humidity though checks decay causes excessive shrinkage, shriveling and peel break down.

**(4) Washing and drying:** Most of the fruits and vegetables are washed after harvesting to improve their appearance, prevent wilting and remove primary inoculum load of micro organisms. Hence fungicide or 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 this would otherwise encourage microbial spoilage. Root and tuber crops are often washed to remove the soil adhering to them.

**(5) Sorting and grading:** Immature, diseased and badly bruised fruits and vegetables are sorted out. Most of the countries have their own set of standards of domestic trade and for international trade standards have also been defined. Grades are based on size, weight, colour and shape. Grading is done manually or mechanically.

**(6) Dis-infestation:** Papaya, mango, melon and other fruits are susceptible to fruit fly attacks. Dis-infestation is done either by vapour heat treatment at 43°C with air saturated with water vapour for 6-8 hours, by ethylene dibromide fumigation (18-22g of EDB/cubic meter for 2-4 hours. Residues of inorganic bromide must not exceed 10Vg/g) or by cold treatment (exposure of fruits to near freezing temperature for a specified period.)

**(7) Post harvest treatments:** Post harvest application of Bavistin (0.1%) and topsin (0.1%) controls storage diseases in mango. In Nagapur mandarins, hot

water treatment with Imazalil (0.1%), Bavistin (0.1%) and Benlate (0.1%) is most effective. A complete inhibition of sprouting of cool chamber (evaporatively cooled) stored potatoes for 4 months and 5 months is achieved by spraying them with an aqueous emulsion of CIPC @ 50mg and 100 mg/kg of tubers respectively before completion of dormancy period.

**(8) Waxing:** Fruits and vegetables have a natural waxy layer on their outer surface which is partly removed by waxing. An extra layer of wax is applied artificially with sufficient thickness and consistency to prevent an aerobic condition within the fruits provides necessary protection against decay organisms. Waxing is especially important if tiny injuries and scratches on their surface are present. These can be sealed by wax. Waxing also enhances the glossiness of fruits or vegetables. Therefore, appearance is improved making them more acceptable.

If refrigerated storage facilities are not available, protective skin coating with wax increases the storage life of fresh fruits and vegetables at ambient temperature.

There are two types of wax emulsions. **Wax-W**-which does not impart any glass to fruits and vegetables, where as **wax 'O'** impart glass.

The application of wax emulsion to freshly harvested healthy produce protects them against excessive moisture loss, higher rate of respiration, heat build up or thermal decomposition. The texture and quality of fresh produce is maintained as nearer to the fresh conditions as possible for a long time.

The wax emulsion without fungicide doesn't protect fruits and vegetables against microbial spoilage. So, to protect fruits and vegetables from microbial spoilage suitable fungicides are added to the wax emulsion.

**(9) Control of ripening process:** Ripening transforms a physically mature but inedible plant organ in to a visually attractive taste and smell sensation. It marks the completion of development and commencement of senescence with the life of a fruit and is normally an irreversible event.

For ripening adequate quantity of ethylene should be used in the ripening room at regular intervals. A concentration of CO<sub>2</sub> above 1% delays ripening. Hence, thorough ventilation is necessary. By use of ethephon commercially known as ethrel, making it alkaline using caustic soda (3 g of soda for 20ml of ethephon). Calcium carbide can also be used for ripening (100g for 100kg of fruits). Ripening in fruits and vegetables can be retarded by using proper packaging, low temperature, ethylene absorbents, skin coating of waxol, growth retardants and using fungicides for controlling their spoilage.

**Frutox** (fungicidal waxol) and **Tal prolong** (1.0-1.5%) retarded ripening in mango.

**Frutox** is more efficient than **Tal prolong** to retard ripening.

Use of **cycocel** (500mg/lit), **Alar** (500mg/lit), **GA** (250mg/lit) significantly retards ripening.

Use of **Purafil** (alkaline potassium permanganate on a silicate carrier) is effective in the complete absorption of ethylene in banana held in sealed polythene bags.

**(10) Pre-packaging in plastic films:** This increases shelf life by creating a modified atmosphere with an increase in concentration of CO<sub>2</sub> in the package. The packaging material should provide reasonable access to oxygen. For this, breathing film like polyesterine and cellulose acetate are used. But tougher LDPE films which have high O<sub>2</sub> and CO<sub>2</sub> transmission rates are more durable.

The pouches must have perforations to transmit O<sub>2</sub> and CO<sub>2</sub> rapidly enough for the respiration of fresh produce. The pouches used reduce bruising, facilitates inspection, reduces moisture loss (weight loss) and prevents dehydration. It also creates modified atmosphere.

**(11). Palletization:** Pallets are widely used for the transport of fruit & vegetable packages, in all developed countries. Loading and unloading are very important steps in the post harvest handling of fruits and vegetables but are often neglected. Loading and unloading are done manually in India. Due to low unit load there is a tendency to throw, drop or mishandle the package damaging the commodity. This loss can be considerably reduced by using pallet system. However; this requires the standardization of box dimensions. For each commodity it should be worked out. Once this is accomplished, mechanical loading and unloading become very easy with the fork lift system.

**The advantages of handling packages on pallets are:**

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

**(12). Transportation:** For selecting the mode of transport, the distance to reach the destination as well as perishability of the commodity should be considered. For highly perishable ones there should be minimum temperature rise during transit. Transport should be preferred for perishable commodities than rail transport. For local transport the produce is brought by bullock carts or tractor trolleys, carts, trailers and trucks used in the field should have good suspension and low tyre pressure to avoid excessive jolting of produce. They should be driven slowly. Lining of the trailer with straw or leaves can also help prevent damage.

**(13). Storage:** The marketable life of most fresh vegetables can be extended by prompt storage in an environment that maintains product quality. Storage methods can be grouped into two.

**Traditional methods (Low cost storage structures)**—In-situ, clamps, wind breaks, cellar storage, barns, night ventilation, sand and coir, night temperature cooling, natural ice and well water cooling.

**Advanced methods (Low temperature storage -cold storage)** Hydro cooling, hypobaric storage, evaporative cooling, forced air cooling, controlled atmospheric storage and modified atmospheric storage.

**(14) Irradiation:** Application of irradiation for suppressing sprouting and hence extension of shelf life has been allowed in India. Sprouting onion can be checked by gamma irradiation at a dose of 0.06-0.1 kGY. In potato gamma irradiation at 0.1 kGY can inhibit sprouting completely. The irradiated potatoes could be stored successfully for 6 months at 15°C with 10% loss.

Irradiation in Banana, Guava, Mango and papaya improves shelf life due to delay in rate of ripening and senescence.

## Ripening

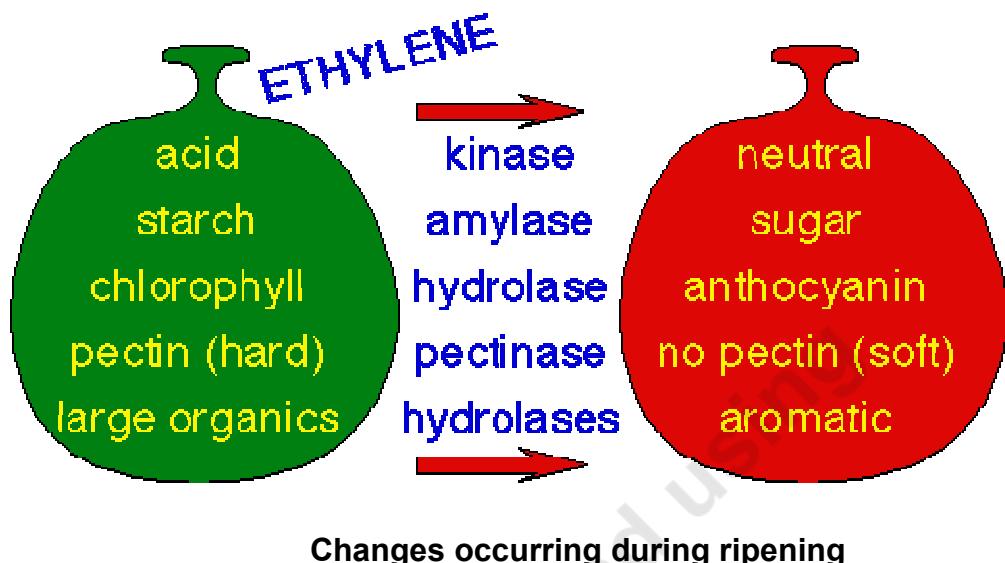
Ripening refers to the changes that occur in a mature fruit either before harvest or after harvest. Ripening renders the product edible. Unripe fruits are not edible in most cases. Ripening fruits undergoes many physico chemical changes after harvest that determines the quality of the fruit eventually purchased by the consumer. Ripening is a dramatic event in the life of a fruit – it transforms a physiologically mature but inedible plant organ into a visually attractive olfactory and taste sensation. Ripening marks the completion of the development of a fruit and the commencement of senescence, and it is normally an irreversible event. Ripening is the result of a complex of changes, many of them probably occurring independently of one another.

Some fruits ripen on the tree itself, while others ripen only after harvest. Those, which don't normally ripen on the tree, drop off from the tree after attaining maturity if they are not harvested in time. There are two characteristic types of fruit ripening that shows different patterns of respiration.

**Non climacteric fruit ripening**—refers to those fruits which ripen only while still attached to the parent plant .Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase further. Respiration rate slows gradually during growth and after harvest. Maturation and ripening are a gradual process. Eg. Cherry, cucumber, grape, lemon, pineapple, grape, citrus, straw berry etc.

**Climacteric fruit ripening**—refers to the fruits that can be harvested when mature but before ripening has begun. These fruits may be ripened artificially. The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Eg.apple, banana, mango, sapota melon, papaya, tomato etc.

# Fruit Ripening



During ripening, changes occur in colour, texture, taste, aroma and chemical constituents. These changes progress till the maximum edibility or taste is attained and thereafter the degradation or break down of tissues starts, rendering it unfit for eating. These changes are closely associated with the rate of respiration of the fruit.

**Colour:** Colour change is the most obvious signal; it occurs in many fruits and is often the major criterion used by consumers to determine whether fruits ripe or unripe. Marketability of fruit depends largely on the attractive colour it develops.

The colours arise from carotene, xanthophylls and anthocyanin pigments. Carotene and xanthophylls are yellow in colour and other colours of fruits like red, pink, violet etc are imparted by anthocyanin pigments.

The most common change is the loss of green colour. With a few exceptions, e.g. avocado, kiwifruit and granny smith apple, climacteric fruits show rapid loss of green colour on ripening. Many non-climacteric fruits also exhibit a marked loss of green colour with attainment of optimum eating quality, for example citrus fruit in temperate climates (but not in tropical climates). The green colour is due to the presence of chlorophyll, which is a magnesium–organic complex. The loss of green colour is due to the degradation of the chlorophyll structure.

The disappearance of chlorophyll is often associated with the synthesis of pigments ranging from yellow to red. Many of these pigments are carotenoids, which are unsaturated hydrocarbons. Carotenoids are stable compounds and remain intact in the tissue even when extensive senescence has occurred. Carotenoids may be synthesized during the development stages on the plant, but they are masked by the presence of chlorophyll. Following the degradation of chlorophyll, the carotenoid pigments become visible. With other tissues, carotenoid synthesis occurs concurrently with the chlorophyll degradation.

Banana peel is an example of the former system and tomato of the latter. As the tomato fruit matures, the predominant carotenoid that is synthesized is carotene.

Anthocyanins provide many of the red purple colours of fruit and vegetables and flowers. Anthocyanins are water soluble phenolic glucosides that can be found in the cell vacuoles of fruit and vegetables such as beet root, but are often in the epidermal layers as with apple and grape. They produce strong colours, which often mask carotenoids and chlorophyll. Some fruits like grapes, pomegranate produces anthocyanins when mature. In tomato another pigment accumulates during ripening is lycopene.

The factors that effects fruit colorations are weather, temperature humidity, carbohydrate accumulation, and practices like ringing or girdlings and basketing of fruits. Manuring and irrigation also influence the brightness of colour. Excessive nitrogen tends to delay colour development. Shaded fruits don't develop good colour.

**Organic acids:** Usually organic acids decline during ripening as they are respired or converted to sugars. Acids can be considered as reserve source of energy to the fruit and would therefore, be expected to decline during the greater metabolic activity that occurs on ripening. There are exceptions, such as banana, where the highest level is attained at the full ripe stage, but the level is not high at any stage of development compared to the other produce.

**Texture:** Terms such as firmness, crispness, mealiness, juiciness and hardness are all related to the texture of fruits and is controlled by the wall to wall adhesion of cells. Fruits become soft on ripening, mainly due to the dissolution of pectic substances in the cell walls. The softening is due to enzymatic hydrolysis of polysaccharides. The cell wall is made up of cellulose, hemicellulose, calcium pectatae, polyuronoides and glycoproteine. The enzyme pectinase break down pectin between the fruit cells resulting in softening of the fruit

**Taste:** Taste depends on the proper proportion of sugars and acids. So, it is convenient to measure taste as sugar-acid ratio (Brix-acid ratio). Acidity and astringency gradually disappear, while sweetness increases due to conversion of starch to sugars during the course of fruit ripening. Starch content of banana decreases from initial 21% to about 15% in ripened fruit. This is accompanied by accumulation of sugars mainly sucrose to the extent up to 20% by fresh weight.

**Aroma:** Aroma plays an important part in the development of optimal eating quality in most fruit. It is due to synthesis of many volatile organic compounds (often known merely as volatiles) during ripening phase. Together with taste, it constitutes flavour. Aroma usually develops during ripening but occasionally in storage also. During ripening enzymes break down large organic molecules into

smaller one that can be volatile (evaporate into the air) and can be detected as an aroma.

The flavouring compounds are found to be different in different types of fruit but all of them are volatile. The aroma of fruit is not due to a single chemical compound but it is a mixture of no. of chemicals, which may be derived from aliphatic compounds, alcohols, acetates, ketones or esters and terpinoides. In most of the fruits, the bioconversion of flavouring compounds increase with the advent of ripening. The process needs specific temperature for difficult types of fruits.

The major volatile formed is ethylene, which accounts for about 50-75% of the total carbon in the volatiles; ethylene does not contribute to typical fruit aromas. The amount of aroma compounds is therefore extremely small. Non-climacteric fruits also produce volatiles during the development of optimum eating quality. The fruits doesn't synthesize compounds as aromatic as those in climacteric fruit; nevertheless, the volatiles produced are still important in consumer appreciation.

**Abscission:** During ripening the pectinase enzyme also unglue the cells of the abscission zone (the layer of cells in the pedicels often called abscission zone). So, the cells in this zone become weak and the weight of the fruit will cause it to fall from the plant.

**Development of surface wax:** The delicate waxy or powdery substance develops on the surface of certain fruits like grape and berries.

**Respiration rate:** It is essential for ripening as it provides the energy required to drive many of the reactions and changes. If respiration is inhibited, ripening is also inhibited. Based on respiration characteristics fruits and vegetables can be divided into climacteric and non-climacteric. In non-climacteric fruits relatively low, consistant rate of respiration is maintained during ripening. The fruits often don't have large carbohydrate reserves and ripening occurs while attached to the plant. Cucumber and olive are vegetables that are non-climacteric.

In contrast, in climacteric fruits the respiration declines during the final stages of maturation, as ripening proceeds the respiration rate increases rapidly reaching peak (often referred as climacteric peak) after which there is a subsequent decline in respiration. Tomato and bitter melon exhibit climacteric ripening.

**Chemical changes:** Starch is hydrolyzed in to sugars (Glucose and fructose), pectin's become soluble, acids disappear and tannins responsible for astringency are eliminated by the action of enzymes.

## Factors influencing ripening

**Temperature:** Fruits picked up at right time generally ripen at any temperature between two critical limits. In certain cases fruits may require a cold treatment before being placed in the temperature limit for ripening.

Temperature affects the rate of synthesis of specific pigments and their final concentration in the fruit. The optimum and maximum temperature for synthesis of a specific pigment varies between species. For example lycopene synthesis in tomato is inhibited at 30°C where as in watermelon; synthesis is not prevented until the fruit temperature rises above 37°C.

**Carbon- di- oxide:** Elevated levels of CO<sub>2</sub> will inhibit ripening due to decrease in respiration.

**Oxygen:** Reduced levels of oxygen inhibit the ripening of fruits and vegetables. The use of elevated CO<sub>2</sub> and reduced O<sub>2</sub> levels in refrigerated storage is called Controlled atmospheric storage.

Oxygen is essential for carotenoid synthesis and increasing the oxygen concentration enhances the synthesis of this pigment.

**Radiation:** May act as inhibitors or stimulators of ripening. Grapes ripen more quickly under treatment with 'infrared' radiations. Banana irradiated with 'X' rays exhibited a decrease in softening but an increase in skin blackening.

**Air humidity:** The relative humidity and velocity of the air in the vicinity of the fruit influence the maturity, especially in the evolution of flavour. Saturated air hinders the development of good flavour in pears. Apples show blackening of the core.

**Volatiles:** Non-ethylic volatiles can stimulate ripening. Air purification with activated carbon, H<sub>2</sub>SO<sub>4</sub> 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.

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 is 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.

The shelf life of fruits like apple, banana and others can be improved by storing the fruit in low oxygen tension (20%) or by absorbing ethylene with a suitable absorbent like alumina or silica gel impregnated with potassium permanganate. MH, GA( $10^{-6}$ M), IAA( $10^{-6}$ M) sprays one to two weeks before harvesting and post harvest dip of cycocel, Alar, GA(150ppm), Vit K<sub>3</sub>, KMNO<sub>4</sub>, Ca Cl<sub>2</sub>, Waxol delays ripening.

**Harvest:** The extent to which certain fruits are pre-climacteric or post climacteric at the time of harvest is an important factor affecting ripening. The mere act of picking may influence the ripening rate of certain fruits. Detachment accelerates ripening of fruits like avocado and apple. It has been postulated that an inhibitory auxin was contributed by the leaves while the fruit is attached to the tree. In fruits like citrus, apples, bananas and avocados bruising often stimulates ripening. so; careful handling of fruits at the time of harvest is required.

**Chemicals that delay ripening and senescence:** (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) KMnO<sub>4</sub> (b) Fumigants like methyl bromide (c) Reactants

### **Chemicals for hastening and delaying ripening of fruits and vegetables**

**Hastening ripening:** These sometimes 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..

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**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 is 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.

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### **Storage of fruits and vegetables**

Proper marketing of perishable commodities such as fruits and vegetables often requires some storage to balance day to day fluctuations between harvest and sale for long term storage. Storage improves commodities quality, usefulness and also controls a market glut. The principal goal of storage is to control the rate of transpiration, respiration, disease and insect infestation. Storage life can be prolonged by harvesting at proper maturity, control of post harvest diseases, regulation of atmosphere, chemical treatments, irradiation, refrigeration and controlled and modified atmosphere.

#### **The main goals of storage are:**

- Slow the biological activity without chilling injury
- Slow the growth of micro-organisms.
- Reduce transpiration loss.

#### **The factors which need to be taken into account before embarking on crop storage are:**

- Knowledge of the appropriate storage conditions
- Cultivar or variety of crop suitable for storage
- Availability of appropriate storage facilities
- Availability of suitable management.

