Post Harvest Management of Fruits and Vegetables

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Chapter I

POST HARVEST MANAGEMENT OF FRUITS AND VEGETABLES

The varied agro-climatic conditions in different parts of India provide an enormous scope for the cultivation of a wide variety of tropical and subtropical fruits and vegetables and maintain the inflow of almost all varieties throughout the year. At present, India has emerged as the largest producer of fruits and second largest in case of vegetables, next only to China. The significant growth of production of fruits and vegetables can be established by the fact the production in the country has tripled after independence. The production figures for last few years are given in Table 1. Presently the area under fruits and vegetables are estimated to be 3.94 million hectares and 15 million hectares respectively.

However, though the production figures can make us believe in our strength for self sustainability, a significant amount of qualitative and quantitative losses occur in the produce from the period of harvest till consumption. The magnitude of post-harvest losses estimated in fresh fruits and vegetables range between 5 and 25% in developed countries, and between 20-50% in developing countries. Several studies in India indicate the loss as 22 to 40 per cent, which amounts to loosing of about Rs.30,000-40,000 million annually.

Odisha produces a variety of horticultural crops under the categories of fruits, vegetables, spices, flowers, plantation crops and medicinal plants. In general the post-harvest losses in horticultural produce have been reported to be in the range of 10 to 40%. However, if suitable steps are initiated for proper post harvest management and value addition, the horticulture sector can serve as a very important tool for increasing the nutrient availability and income for the common man. Horticultural crops are right materials for diversification and value addition because they are more profitable through effective land use and optimum utilization of natural resources, environment friendly, and rich in health promoting compounds, flavors, aroma, oleoresins, etc. Besides making agriculture competitive, value addition also helps in avoidance of post harvest losses, and promote industrialization, employment generation, export, extended availability of produce, foreign exchange earning and product diversification, easy marketing.

In the present agricultural scenario, when the globe has become a single market, agriculture needs to be competitive. Diversification, quality enhancement and value addition have become key words of success in agricultural trade at international level. Quite naturally, for our horticulture to be competitive, due importance has to be given for value addition and increase in the range of fresh as well as processed products for harnessing full advantage from present scenario and development. It is, therefore, appropriate time for us to come out of just a little bit of primary processing and bulk exporting of pulps and get into newer produce development and marketing of ready-to-consume product through value addition.

Horticulture deals with production, processing and improvement of a large group of fruits, vegetables, flower crops, spices, plantation crops, medicinal and aromatic crops. Under each group a large number of crops are being grown and many more could be added due to availability of diverse agro-climatic conditions and under each crop there are large number of varieties. For example, mango has thirty commercial cultivars, banana has twenty, guava ten, etc. At this stage, it is also important that we must encourage the production of crops which
belong to us and possess great medicinal, nutritional, health promoting values. A few examples are aonla, ber, woodapple, pineapple, jackfruit, custard apple, etc.

India is the second largest producer of fruits and vegetables and number one in coconut, cashew, number of spices and plantation crops and like tea, coffee, etc. and less than 10 percent of that horticultural produce is subjected to processing vis-a-vis many developed and developing countries where 40-80 per cent produce is value added. Thus, we have immense quantity and variety of produces for value-addition.

Horticultural crops provide varied type of components, which can be effectively and gainfully utilized for value-addition like pigment, amino, oleoresins, antioxidants, flavors, aroma, etc.

Therefore, horticultural crops are right material for value addition in the present context of agricultural scenario and we should go in for few produce development to be unique and novel.

**Objectives of PHM of fruits and vegetables**

The post harvest management of fruits and vegetables is different from the grains because the fruits and vegetables are perishable commodities and the normal storage life varies from even one day to several days.

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<tr>
<th>Proper post harvest management of fruits and vegetables helps us in many ways as follows.</th>
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<td>• It extends the period of availability of the specific fruits and vegetables and helps us to get a wide range of fruits and vegetables round the year.</td>
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<td>• It helps in prevention of seasonal market gluts; we do not have to sale the crop at a throw away price during the harvest season and pay much higher price for the same commodity in the off-season. In other words, it helps in orderly marketing and better return to growers.</td>
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<td>• It helps in preservation of quality of these essential and highly nutritional commodities.</td>
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We must realise that the production of fruits and vegetables will have significance only when they reach the consumer in good condition and at a reasonable price. Thus, utilization of full amount of production in one form or the other should be the motto. This is only possible through integrated post harvest management.

**We have two broad types of activities in post harvest management of fruits and vegetables.**

We have to store the commodities in such a way that they remain fresh-like for longer period without much loss in nutritive value, or we may change the form of the commodity like we do in the preparation of pickles, jams, jellies, etc. Beyond the basic objective of storage and preservation, we can also add value to the produce and prepare a variety of the products, like we prepare potato chips, canned foods, etc.