Fruits and vegetables are living organisms. Their condition and marketable life will deteriorate during storage through—

- 1) Loss of moisture

- 2) Loss of stored energy—carbohydrates
- 3) Loss of other foods
- 4) Physical losses through pest and disease attack
- 5) Loss in quality from physiological disorders,
  - Fibreness (asparagus)
  - Greening (potatoes)
  - Rooting (due to increased humidity)
  - Shoot growth and elongation (asparagus,carrot,beet)
  - Seed germination
  - Fruit growth
  - Sprouting (potatoes, onion, ginger, garlic)
  - Toughening (due to high temperaturein beans and sweet corn)

#### **Factors affecting storage:**

- a) Temperature
- b) Relative humidity
- c) Air velocity
- d) Atmosphere composition
- e) Light
- f) Storage operations

**Methods of storage:** Mainly there are two methods of storage i.e. traditional methods and advanced methods.

**I. Traditional methods** (Low cost storage structures) not requiring refrigeration include: *in situ*, sand, coir, pits, clamps, windbreaks, cellars, barns, evaporative cooling, and night ventilation:

- a) **In situ.** This method of storing fruits and vegetables involves delaying the harvest until the crop is required. It can be used in some cases with root crops, such as cassava, but means that the land on which the crop was grown will remain occupied and a new crop cannot be planted. In colder climates, the crop may be exposed to freezing and chilling injury. In some commodities development of undesirable fibre and starch occurs. There are chances of occurring damage due to insect pests and diseases.
- b) **Sand or coir:** This storage technique is used in countries like India to store potatoes for longer periods of time, which involves covering the commodity under ground with sand.
- c) **Pits or trenches:** These are dug 1.0-1.5m deep at the edges of the field where the crop has been grown. Usually pits are placed at the highest point in the field, especially in regions of high rainfall. The pit or trench is lined with straw or other organic material and filled with the crop being stored,

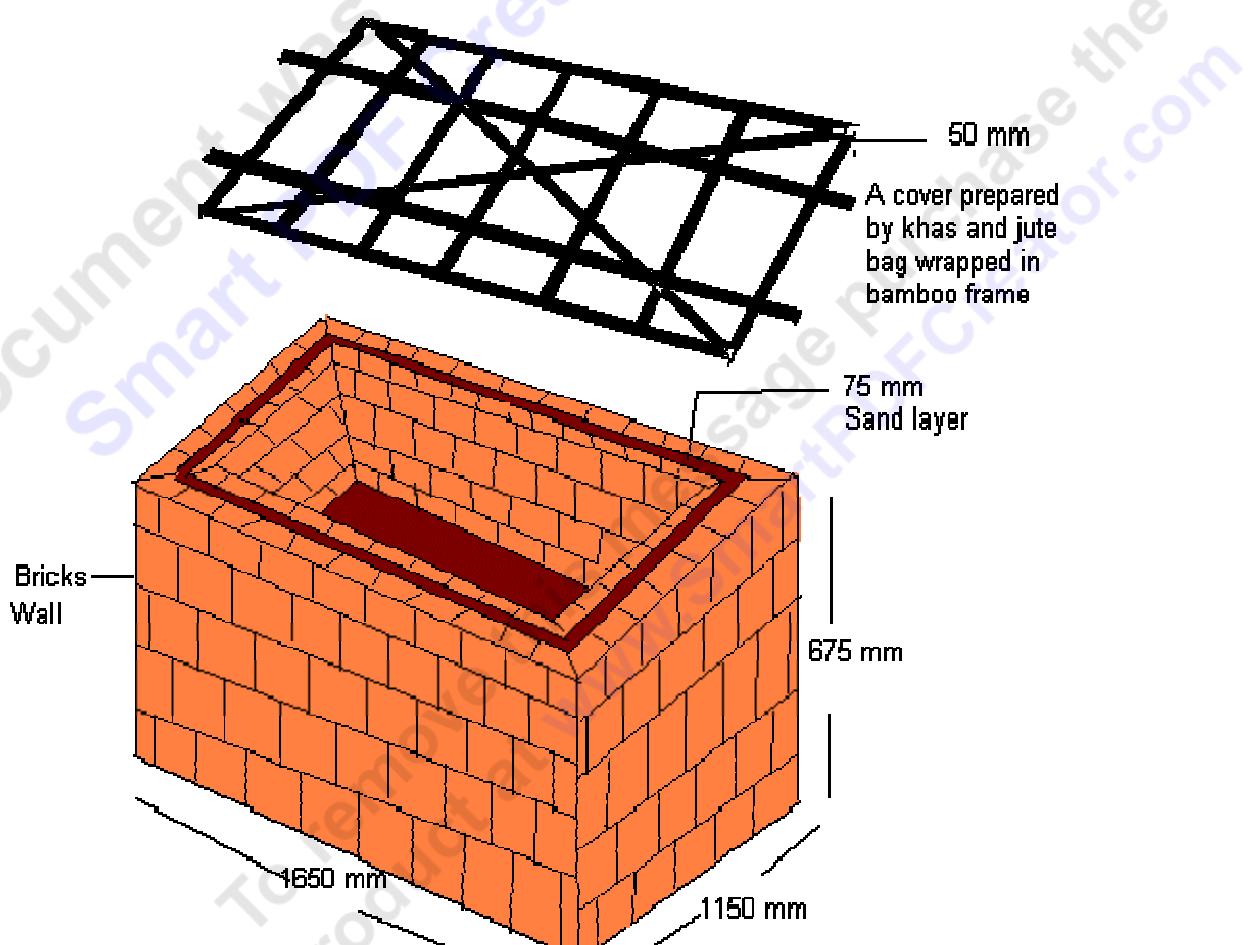
then covered with a layer of organic material followed by a layer of soil. Holes are created with straw at the top to allow for air ventilation, as lack of ventilation may cause problems with rotting of the crop. This method is suitable for storing **ginger**.

This method is not suitable for fruits and leafy vegetables demanding high humidity because it cannot maintain high humidity. The stored commodity can not be examined frequently for rotting etc.

- d) **Clamps.** This has been a traditional method for storing **potatoes, cassava** etc. in some parts of the world, such as Great Britain. A common design uses an area of land at the side of the field. The width of the clamp is about 1 to 2.5 m. The dimensions are marked out and the potatoes piled on the ground in an elongated conical heap. Sometimes straw is laid on the soil before the potatoes. The central height of the heap depends on its angle of repose, which is about one third the width of the clump. At the top, straw is bent over the ridge so that rain will tend to run off the structure. Straw thickness should be from 15-25 cm when compressed. After two weeks, the clamp is covered with soil to a depth of 15-20 cm, but this may vary depending on the climate. Produce may desiccate because of low relative humidity. Large heaps may result in more incidence of rotting.
- e) **Windbreaks** are constructed by driving wooden stakes into the ground in two parallel rows about 1 m apart. A wooden platform is built between the stakes about 30 cm from the ground, often made from wooden boxes. Chicken wire is affixed between the stakes and across both ends of the windbreak. This method is used in Britain to store onions.
- f) **Cellars.** These underground or partly underground rooms are often beneath a house. This location has good insulation, providing cooling in warm ambient conditions and protection from excessively low temperatures in cold climates. Cellars have traditionally been used at domestic scale in Britain to store **apples, cabbages, onions, and potatoes** during winter. Produce may desiccate due to low relative humidity.
- g) **Barns.** A barn is a farm building for sheltering, processing, and storing agricultural products, animals, and implements. Although, there is no precise scale or measure for the type or size of the building, the term barn is usually reserved for the largest or most important structure on any particular farm. Smaller or minor agricultural buildings are often labeled as sheds or outbuildings and are normally used to house smaller implements or activities.
- h) **Evaporative cooling.** When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a

pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage.

- i) **Zero energy cool chamber (ZECC):** It is a low cost storage structure suitable for short duration storage fruits and vegetables. There is no need of any power source i.e. electricity, diesel, petrol etc. for cooling, thus, the name zero energy cool chamber. The zero energy cool chamber based on evaporative cooling system. Evaporation occurs when air that is not already saturated with water is blown across any wet surface. Thus an evaporative cooler consists of a wet porous bed through which air is drawn, cooled and humidified by evaporation of water. In summer, when outside temperature is  $44^{\circ}\text{C}$ , the maximum temperature inside the chamber never goes beyond more than  $28^{\circ}\text{C}$ , the relative humidity being 90%.



- j) **Night ventilation.** In hot climates, the variation between day and night temperatures can be used to keep stores cool. The storage room should be well insulated when the crop is placed inside. A fan is built into the store room, which is switched on when the outside temperature at night becomes lower than the temperature within. The fan switches off when the temperatures equalize. The fan is controlled by a differential thermostat, which constantly compares the outside air temperature with the internal storage temperature. This method is used to store bulk onions.

k) **Controlled atmospheres** are made of gastight chambers with insulated walls, ceiling, and floor. They are increasingly common for fruit storage at larger scale. Depending on the species and variety, various blends of O<sub>2</sub>, CO<sub>2</sub>, and N<sub>2</sub> are required. Low content O<sub>2</sub> atmospheres (0.8 to 1.5%), called ULO (Ultra -Low Oxygen) atmospheres, are used for fruits with long storage lives (e.g., apples).

## **II. Advanced (high cost) methods of storage:**

**1. Low temperature storage (Refrigerated or cold storage):** Microbial growth and enzyme reactions are retarded in food storage at low temperatures. The lower the temperature, the greater the retardation. Low temperatures employed can be

- a) Cellar storage temperature (about 15°C)
- b) Refrigeration or chilling temperature (0°C to 5°C)
- c) Freezing temperature(Cold storage) (-18°C to -40°C)

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

**1(b) Refrigeration or chilling temperatures (0°C to 5°C):** Refrigerated storage or low temperature storage is the most common method of storage through out the world both for fruits and vegetables. Refrigeration is the process of removing heat from an enclosed space or room or a substance or commodity. The primary purpose of refrigeration is lowering the temperature of the enclosed space or substance or commodity and then maintaining that lower temperature.

**1(c) Cold storage:** At temperatures below the freezing point of water (-18°C to -40°C) growth of micro organisms and enzymes activity are reduced to the minimum. Most perishable foods can be preserved for several months if the temperature is brought down quickly(called quick freezing) and food held at these temperatures. Foods can be quick frozen in about 90 minutes or less by (1) placing them in contact with the coil through which the refrigerant flows(2) blast freezing in which cold air is blown across

the food,(3) by dipping in liquid nitrogen. Quick frozen foods maintain their identity and freshness when they are thawed (brought to room temperature) because of very small crystals are formed when foods are frozen by these methods. Many micro-organisms can survive this treatment and may become active and spoil the food if the foods are held at higher temperatures. Frozen foods should always ,therefore be held at temperatures below -5°C. Enzymes in certain vegetables can continue to act even after being quick frozen and so vegetables have to be given heat treatment called blanching(above 80°C) before they are frozen to prevent development of off flavours.

**(2) Controlled / Modified atmosphere storage:** In this system the produce is held under atmosphere conditions modified by package, over wrap, box liner or pellet cover. The first requirement of CAS is sufficiently gas tight envelops around the produce and the second requirement is some means of maintaining the concentration of CO<sub>2</sub> and O<sub>2</sub> at the desired level. This method in combination with refrigeration markedly enhanced the storage life of fruits. The fruit that has derived the most benefit is apple. Among the tropical fruits, the best atmosphere for storage of mangoes is 5% CO<sub>2</sub> and 5% O<sub>2</sub> at 13°C. CAS improved the appearance of pine apple fruit by reducing the superficial mould growth. The optimum O<sub>2</sub> level was 2%. Levels of oxygen below that were ineffective in extending storage life. Benefits could be obtained with papaya when the fruits are stored in 5% CO<sub>2</sub> and 1 % O<sub>2</sub> for 3 weeks at 13°C. Initiation of ripening in banana can be delayed for weeks or months by holding the green banana fruits in an atmosphere of 1-10% O<sub>2</sub>, 5-10% CO<sub>2</sub> or low O<sub>2</sub> and high CO<sub>2</sub> combination, In general, the response of citrus fruits to CAS has been disappointing. In MAS the composition of the storage atmosphere is not closely controlled.

**(3) Hypobaric (Sub atmosphere) storage:** The commodity is placed in a vacuum tight and refrigerated container and evacuated by a vacuum pump to the desired low pressure. The process of ripening and senescence are greatly retarded by decreasing

respiration and evacuation of ethylene given out by the produce. This is an expensive method.

**(4) Irradiation:** Application of irradiation for suppressing sprouting and hence extension of shelf life has been allowed in India. Sprouting onion can be checked by gamma irradiation at a dose of 0.06 - 0.1 kGY. In potato gamma irradiation at -0.1 kGY can inhibit sprouting completely. The irradiated potatoes could be stored successfully for 6 months at 15°C with 10% loss. Irradiation in banana, guava, mango and papaya improves shelf life due to delay in rate of ripening and senescence.

### **Packing (packaging) and Packaging materials**

Packing of fruits and vegetables and also their processed products plays a vital role in day to day life.

Packaging can be defined as; " **Techno-economic**" function arrived at minimizing cost of delivery while maximizing sales. It is a coordinated system of packaging

goods for transport, distribution, storage, retailing and use. Packaging plays a vital role in the conservation, preservation and transport.

### **Importance of packaging:**

Food packaging is an integral part of food processing and it is link between food processor and consumer.

Packaging protects the contents against dehydration, oxidation, light, flavour loss, environmental factors and mechanical damage. It serves as a processing aid.

Package is a convenience item for the consumer, can also be cost saving device.

Package provides handling facilities for loading, transport, storage for long for both the processor and consumer.

### **Methods of packaging / Packing:**

**(1)Edible film 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.

The most common form of coating fruits and vegetables is wax coating to retard respiration, dehydration and senescence. Edible films selected should meet the requirements such as physicochemical and microbial stability, good sensory qualities, high carrier and mechanical efficiencies, free of toxic and safe for health, simple technology, non-polluting and low cost of material and process.

**(2)Modified humid packaging:** Mostly used for highly perishable commodities like green leafy vegetables. MHP systems are designed to control not only dehydration but also condensation. Water absorbents like  $\text{CaCl}_2$ , Sorbitol or xylitol in the package or by use of packaging with good permeability enables to provide required MHP system.

**(3) Protect packaging:** The term is used to packaging which is primarily designed to protect the product than for appearance, or presentation so, generally is used to the outer containers used for transporting goods from the manufacturer to the point of sale and filling materials inside the outer container, e.g, nylon barrier sealed bubble packaging.

**(4) Shrink wrap/Individual seal packaging:** Individual seal packaging involves the use of heat shrinkable film (usually HDPE) that is wrapped around the individual units of fruits and vegetables and shrunk by blowing hot air over the

package. Advantages of this packaging are ripening is delayed by micro atmosphere created around the product. The films act as good barrier to water. Prevents the spread of disease from one product to another, improve the handling and sanitation of the product, and facilitates pricing and labeling of individual products. However, off odours may occur with result of poor gas exchange and high RH.

**Active packaging:** Another way of modifying the atmosphere pack is by using, "Active packing". Packaging is termed as "Active", when it performs some desired role other than to provide an inert barrier to the external environment. The goal of developing such packaging is to create a more ideal match of the properties of the package to the requirements of the food. A wide variety of materials have been used for this purpose. Active packaging can be created by using oxygen scavengers, carbon-di-oxide absorbents / emitters, ethanol emitters and ethylene absorbents. The appropriate absorbent material is placed along side the fresh produce. It modifies the head space in the package and thereby contributes to the extension of shelf life of the fresh produce.

**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 atmospheric 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 atmospheric pressure due to vacuum inside the package, then the packages are flushed with inert gases like Nitrogen and CO<sub>2</sub> after evacuation.

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. Vacuum packaging prevents freezer burn by preventing the food from exposure to the cold, dry air.

**Controlled and Modified Atmospheric Packaging (CAP and MAP)--**  
The normal composition of air is 78% Nitrogen, 21% Oxygen, 0.03% Carbon dioxide and traces of other 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 Packaging (CAP)**--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<sub>2</sub> or high CO<sub>2</sub> 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 (Modified Atmosphere) 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 (Equilibrated Modified Atmosphere) 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 as a scavenger to carbon dioxide. Potassium permanganate 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. For the actively 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 shown to extend the shelf life of a wide variety of fruits and vegetables. If the shelf life of a commodity is one day under CA storage, then the

shelf life of a commodity at 20-25°C by employing MAP, it will get doubled, whereas refrigeration can extend the shelf life to 3, and refrigeration combined with MAP can increase it to four days. 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.

### **Packaging materials for fresh fruits and vegetables**

The packages for fresh fruits and vegetables can be classified as (1) Consumer/Retail packs and (2) Transport/Bulk packs.

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

**(1) Flexible plastic films:** Different types of flexible plastic films LDPE (low density poly ethylene), PVC (poly vinyl chloride), PP (poly propylene) and cellulose acetate films are used for packing. These films are mostly used as pouches with holes punched at regular intervals to allow respiration. They are available in wide range of thickness and grades and can be used to control the environmental gases inside the pouch. LDPE is the most widely used material.

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

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

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

These containers are food grade, odourless, light weight, stackable and recyclable and give good presentation. These are either made of PET (poly ethylene terephthalate), PVC or PP.

**(4) Plastic net bags (extruded and oven):** The plastic net bags have the feature to stretch and accommodate all sizes and shapes of produce. These bags are available in roll form or in precut lengths with the stretch width of 200mm – 400mm. By allowing air to circulate in and around the produce; the net bags prolong the freshness and shelf life of the product. These also eliminate pack condensation there by preventing spoilage and wastage. They make a colourfull point of sale display allowing clear visibility of the contents, enhancing the natural colours of fresh produce. These are generally made of HDPE or PA (poly amide).

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

**Shrink film wraps:** Films such as Polypropelene, polysterine, Polyethelyene and rubber hydrochloride can be converted into shrink films by molecular orientation methods. After the shrink film is applied to the filled trays or in tubular or heat-sealed wrap form, the packages are sent through a heat tunnel to shrink the film cover. This immobilizes the commodity to reduce the possibility of physical damage during handling.

**Transport or bulk packs:** Transport or bulk packages are designed for long distance transportation in capacities ranging from 4-5 kg to 20-25 kg. These packs must withstand impacts, compression and vibration during transport.

Packaging material for transport or bulk packing can be broadly categorized as rigid containers made of wood (wooden crates), corrugated fiber board boxes, plastic crates and flexible containers such as sacks made of plastic. Along with these materials some traditional materials used are jute (jute sacks) and baskets made of woven strips of leaves, bamboo, plastic etc.

**(1) Natural materials** - Baskets and other traditional containers made from bamboo, rattan, straw, palmleaves, etc.,are used throughout the developing world. Both raw materials and labour costs are normally low, and if the containers are well made they can be reused.

#### **Dis- advantages:**

- 1) They are difficult to clean when contaminated with decay organisms.
- 2) They lack rigidity and bend out of shape when stacked for long distance transport.
- 3) They load badly because of their shape.

- 4) They cause pressure damage when tightly filled.
- 5) They often have sharp edges or splinters causing cut and puncture damage.

**(2) Wooden boxes/Crates:** The conventional baskets have been replaced by wooden boxes as they give better protection to the fresh produce against transportation hazards. They have high puncture resistance, good tensile strength. Wooden boxes are rigid and reusable and if made to a standard size, stack well on trucks.

However, the use of wooden boxes is discouraged now a days as it promotes deforestation.

**Dis- advantages:**

- 1) They are difficult to clean adequately for multiple use
- 2) They are heavy and costly to transport
- 3) They often have sharp edges, splinters and protruding nails requiring some form of liner to protect the contents.
- 4) The nails cause injuries to the produce during long transportation.
- 5) They occupy more space and add on to the tare weight.

**(3) Card board (fibre board)/corrugated fibre board boxes:** Containers are made from solid or corrugated card board. The types closing with either fold over or telescopic (separate) tops are called boxes or cases. Shallower and open topped ones are called trays. Boxes are supplied in collapsed fore that is flat and are set up by the user. The setting up and closing of boxes requires tapping, gluing, stapling or the fixing interlocking tabs.

Are used for tomato, cucumber, and ginger transport. They are easy to handle, light weight, come in different sizes, designs and strengths and come in a variety of colours that can make produce more attractive to consumers. These have good cushioning properties, low cost to strength and weight ratio. These are reusable and recyclable, easy to setup and collapsible for storage, smooth and non-abrasive surface with good printability on the outer surface of the board. Ventillation can be provided by punching holes and have good printability on the outer surface of the board.

Since these boxes have poor wet strength, now a days they are laminated with plastic film like LDPE, PP or PVC. Plastic corrugated boxes made of PP and HDPE are partly replacing CFB boxes because of their low weight to strength ratio, high degree of water resistance and reusability. However, it's cushioning properties are not comparable to CFB boxes

**Dis-advantages:**

- 1) They may if used only once, prove an expensive recurring cost.
- 2) They are easily damaged by careless handling and stacking
- 3) They are seriously weakened if exposed to moisture
- 4) These boxes are often of lower strength compared to wooden or plastic crates, although multiple thickness trays are very widely used.
- 5) They can be ordered economically only in large qualities; small quantities can be prohibitive expensive.

**(4) Moulded plastic crates:** Re-usable boxes moulded from high density polythene are widely used for transporting produce. They can be made to almost any specifications .They are strong, rigid, smooth ,easily cleaned and can be made to stack when full of produce and nest when empty in order to conserve space.

**Dis-advantages:**

- 1) They can be produced economically only in large numbers but are still costly.
- 2) They have to be imported into most developing countries, adding to the cost and usually requiring foreign currency for their acquisition
- 3) They often have many alternative uses (as wash tubs) and are subject to high pilferage rates.
- 4) They require a tight organization and control for use in a regular go and return service
- 5) They deteriorate rapidly when exposed to sunlight (especially in the tropics) unless treated with an ultraviolet inhibitor, a factor adding to the cost.

Despite their cost, however, their capacity for reuse can make them an economical investment.

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

**(5) Natural and synthetic fibres:** Sacks or bags for fresh produce can be made from natural fibres like jute or sisal or from synthetic polypropylene or polyethylene fibres or tapes. 'Bags' usually refers to small containers of up to about 5 kg capacity. They may be woven to a close texture or made in net form. Nets usually have a capacity of about 15kg.Bags or sacks are mostly used for less easily damaged produce such as potatoes, sweet potatoes, onions, but even these crops should have careful handling to prevent injury.

These are very useful because of low cost, high strength, re-usability and require less space for empties.

### **Dis-advantages**

- 1) They lack rigidity and handling can damage contents
- 2) They are often too large for careful handling; sacks dropped or thrown will result in severe damage to the contents
- 3) They impair ventilation when stacked if they are finely woven
- 4) They may be so smooth in texture that stacks are unstable and collapse; they are difficult to stack on pallets.

**(6) Paper or plastic film:** Paper or plastic film is often used to line packing boxes in order to reduce water loss of the contents or to prevent friction damage.

Paper sacks can have walls up to six layers of Kraft (heavy wrapping) paper. They can have a capacity of about 25 kg and are mostly used for produce of relatively low value. Closure can be done by machine stitching across the top (recommended for large scale crop production) or in the field by twisting wire ties around the top by means of a simple tool.

### **Dis-advantages:**

- 1) Walls of paper are permeable by water or vapour and gases (walls may be water proofed by incorporating plastic film or foil, but sacks then retain gases and vapour)
- 2) Heat can be slow to disperse from sacks of stacked produce, thus damaging fruit or leafy vegetables.
- 3) Limited protection to contents if sacks are mishandled.
- 4) Plastic film bags or wraps are used because of their low cost, widely used in fruit and vegetable marketing, especially in consumer packs.

### **Modern packaging must comply with the following requirements**

- a) The package must have sufficient mechanical strength to protect the contents during handling, transport, and stacking.
- b) The packaging material must be free of chemical substances that could transfer to the produce and become toxic to man.

- c) The package must meet handling and marketing requirements in terms of weight, size, and shape.
- d) The package should allow rapid cooling of the contents. Furthermore, the permeability of plastic films to respiratory gases could also be important.
- e) Mechanical strength of the package should be largely unaffected by moisture content (when wet) or high humidity conditions.
- f) The security of the package or ease of opening and closing might be important in some marketing situations.
- g) The package must either exclude light or be transparent.
- h) The package should be appropriate for retail presentations.
- i) The package should be designed for ease of disposal, re-use, or recycling.
- j) Cost of the package in relation to value and the extent of contents protection required should be as low as possible.

### **Cushioning materials for packaging fruits and vegetables**

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. The cushioning materials mostly used for packaging fruits and vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds etc., which are easily available locally and less costly. These are unhygienic and don't allow respiratory heat to escape from the packing box.

For cushioning material to be useful, it should in addition to have resilient property, the availability to dissipate the heat of respiration of the produce. It should be free from infection so that it doesn't pass on the same to the fruit and vegetables. It is important that the cushioning materials itself should be physiologically inactive.

Recently fibre board (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 etc., are used for replacing the cushioning material in costly commodities and for export purposes.

### **Purpose using cushioning materials:**

- 1) Protect the products which are sensitive to mechanical stresses and those to be protected from damage due to impact, Jolting or vibration in transit.

- 2) Fragile goods such as ceramics, glass, porcelain containers are protected from mechanical stresses by cushioning material
- 3) To adjust the packages to standard size as they act as adapters between non-standard package contents and the packaging

**Mode of action:** They absorb a portion of kinetic energy arising when the package suffers impact or is dropped and increase the breaking distance of the packing containers.

**Characters of cushioning materials:**

- 1) **Recovery:** If the recovery is too low, the breaking distance on constant exposure to stress, such that the resultant kinetic energy can no longer adequately be absorbed and the package contents may be damaged.
- 2) **Insensitive to climatic conditions:** Moisture due to elevated RH, direct solar radiation and extreme variations in temperature are important. The cushioning material must not be impaired by such exposure.
- 3) They are not hygroscopic and don't promote corrosion.
- 4) Use of cushioning material must be effective, simple, environmentally compatible and cost effective.

## **VALUE ADDITION OF FRUITS AND VEGETABLES**

### **Importance and scope of fruit and vegetable processing in India**

The green revolution and subsequent efforts through the application of Science and technology for increasing food production in India have brought self-reliance in food. Numerous hybrids, improved management practices have resulted in increased food production.

Among the food produce, fruits and vegetables are the perishable commodities and also source of vitamins and minerals are important in the human diet, which are known as “protective foods”.

Higher production of perishable fruits and vegetables produced during a particular season result in glut in the market and became scarce during the other seasons. Therefore fruits and vegetable processing has been engaging the attention of planners and policy makers as it can contribute to the economic development of rural population. The utilization of resources both material and human is one of the ways of improving the economic status of the family.

India's wide diversity in climate and soil provides much scope for growing a wide variety of horticulture produce than in most of the countries in the world. India is the second largest producer of fruits and vegetables in the world after Brazil and China respectively. However, if combined production of fruits and vegetables are taken, India ranks first in the world.

Presently, the horticulture crops covers 13.6 million hectares i.e. roughly 7% of the gross cropped area and contributes 18-20% of the gross value of India's agricultural out put.

The export value of fruits and vegetables has increased from Rs.987 crores in 2002 to Rs.1086 crores in 2003.Further the value of processed fruits and vegetables increased from Rs1100 crores in 2002 to 1207 crores during 2003.(Proceedings of national seminar,2003).

After the start of green revolution and attainment of self sufficiency in food production, the need for food processing was realized. It is estimated that 30-35% of fruits and vegetables worth of about Rs.23,000 crores perish due to want of post harvest facilities and also lack of sufficient processing industries to process the fruits and vegetables during glut, thus depriving the farmer the fruits of his labour.

Only around 2% of the total fruits and vegetables produced in India are processed as against 40% in some developing countries and 70-80% in developed countries. There is therefore, a vast unexploited potential in agro processing, as it can immensely contribute to the growth of the countries economy, nutritional security, trade and increasing the purchasing power of the middle class sections of the society and in changing food habits and life styles.

Over the last few decades, both developed and developing countries experienced many lifestyle changes including food habits that have led to an increased demand for processed foods. Processed foods now represent over 50% of the diet of many developed countries. The demand for ready to eat foods is increasing presumably with more and more women folk venturing the out of house work culture.

#### **Advantages of fruit and vegetable preservation:**

- 1) Processing and preservation of fruit and vegetables will extend the consumption period available round the year and retains its nutritive value.

- 2) Maximize the fruit and vegetable utilization; minimize the post harvest spoilage and surplus production losses.
- 3) Encourages contract farming, commercial growing and quality production.
- 4) Value addition to the fruit and vegetable products.
- 5) Increase in storage time by processing has great potential to expand markets beyond the region and country and can earn foreign exchange.
- 6) Possibility of diversification to a range of products suitable to consumers.
- 7) Processing of fruit and vegetables makes available ready for preparation and consumption.
- 8) Provides on farm and off farm employment, strengthening the rural economy
- 9) By dissemination of technology among the rural families particularly the women, small scale processing industry can be developed.

### **Status of fruit and vegetable Processing in India**

The installed capacity of fruits and vegetables processing industry has increased from 1.1 million tonnes in January 1993 to 2.1 million tonnes in 2006. The processing of fruits and vegetables is estimated to be around 2.2% of the total production in the country. The major processed items in the fruit and vegetable segment are fruit pulps and juices, fruit based ready-to-serve beverages, canned fruits and vegetables, jams, squashes, pickles, chutneys and dehydrated vegetables. Some recent products introduced in this segment include vegetable curries in sealable pouches, canned mushroom and mushroom products, dried fruits and vegetables and fruit juice concentrates.

The fruits and vegetable processing industry is highly decentralized, and a large number of units are in the cottage, household and small-scale sector, having small capacities of up to 250 tonnes per annum. Since 2000, the food processing industry has seen significant growth in ready-to-serve beverages, fruit juices and pulps, dehydrated and frozen fruits and vegetable products, pickles, processed mushrooms and curried vegetables, and units engaged in these segments are export oriented.

### **Exports of Fruit & Vegetables**

(Quantity in MT, Value in Rs Mn)

	2001-02	2004-05	CAGR

	Quantity	Value	Quantity	Value	Quantity	Value
Dried & Preserved Vegetables	209157.8	5371.5	351034.3	7657.5	18.8	12.5
Mango Pulp	76735.18	2413.4	90988.6	3008.6	5.8	7.6
Pickles & Chutney	38758.97	1203.4	67193.29	1205.8	20.1	0.1
Other Processed Fruits & Vegetables	61332.39	2017.4	80760.5	2755.3	9.6	10.9
<b>Total</b>	<b>385984.3</b>	<b>11005.7</b>	<b>589976.7</b>	<b>14627.2</b>	<b>15.2</b>	<b>9.9</b>

**Source: Ministry of Food Processing Industries, Annual Report 2005-06**

The domestic industry has to change its preference in favour of processed foods. Consumption of value added fruits and vegetables are low compared to the primary processed foods, and fresh fruits and vegetables. The inclination towards processed foods is mostly visible in urban centers due to a high purchasing power. A remarkable push can be given to this sector by strengthening linkages between farmers and food processors. The poor and weak linkage between farmers and markets, as well as, farmers and processing companies has brought about inefficiencies in the supply chain and encouraged the involvement of middlemen leading price rise to the products. The Government of India's National Agriculture Policy envisages the participation of the private sector through contract farming and land leasing arrangements which not only assures supply of raw material for processing units, but also a market for agriculture produce, accelerate technology transfer and capital inflow into the agriculture sector.

Innovative practices like contract farming in wheat practiced in Madhya Pradesh by Hindustan Lever Ltd and by Pepsi Foods Ltd in Punjab for tomatoes, food grains, spices and oilseeds are some successful examples of contract farming in India, which changed the farming landscape and promoted the cultivation of processable variety of farm produce this will certainly power the fruits, vegetables and grain processing industry. Besides such initiatives, fiscal incentives and tax concessions will also give impetus to the sector. The five-year 100% tax exemption announced by the Government in the financial year 2005 was one such incentive for upcoming fruits and vegetable processing units.

#### **Value Addition of Fruits and Vegetables**

India is the second largest producer of both fruits and vegetables. Fruits and vegetables are the reservoir of vital nutrients. Being highly perishable, 20-40% of the total production of fruits and vegetables goes waste from the time of harvesting till they reach the consumers. India is, therefore, incurring a precious loss not only in terms of revenue, but also in terms of health, because fruits and vegetables play a vital role in human diet as fresh food sources of calories,

vitamins, dietary fibre and special nutraceuticals. Only 2% of the produce is processed in India. It is, therefore, necessary to make them available for consumption throughout the year in processed or preserved form and to save the sizeable amount of losses. Fruits and vegetables have great potential for value addition and diversification to give a boost to food industry, create employment opportunities and give better returns to the farmers.

After harvest, the biological produce can be either preserved or processed. Value addition is a terminology used to define the processing of biological produce. Through processing the value of the commodities can be increased by converting it to different products by using conventional or modern processing techniques, thereby the storage life of the produce is enhanced.

#### **Value added products-**

**1. Fruit Juice:** It is a natural juice obtained by pressing out the fruits. Fruit juices may be sweetened or unsweetened.

**2. RTS:** It is prepared from fruit juices which must have atleast 10 per cent fruit juice and 10percent total sugar.

**3. Fruit Juice Powder:** The fruit juice is converted into highly hygroscopic powder. These are kept freeze dried and used for fruit juice drinks by reconstituting their composition.

**4. Fermented fruit beverages:** These are prepared by alcoholic fermentation by yeast of fruit juice. The product thus contains varying amounts of alcohols e.g.; Grape wine, orange wine and berry wines from strawberry, blackberry etc.

**5. Jam:** Jam is a concentrated fruit pulp processing a fairly heavy body form rich in natural fruit flavour. It is prepared by boiling the fruit pulp with sufficient quantity of sugar to a reasonably thick consistency to hold tissues of fruit in position

**6. Jelly:** Jelly is a semi solid product prepared by cooking clear fruit extract and sugar.

**7. Marmalade:** It is usually made from citrus fruits and consists of jelly containing shreds of peels suspended

**8. Tomato Ketchup:** It is prepared from tomato juice or pulp without seeds or pieces of skin. Ketchup should contain not less than 12 per cent tomato solids and 28 per cent total solids.

**9. Pickles:** Food preserved in common salt or in vinegar is called pickle. Spices and oil may be added to the pickle.

### **Principles and methods of preservation of fruits and vegetables**

#### **Principles of preservation of fruits and vegetables**

**Preservation:** Preservation means just protect the foods against the spoilage, but scientifically it may be defined as a science which deals with the process for prevention of decay or spoilage of the food is called preservation.

In other words preservation is just controlling the physical, chemical or microbial changes in the food.

**1. Physical Changes:** Colour, flavour, texture and taste etc.

**2. Chemical Changes:** Carbohydrates, fats, proteins, vitamins and minerals.

**3. Microbial changes:** Mould, yeasts and bacteria.

### Why do we preserve food?

- To increase the shelf life of the food for increasing the supply.
- To make the fruits and vegetables available throughout the year.
- To add the variety to the diet.
- To save time by reducing preparation, time and energy by fire.
- To stabilise the prices of the food in the market.
- To improve the health of the population.

**Principles of preservation**-- There are three main principles:

1. Prevention or delay the microbial decomposition of the food.
2. Prevention or delay the self decomposition of the food.
3. Prevention or damage by insects, animals, mechanical causes.

### 1. Prevention/delay the microbial decomposition of the food:

1.	By keeping out the micro organisms	---Asepsis
2.	By removal of micro organisms	---Filtration
3.	By hindering the growth and activity of micro organisms	---Anaerobic condition
4.	By killing the micro organisms	---Exposing at high temperature

**A. Asepsis:** It means preventing the entry of micro organisms by maintaining of general cleanliness, while picking, grading, packing and transporting of fruits and vegetables, increase their keeping quality and the product prepared from them will be superior quality.

**B. Filtration:** Fruit juice, bear, soft drinks, wines etc. enter through a bacteria proof filter which is made of asbestos pad or unglazed porcelain type of materials. These filters contain the micro organisms and allow the water or juice to percolate through with or without pressure.

**C. Anaerobic conditions:** It can be maintained by:

- Replacing the O<sub>2</sub> by CO<sub>2</sub> ----- Carbonation
- Evacuating the sealed container (fruit juice)

- Use of oils from top of the food (pickles)

**D. Exposing at high temperature:** Fruits can be exposed to high temperature such as;

- **Canning:** Food is exposed to a high temperature ( $>100^{\circ}\text{C}$ ) which reduces spoilage and inactivate the enzyme present in the food. The process of sealing food stuffs hermetically (air tight, protecting from outside agencies) in containers and sealing them by heat for longer storage is called canning.
- **Irradiation:** In case of irradiation, the food is exposed to the radiations to kill the surviving micro organisms by ionising and non-ionising radiation like  $\alpha$ ,  $\beta$  and  $\gamma$  rays. Here, food is exposed to electromagnetic or ionizing radiation or various frequencies ranging from low frequency electromagnetic rays to high frequency i.e. gamma rays which destroy the micro organisms present in the food.

## **2. prevention/delay the self decomposition:**

- a. By destruction or inactivating the enzyme – Blanching.
- b. Prevention / delay the non-enzymatic chemical reactions – Antioxidant

**A. Blanching:** Treatment of fruits and vegetables with boiling water or steam for short periods followed by cooling prior to canning is called "blanching".

- It is a primary treatment which has to soften the tissues to facilitate packaging.
- To preserve the original colour and flavour.
- To destroy certain enzymes which are undesirable.
- Elimination of the air.
- Mostly done for vegetables.
- Remove micro organisms
- Remove astringent taste and toxins.

**B. Antioxidant:** Anti-oxidants are substances which are used to protect the food against deterioration caused by exposure to the air.

- BHA- Butylactic Hydroxy Anisole & BHT- Butylactic Hydroxy Toluene (vegetable oils)
- Gellales : Animal fat, Vegetable oil
- Tocopherols: Animal fat
- Ascorbic acid: Fruit juices, Citrus oil, Wine, Beer etc.
- Lactic acid: Processed fruits and vegetables, canned fruits.
- Phosphoric acid: Vegetable oil, Animal fat and Cola drinks.

**3. Prevention or damage by insects, animals, mechanical causes:** This principle of preservation deals with the prevention of damage caused by various external agencies other than micro-organisms and enzymes i.e. animals, man, insects, rodents etc. These agencies generally cause

physical damage to the food material eg.rats may eat peels of oranges in a storage, animals may also eat the food if kept within their reach etc. But in none of these cases these damages are deleterious to human health. If you consume a half eaten apple or orange you are generally never going to die or experience any health risks, but if the food is spoilt by micro organisms, and you consume the spoilt food your health shall definitely be at risk. The damage of food by animals, man, insects, rodents etc. may later on give way for the initiation of microbial and self decomposition.

Proper packing of the food is predominantly the effective solution for prevention of damage caused by the agencies considered under this principle of preservation. Over all from the food processors point of view the three principles are to be considered in decreasing order of importance and emphasis. Highest emphasis is given on control of microbial decomposition followed by self decomposition, ultimately followed by damage caused by animals, insects, rodents etc.

## **ESTABLISHMENT OF A FRUIT AND VEGETABLE PRESERVATION FACTORY**

Before establishing a fruit and vegetable preservation factory, it is necessary to consider certain important factors such as investment, site, building, water supply, staff, labour, etc. which are essential for the successful running of a large-scale factory.

**Investment:** The capital outlay includes investment on land, factory building and machinery. The running or operational expenses include the cost of raw material, labour, processing, storage, transport and distribution. As a first step, the entrepreneur should plan carefully the type and size of production, which would be most advantageous. He should then decide about the plant and other requirements.

**Factory Site:** In selecting site for the factory, the following points should be considered carefully:

- 1) Adequate quantities of the right type of fruits and vegetables should be readily available in the locality, because fruits and vegetables are highly perishable and deteriorate in long distance transport.
- 2) There should exist proper transport facilities for the movement of raw materials and finished products.
- 3) The environment should be clean and free from debris, dust etc, as far as possible. The site should be at a considerable distance from other industrial factories spreading soot, smoke, and disagreeable odours, which would affect adversely the quality of the canned product. There should also be facilities for disposal of the cannery wastes.
- 4) There should be scope for future orderly expansion of the factory.

**Factory Building:** The factory building may be single- storied or multi storied -. Where the plant is comparatively small one and works for short periods during the year, a single-storied building of light construction will do. In the case of larger plants, that have to run almost throughout the year, multistoried construction is desirable as it

would facilitate and cheapen the movement of raw as well as finished products.