**Influence of varieties, pre-harvest parameters and harvesting methods on PHM**

*Though the post harvest operations start after harvest, however, the quality of the end product depends not only on the post harvest operations, but also on several pre-harvest factors*. Some of these factors are as follows.

1. Genetic factors, varieties, etc.
2. Environmental, cultural factors, treatments, etc.
3. Harvesting: stage of maturity at harvest, time of harvest, harvesting methods, etc.
4. Post harvest activities: handling methods, packaging, pre-storage treatments, pre-cooling, storage methods, etc.

The characteristics of the fruits and vegetables differ, and hence, all varieties are not suitable for consumption in fresh or raw form, nor all varieties are suitable for processing. For instance, we must have observed that the qualities of tomatoes differ and there are specific varieties of tomatoes for processing purpose. The tomato varieties with good pulp are suitable for processing purposes. The varieties of mango which are suitable for direct consumption are Dasheheri, Himsagar, Langra, Neelum, Mallika, etc., whereas Totapuri is a variety used for processing. The Alphonso and Banganpali can be used for pulping and canning purpose. Kufri Chipsona and Jyoti are good potato varieties for processing and preparation of chips. The ginger varieties with less fibre should be used for preparation of paste and candies, etc., whereas for extraction of ginger oil and oleoresin, the fibres do not pose any such problem. In other words, the processable varieties may differ from the varieties for consumption in fresh form, and we must judiciously select the variety before deciding on the processing and value addition aspects.

The stage of harvesting, i.e. the maturity of the crop at the time of harvest is very important. For example, the fibre content of ginger increases if the harvest is delayed. The total soluble solids (TSS) of fruits change with the maturity level. Hence, the crop should also be harvested at proper maturity level depending on the use. For determining optimum harvest maturity for some crops, there are specific guidelines (or say thumb rules). For example, for most of the processing operations as canning, drying, etc. the fruits should be harvested at firm ripe stage. Late harvested fruits can be used for preparation of juices/syrups, etc. Similarly, we know that the quality of vegetables change during maturity and proper maturity is important for storage and processing.

We should harvest the fruits with utmost care. For extended shelf life of the commodity, the individual fruits should not have any external damage as well as tissue damage. So careful plucking and picking of the fruits are important. It is very beneficial if the fruit is sold in raw form to high end users or in overseas markets.

General unit operations in PHM

The fruits and vegetables vary widely in their characteristics and hence the post harvest operations differ. However, the basic post harvest operations for fruits and vegetables to be sold in fresh form are as follows.

1. Pre-cooling
2. Cleaning/washing
3. Sorting and Grading
4. Transportation
5. Storage

During the food preservation and value addition process, whether it is drying or canning or chemical preservation, in addition to above unit operations there are some other common unit operations as follows.

1. Peeling
2. Size reduction (Cutting, slicing, shredding, crushing, etc.)
3. Blanching
4. Sulphuring

In the following paragraphs we will discuss about the above unit operations, except ‘storage’ of fruits and vegetables briefly. We will discuss about the ‘storage of fruits and vegetables’ in the next chapter.

Pre-cooling

The fruits and vegetables have high moisture content. They are highly respiring commodities and generate good amount of heat. The process also enhances other biochemical reactions. These are some important reasons, which cause less shelf life of fruits and vegetables as compared to the grains. We also know that the rate of most chemical reactions can be reduced by reducing the temperature. So if we cool the fruits and vegetables immediately after harvest to as low a temperature as possible, we will be able to increase the shelf life. The operation is known as pre-cooling, which can be done in the field immediately after harvest.

Pre-cooling is a process of cooling the commodities immediately after harvest to reduce the metabolic activities. The main purpose of pre-cooling is to reduce the respiration rate of the commodities and to delay the ripening process.

The basic aim is to quickly remove the field heat/ respiratory heat of the commodity and to reduce the metabolic activities. In addition, it helps in reducing ethylene production and delays the ripening of fruits. It also helps in healing of damaged skins that might have developed during harvesting.

Methods of pre-cooling

The pre-cooling of the commodities can be done by cold air, cold water, by putting in ice boxes or by vacuum cooling.

**Air cooling.** In this method, the commodity is placed in a room and allowed to cool by cold air. The room is insulated and a refrigeration unit attached to it supplies the cold air. Usually it is a slow method, though to improve the effectiveness in big chambers, some auxiliary fans are installed.

Cold air can also be forced through stacked product for rapid removal of heat. The cooling rate is much faster than that in still air cooling. However, **forced air cooling may cause dehydration of the commodity and hence humidified air should be used or water may be sprayed on the commodity.** Humidified air cooling is also preferred for dry climates and for chilling sensitive commodities.