Flooring should be firm and of good cement to withstand the constant use of water and the movement of heavy-wheeled trucks. A slope of about one quarter of an inch per foot is necessary for proper drainage. All doors, windows and ventilators should be provided with fine wire-gauze to prevent entrance of flies, wasps and other insects. The roof of the building should be high and well ventilated to provide outlet for vapours and steam. The windows should have large glass panes, and part of the roof should be of ground glass to permit gentle light inside. There should be provision for efficient artificial lighting as the cannery will have to work at night quite often.

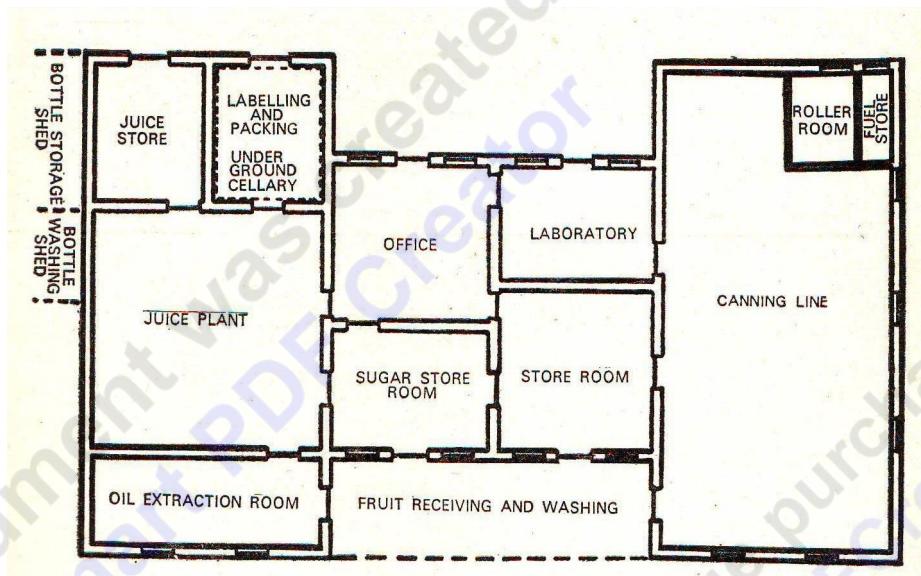
A sufficient number of dressing and toilet rooms should be provided separately for men and women workers in the factory premises. The workers should be taught the importance of personal hygiene. There are important considerations for handling food-stuffs for human consumption.

**Water Supply and Drainage:** There should be abundant supply of potable water. Large quantities of water are required for cleaning fruits and vegetables, making syrup and brine, washing floors and machinery, etc. The water system should work at sufficiently high pressure, so that supplies can be made at different points in the cannery without a break. The water should not be alkaline or very hard and should be free from organic matter. Saltish water should be avoided as it would affect the taste of the products. Presence of iron and sulphur compounds in it renders it unsuitable for making syrups and brines. Saltish water should be avoided as it would affect the taste of the products. If supplies of the desired quality are not available, it would be necessary to install a water softening plant. Further, the boiler feed water requires ion-exchange treatment to bring it to the desired pH and freed from scale-forming ions.

**Labour:** All the workers in the factory, whether employed on regular basis or recruited during rush periods, should have clean clothes and aprons to ensure hygienic conditions.

They should be medically examined at regular intervals as a precaution against infectious diseases. An efficient system of chemical and microbiological control at various stages of the manufacturing process should be maintained to guard against the risk of contamination and food-poisoning. There should be a trained chemist with assistants to supervise the work and to ensure the desired standard of production.

Plan of a fruit preservation factory



**Machinery and Equipment:** Great care is needed in the selection of machinery and other equipments. Different types of units are in use, but every manufacturer will have to determine his own requirements.

The whole equipment should be arranged in a proper order so that minimum time and effort are needed in handling the products at all stages of manufacture. In short, the raw product should move practically in a straight line till it emerges as finished product, ready for labeling and packing. During the off-seasons, the entire machinery should be over hauled, greased and painted.

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## **Methods of preservation of fruits and vegetables**

The important methods of preservation of fruits and vegetables are:

**(1) Preservation by high temperature--** In this method, food material is exposed to higher temperature and high temperature helps to killing of the micro organisms due to coagulation of protein. It helps in inactivation of enzyme. Here moist heat is more effective than dry heat. At low pH high temperature is required than the higher pH. High temperature can be employed by following methods:

- (i) Pasteurization : below  $100^{\circ}\text{C}$

- (ii) Boiling/Cooking : at  $100^{\circ}\text{C}$
- (iii) Canning : above  $100^{\circ}\text{C}$

**(i) Pasteurization:** It is a mild heat treatment. By pasteurization milk is pasteurized by HTST at  $72^{\circ}\text{C}$  for 15 sec. Fruit juices are pasteurized at such temperature and for such periods as would render them sterile, without impairing their flavor. Usually, the juices are pasteurized at about  $85^{\circ}\text{C}$  for 25-30 min., according to the nature of the juice and the size of container. Acid fruit juices require lower temperature and less time for pasteurization than the less acid ones.

#### **Juices can be pasteurized in two ways**

- (1) By heating the juice at a low temperature for a High time (LTHT) and
- (2) By heating the juice at high temperature for a short time only (HTST).

#### **(ii) Boiling/Cooking :**

The primary objective of cooking is to produce a palatable food. Cooking results in:

1. Destruction or reduction of micro organisms and inactivation of undesirable enzymes.
2. Destruction of potential hazard in the foods which are present naturally through micro-organism.
3. Improvement of color, flavor and texture of the food.
4. It improves the digestibility of food component.
5. Putting the temperature about  $100^{\circ}$ . By this method, food can be preserved for 10-24 hours at low temperature.

**(iii) Canning:** Canning is done at or above  $100^{\circ}\text{C}$ . In case of fruits which are acidic, they are canned at  $100^{\circ}\text{C}$ , while in case of vegetables those are non-acidic; they are canned at above  $100^{\circ}\text{C}$ . Here, high temperature can be obtained by using steam pressure; time varies according to the type of foods. Due to anaerobic condition any survivable organism would not grow.

**(2) Preservation by low temperature--** Low temperature retards the microbial growth and enzyme reaction because it retards the chemical reactions. This is not a permanent method because some micro organisms can also grow at low temperature.

- 1. Cellar storage : ( $\text{Above } 15^{\circ}\text{C}$ )
- 2. Refrigerated storage : ( $0 \text{ to } 5^{\circ}\text{C}$ )
- 3. Freezing storage : ( $-18 \text{ to } -40^{\circ}\text{C}$ )

**1) Cellar Storage:** Cellar Storage (about  $15^{\circ}\text{C}$ ). 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

$15^{\circ}\text{C}$ . Root crops, potatoes, cabbage, apples, onions and similar foods can be stored for limited periods during the winter months.

- 2) **Refrigeration:** Refrigerated (or) chilling ( $0\text{ to }5^{\circ}\text{C}$ ). Chilling temperature are obtained and maintained by means of ice or mechanical refrigeration. Most perishable foods, including eggs, dairy products, meats, sea foods, vegetable 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.

Fruits and vegetables can be stored for 2-7 days. Semi-perishable crops, such as potatoes, apples etc. can be stored, in the commercial cold storage with proper ventilation, automatic controlled temperature for one year.

- 3) **Freezing:** Freezing ( $-18$  to  $40^{\circ}\text{C}$ ). At temperature below the freezing point of  $\text{H}_2\text{O}$ , growth of microorganisms and enzyme activity are reduced to minimum. But, sometimes enzymes are active even below the  $0^{\circ}\text{C}$ . In this case before freezing, 'Blanching' is necessary for vegetable freezing. 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.

(3) **Preservation by drying** --- Drying is just removal of moisture from the food to a certain level at which micro organisms can not grow is called drying, It can be done by two methods:

(i) **Application of heat :**

- (a) Sun drying
- (b) Mechanical drying
- (c) Vacuum drying
- (d) Freeze drying

(ii) **Binding the moisture in the food :**

- (a) Use of Sugar
- (b) Use of Salt

(i) **Application of heat :**

- (a) **Sun drying:** Sun drying is the method in which food is directly exposed to sunlight. It is generally done in the places where plenty of sunshine is available for long period e.g. Rajasthan. The dried product in this method is inferior in quality.

**(b) Mechanical drying:** This is a method of drying where application of heat is applied by a mechanical dryer under the controlled conditions of temperature, humidity and air flow.

**(c) Vacuum drying:** The temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and intensity of heat input.

**(d) Freeze drying:** In this method, the food is dried by sublimation process, i.e., just converting the food into ice without passing through the liquid form of water by means of vacuum plus heat applied in the drying chamber. In this method, the product is first frozen, then water is removed by vacuum and application of heat which occurs simultaneously in same chamber.

**(4) Preservation by filtration --** Filtration is the only successful method for the complete removal of organisms and its use is limited to clear liquids. The liquid is filtered through a previously sterilized 'bacteria proof' filter made of sintered glass, diatomaceous earth, unglazed porcelain, membrane pads, (or) similar material and the liquid is forced through by positive or negative pressure. This method has been used successfully with fruit juices, beer, soft drinks, wine and water.

**(5) Preservation by use of chemical preservatives--** Chemical preservatives are substances which are added to food just to retard, inhibit or arrest the activity of micro organisms such as fermentation, pacification and decomposition of the food.

**Chemical preservatives are of two types:**

**Class-1 preservatives:** common salt, sugar, dextrose, spices, vinegar, Ascorbic acid etc.

**Class-2 preservatives :** Benzoic acid and its salt, SO<sub>2</sub> and the salts of sulphuric acid, nitrates, ascorbic acid and its salts, propionic acid and its salts, lactic acid and its salts.

Among the class-2 preservatives, only two chemical preservatives are used in fruits and vegetables preservation:

**(i) KMS(Potassium Meta bisulphate) :**

- (1) It releases the SO<sub>2</sub> and it is unstable.
- (2) It is used for the fruit which have non water solvent pigment (colourless).
- (3) It can not be used in naturally coloured juices such as phalsa, jamun because they have the Anthocyanin pigment.
- (4) It can not be used in the product which is packed in container because it acts on the tin containers and oil, Hydrogen Sulphide (H<sub>2</sub>S) which has an unpleasant smell and also form a black compound with the base plate of containers.
- (5) Best to control moulds than bacteria.

(6) 350 ppm KMS is mostly used in fruit juice products.

**(ii) Sodium Benzoate :**

- (1) It is a salt of benzoic acid and soluble in water.
- (2) It delays the fermentation in the juices.
- (3) It is commonly used in the product which are having natural colour such as anthocyanin pigment.
- (4) It is more effective against the yeast.
- (5) 750 ppm Sodium benzoate is mostly used in fruit juices, squashes and cordials.

**(6) Preservation by use of food additives (Sugar, Salt, acids and vinegar):**

Food additives are substances or mixture of substances other than basic foodstuffs, which are present in the foods as reagent of any aspects of production, processing, storage, packaging etc. Food additives are (i) **sugar**, (ii) **salt**, (iii) **acids**, (iv) **spices**.

In case of sugar and salts, they exert osmotic pressure and water diffuses from the product through a semi-permeable membrane until the concentration reached equilibrium. They kill the micro organisms or do not allow them to multiply.

**(i) Sugar:** The concentration of 68-70% is used for preparation of jam, jelly, marmalades etc. Sugar acts as a preservative by osmosis and not as a true poison for micro organisms. It absorbs most of the available water, so little water available for the growth of micro organisms.

**(II)Salt:** The concentration of 15-20% is used for the preparation such as pickles. Salt inhibits enzymatic browning and discolouration and also acts as an anti-oxidant. It exerts its preservative action by:

- (i) Causing high osmotic pressure resulting in the plasmolysis of microbial cells.
- (ii) Dehydrating food and micro organisms by tying up the moisture.
- (iii) Ionizing to yield the chloride ion which is harmful to micro organisms, and
- (iv) Reducing the solubility of oxygen in water, sensitizing, and the cells against  $\text{CO}_2$ .

**(III)Acids:** Many processed foods and beverages need the addition of acids to impart their characteristic flavor and taste in the final product because acids provide desired flavour and taste. They adjust the sugar and acid ratio in the food .proper balance of flavor of the food. They are also playing the role for controlling the pectin-gel formation.

**Main acids are the following:**

1. Acetic acid (Vinegar)
2. Citric acid (Lime juice)
3. Lactic acid (Lactose)

1. **Acetic acid:** It is commonly used for pickles, chutney, sauce and ketchup, just to inhibit the growth of micro organisms.
2. **Citric acid:** It is used for the preparation of jam, jelly, squash, nectar etc. just to increase the acidity.
3. **Lactic acid:** It is used for the formation of curd from milk.

**(7) Preservation by oil----** A layer of oil on the surface of any food produces anaerobic conditions which prevent the growth of moulds and yeasts. Eg., pickles

**(8) Preservation by fermentation** -- Decomposition of carbohydrates by microorganisms or enzymes is called fermentation. 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.

In wines – 14% alcohol acts as a preservative. About 2% acetic acid prevents spoilage in many products.

**(9) Preservation by Carbonation** -Carbonation is the process of dissolving sufficient CO<sub>2</sub> in water or beverage so that the product when served gives off the gas as fine bubbles and has a characteristic taste. Fruit juice beverages are generally bottled with CO<sub>2</sub> content varying from 1 to 8 g/l, it is sufficient for supplementing that effect of acidity on pathogenic bacteria. For complete inhibition of microbial activity (14.6 g CO<sub>2</sub>/l) creating an anaerobic condition, which reduces the oxidation of ascorbic acid and prevents browning.

Although carbonated beverages contain sugar much below 66%, the absence of air and the presence of CO<sub>2</sub> in them help to prevent the growth of moulds and yeasts.

The keeping quality of carbonated fruit beverages is enhanced by adding about 0.005% sodium benzoate. The level of carbonation required varies according to the type of fruit juice and type of flavor.

**(10) Preservation by Antibiotics**-- Certain metabolic products of microorganisms have been found to have germicidal effect and are termed as antibiotics.

**Nisin** is an antibiotic produced by *Streptococcus lactis*. Commonly found in milk, curd, cheese and other fermented milk products. It is non-toxic. Used in the food

industry especially for preservation of acid foods in which it is more stable. Used in canning of mushrooms, tomatoes and milk products. Nisin suppresses the growth of mainly the gas-producing spore-forming bacteria and toxin-producing *Clostridium botulinum*

**Subtilin** - an antibiotic obtained from certain strains of *Bacillus subtilis* is used in preservation of asparagus, corn, and peas. It is most effective against gram-positive bacteria and spore-forming organisms. Canned peas and tomatoes containing 10 and 20 ppm of subtilin respectively.

**Pimaricin**- an antifungal antibiotic can be used for treating fruits and fruits juices. Use of antibiotics along with other sterilizing agents including heat and radiation offer good promise.

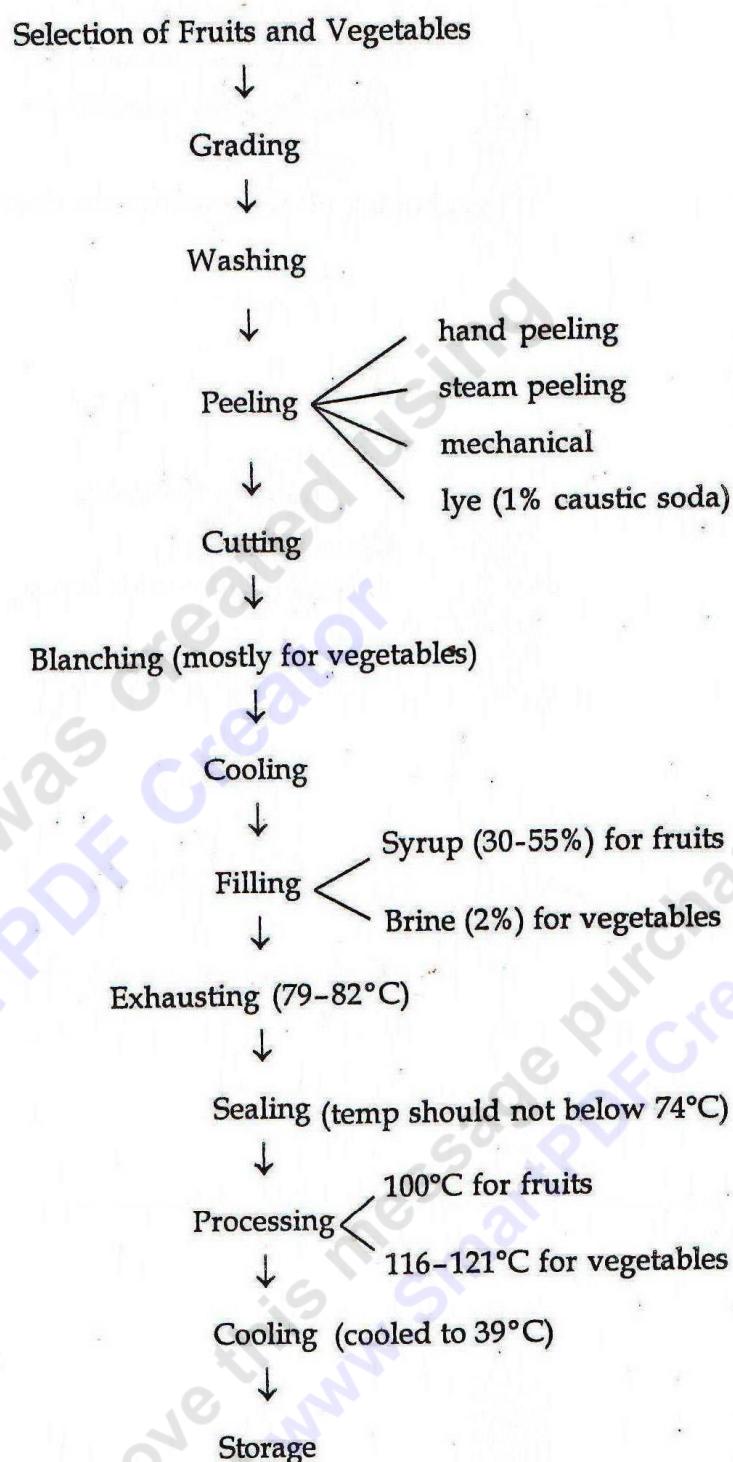
**(11) Preservation by irradiation--** Sterilization of food by ionizing radiations is a recently developed method of preservation. The unacceptable flavor of some irradiated foods and the fear that radioactivity might be induced in such food has come in the way of its greater use.

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 up to 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.

## FLOW CHART FOR CANNING PROCESS



## CANNING OF FRUITS AND VEGETABLES

The process of sealing food stuffs hermetically (air tight, protected from outside agencies)

in containers and sterilizing them by heat for longer storage is known as canning.

In 1804, Nicholas 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 named as

"appertizing". Saddington, in England was the first to describe a method of canning of foods in 1807. In 1810 Peter Durand, another English man, obtained the first British Patent on canning of foods in tin containers. William Underwood in 1817 introduced canning of fruits on a commercial scale in USA.

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 farmers.

For canning, fruits and vegetables should be fresh, ripe but firm and evenly matured. It should be free from all blemishes, insect damage, mechanical injury and malformation.

Over ripe fruit is generally infected with micro organisms and would yield a pack of poor quality. Under ripe fruit will shrivel and toughen on canning. The vegetables should be tender except tomatoes and free from soil, dirt etc. Tomatoes should, however, be firm, fully ripe and deep red colour. The fruits and vegetables pass through several processes in canning as detailed below.

**Sorting and grading:** This is necessary to obtain a pack of uniform quality. This is done by hand or machines. There are several mechanical graders, such as screen graders, roller graders, cable graders etc. Screen graders, which are fitted with six vibrating screens with different size circular openings are most commonly employed. Soft and berry fruits are generally graded by hand.

**Washing:** The graded fruits and vegetables are washed with water either by soaking or agitating in water or hot water sprays etc. Vegetables may preferably be soaked in dilute potassium permanganate solution to disinfect them. Root crops that loosen in soil are washed by soaking in water containing 25--50ppm of chlorine as detergent. Spray washing is however the most efficient method.

**Peeling, coring, pitting:** Fruits and vegetables are prepared for canning by peeling, coring and pitting. The peeling is done in a variety of ways.

(1) **Hand peeling:** It is done mostly in case of fruits of irregular shape e.g. mango and papaya where mechanical peeling is not possible. Many of the fruits and vegetables are peeled and cut by hand with the help of peeling knife which have curved blades with a special guard to regulate the depth of peeling.

(2) **Mechanical peeling:** Mechanical peeling, coring and cubing machines for pears, apples, peaches and cherries and also for root vegetables like carrots, turnips, potatoes etc are available.

(3) **Peeling by heat:** certain varieties of peaches and potatoes etc are scalded in (burning in) steam or boiling water of 40°C for 10-60 seconds to soften and loosen the skin, which is removed later by hand. The heat peeled fruit absorb sugar more readily. Recently, infra red heating has been successfully employed for peeling apples, tomatoes etc.

(4) **Lye peeling:** Peaches, apricots, quinces, sweet oranges tangerines, carrots and sweet potatoes are generally peeled by dipping them in boiling caustic soda (lye) solution of 1-2 percent strength for 30 seconds to 2 minutes depending on their nature and maturity. The hot lye loosens the skin from the inner flesh by dissolving the pectin and the skin is removed by hand. The peeled fruit or vegetable is washed thoroughly in running water or preferably by dipping it for few seconds in a weak citric acid or hydrochloric acid to remove any trace of

alkali. This method is quick and reduces wastage and cost of peeling. The use of aluminium in this lye dip equipment should be avoided as it reacts with sodium hydroxide.

(5) **Flame peeling;** it is used only for garlic and onion which have a papery outer covering. This is just burnt off.

**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.

**Blanching:** Treatment of fruits and vegetables with boiling water or steam for short periods followed by cooling prior to canning is called "blanching". It is also known as scalding/Para boiling or pre cooking .The objective of blanching is to soften the texture and to enable a greater weight to be pressed in to the container without damage to the individual fruit.

**Advantages in blanching:** Blanching loosens the skin, facilitates close filling in the can, drives out the air from the tissues, helps to clean the fruit or vegetable and eliminate micro organisms. It also inactivates the enzymes, thus preventing the discolouration.By removing undesirable acid elements and astringent taste of the peel; it also improves the taste and flavour.

**Disadvantages in blanching –** Blanching makes water soluble materials like sugar and anthocyanin pigments are leached by boiling water. Fruits lose their colour, flavour and sugar.

For blanching, fruit or vegetable is placed in a wire or perforated basket, which is dipped in hot water for 2 to 5 minutes and then in cold water. Avoid hard water for blanching, as it toughens the tissues and destroys the natural texture .In large canneries, blanching is done on belt conveyors passing through boiling water or steam or in a horizontal rotary cylinders.

**Can filling:** Thoroughly washed and sterilized cans are to be used for filling with fruit or vegetable. Plain cans are generally used. In case of coloured fruits like red plums, black grapes, straw berries etc. fruit lacquered cans are employed. In large canneries can filling is done by automatic can filling machines.

**Syruping or brining:** The loaded cans are filled with hot sugar syrup for fruit and with hot brine for vegetables. It improves the taste of the canned product and fills up the interspaces between fruits or vegetables in the can. It also facilitates further processing. The syrup or the brine should be added to the can at a temperature of 79°C to 82°C, having a head space in the can so that when the filled can is closed on the double seaming machine, the space left inside ranges from 0.32 cm to 0.47cm. In large canneries, syruping or brining is done on automatic machine which are available in various capacities.

**Lidding or clinching:** Formerly, the cans after being filled were covered loosely with the lid and passed through the exhaust box. It has the disadvantage of spilling of the contents, toppling of the lid etc. Therefore to avoid spilling and toppling of lid, the clinching process in which the lid is partially seamed to the can by a single first roller action of a double seamer. The lid remains sufficiently loose to permit the escape of the dissolved as well as free air from the contents and also the vapour formed during exhaust process.

**Exhausting:** It is necessary to remove practically all the air from the contents before final sealing of the can. The process by which this is achieved is known as 'exhausting'. By removing the air from the container, risk of corrosion of the tin plate and pin holing during storage, as also discoloration of the product, are reduced because oxidation is prevented. Exhausting also helps in better retention of vitamins especially vitamin C. The tendency of fruits and vegetables to expand or shrivel during heating the exhaust process will be of assistance in avoiding over filling or under filling of the can. For instance corn and peas expand in brine and straw berries shrivel in sugar syrup when boiled. The other

advantages of exhaust process are prevention of bulging of can when stored at high altitudes or in hot climates; reduction of chemical reaction between the container and the contents and prevention of excessive pressure and strain during sterilization. Fruits and vegetables sometimes react slowly with the metal can and produces hydrogen gas which builds up pressure. If there is no vaccume inside the can to start with, bulging will takes place and the marketability of the product would suffer. The vaccume in the can after exhaust depends on several factors such as the time and temperature of the exhaust, the headspace in the can and altitude etc.

Containers are exhausted either by heat treatment or by mechanical means. The can is passed through a tank of hot water at 82-87°C or on a moving belt through a covered steam box. The time of exhaust varies from 5 to 25 minutes. Depending on the product nature. At the end of exhaust the temperature at the centre of the can should be about 79°C. In the case of glass jars, vaccume closing machines are generally used. The jar is placed in a closed chamber in which high vaccume is maintained.

**Sealing:** After exhausting, the cans are sealed air tight by double seamers. There are hand operated as well as semi automatic and fully automatic seamers.

**Processing:** It means heating or cooling of canned foods to inactivate bacteria. Processing consists in determining just the temperature and the extent of cooking that would suffice to eliminate all possibilities of bacterial growth. Over cooking should be avoided as it spoils the flavour and product appearance. Generally almost all fruits can be processed satisfactorily at 100°C temperature, as the presence of acids in fruits retards the growth of bacteria and their spores. On the other hand vegetables ,which are non-acidic (except the acidic tomato and rhubarb required to be processed at high temperatures of about 115°C to 121°C. The centre of the cans should reach these temperatures and maintained for a sufficient period to destroy the spores of the more resistant bacteria.

The sound ness of fruits and vegetables is due to their acid content (measured in pH) which has a great influence upon the destruction of micro organisms. 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.

**On the basis of acid, foods are divided in to four different groups:**

Class	pH	Product
<b>Low acid (Non-acid)</b>	> 5.0	Vegetables such as peas, lima beans, asparagus, cauliflower, potato, spinach, beet, corn, French bean
<b>Medium acid</b>	4.5—5.0	Turnip, carrot, okra, cabbage, pumpkin, beet green, bean etc. and products like soups and sauces.
<b>Acid</b>	3.7—4.5	Tomato, pear, banana, mango, jackfruit, pineapple, sweet cherry, peach, apple and other fruits.
<b>High acid</b>	3.7	Citrus juice, rhubarb, prune, saukeraut, pickle, chutney etc.

**Cooling:** After processing the cans are cooled rapidly to stop the cooking process and to prevent stack burning. Especially in cans at the centre of large stacks where they remain hot for several hours. Prolonging heating results in inferior and uneven pack. For example peaches and pear became dark in colour ,tomatoes turn brownish and become bitter in taste ,while peas become mashy with a cooked taste .In vegetables prolonged heating due to improper cooling may result in development of '**Flat sour**' by the heat resistant spore forming bacteria, which survives ordinary commercial processing. In this case the cans don't show any bulging, but the contents will be sour.

Cooling is done by:

- Immersing or passing hot cans in tanks containing cold water.
- By spraying with jets of cold water.
- By turning the cold water into the pressure cooker.
- By exposing the cans to air in small lots when water is scarce

**Labelling, Storing and Packing:** The outer surface of the can should be dry perfectly. It is advisable to lacquer the can outside to prevent rusting during storage near the sea or in damp and moist regions.

The cans are then labeled and packed in strong wooden cases or corrugated card board cartons, in standard packings. They should be stored in a cool dry place. In tropical hot areas, basement stores are useful, especially during summer months, as the temperature is lower by about 6 to 8° C, compared to the out side temperatures .Storage at higher temperatures should be avoided, as it shortens the shelf life of the product.

**Containers for canning:** Tin and glass containers have so far been successfully employed for canning foods. In recent years plastic containers and heat sealable pouches are being tried as possible substitutes for the familiar tin and glass containers.

Both tin and glass containers are employed, although the tin containers are more common in use on account of the following reasons. These are fabricated readily and are strong enough to withstand processing, they are light in weight, easy to handle and fairly cheap, they can be handled in high speed machines.

Glass containers are fragile and require extra care in handling and during processing .They however possess two definite advantages over the tin cans, the contents being visible can be easily displayed and the containers can be used over and over again.Further,since glass of high quality doesn't contaminate the contents, glass containers are preferred for packing baby foods.

**Other new type of containers introduced recently**

**1. Plywood containers** for dairy products like butter, sweetened milk, milk power, lemon cheese, minced meat, confectionary etc. These might also be useful for packing jam, jellies and marmalades.

**2. String opening composite container** developed by metal Box Company, Calcutta, which is easily opened by sharply pulling a rip-card fixed to the body of the container is said to be ideal for packing baby foods, custard powders, confectionary, biscuits etc.

**3. Self heating can** is being used by armed forces of UK and USA. A mixture of calcium silicate plus  $\text{Fe}_2\text{O}_3$  (Ferrous oxide) or  $\text{Fe}_3\text{O}_4$  (Ferric oxide) which is placed in a central tube fixed to the inside of the can is ignited by means of a cigarette end or match stick. The heat of reaction warms the contents of the can quickly to about  $50^\circ\text{C}$  in 4 or 5 minutes. These cans are highly useful for products like thin soups, cocoa, milk shakes etc, for use in the field, air travel, picnics and other outdoor activities.

**Tin containers:** These are made of thin steel plate of low carbon content, lightly coated on either side with tin metal to a thickness of 0.00025 cm. Tin plates are of several grades. The usual weight of tin coating is 0.681 kg of tin per base box, which gives a thickness of tin coating of 0.00025 cm. One base box is equivalent to 112 sheets, each 50x35cm (Or)  $19.6 \text{ m}^2$  of tin plate weighing 48.8 kg net. These are called **IC plates**. Plates thinner than IC are called **lights** and those thicker than IC are **crosses**.

**Lacquering:** Small microscopic spaces are always left uncoated in steel plates with tin, although the coating may appear perfect to the eye. The contents of the can may react with these uncoated spots and cause discolouration of the product or corrosion of the tin plate. When corrosion is severe, the steel is attacked and black stains of iron sulphide are produced. It is therefore necessary to coat the inside of the can with some material like lacquer, which would prevent discolouration. This is achieved by lacquers (a) acid resistant and (2) sulphur resistant.

**Acid resistant cans:** Acid resistant lacquer is ordinary gold coloured enamel, and the cans when treated with it, are called **R- enamel** cans. These are used for canning fruits and vegetables of acid group with soluble colouring matter. Acid fruits are of two types (1) those in which the colouring matter is insoluble in water (Peach, pineapple, apricot, grape fruit etc),(2) those in which it is water soluble (Rasp berry, straw berry, red plum and colored grapes).Fruits of group (1) are packed in plain cans and those of (2) group in lacquered cans.

**Sulpher resistant:** This lacquer is also of golden colour enamel, and the cans coated with it, are called **C-enamel cans (Or) S.R Cans**. These cans are used for non-acid products like peas, corn, beans etc.to prevent discolouration of the contents and the staining of the inside container. These cans should not be used for any highly acid product as acid eats in to the lacquer.

**Testing for defects:** In a factory, the finished cans should be finally tested for **leak or imperfect seals**. The simple methods employed are:

1. Tap the top of the can with a short steel rod. A clear ringing sound indicates a perfect seal, while a dull and hollow sound shows a leaky or imperfect sealed can. Although it is rapid, seldom fails to detect a defective seal.
2. Test the vacuum inside the cans by means of vacuum gauge fitted with a sharp point, which is protected with a thick rubber gasket. The sharp point is pierced in to the lid of the can, and a short twist given, when rubber gasket presses against the puncture made and gives air tight seal. The vacuum in the can is directly read on the dial of the gauge. Faulty cans don't show any vacuum.

3. The vacuum can also be tested with a vacuum tester without puncturing the can. This is a non-destructive type. This is based on the measurement of concavity of the lid of the can, which is proportional to the degree of vacuum inside the can. A battery operated electrical circuit with a ringing bell facilitates the measurement of concavity and hence the vacuum inside (Method of CSIRO, Australia).

4. A Flip tester is also employed to determine the vacuum inside the can by placing the can in a glass chamber and evacuating it. The can lid will give a flip sound when the vacuum outside becomes slightly more than that inside the can. It is also a non-destructive type and can be operated on the mains or with a dry cell. It is portable and handy (Method of CFTRI-INDIA).

#### Spoilage in canned foods

Canned foods are liable to spoilage in storage for various reasons. The two important kinds of spoilages are: (1) **Spoilage by micro-organisms** (2) **spoilage due to physical and chemical changes.** Various indications (Symptoms) of spoilage in cans are –

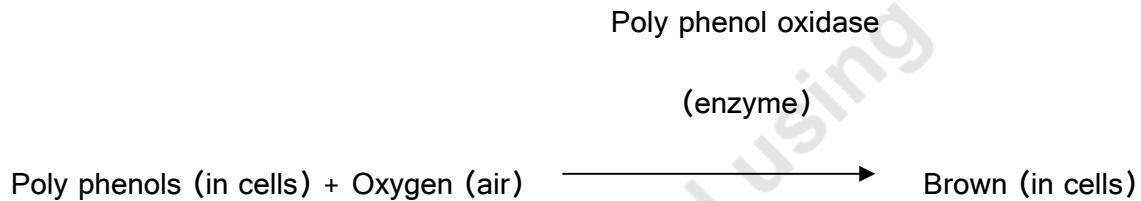
1. **Swell:** In swelled can, the ends are tightly bulged due to the formation of CO<sub>2</sub> or other gas inside the can as a result of decomposition of the contents by micro-organisms. The decomposed food in the can has an offensive and sour odour and is discoloured. It is not fit for consumption and even may contain toxins produced by bacilli like *Clostridium botulinum*.
2. **Hydrogen swell:** Hydrogen formed by the action of the acids present in the fruit on the tin plate causes the can to bulge at both the ends. In such cases, the food remains free from harmful micro-organisms and is still fit for consumption.
3. **Springer:** A mild swell at one or both ends of a can is called a ‘Springer’. It may be an initial stage of hydrogen swell or may be caused by insufficient exhausting or by over filling of the can. Food generally remains fit for consumption.

- 4. Flipper:** The cans appear normal, but when struck against a table top one or both ends become convex and spring or flip out, but can be pushed back to normal condition by a little pressure. Such a can is termed as 'flipper'. It may be an initial stage of swell or hydrogen swell, but does more frequently, owe to over filling or under exhausting.
- 5. Flat sour:** it is caused mostly in non-acid foods like vegetables by micro-organisms like thermophilic bacteria (*B.coagulens* and *B.sterothermophilus*) which produce acid without formation of gas. The thermophilic bacteria thrive at a high temperature of 100°C. If cans are stored without adequate cooling, the contents remain at a temperature favourable for incubation of such bacteria for fairly long time, which results in their multiplication and spoil the product. It is therefore difficult to detect from the external appearance. It may be due to by under sterilization (processing). Therefore the thermophilic bacteria would be of significance. The product has a sour odour, and its acidity much be higher than that of the normal product. It is not fit for consumption.
- 6. Leakage:** A leaking can is known as leaker. A very small leak may appear in the can owing to (1) defective seaming, (2) nail holes caused by faulty nailing of cases while packing (3) excessive internal pressure due to microbial spoilage sufficient to burst the can (4) internal or external corrosion (5) mechanical damage during handling.
- 7. Breathing (Breather):** There may be a very tiny leak in the can through which air may pass in and destroy the vacuum but not the micro-organisms. Consequently the vacuum in the can is always nil, and the pressure inside the can is equal to that of atmosphere. The damage to food is usually owing to rusting of the can caused by oxygen in the air but still the food remains fit for consumption.
- 8. Bursting of the can:** Cans may some times burst. This may be due to excess of pressure caused by the gas inside, produced by the decomposition of the food by micro-organisms, or by hydrogen gas formed by chemical action of acids of the food on the tin plate. Thus the canned product becomes a total loss.

**Discolouration of the fruit products:**

Discoloration of the canned foods may be owing to bio-logical causes or metallic contamination or both.

**Biological causes:** Cut and peeled apples and pears when kept in air, turn brown due to oxidation. This change is induced by co-oxidases (enzymes) present in the fruit and can be avoided by placing them in 2 or 3 per cent common salt solution.



Brown discolouration of the fruit products may also be caused by reactions other than enzymatic.

The colour changes may be caused by reactions between:

- Nitrogenous matter and sugars
- Nitrogenous matter and organic acids
- Sugar and organic acids and
- Organic acids among themselves.

These reactions, generally known as '**Maillard**' reactions (also known as Millard browning). Due to these reactions colour, flavour, odour and some times texture changes occur, which results from a chemical reaction between the above) are of great importance to food preservation. It is named after the French man Millard who discovered it.

**Metallic contamination:** This type of discolouration is caused by iron and copper salts mostly. The following are important among them.

1. **Ferric tannate:** Some fruits and vegetables contain tannins which on contact with the exposed iron of the tin plate form ferric tannate. This is black and spoil the appearance of the product.
2. **Iron sulphide:** Sulphur dioxide either from the source of sugar or formed owing to the decomposition of the proteins in the product may react with the hydrogen

formed by fruit acid acting on the tin plate and gets reduced to  $H_2S$ . This  $H_2S$ , in turn will react with the iron of the can and form black iron sulphide. Therefore, the product appearance is spoiled and the obnoxious smell of  $H_2S$  will also persist.

**3. Copper sulphide:** When the plant is shut down for some time, even for a few days, a thin film of copper oxide will be formed on the surface of the equipment made of copper or brass. Although the equipment may be cleaned thoroughly before use again, small traces of copper oxide or copper salts may still remain sticking to the surface of the metal. When the plant is started again, the first lot of product will react with copper compounds and dissolve the copper. The product coming into contact with hydrogen sulphide which may be formed inside the can due to several causes will form black copper sulphide, which will discolour the product.

**4. Hydrogen:** Fruit acids, reacting on the metal can produce hydrogen. The hydrogen thus formed will react with the red or purple pigments of fruits like straw berries, red plums, damsons etc. and bleach them. The remedy for this is to ensure that lacquering is complete and perfect.

### Bottling of Fruits and Vegetables

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 care fully handled. The fruits look attractive through the glass and don't develop metallic flavour. Bottling does not need a sealing machine but is not suitable from the manufacturers point of view as the initial capital required is high. Cans are cheaper, quite hardy and lighter and loss due to breakage is less. Hence, on commercial scale tin cans are preferred to glass jars or bottles.

There are many types of glass containers of different shapes and sizes and with various types of hermitic seals. Jars fitted with wire clamps are considered to be the best. The products remain in a very hygienic condition and does not come into contact with rubber or metal.

Essential equipment and method of selection of the fruit, grading, sorting, washing, peeling, slicing and coring are the same as for canning of fruits and vegetables.

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Drying preserves foods by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 5 to 25 percent depending on the food. Successful drying depends on:

- Enough heat to draw out moisture, without cooking the food;
- Dry air to absorb the released moisture; and
- Adequate air circulation to carry off the moisture.

When drying foods, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavor, texture and color of the food. If the temperature is too low in the beginning, microorganisms may grow before the food is adequately dried. If the temperature is too high, affect the flavor, texture and color of the food.

Dehydration is an alternative to canning / bottling and freezing fruits and vegetables.