**Hydro-cooling** (or water cooling). The commodity is cooled by cold water either by immersion or by sprays/showers. Here the time required for cooling is usually less than the air cooling. It also requires more investment than air cooling. It is applied for stem, leafy vegetables, some fruits, etc.

**Packaged-icing.** Boxes of produce are cooled by keeping crushed or flaked ice on top of the boxes. Ice melts and cold water runs down through the produce, which cools the produce.

**Vacuum cooling.** The principle of vacuum cooling is that if some moisture is lost from the commodity, there will be cooling due to release of latent heat of evaporation. So the produce is stored in a vacuum chamber for allowing some evaporation of moisture. At reduced pressure (4.6 mm mercury), water from the surface of the produce rapidly evaporates, which removes the field heat. The method is very rapid and energy-efficient, but the vacuum coolers are expensive to purchase and difficult to operate, hence have limited use.
After harvesting the crop in the field, we should immediately take out the damaged fruits and load the good ones in to the pre-cooling chamber. Even the transportation of the commodity in refrigerated/cool vans from the field to the cold room or packing centre would be better. In the cold room, the commodity is cooled down from the field temperature to a temperature less than 8-10°C (depending upon the fruit) in as short time as possible.

Cleaning

We have discussed under grain processing the specific purpose of cleaning operations as improving the grade (quality) and protecting processing machines. But in case of fruits and vegetables, as we remove the soil from the fruits and vegetables, we also reduce the load of microorganisms present on the surface of the commodities and hence subsequently, less severe processing conditions are required. The cleaning of fruits and vegetables should be done as early as possible after harvest.

Fruits and vegetables are usually washed to remove the soil, sticking dirt, or deposits of wax on the surface. For example, we must have seen that potato, ginger, etc. when harvested, contain a lot of adhering soil on it and simple cleaning by screens does not clean them. Washing also removes the insecticide/pesticide residues from the material.

The washing of fruits and vegetables by cold water is preferred, because in addition to cleaning, they also help to remove the field heat. In big fruits and vegetable processing units, the conveying and washing are done together.

Different types of washing methods (and equipment) are available as the soaking drum/floatation washer, spray washer, rotary drum washer, brush washer, or shuffle or shaker washer. Depending on the shape and size of the commodity and the textural quality, the type of washer is selected. For example, the potato can be washed by a soaking drum or a shuffle washer, whereas for washing of ginger, we may go for a brush type or a rotating drum type washer. In some cases, we soak the commodities for some time, then wash them by vigorously shaking in water. The mustard seeds (an example of oilseed) are also cleaned by water and then dried to reduce the moisture content for safe storage.

The above methods are also known as wet cleaning methods. Some fruits and vegetables are also cleaned without using water such as by blowing away the impurities or by screening. These are known as dry cleaning methods.

Fig. 1.1 shows the schematic diagram of a soaking drum for fruits and vegetables. During soaking, the soil is loosened and settles down to the bottom of the tank. The commodities may be stirred manually to remove the tightly adhering dirt. The fruits and vegetables are collected from the top. After 2-3 washings, the mud settled at the bottom of the tank is removed by a tap fitted for the purpose.

![Fig. 1.1 Soaking drum](image)
In a rotary drum washer, a perforated drum is kept in a slightly inclined position in a tank of water. The drum may also be constructed of thick wire mesh. The drum has some spiral flights inside to guide the movement of the commodities from one end to the other when the drum is rotated. Thus, the commodities move from one end to the other end of the rotating drum being immersed in water, and hence, the soil is loosened and removed. The rubbing of the surface among themselves and with the wire mesh causes further loosening of soil. The equipment can be operated batch wise or in a continuous manner.

**Fig. 1.2 A drum washer**

In case of spray washer, sprays of water are forced onto the commodity to loosen the tightly sticking dirt and soil. The brush washer has a series of soft nylon brushes which rub the surfaces of fruits and vegetables to loosen the dirt. The shaker washer has a device to agitate the wash water so as to make the washing more efficient.

**Fig. 1.3 Brushes for fruits and vegetables**

*As we observe, the washers operate on very simple principles and their construction does not require much skill. So if commercial washers matching our need or investment capability are not readily available, we can go for fabrication of such a washer locally.*

The washers can be either batch type of continuous type depending on the throughput capacity of the operations. The continuous washers are more costly than the batch washers, but they are more economical in long run, as they require less water and labour.

For better effectiveness of washing and to reduce the load of microorganisms, chlorinated water (1.5% hydrochloric acid solution) or detergents can be used. We have to be very careful in monitoring the chlorine level to avoid flavour taints. The water should be changed/recycled after each treatment.

*Another important aspect during washing is that the damaged fruits must be removed before washing. If not removed, the damaged fruits (particularly those with damaged skin and rotten ones) may pollute the wash water and the other commodities, and instead of getting cleaned, they are rather contaminated.*
Sorting

Sorting and grading of the commodity helps in removing the damaged as well as inferior quality crops and classifying the crop into different grades. For example, the mango can be sorted on the basis of size and tomato can be sorted on the basis of colour or maturity, etc. The premium grades always command better price in the market. In addition, when we remove the damaged/ infected/over ripe ones, we also help improve the shelf life of the commodity.

Before the processing operations also, it is very important to sort the commodities on the basis of different properties as they directly affect the processing operations and quality of final products. For example, we need to have a particular size of potato for making potato chips. The maturity of tomato directly affects the processing operations. Particularly in heat processing methods the size and maturity are very important.

Preliminary sorting can be done in the field itself to remove the damaged ones, and the final sorting is done in the collection/ processing/ packing centres.

In most cases, sorting is done by skilled workers. However, different types of sorters are also available, which sort the produce on the basis of size, shape, weight, specific gravity, etc. Sophisticated units use colour sorters for distinguishing the grades.

Sorting by size- screens

The size sorting is usually done by screens of desired openings. The screens can have same size perforations along the whole surface or the size of the holes can increase from the feed end to the discharge end. (They are also sometimes known as fixed aperture or variable aperture screens). If the perforation size is uniform throughout the screen surface, we can have two fractions, i.e., one size bigger than the hole size and the other smaller than the hole size.

But in variable aperture screen, the sizes of openings progressively increase from the feed end to the discharge end. So while the fruits travel along the screen, depending on the size of holes the fruits are separated into many fractions, like very small, small, medium, big, very big, etc.

The screens can be flat types or rotating drum types. The rotating drum type screens (Fig. 1.4) have less problem of blockage of the holes. They normally have higher capacity than flat bed types. A number of drums with different size perforations may be fixed in series for separating the materials in more than one sizes (Fig. 1.5).

Fig. 1.4 Sorting on a drum screen
The capacity of a screen is given by the amount of food that passes through per m²/s. So before deciding to buy a sorter, we should know the capacity of individual sorters and our requirements.

**Sorting by size- grizzly**

Grizzly is a small equipment made with metal bars (or rollers), in which the gap between metal bars increase from feed end to discharge end (Fig. 1.6-6.7). The gaps may be continuously increasing or stepwise increasing type. In such device, the handling of fruits takes place in a gentler manner than screens. Stepwise increase in gaps can be made by a set of rollers with an inclined conveyor belt (Fig. 1.8).
If we can not afford machines for sorting, we can go for manual size sorting. However, to make the manual sorting easier, more efficient and accurate, some small tools are available/ can be fabricated with the help of local artisans.

The **sizing rings** (Fig. 1.9) are small tools made up of metal/ thick plastic sheets, which can be used for sorting the fruits and vegetables on the basis of size. The sizing rings can be single or multiple sizing rings. Fig. 1.10 shows a **sorting table** with perforations on the surface and a net for collection of materials below.

In industries, manual sorting is also carried out as the fruits travel on a conveyor belt. People standing along the conveyor belt pick out the unwanted materials from the belt and put them in a separate container. This method is also very efficient as the fatigue of the labour is reduced.

**Aspiration and floatation sorting**
In this method, sorting is done by blowing air or by floatation in water (or in salt solution). For example the peas and lima beans are sorted by floatation in salt solution. Here the denser, starchy over-mature peas sink whereas the younger ones float.

**Weight sorting**

Sorting on the basis of weight is another practice, which is more accurate than other methods and is therefore used for valuable foods (e.g. mango for export purpose). In a particular type of equipment, the individual fruits are weighed as they move on a specifically designed conveyor consisting of small pans. As the weight exceeds a certain limit, the material drops down from the conveyor-weigher. By varying the spring tension of the weighers, we can separate the materials in to many fractions on the basis of weight along the length of the conveyor.

*It is also worth mentioning here that, except the weight sorters, all other type of sorters as discussed above are very simple in construction and can be fabricated locally.*

Other advanced methods as image processing and colour sorting are also used in processing industries.

**Image processing**

In this method, sorting of fruits is done on the basis of length, dimension, surface defects, etc. In such systems, images of individual fruits are taken from different angles as they pass on a conveyor, are analysed and compared with pre-programmed specification. Product is either accepted or rejected.

**Colour sorting**

This method is applicable for small-particulate foods/ fruits, etc. It contains a microprocessor controlled colour sorting equipment in which particle pass a photo detector one at a time. The photo-detectors measure the reflected colour of each piece and compare it with preset standards. Defective foods are separated by a short blast of compressed air.