The practice of drying food stuffs especially fruits and vegetables for preserving them are very old.

The term drying and dehydration means the removal of water. The former term **drying** 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 producing them from getting spoiled due to souring. Souring or turning acidic is usually due to growth of micro organisms which converts the carbohydrates in the food to acid. Quick removal of moisture prevents the growth of the micro-organisms.

**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 are spread on trays which are placed inside the dehydrator. The initial temperature of the dehydrator is usually  $43^{\circ}\text{C}$  which is gradually increased to  $60\text{-}66^{\circ}\text{C}$  in the case of vegetables and  $50\text{-}71^{\circ}\text{C}$  for fruits.

On account of the concentrated form, low cost, convenience and easy transportability dried / dehydrated fruit and vegetable products become highly popular among the armed forces.

Dehydration techniques have been greatly improved to get over defects like undesirable changes in colour, taste and flavour during storage and distribution.

### **The rate of drying of fruits and vegetables depends on:**

- The exposure of a large surface area of the produce, which speeds drying; The produce should be cut into strips not more than 5 mm thick;
- Drying time is lengthened if the produce has very high water content, a small surface area or waterproof skin.
- The temperature should be high enough ( $50-70^{\circ}\text{C}$ ) to give rapid moisture removal; temperatures over 70 degrees cause discoloration of the product;
- Drying time is increased if the relative humidity of the air is high. In other words, if the air already holds nearly all the water it possibly can, it will be unable to take much more, and the fruit will not be able to lose enough moisture to become dehydrated.
- As water evaporates from a piece of fruit or vegetable, the air surrounding the fruit or vegetable becomes saturated with water, causing the rate of evaporation to slow down and eventually stop. To prevent this from happening and to keep the rate of evaporation as high as possible, it is essential that air be kept in constant motion near the fruit/vegetable to carry away the moisture laden air. So to increase the rate at which fruits and vegetables force warm, dry air over produce being prepared to enhance the evaporation of water.

### **Advantages of dehydration over sun drying:**

- ✚ The process of dehydration is very rapid
- ✚ Dehydration requires less floor area
- ✚ Dehydration is done under hygienic condition
- ✚ Mechanical dehydration is not dependent on the weather
- ✚ The colour of dehydrated product remains uniform

### **Advantages of drying /Dehydration over other methods of Preservation:**

- 1) The weight of the product is reduced to  $1/4^{\text{th}}$  to  $1/9^{\text{th}}$  of its original or fresh weight and thus ,the costs associated with its further operations is reduced drastically.
- 2) Due to reduction in bulk of the produce, it requires less storage space.

- 3) No preservative is added for its preservation
- 4) Cost of processing is very low
- 5) Per unit weight of fruit or vegetable nutrients concentration is very high.
- 6) Many fruits and vegetables are available only during seasons. With the help of dehydration /drying preserve them for all seasons.
- 7) Dehydration produces are convenience items. For example instant coffee, fruit juice concentrate, fruit juice powders, instant mashed potatoes etc. The consumer simply add water and stir or mixes.
- 8) Spoilage of foods is easily controlled in drying process.
- 9) It retains the size and shape of the original food.ex.Freeze dried food.

**Principles of drying and dehydration:** The micro organisms require plenty of free water for their survival. Drying or dehydration removes biologically active water, thus growth of micro organisms is stopped. This also results in reduced rate of enzyme activity and chemical reactions. The food value, natural flavour and characteristic cooking quality of fresh material are retained after drying. Fruits show no sign of moisture or stickiness and vegetables become brittle on drying. The residual moisture should not be more than 6-8 percent in vegetables and 10-20 percent in fruits. Dried fruits can be used as such or after soaking, while dried vegetables are usually soaked in water over night before cooking.

#### **Process of drying:**

##### **During Preparation**

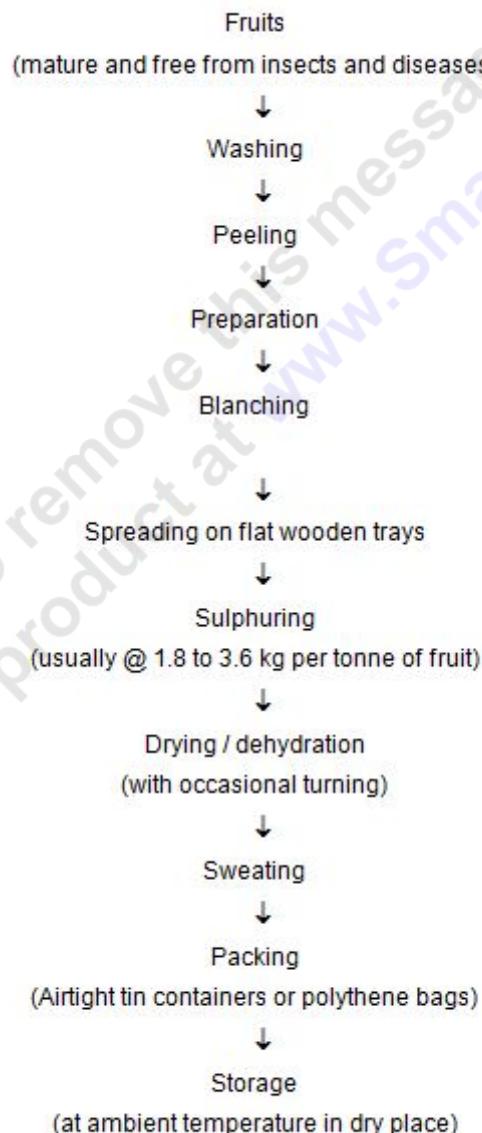
1. **Select the best fruit and vegetables-** As with canning and freezing, dehydrated foods are only as good as the fresh fruit or vegetables. When selecting fruits and vegetables for dehydration, choose ones that are ripe, unbruised and at peak-eating quality.
2. **Prepare fruits or vegetable to be dehydrated** --Apples, for example, may be sliced, cut into rings, or pureed for fruit leather.
3. **Keep pieces uniform in size and thickness for even drying**-- Slices cut 1/8 to 1/4-inch in thickness will dry more quickly than thicker pieces.
4. **Some foods should be washed before drying**-- Foods such as herbs, berries and seedless grapes need only be washed before dehydrating.
5. **To prevent browning**-- Try steaming, sulfuring or coating light-coloured fruits and vegetables with acids such as lemon juice or ascorbic acid before drying. Steaming or blanching is recommended for vegetables to

inactivate enzymes that cause vegetables to mature, or toughen during drying.

## During Drying

1. **Select the right drying method and equipment-**. Foods can be dried in a conventional oven, a commercial dehydrator, or in the sun. Drying times vary with the method and foods chosen. Be sure to read the instructions with your dehydrator.
2. **Maintain 130°F to 140°F with circulating air:** Remove enough moisture as quickly as possible to prevent spoilage. A drying temperature of 130°F to 140°F allows moisture to be removed quickly without adversely affecting food's texture, color, flavour and nutritive value. If the initial temperature is lower, or air circulation is insufficient, foods may undergo undesirable microbiological changes before drying adequately. If the temperature is higher, or humidity too low, nutrients can be lost or moisture may be

### FLOW-SHEET FOR DRYING / DEHYDRATION OF FRUITS



removed too quickly from the product's outer surface. This causes the outer surface to harden and prevents moisture in the inner tissues from escaping. When testing for sufficient dryness, cool foods before testing.

3. **Know whether food is dry or not:** Some foods are more pliable when cool than warm. Foods should be pliable and leathery, or hard and brittle when sufficiently dried. Some vegetables actually shatter if hit with a hammer. At this stage, they should contain about 10 percent moisture. Because they are so dry, vegetables do not need conditioning like fruits.

#### **After Drying (for fruit only)**

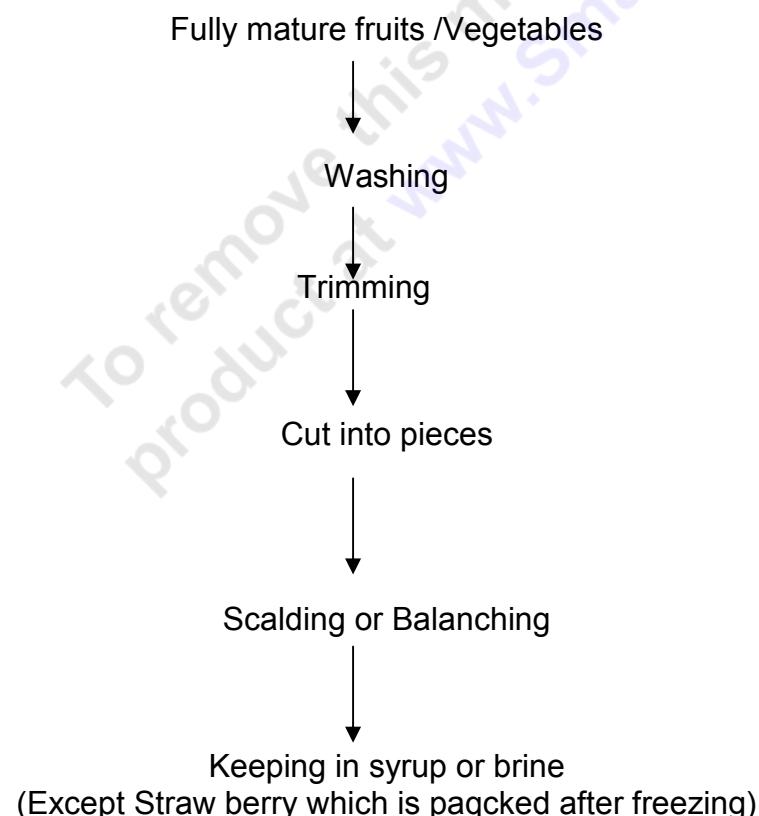
1. **Allow dried FRUIT (not vegetables) to "condition":** When dry, allow fruit to "condition" for four to 10 days before packaging for storage. The moisture content of home dried fruit should be about 20 percent. When the fruit is taken from the dehydrator, the remaining moisture may not be distributed equally among the pieces because of their size or their location in the dehydrator. Conditioning is the process used to equalize the moisture. It reduces the risk of mould growth.
2. **To condition the fruit** take the dried fruit that has cooled and pack it loosely in plastic or glass jars.
3. **Seal the containers and let them stand for 7 to 10 days.** The excess moisture in some pieces will be absorbed by the drier pieces.

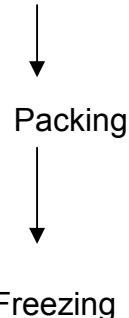
4. **Shake the jars daily to separate the pieces and check the moisture condensation.** If condensation develops in the jar, return the fruit to the dehydrator for more drying.
5. **After conditioning, package and store the fruit.**

**Blanching:** Most vegetables and some fruits are blanched before drying to inhibit enzyme activity and to help preserve the colour. The material is cut into appropriate sized pieces and plunged into boiling water for up to 5 minutes. They should be blanched in small batches to ensure that each piece is properly heated through. If too many pieces are put into the water at one time, the water temperature will drop and prolong the blanching time. After blanching for the required time, vegetables are rapidly cooled by plunging into cold (or iced) water.

**Sulphuring :** is an optional stage of processing. The main benefit of sulphuring is to preserve the fruit colour. Some consumers object to chemical preservatives and prefer naturally dried fruits. Sulphur dioxide gas ( $\text{SO}_2$ ) is applied to the fruit pieces by placing them in a cabinet or tent in which sulphur is burned. The gas is absorbed by the fruit. For most fruits, 5-6g sulphur per kg food is adequate. The gas given off is toxic and corrosive. Therefore, sulphuring should be carried out in a well ventilated place, using appropriate equipment.

#### **FLOW CHART FOR FREEZING OF FRUITS AND VEGETABLES**





### **Freezing of Fruits and Vegetables**

Freezing as a preservation method probably was observed by pre-historic people during cold weather; and until frozen storage cabinets were developed in the late 1980's, naturally occurring snow and ice were used to freeze foods outside.

With the development of mechanical refrigeration and quick freezing techniques, the frozen food industry has expanded rapidly. Even in homes, freezing of foods has now become common because home deep freezers are readily available. Under the usual conditions of storage of frozen foods microbial growth is prevented completely and action of food enzymes greatly retarded. The lower the storage temperature, the slower will be the rate of a chemical or enzymatic reaction, but most of them still continue at any temperature. Therefore, it is a common practice to inactivate enzymes in vegetables by scalding or blanching the latter before freezing when practicable. The rate of freezing of food depends upon a number of factors such as the method employed, the temperature, circulation of air or refrigerant, size and shape of package, kind of food etc.

When compared to most other food preservation methods, freezing requires the least amount of food preparation before storage and under optimum conditions it has the best nutrient, flavour and texture retention. Since food remains micro biologically safe during freezing, its shelf life is determined by chemical and physical changes that occur during storage.

At 0°F (-18°C) fruits can usually retain good quality for 12 months and vegetables for 8-12 months. Increasing storage temperature results in shorter shelf lives. For each 18°F (10°C) increase in temperature, the storage time is approximately cut in half.

Freezing is cheaper than canning, frozen products are of better quality than canned products, but for storage of frozen products uninterrupted supply of electricity is essential which is a problem at least in homes.

#### **Methods of freezing:**

**1. Sharp/slow freezing:** It 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 -72 hours. The ice crystals formed are large and rupture cells. The thawed tissue cannot regain its original water content. The first products to be sharp frozen were meat and butter.

**2. Quick freezing:** In this process the food attains the temperature of maximum ice crystal formation (0 to -4°C) in 30 minutes. Such a speed results in formation of very small ice crystals and hence minimum disturbance of cell structure.

Most of the foods are quick frozen by one of the following 3 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.

**(b) By direct contact with refrigerant:** Indirect freezing may be defined as freezing by contact of the product with a metal surface which itself is 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 which the refrigerant flows at -18 to -46°C.

**(c)By air blast freezing:** This refers to vigorous circulation of cold air in order to freeze the product. Freezing is done by placing the food stuffs on trays or on belt which are then passed slowly through an insulated tunnel containing air in it. Here the air temperature is approximately -18 to -34°C or even lower. This process is economical and a variety of sizes and shapes can be accommodated.

**3. Dehydro- freezing:** This is a process where freezing is preceded 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 food. Dehydration does not cause deterioration and dehydro frozen foods are relatively more stable.

**4. Freeze drying:** In this process food is frozen at  $-18^{\circ}\text{C}$  on trays in the lower chamber of a freeze drier and the frozen material dried (Initially at  $30^{\circ}\text{C}$  for 24 hours and then at  $20^{\circ}\text{C}$ ) under high vacuume ( $0.1\text{mm Hg}$ ) 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 dehydrated by this method.

**5. Cryogenic freezing:** Although most foods retain their quality when quick frozen by the above methods, a few (mush rooms, sliced tomatoes, whole straw berries and rasp berries) require ultra fast freezing. Such materials are subjected to cryogenic freezing which is defined as freezing at a very low temperature (below  $-60^{\circ}\text{C}$ ).The refrigerants used at present in cryogenic freezing are liquid nitrogen and liquid carbon- di- oxide.

**6. Accelerated freeze drying:** In this, low temperature is employed for drying and the technique of drying the solid pieces of the product without unduly disturbing the shape and texture, the dried material has good reconstitution properties and possesses excellent taste and flavor and as such has been well accepted by consumers. The dried product is highly useful in the preparation of emergency food packs and rations for use by the defence services under difficult and adverse conditions of climate and terrains such as high altitude, mountain regions etc.This method is adopted for drying fish and meat and not adopted for fruits and vegetables.AFD products are of excellent quality in every respect.

#### Spoilage of dried fruits and Vegetables:

Sl.No	Spoilage	Cause	Remedy
1.	Moulding	High moisture above equilibrium RH to water activity of 0.70	Reduce water content. Pack in hermetically sealed air tight containers
2.	Infestation	Presence of larvae or insects in dried produce	Storage room disinfestations. Fumigation of packed products
3.	Browning	Maillard reactions ( Chemical reaction )	Reduce the moisture content store at low temperature
		Enzyme related reaction	Enzyme inactivation by blanching or steaming before drying
4.	Reduced rehydration	Too hightemperaturein storage	Control the storage temperature

	ratio	
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### Fruit Juices

Fruit juices are preserved in different forms such as pure juices, squashes, cordials, fermented juices etc. These are broadly defined as follows:

**Unfermented fruit juice or pure fruit juice:** Fruit juices which don't undergo alcoholic fermentation are termed as unfermented fruit juices. This is the natural juice pressed out of the fruit and remains practically unaltered in its composition .It may be diluted before it is served as a drink.

**Fruit juice beverage:** This is a fruit juice which is considerably altered in composition before consumption. It may be diluted before it is served as a drink.

**Fermented fruit beverage:** This is fruit juice which has undergone alcoholic fermentation by yeast. The product contains varying amounts of alcohol. The typical examples of this kind of beverage are grape wines, apple ciders, berry wines etc.

**Fruit juice squash:** This consists essentially of strained juice containing moderate quantities of fruit pulp to which cane sugar is added for sweetening. It contains at least 25% fruit juice or pulp and 40-50% TSS, commercially. It also contains about 1% acid and 350ppm SO<sub>2</sub> or 600ppm sodium benzoate. It is diluted before serving.

Eg.Orange squash, mango squash, lemon squash, pineapple squash.

**Fruit juice cordial:** This is a sparkling, clear sweetened fruit juice from which all the pulp and other suspended materials have been completely eliminated. It contains at least 25% juice and 30%TSS. It also contains about 1.5% acid and 350ppm of SO<sub>2</sub>. This is very suitable for blending wines.

Eg. Lime juice cordial.

**Sherbat:** This is a clear sugar syrup which has been artificially flavoured .

Eg.Sherbats of sandal, Sangtra, Almond, Rose, khus-khus, Sarasaparilla, Kewra etc.

**Fruit juice concentrate:** This is a fruit juice which has been concentrated by the removal of water either by heat or by freezing. Carbonated beverages are made from this. They contain pure juice with at least 32% TSS.

**The major advantages of concentrates are:**

- ❖ Reduced weight and bulk compared to juice result in economy in packing, storage and transport.

- ❖ The whole crop of fruits is fully utilized during peak season, thus helping to stabilize the price.
- ❖ The product can be used as base material for making various food and beverage formulations.

#### **Problems with concentrates:**

- ❖ Fermentation is not prevented
- ❖ Non-enzymatic browning occurs
- ❖ Gel formation takes place.

**Fruit juice powder:** This is fruit juice which has been converted into a free flowing, highly hygroscopic powder by puff drying, freeze drying, vacuum drying, and spray drying or drum drying. The powder has the advantage of long shelf life and is soluble in cold water. But during the drying process much of the characteristic fresh flavour is lost, which is compensated by adding to the juice powder natural fruit flavour in powder form. Reconstitution of the powder mixture yields full strength, full-fruit, fruit juice drink. Freeze dried fruit juice powders form the last word among the sophisticated fruit juice products.

**Steps in processing of fruit juices:** The most important steps in processing of fruit juices are (1) selection and preparation of fruit (2) extraction of juice (3) deaeration (4) straining, filtration and clarification and (5) preservation. The quality of the juice will depend on the manner in which these several processes are carried out.

1. **Selection and preparation of fruit:** Fully ripe mid season fruits particularly citrus fruits generally yield juice superior to that of fruits picked early or late in the season. The fruits should be washed thoroughly with water. Scrub while washing to any adhering dust and other extraneous matter. Residues of sprays

of arsenic and lead should be removed with dilute HCl (23 liters of HCl in 455 liters of water). All mouldy and decayed parts should be removed.

**2. Juice extraction:** The variety of fruit, its maturity and the locality in which it is grown have a marked effect on its flavour as well as its keeping quality. The best juice is therefore extracted from freshly picked, sound and suitable varieties when they are at optimum stage of maturity. Generally juice from fresh fruits is extracted by crushing and pressing them. The admixture of the extraneous constituents with the juice should be avoided as far as possible by adopting a suitable method of extraction. During the extraction, the juice should not be unduly exposed to air, as oxygen of the air will adversely affect the colour, taste and aroma and also reduce the vitamin content of the juice. Citrus juice, tomato juice, apple juice, and grape juice deteriorates rapidly in quality, when they are extracted by adopting methods which expose them to air for longer periods.

**3. Deaeration:** Fruit juices do retain some air due to the presence of air in the intercellular spaces of the fruit. Most of the air is present on the surface of the fruit particles, while some is found dissolved in the juice. Therefore immediately after extraction, the juice is subjected to a high vacuum whereby most of the air as well as other gases are removed. This process is known as deaeration.

**4. Straining, filtration and clarification:** Fruit juices always contain varying amounts of suspended matter, which consists of broken fruit tissue, seed and skin and also various gums, pectic substances and proteins in colloidal suspension.

The coarse particles of pulp, seeds and pieces of skin are removed by means of non-corrodible metal sieves or by sedimentation. The presence of these generally causes deterioration in the quality of the final product. Recently a high speed

centrifuge having an automatic sediment discharge device has been introduced for removal of pulp from orange juice.

The complete removal of all suspensions is effected either by filtration or by clarification. For this enzymes and fining agents are employed .Filtration is necessary for removing completely all the fine and colloidal suspensions .In this process the strained fruit juice is forced through a filtering medium which consists of fibre cloth ,asbestos pads, cotton pulp, porous porcelain or wood pulp. The colloidal suspension tends to clog the filters in the press. To prevent this filter aids such as diatomaceous or infusorial earth (kieselguhr, Kaolin, Spanish clay etc.) are added to the juice to facilitate filtration .However, earth material tends to impart to the juice a sort of earthy taste. These aids therefore, should be used with caution and in little quantities. For clarification of apple juice, use of ignited kaolin as filter aid -1 kg per 100 kg of juice was recommended. The resulting juice will be clear and sparkling.

**Use of fining agents:** This method aims at producing a voluminous flocculent precipitate which settles gradually, carrying down with it finely divided particles and colloidal suspensions that are responsible for cloudiness.Fining agents are of three kinds (1)enzymes which destroy the colloids present in the juice,(2)finings which are purely physical in their action(infusorial) and (3)chemical finings which act on the gummy and colloidal substances present in the juice to form insoluble coagulates that settles down easily (gelatin, albumin and casein).

**1.Enzymes:** Enzymes such as proteolytic ,pectin decomposing ,hydrolytic, starch liquefying enzymes etc are used to remove pectin, protein and starch from fruit juices. They are marketed in trade as pectinol, filtragol, ido, pectasine etc.Pectynol enzymes are prepared from the mould *Pennicilium glaucum*, which is found growing on

grapes. Pectinol breaks down pectin into soluble form, thereby freeing the suspended particles, which subsequently settles down speedily, leaving the solution clear.

Filtragol is another pectin decomposing enzyme developed for the clarification of fruit juices of kernel fruits, stone fruits and grapes. If the juice is to be filtered soon after the addition of the enzyme, a slightly larger quantity of filtragol should be added.

**The following are the advantages of using filtragol:**

- ✓ The heating of the fruit juice is not necessary if filtragol is employed while it is necessary to heat the juice if other enzymes are used.
- ✓ The filtration takes less time
- ✓ In the presence of filtragol, the colouring matter of the fruit is solubilised without any heating, which would otherwise be necessary to extract the colour from the fruit tissues.
- ✓ The efficiency of filtragol is not impaired by the addition of sulphur-di-oxide to the juice at 30-60ppm concentration which is necessary to prevent any fermentation.

**Doses of filtragol:** 0.5 to 1.5 g per litre of kernel fruit, stone fruit and grape juice.

1.5 to 2.0 g per litre of raspberry, black berry, currants etc.

**2. Physical or mechanical fining agents:** The infusorial earths such as Spanish clay, china clay, kaolin, and bentonite are suitable for this purpose. These should not react with the acids of the juices, should not impart any undesirable taste and flavour to the juice and should not form any colloidal suspension. To ensure these, these earths are heated to dull red to burn away all the organic matter present and subsequently treated with 1.0 -1.5 % of citric or tartaric acid . Finally washed in water, dried and powdered before use. Usually 0.5 to 0.6% of the earth is mixed with the juice. However in the case of unfermented apple juice, kaolin is added @ 1kg to 100 kg of juice.

**3. Chemical finings:** The colloidal substances such as proteins and pectin's carry negative electrical charge on them. These are precipitated when this charge is neutralized by the addition of positively charged colloids like gelatin and casein. The precipitates thus formed settles down carrying with them other suspended particles too. Gelatin is an excellent fining material and is widely used for the clarification of fruit juices. Sufficient tannin is also added to the juice to minimize the bleaching action of gelatin.

**Albumen:** It is the white of eggs and can be liberated by heating in a small quantity of water. Usually 2% solution of albumen gives satisfactory results.

**Casein** It is prepared from skimmed milk by precipitating it with hydrochloric acid. The precipitated casein is washed in water, dried and powdered. It is dissolved in liquor ammonia, boiled and diluted to 2% strength solution. This solution is mixed with the fruit juice.

**Clarification by freezing:** Colloidal suspensions when subjected to freezing are readily precipitated on thawing. Apple juice responds very well to this treatment followed by grape juice. The clear juice is then bottled.

**Clarification by heating:** Colloidal material in fruit juices usually coagulates, when the juice is heated and settles down readily. The juice is heated to  $82^{\circ}\text{C}$  for a minute or less and then cooled down rapidly. The heating is effected in flash-heaters to avoid oxidation by air. After cooling the juice is mixed with the filter aid and passed through the filter press. Clarification of pomegranate juice is a typical example of this process.

**Preservation of fruit juices:** To retain natural taste and aroma of the juice, it is necessary to preserve it soon after extraction. The methods generally used are:

**a) Pasteurization:** preservation of fruit juices by heat to  $100^{\circ}\text{C}$  for sufficient time to kill micro organisms is called pasteurization. Fruit juices can be pasteurized in two ways:

- 1) By heating the juice at low temperature for a long period.
- 2) By heating the juice at a high temperature for short time only (HTST) method.

**Methods of pasteurization:**

1) **Bottle method (Holding pasteurization):** The bottles are filled with juice leaving a head space for expansion on heating. The bottles are sealed air tight.

2) **Pasteurization by over flow method:** The juice is heated to a temperature about  $2.5^{\circ}\text{C}$  higher than that of Pasteurization temperature, and filled into the sterilized bottles up to the brim and sealed. The sealed bottles are pasteurized.

3) **Flash Pasteurization:** The juice is heated to  $5.5^{\circ}\text{C}$  higher than the Pasteurization temperature rapidly and is held at that temperature for a minute and then filled into the containers. The containers are sealed and pasteurized.

**b) Preservation with chemicals:** Pasteurized squashes and cordials have a cooled flavour. After the container is opened, they ferment and spoil within a short period. To avoid this chemicals are used. The two important chemical preservatives permitted in many countries as well as in India according to FPO of 1955 are:

- Benzoic acid (including benzoates).
- Sulphur Dioxide (including sulphites).

**Sodium benzoate:** It is a salt of benzoic acid and is an effective agent. As it is sparingly soluble in water, its sodium salt, which is water soluble, is generally used. In the case

of fruit juices which have a pH of 3.5 to 4.0. Addition of 0.06 to 0.10 % ( 600-1000mg) of sodium benzoate is sufficient per litre of juice.

**Potassium meta bi-sulphite ( $K_2O$ ,  $2SO_2$ , or  $K_2S_2O_5$ ):** It is commonly used as a stable source of sulphur di-oxide . Being a dry chemical , it is easier to use than a liquid or gaseous sulphur di-oxide. Potassium meta bi-sulphite a crystalline salt and is fairly stable in neutral or alkaline media. When it is added the potassium radical reacts with the acid of the juice forming the corresponding potassium salt (as potassium citrate or potassium tartarate etc.) and the sulphur di-oxide which is liberated, forms sulphurous acid with the water of the juice. According to FPO, the maximum sulphur di-oxide allowed is 350ppm. This corresponds to 28 g of KMS to 454 kg of squash or cordial. It has a strong effect in retarding oxidation, prevents discolouration and loss of flavour in the product. However, it cannot be used in naturally coloured juices like phalsa, jamun, pomegranate, strawbrry, grapes etc. on account of its bleaching action.

**C) Preservation by addition of sugar:** Sugar absorbs most of the available water with the result that the latter is not available for the growth of micro-organisms. The sugar acts as a preservative by osmosis and not as true poison for microorganisms. Sugar syrup of 66% sugar inhibits the growth of micro-organisms.

**d) Preservation by freezing:** It is the best method of preserving fruit juices as it retains its freshness, colour and aroma for a long time. The juice is first de-aerated and the vacuum released with nitrogen gas. The juice is then transferred into containers which are hermetically sealed and frozen at  $-12^{\circ}C$  to  $-10^{\circ}C$ . The juice is defrosted before its consumption.

**e) Preservation by drying:** The juice is sprayed in the form of a very fine mist into an evaporating chamber through which hot air is passed. The dry juice falls on the floor of

the chamber in the form of a fine powder. The powder collected and packed in dry containers, which are then sealed air-tight.

**f) Preservation by carbonation:** The filtered juice is carbonated which will keep the juice without fermentation. The oxygen of the air which is present in the solution is displaced with carbon dioxide. This prevents the growth of moulds and yeasts. High carbonation should be avoided as it destroys the delicate flavours of the juice.

**g) Preservation by filtration:** The juice which has been clarified is passed through specialized filters which are capable of retaining yeasts and bacteria. Various types of germ proof filters are used for this purpose in USA and Germany.

**h) Other methods:** Methods of sterilizations such as use of electric current, UV rays, Olygodynamic properties of silver etc. have been recently used in developed countries.

## **Chutneys and Pickles**

**Chutney:** Chutney is a pungent relish of Indian origin made of fruit, spices and herbs. Although originally intended to be eaten soon after production, modern chutneys are often made to be sold and so require preservatives - often sugar and vinegar - to ensure it has a suitable shelf life. Chutney of good quality should be palatable and appetizing.

The fruit or vegetable is cut into slices of suitable size and softened by boiling in water. Slow cooking at low temperature yields better product. Onion and garlic are added at the start to mellow their strong flavours. Spices are coarsely powdered and added to the product. Spices as well as vinegar extract should be added just a little before the final stage of boiling to avoid the loss of essential oils of these spices and vinegar.

**Pickles:** The process of preservation of food in common salt or in vinegar is called pickling. Spices and edible oils may be added to the product .Pickles are good appetizers and add to the palatability of a meal. They aid in digestion by stimulating the flow of gastric juice. The pickles contain nutrients of varying amounts. The food value of cucumber pickle exceeds that of eggs, rice, fresh onions and tomatoes.

**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.

**1. Dry salting:** The vegetable is treated with dry salt. The salt extracts the juice from the vegetable and forms the brine, which is fermented by lactic acid forming bacteria. The method is as follows:

The vegetable is prepared .For every 100 kg prepared vegetable, three kg of salt is used. The vegetable is placed about 2.5cm deep in the keg or barrel and is sprinkled with salt. Another layer of vegetable is added and again sprinkled with salt. Like this salt and vegetable are added layer by layer till the keg is 3/4<sup>th</sup> full Then one or two fold cheese cloth is spread over the salted vegetable. Place a wooden board on the top of it. A clean stone or weight is placed on the wooden board to press the vegetable. The brine is formed in 24 hours generally.

The keg is placed in a warm and dry place and fermentation is allowed to proceed. As soon as the brine is formed, the fermentation starts and bubbles of CO<sub>2</sub> begin to rise. Fermentation is usually completed in 8 to 10 days under favourable conditions of 30°C. The product is now ready for preserving by excluding air ,which can be done by three ways. (1) Pouring edible oil (2) Pouring brine and (3) Placing hot molten paraffin wax.

**2. Fermentation in brine:** Steeping of vegetable in a salt solution of predetermined concentration for a certain length of time is called brining. This method is adopted in cucumber pickles which don't contain sufficient juice to form brine with dry salt.

### **Raw materials used in Pickling**

**Salt:** Free from impurities and salts such as lime (Cao), iron (blackening), magnesium (results in bitter taste) and carbonated (makes the product soft in nature).

**Vinegar:** Vinegar of good quality should contain at least 4% acetic acid. Synthetic low quality vinegar is not suitable for pickle preparations. Usually maleic and citric vinegar is used. In order to ensure good keeping quality pickle, the final concentration of citric acid in the pickle should not be less than 2%. Citric acid (Commercial) is used because it is highly concentrated.

**Sugar:** Used in the preparation of sweet pickles.

**Spices:** Spices are added to all the pickles. The quality added depends upon the type 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, asafetida etc.

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

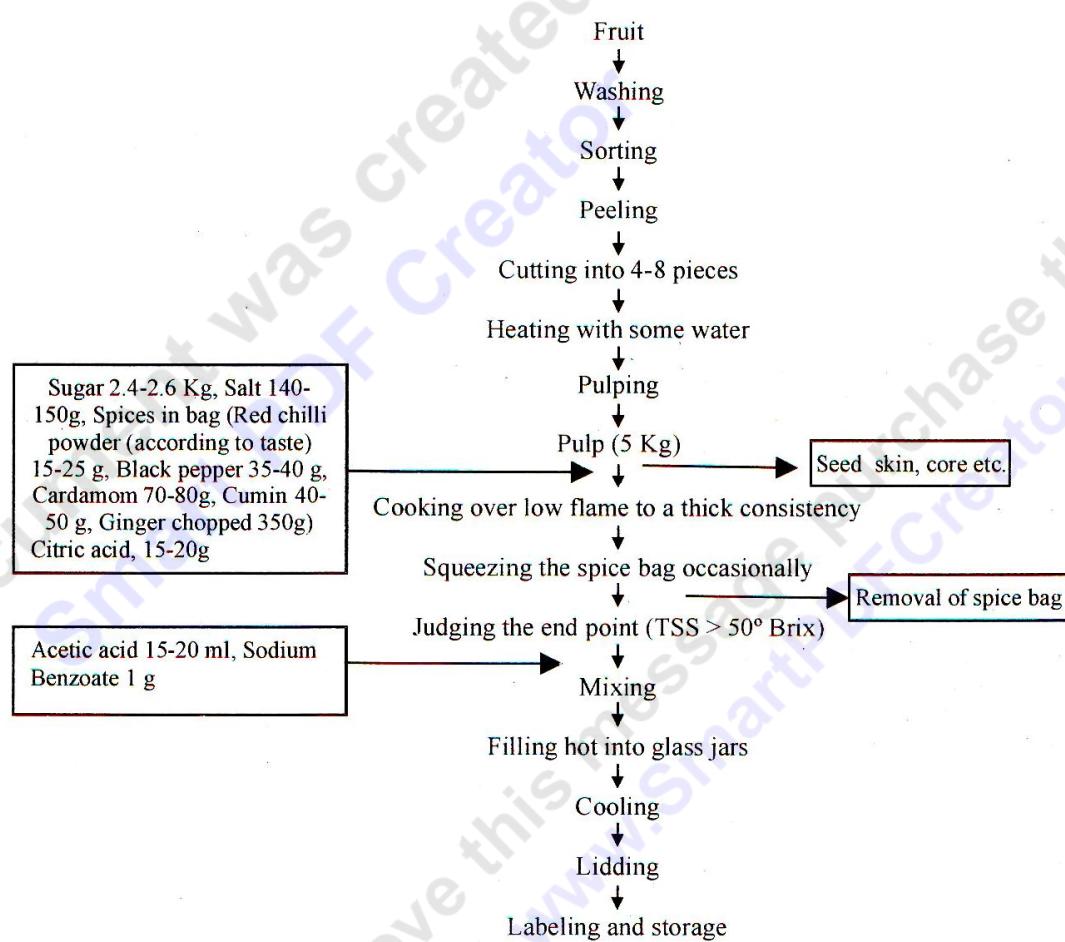
**Cooking utensils:** Metallic vessels should not be corrodible. Vessels made of iron and copper are not suitable. Glass lined vessels and stainless steel vessels are preferred. The laddels, spoons and measuring vessels should also be made of non-corrodible materials.

### **Causes and kinds of spoilage in pickles:**

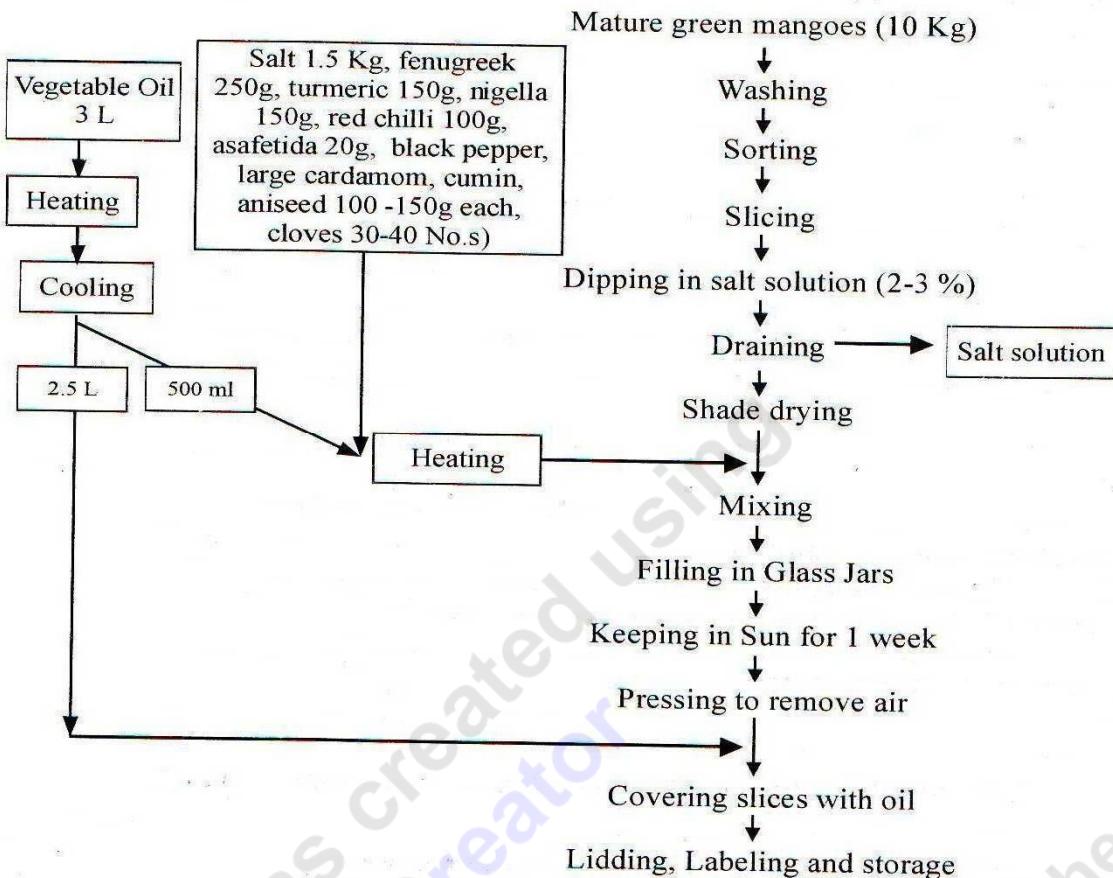
- 1) **Shriveling:** vegetable like cucumber when placed directly in a very strong solution of salt, shriveling occurs.
- 2) **Bitter taste:** The use of strong vinegar or cooking the spices for a long time and over spicing are the causes.
- 3) **Blackening:** It is due to iron, which enters through the brine or equipment.
- 4) **Dull or faded product:** Insufficient curing or using inferior quality material may be responsible.
- 5) **Softness or slipperiness:** This is due to the action of bacteria. In adequate covering of pickle with brine or using weak brine are responsible.
- 6) **Scum formation:** In the presence of air, the growth of wild yeast may form on the surface. It retards the formation of lactic acid. This action helps the growth of

putrefactive bacteria, which makes the vegetable soft or slippery. Addition of 1 % acetic acid helps to prevent the growth of wild yeast on the brine.