**Transportation of fresh fruits and vegetables**

The time of storage as well as transportation for the commodities to be sold in fresh from should be as less as possible. The temperature should also be low. *Refrigerated vans can help maintain the quality of the produce during transportation. If such facilities are not available, then we should take the help of natural air cooling, evaporative cooling or ice cooling, etc. to maintain a low temperature during transit.* The transportation device (say truck) should also have a good suspension system so that the vibration of the crop during transit is minimum. Handling of the commodities with utmost care to avoid any type of impact and compression on the commodity is desirable. *The use of plastic crates than gunny bags can help reduce the compression load for many commodities during storage and transportation.*
Peeling

The peeling of fruits and vegetables can be done by hand with the help of knives and specifically designed peelers. In addition, **mechanical peelers having rotating knives, rotating carborundum stones, rotating sieve drums and brushes, etc. are also available.**

A common example is the potato peeler, which uses a carborundum stone for peeling potatoes. Such peelers are known as abrasive peelers. The peelers can be operated in batch/continuous manner. Water spray is used to flush out peel fragments. Such systems work best with uniform, round, undamaged potatoes.

We can peel root vegetables by abrasive peelers or with the help of brush peeler. Brushes having varying degrees of stiffness are available for the purpose. Usually the peels of freshly harvested crops are more soft than stored ones, and hence, require soft nylon brushes and light carborundum stones.

Rotating sieve drums are also used for root vegetables like ginger or turmeric.

Sometimes the peeling operation is combined with washing (potatoes, carrots, etc.).

**Chemical peeling** is the method, in which we use caustic soda (sodium hydroxide) solution to separate the outer peel. The vegetable is dipped in caustic soda solution (or the solution is sprayed on the produce) **for a maximum time of about 3 minutes** and then the loosened skin is washed away. **The sodium hydroxide solution at a concentration of 0.5-3% and at 90 to 100°C is used.** The chemical concentration must be periodically checked and corrected to obtain uniform results. A short boiling in water or immersion in dilute citric acid solutions helps to avoid enzymatic browning. However, now a day, chemical peeling is being discouraged.
In another method, known as thermal peeling or heat peeling, we try to loosen the skin by heating in flame (as for onion and peppers) or by steam (for vegetables with thick skin such as beets, potatoes, carrots and sweet potatoes, etc.). The produce is immediately washed with cold water to take away the loosened skin and as well to cool the commodity. In this method, no chemical residue remains. High pressure thermal peelers are also available, which are mostly batch type and require more time for loading and unloading than other systems.

Size reduction (Cutting, slicing, shredding, crushing, etc.)

Cutting, slicing, shredding, crushing are some size reduction operations for food processing and value addition. For example, for potato chips preparation, we require slices of uniform thickness. Similarly there are requirements to get the commodities in form of dices or cubes. Slices may be flat or wrinkle or wavy types. Special types of slicing or dicing machines are available for such specific needs.

The selection of cutter depends on the type of product. Special care is to be taken for dry commodities and for sugar containing products as well as fibrous products. Overheating during shredding or chopping should also be avoided.

We go for crushing or chopping for fruits that are fully ripened and too soft for whole or diced or sliced packs. Crushing of products by chopping them into small pieces prior to heating speeds enzyme activity. Hence, direct super heated steam is introduced into the chopper or crusher to remove the air. Super heated steam helps in creating a partial vacuum. It also helps in creating a better consistency in the final product. Removal of the air should be done at the time of crushing and immediately after crushing.

Blanching

If we keep cut potatoes in air, after some times the cut surface becomes brown. Similar type of browning is also seen in most fruits and vegetables and dried products. The browning takes place due to the action of enzymes, which has to be stopped. The process of stopping the enzyme activity by hot water or steam treatment is known as blanching.

In fact, blanching is defined as the method of hot water treatment that helps to inactivate enzymes. In addition, the activity reduces number of contaminating micro-organisms on the surface of foods, softens vegetable tissues to facilitate filling into containers, and removes air from intercellular spaces, which assists in the formation of head space vacuum in cans. In some commodities as beet root and tomatoes, the skin is loosened. Blanching also improves colour. It also affects flavor and texture.

Blanching is an essential step for many vegetables before drying or freezing operations. A few vegetables such as onion, green pepper and garlic are not blanched because it reduces their flavour/pungency.

Commercial blanchers are available which use either steam or hot water for blanching. However, we may also carry out the operation in big kettles that can heat water and hold the hot water at that temperature for specific time.

To achieve adequate enzyme inactivation, food is heated rapidly to a preset temperature, held for a pre-set time, and then cooled rapidly to near ambient temperatures. The temperature and time depend on the type of commodity. Usually the temperature is 70-100°C and time maintained is 2-5 minutes for hot blanching. Individual quick blanching (IQB) methods use steam for a time of less than 1 minute. One thing we must be very careful is that under-blanching may cause more damage than no-blanching. Blanching is also combined with peeling and / or cleaning.
The different factors influencing selection of blanching method/effectiveness are the type of fruit or vegetable, size of pieces of food, blanching temperature and the method of heating.

Sulphuring
Sulphuring is the common antioxidant treatment for preserving colour for fruits. This method is very effective. It will reduce vitamin loss, flavour loss, browning, and deterioration during storage. It is not a preservative in itself, but it discourages insects and microbes, which can cause spoilage. There are two ways for sulphuring, each with their own advantages and disadvantages.

Using sulphur fumes. Sulphur fumes are more effective than sulphur solutions, but this method takes more time and special equipment. Fruits sulphured by this method should not be dried indoors because the odour of the fumes is unpleasant.

The SO₂ gas is mostly used for fruits like grapes to prevent browning during the drying process. Such fruits are usually not blanched. The gas is applied to the fruits in a specific gas chamber or fume hood. The process is also known as smoking.

Sulphite solution method. Soaking fruit in a sulphite solution is easy. First we have to prepare a solution of 1 tablespoon sodium bisulphite (or 2 tablespoons sodium sulphite, or 4 tablespoons of sodium metabisulphite) in about 5 litres of water. Then the fruit slices should be soaked for about 5 minutes in the solution. For halves of fruits the time required is more, say 15 minutes. Thereafter, we have to take the fruit out, rinse lightly under cold tap water and dry it. With this method the pieces of fruit are, however, less thoroughly sulphured than they are by fumes. Because of the soaking involved, the fruit absorbs some water, so the drying time is increased. Fruit that is sulphured by this method may be dried indoors or outside.

We must remember that sulphite-sensitive people should not use this method and should not eat food treated with sulphur.

Ripening of fruits
Controlled ripening of fruits is another important post harvest operation, particularly for fruits like mango and banana. The ripening process of fruits can normally take place in the plant. However, if we have the ripening chambers, then we can harvest the fruits prior to full ripening. It will be helpful as the fully ripened fruits have a short shelf life. Besides, as the ripe fruits are soft, they are considerably damaged when transported to a long distance. Instead, if we have a facility of artificial ripening at a point close to the sale, then we can transport the green fruits and then ripen them artificially. Ripening chambers can also give even and controlled ripening. These are specifically designed rooms in which ripening agents (usually the ethylene gas) are used to speed up the ripening process.

The process of ripening is helpful for fruits such as apples, bananas, mangoes, papaya,
avocados, plum, apricots, kiwi, peach, etc. These fruits (known as climacteric fruits) are able to continue ripening even after they are picked from the tree, and the process is accelerated by ethylene gas. We must remember that the non-climacteric fruits can ripen only on the plant and thus have a short shelf life if harvested when they are ripe.

We control the ripening process by controlling the temperature, relative humidity, and the ethylene and carbon dioxide concentrations of the storage environment. The exposure to ethylene, pre-cooling and ripening temperature, and humidity for fruit ripening differ for all fruits. As an example, the conditions favourable for mango ripening are 20-22°C temperature, 90-95% relative humidity and 100-150 ppm (parts per million) ethylene. The carbon dioxide concentration in the room should be less than 1%. In this condition the fruits are kept for 12-24 hours. The banana is kept at 14-18°C temperature for 24-48 hours with other parameters remaining same.

The ripening times may differ even for the same variety of mango. The early season mangoes may take longer to ripen than middle-to-late season ones. The usual stages of operations are as follows.

- We should store and ship mature green mangoes at temperatures of about 13°C.
- Before ripening begins, the fruit pulp temperatures should be raised to 20 to 22°C.
- Once the fruit pulp temperature stabilizes, we have to apply 100 ppm ethylene for a minimum of 12 hours. Actual time of exposure to ethylene is determined by the maturity of the fruit; a slight change in fruit colour indicates that the mangoes are producing ethylene and the external ethylene source is no longer needed.
- After ethylene application, keep pulp temperature at 18 to 22°C until desired level of ripeness is attained (typically 5-9 days).
- Then store ripened mangoes at 10 to 13°C in a high humidity environment and ship to final destination soon.

Ripening of mango can also be induced by treating with ethral, which is an ethylene releasing compound. Normally mango is treated with ethral (1ml/ lit of water) at 52°C for 3 minutes. It not only induces early fruit ripening, but also reduces the development of post harvest diseases to a minimum in mango.

The procedure for ripening banana is to first precool the bananas for 18 to 20°C. Then we should start dosing the room and when set amount has been reached leave the room locked for 16 hours without intervention.