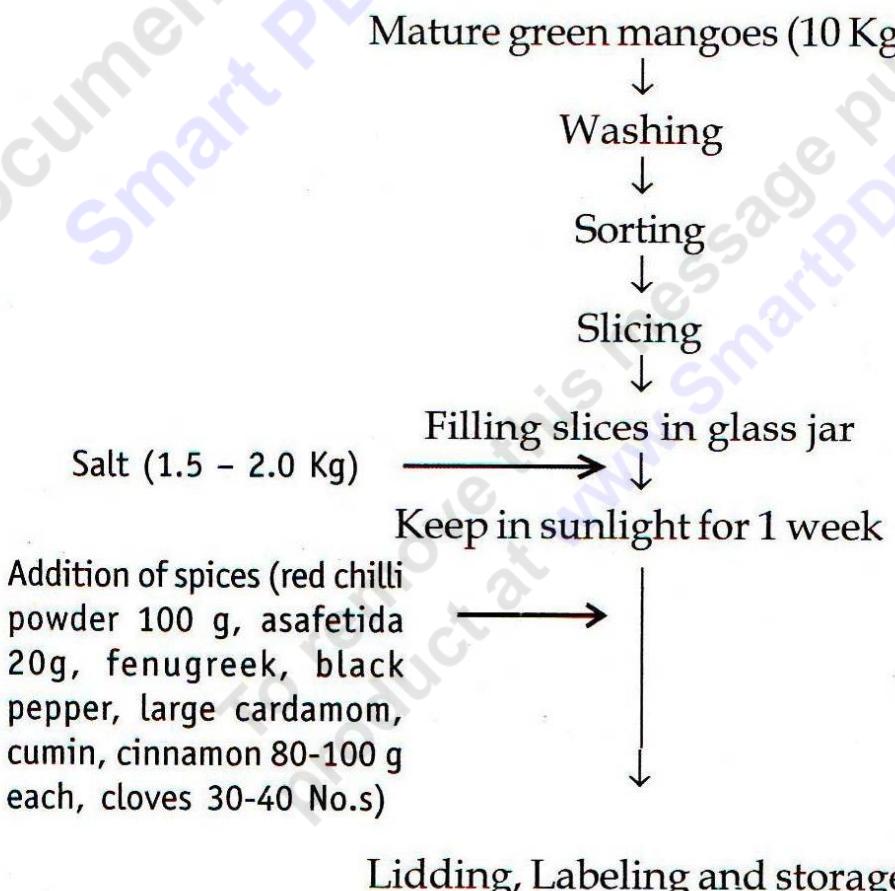
- 7) **Cloudiness:** In case of onion and other vegetables, the acetic acid in the vinegar may not penetrate deep enough to prevent the activity of bacteria or other microorganisms that may not present in them. Therefore, fermentation starts from inside, rendering the vinegar cloudy. This activity of microorganisms can only be checked by brining. Cloudiness may also be caused by the use of inferior vinegar or by possible chemical reaction between the vinegar and the impurities such as calcium, magnesium and iron compounds of salt.
- 8) **Blemishes in pickles:** In onion pickles, a white blotch under the first layer of skin is seen. This is owing to a kind of fermentation or non-removal of all the brine prior to the final pickling of cured onion in vinegar.



**Flow Chart for Preparation of Chutney**



**Flow Chart for Preparation of Mango Pickle (Preservation in oil)**



**Flow Chart for Preparation of Mango Pickle (Preservation in Salt)**

## Ketchup,Sauces and Puree

**Sauces:** Sauce is a product similar to ketchup, prepared from pulps of tomato or other fruits / vegetables having TSS not less than 15% and cooked to a suitable consistency with added sugar, salt, spices and vinegar (acetic acid). Sugar, salt, spices, acetic acid all act as partial preservatives. According to the FPO fruit should have a minimum of 15% TSS and 1.2% acidity. To ensure its keeping quality the sauces should contain 3% acetic acid. The sugar content may vary from 15-30% according to the kind of sauce made. Preservative and colours may also be added in sauces for increasing storability. Sauces may or may not be prepared from tomato, but ketchups are essentially prepared from tomato.

Some examples of sauces are tamarind sauce, pumpkin sauce, chilli sauce, Soya sauce etc. Sauces are of two kinds and they are the thin and thick sauces. Thin sauces mainly consist of vinegar extract of various flavouring materials like spices and herbs. A sauce which doesn't flow freely and which is highly viscous is called a thick sauce.

**Ketchup:** It is a product made by concentrating tomato juice or pulp without seeds and skin, with added spices, salt, vinegar, onion, garlic etc.so that it contains not less than 12% tomato solids and generally 28% or more total solids (not less than 25% TSS as per FPO specifications)

**Procedure:** For preparing 1 kg of tomato pulp, the following ingredients are required.

Sugar	-75g	Red Chilli Powder	-5g
Salt	-10g	Cinnamon,cardamom, Anil seed,Black Pepper,(all powdered)	-10g each
Onion(Chopped)	-50g	Clove(Headless)	-5g
Ginger(Chopped)	-10g	Vinegar	25ml
Sod.Benzoate	0.25g/kg of final product		

- Selection of fruits:** Select sound ripe tomatoes having deep red colour. Remove all green and yellow portions. Green fruits make the ketchup inferior in colour and flavour.
- Preparation of pulp:** Take the selected tomatoes in an aluminum or stainless steel vessel and crush thoroughly with a wooden handle. Cook the crushed mass for 5 minutes and mash it well while cooking. While it is sufficiently soft. Strain through the fine mosquito net cloth or 1mm mesh stainless steel sieve. Discard the sheds and skins.
- Cooking:** To the pulp add about 1/3<sup>rd</sup> of sugar given in the receipe.Place the spices (onion, garlic, cloves, cardamom, black pepper, jeera, mace, cinnamon and chili powder) in a muslin cloth bag (Jelly bag) and immerse it into the pulp. Heat the pulp till it

thickens and is reduced to about 1/3<sup>rd</sup> of its volume. Remove the bag and squeeze it well to extract the aroma and flavour of the spices. Add vinegar, salt and the remaining sugar .Heat the mass for a few minutes so that the volume of the finished product is about 1/3<sup>rd</sup> of the original pulp.

4. **Addition of preservatives:** To a small quantity of finished product, add the preservative sodium benzoate, at the rate of 295mg/kg of finished product and mix thoroughly. This can be increased up to 885mg/kg as per specifications of FPO, 1955.Transfer the dissolved preservatives to the rest of the product and mix thoroughly.
5. **Cooling and Mixing:** Pour the finished product into a medium size sterilized bottles, seal them air tight with crown cork and pasteurize in boiling water for 30 minutes. Cool the bottle in air and store in a cool dry place.

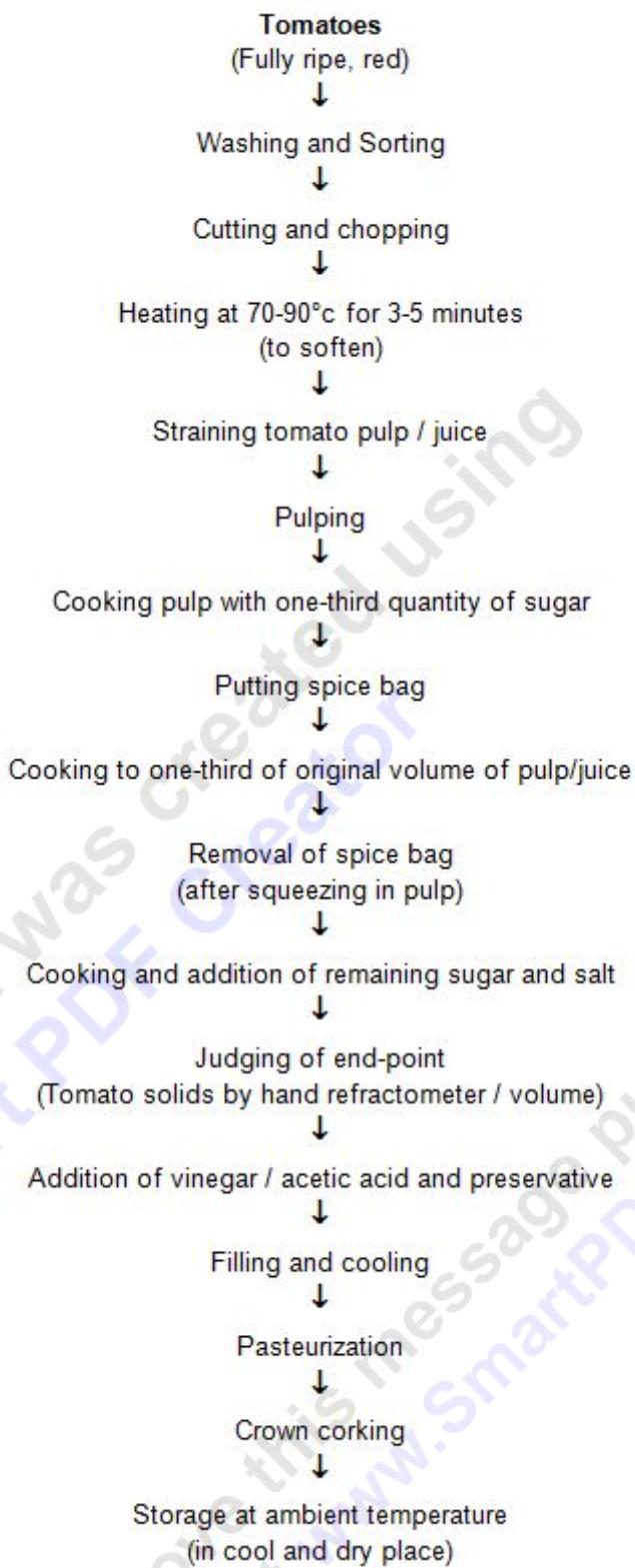
**Judging end point:** End point is determined by hand refractometer.when TSS reaches desired level (28-30%) sauce or ketchup is considered ready. Judging end point by volume is very simple and common in practice. The volume is measured by stick. If the volume of the produce remains 1/3<sup>rd</sup> of its original volume sauce/ketchup is considered ready.

**Note:**

- 1) Chilly powder, spices, onion, ginger and garlic should be tied loosely in a muslin cloth bag.
- (2)Vinegar and colour may be added towards the end of boiling.
- (3)1/3<sup>rd</sup> of sugar may be added in the beginning to preserve the red colour of pulp.
- (4)Instead of clove, cinnamon and cardamom, their essences may be added more conveniently.
- (5)Garlic may or may not be added, depending upon consumer's acceptance.
- (6)Acid magenta II colour is avoided. Choose other red colors or orange colors such as erythrosine, carmoisines, sunset yellow etc.

**Bottling:** Ketchup is filled in bottles at 88<sup>o</sup>C and is pasteurized for 30 minutes in hot water at 85<sup>o</sup>C-90<sup>o</sup>C after cooking. It is preferable to add 250ppm sodium benzoate and then pasteurize the product.

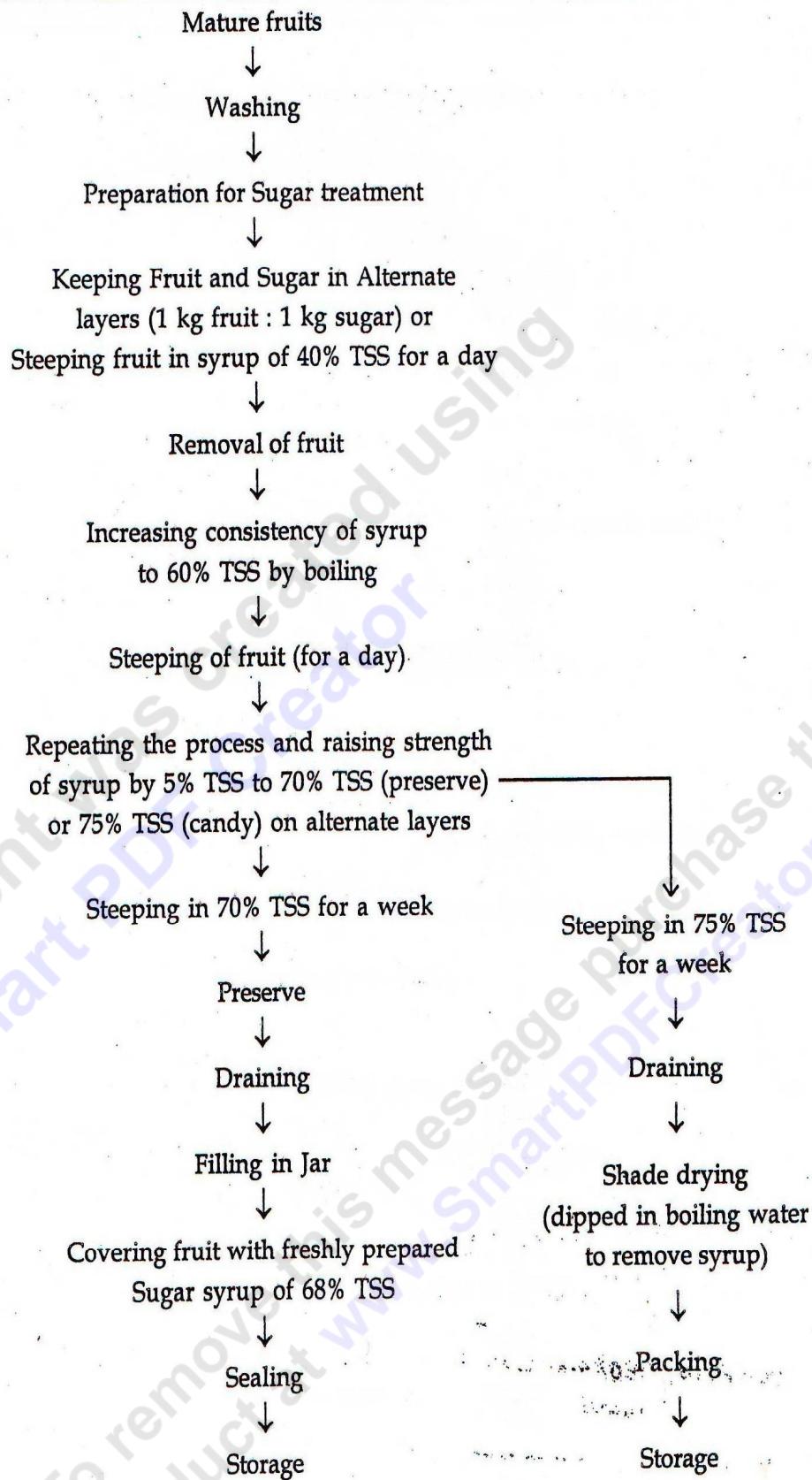
**FLOW CHART FOR TOMATO SAUCE/KETCHUP**



**Tomato Puree:** Tomato pulp without skin and seeds, containing not less than 8.37% of salt free from tomato solids is called as “medium tomato puree”. It is further concentrated to 12% solids to form heavy tomato puree. Pulp is extracted and concentrated in open cookers or vacuum pans and packing is done in glass bottles or cans.

**Flow Chart:** Tomato fruits ---Washing---Sorting---Cutting into 4-8 pieces—Heating in SS pan for 4-5 minutes---pulping---Juice---(Discard seeds and skin)---Heating or boiling till end point( $9-12^{\circ}\text{Brix}$ )---Hot filling at  $85^{\circ}\text{C}$ ---Sealing/Crown corking---Sterilization in boiling water for 25-30 minutes---Cooling---Labeling and storage.

## FLOW SHEET FOR PRESERVE AND CANDY



## **Preserves, candies and crystallized fruits**

**Preserve:** A preserve is made from properly matured fruit, by cooking it whole or in the form of large pieces in heavy sugar syrup, till it becomes tender and transparent. As per FPO specifications, preserve must have 68% TSS and 55% portion of prepared fruit.

A jam differs from a preserve in that it does not contain pieces of whole fruit as in the case of preserve.

Suitable fruits for making preserve are aonla, apple, karonda, pineapple, papaya, carrot, ginger, petha (ash gourd) and other firm textured thick pulped fruits.

For 1kg fruit 1 litre of water and 1 kg of sugar is required.

**Procedure:** The fruit should be washed thoroughly and prepared. The fruit is first cooked slightly in water to make it soft enough to absorb sugar. Cooking of the fruit in syrup is rather a difficult process, because the syrup is to be maintained at a proper degree of consistency so that it can permeate the entire body of fruit without causing it either to shrink or to toughen. If the fruit is cooked straight away in heavy syrup, its juice will be drawn out rapidly due to osmosis; with the result it would shrink and there would consequently be very little absorption of sugar subsequently.

**Cooking in syrup:** There are 3 ways of cooking the fruit in syrup.

- 1) Open kettle one period process
- 2) Open kettle slow process
- 3) Vacuum cooking process.

**Cooling and packing:** The fruit is drained from the syrup and filled into any containers. Freshly prepared boiling syrup of 68°B is then poured into containers and clinched. Later they are exhausted for 8-10 minutes at 100°C in a steam and then hermetically sealed.

**Candied fruit:** It is a product prepared after draining and drying of sugar syrup from preserve.

**Glazed fruit:** Covering of candied fruits with thin transparent coating of sugar imparting it a glossy appearance is termed as glazing. The product thus prepared is termed as glazed fruit.

**Crystallized fruit:** When a candied fruit is coated with crystals of sugar, either by rolling it in finely powdered sugar or by allowing the sugar crystals from dense syrup to deposit on it, it becomes what is called crystallized fruit.

## **Preservatives and Colours permitted and prohibited in India**

The acceptance of a food depends to a large extent upon its attractive colour. The characteristic colour of raw food is due to the pigments naturally present in it. Some times, artificial colour is added during the preparation and processing of foods to make them more attractive.

The colours or dyes used in food products should be pure and free from all harmful impurities. They should not contain more than 10ppm of copper, 20ppm of chromium, 1ppm of arsenic and 10ppm of lead and should satisfy government regulations. In the selection of dyes, it is desirable to choose those which have high solubility in order to obtain a concentrated solution of a particular colour.

Colours are generally available in the form of powders or to use solutions. The powder should first be made into a paste with a little cold water and the requisite quantity of almost boiling water is added to the paste with constant stirring. The solution is allowed to stand still cool and any sediment formed is removed by filtration. To prevent sedimentation glycerin is usually added to the solution to increase its density. Isopropyl alcohol also helps in increasing the solubility of the powder.

Dye solutions can be preserved by addition 10% alcohol (V/V), 25% glycerin for short period storage or 50% glycerin for prolonged storage.

The amount of any permitted coal tar dye or mixture of permitted dyes which may be added to any fruit product should not exceed 0.2g per kg of the final product. Although colours are added to the attractiveness of food products, it is better to avoid their use as far as possible and educate the consumer to use products not containing colourants. Colours can often be used to cover defects in the natural products.

A number of naturally occurring substances are used for colouring foods. According to the fruit products order, India (1955), the following natural colouring matters, whether isolated from a natural source or synthesized, are permitted to be added to any article of food.

Caramine, Carotene and carotenoids, Chlorophyll, Lactoflavin, Caramel, Annato, Ratanjot, Saffron and Curcumin.

**Banned Colours:** According to the public health (preservatives etc. in food) regulations, 1925 (amended 1926 and 1927) of the ministry of health, UK the following colouring matters are not permitted to be added to articles of food

**Metallic colours:** Compounds of any of the metals, antimony, arsenic, cadmium, chromium, copper,, mercury,lead and zinc.

**Vegetable colouring matter:** Gamboge

**Coaltar colours:** Picric acid, Victoria Yellow, Manchester's Yellow, Aurantia and Acerine.

Recently the use of some colours in foods has been banned. In India, Acid Magentall and Blue VRS, which are used in tomato ketchup and canned pear respectively, have been deleted from the list of permitted colours. Both are triphenylmethane dyes. Instead of blue VRS. , Fast green S and Green FCF have been recommended. Red 6 FB and Brilliank Black have also been deleted as being harmful.