A proper ripening room must have the following:

- The room must be as air tight as possible. Air tight rooms help not only in preventing ethylene from leaking, but also allows condensing units to operate efficiently thereby minimizing consumption of electricity.
- The room must have adequate refrigeration. The fruits may produce large quantities of heat when they are ripening. The refrigeration equipment must have the capacity to accurately control the pulp temperature. For cold areas, heating systems may be necessary to maintain the ripening temperature. Electric heating elements should be used for the purpose.
- The room must have adequate air circulation. Because uniform pulp temperatures throughout the load are essential for even ripening, the refrigerated air in the room must circulate at all times and uniformly throughout the load.
- The room must be properly insulated so that proper temperature can be maintained without excess energy consumption.
- Proper air flow patterns are very important. The room should be constructed in such a way that the air flow path from the refrigeration system, through the load and back to the refrigeration system is unobstructed.

Ripening chambers (a. outer view, b. inner view)

The ethylene gas may be applied by the ethylene gas cylinders which are available in different capacities. Catalytic generators are also used to produce ethylene gas simply and safely. Ethylene sensors can be used to precisely control the amount of gas. Covered fruit ripening bowls are also commercially available.

The fully automated ripening systems consist of an ethylene injection system, ethylene and carbon dioxide gas analyzers and an air filtration system. The ripening system automatically injects, monitors and controls the quantity of ethylene gas that is dosed into the ripening chamber. Automated humidification systems are installed in the ripening chambers to help maintain humidity within the chambers.

*Calcium carbide is also used for ripening fruit artificially in many places. Calcium carbide reacts with water to produce acetylene, which acts as an artificial ripening agent. Industrial-grade calcium carbide may contain traces of arsenic and phosphorus which makes it a human health concern. Hence the use of carbide gas for ripening of fruits is prohibited under the PFA act in India.*
Chapter II

STORAGE AND PACKAGING OF FRUITS AND VEGETABLES

We have discussed that fruits and vegetables are highly perishable commodities and respire at a very rapid rate. So the spoilage is also very rapid and hence, the storage of fruits and vegetables in fresh form should be done by refrigerated or frozen conditions.

**Refrigerated storage**

Refrigerated storage is also known as chilled or cold storage, where we normally maintain a temperature of -1° to 8°C and about 80-95% relative humidity (RH). Refrigerated storage helps in reducing the rate of biochemical and microbiological changes, and hence extends the shelf life of fresh as well as processed foods. The most important advantage of the cold storage is that the sensory and nutritional characteristics of the produce do not change much and the original taste and look remains. Chilling is often used in combination with other methods as fermentation or pasteurisation to improve the shelf life of mildly processed foods.

But it is very important to know that in some fruits and vegetables undergo some undesirable changes when the temperature is reduced below a specific level. For example, we must have seen the blackening of banana or lemon when stored in the refrigerators. These types of changes in colour and texture are known as ‘chilling injury’. The browning of inside tissues and external surface, failure to ripen, blemished skin are some common symptoms of chilling injury.

<table>
<thead>
<tr>
<th>Food</th>
<th>Temperature, °C</th>
<th>Relative humidity (%)</th>
<th>Storage life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>11-15.5</td>
<td>85-95</td>
<td>7-10</td>
</tr>
<tr>
<td>Bean (snap)</td>
<td>7</td>
<td>90-95</td>
<td>7-10</td>
</tr>
<tr>
<td>Brocccoli</td>
<td>0</td>
<td>95</td>
<td>10-14</td>
</tr>
<tr>
<td>Carrot</td>
<td>0</td>
<td>98-100</td>
<td>28-42</td>
</tr>
<tr>
<td>Celery</td>
<td>0</td>
<td>95</td>
<td>30-60</td>
</tr>
<tr>
<td>Cherry</td>
<td>-1</td>
<td>90-95</td>
<td>14-20</td>
</tr>
</tbody>
</table>

Chilling injury occurs to apples stored below 2-3°C, avocados at less than 13°C, banana at less than 12-13°C, lemons at less than 14°C, mangoes at less than 10-13°C and melons, pineapples and tomatoes at less than 7-10°C.

So before storage of fruits and vegetables in cold stores/ refrigerators, we must know the recommended storage temperatures (and also the RH) for each commodity. Also all fruits or vegetables can not be stored for same period in the chilled storage.

The recommended temperature, relative humidity and expected storage lives of some fruits and vegetables are given in Table 7.1. The shelf life of the commodity is also affected by many pre and post harvest factors as the part of the crop selected, condition of food at harvest, temperature of harvest, storage, distribution and retail display, etc.

Table 7.1 Optimum storage conditions for some common fruits and vegetables
Cold stores can be constructed of different capacities with matching refrigeration equipment. Small size cold rooms are also available to meet the requirements of small producers/traders and retail stores. Cold rooms can also be self-constructed, purchased as prefabricated units (new or used). However, the advice of experts should be taken in this regard.

![Small cold room](image)

**Fig. 2.1 Small cold room**

The recommended storage conditions for root and tuber crops are different than other crops. The storage temperatures will also vary with the type of use of the crop. As an example, Table 7.2 shows the storage requirement for potato for different uses.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Temp, °C</th>
<th>RH(%)</th>
<th>Potential duration</th>
<th>storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh market</td>
<td>4-7</td>
<td>95-98</td>
<td>10 months</td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td>8-12</td>
<td>95-98</td>
<td>10 months</td>
<td></td>
</tr>
<tr>
<td>Seed potatoes</td>
<td>0-2</td>
<td>95-98</td>
<td>10 months</td>
<td></td>
</tr>
</tbody>
</table>

*Potatoes for processing are should not be stored at very low temperatures as that will help production of sugars which darken when heated during processing. Potatoes meant for consumption must also be stored in the dark*, since the tubers will produce chlorophyll (which will make the potato green) and develop toxic alkaloid solanine if kept in the light.
**Potatoes for use as seed are best stored in diffuse light.** The chlorophyll and solanine that accumulate will aid to protect the seed potatoes from insect pests and decay organisms.

The root and tuber crops must be stored at temperatures that will not cause chilling injury as internal browning, surface pitting and increased susceptibility to decay.

When loading commodities, particularly potatoes, into bulk storage, even distribution of the produce is important for proper ventilation. Uneven loads will inhibit air movement and result in storage losses due to inadequate ventilation. Ducts for ventilation of bulk storage rooms can be laid out vertically as well as horizontally.

Ginger is stored at 12-14°C at 65-75% relative humidity for about 6 months. Cassava can be stored for 2-4 months at 5-8°C temperature and 80-90% relative humidity. At 0-5°C temperature 85-95% relative humidity, it can store for 6 months. The sweet potato can be stored for 6 months at 80-90% RH and 12-14°C temperature.

We must have observed that the bulb crops like onions, garlic, etc. store better in low humidity in storage. Onions and garlic will sprout if stored at higher temperatures. Similarly pungent types of onions will store longer than mild onions, which are rarely stored for more than one month.

**For bulk storage of onion or garlic, ventilated storage systems are beneficial. In such systems, the air can easily flow into all parts of the storage chamber and the heat of respiration is taken out.** If produce is stored in cartons or bins, stacks must allow free movement of air. **Rows of containers should be stacked parallel to the direction of air flow and be spaced six to seven inches apart.** An adequate air supply must be provided at the bottom of each row and containers should also allow air into them. Low cost ventilated onion storage structures can be made of bamboo/ wire mesh, etc.. **It is also better to allow some curing of the crop before handling and storage. Curing helps to dry out the external layers and prevent further water loss during storage.**

![Fig. 2.3 Low cost onion storage structures](Source: www.kvkdelhi.org; www.msamb.com)

**Some basic rules for keeping of fresh commodities in cold stores**

1. Only good quality produce should be stored. The lot of produce must not contain damaged or diseased units. They should be sorted out prior to keeping the produce in storage. We should also check the stored produce at regular intervals and should immediately remove the spoiled or infected produce, if any.
2. Reusable containers and sacks should be disinfected in chlorinated or boiling water before reuse.

3. The containers in which the commodity is stored must be well ventilated and strong enough to withstand stacking.

4. There should be adequate space between containers for adequate ventilation, and to avoid incompatible product mixes.

5. The materials which require dry conditions for storage should be placed on sacks or cartons on the floor so that the floor dampness do not reach them.

6. Placing materials on cartons also helps to reduce the chance of fungal infection, while also improving ventilation and/or sanitation in the store room.

7. Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. As an example commodities like ripe bananas and apples produce high amount of ethylene and hence, can stimulate physiological changes in ethylene sensitive commodities like lettuce, cucumbers, carrots, potatoes, sweet potatoes, etc. causing undesirable colour, flavour and texture changes.

8. As for the grain storage structures, regular inspection of the produce and structure can help reduce losses by minimizing the build up of pests and retarding the spread of diseases.

In addition, some important considerations as regards to the operation of cold stores and getting the maximum benefit from them are discussed below.

**Storage facility**

1. The facility should have device for proper control of temperature and relative humidity, and maintain proper air circulation.

2. Any type of building or facility used for storage of horticultural crops should be insulated for maximum effectiveness. A well insulated refrigerated building will require less electricity to keep produce cool.

3. If the structure is to be cooled by evaporative cooling or night air ventilation, a well insulated building will hold the cooled air longer.

4. Usually for our conditions, the storage structures may be built with ferro-cement with thick walls to provide insulation. Construction of the facility in higher altitudes can help maintain lower temperature and help in quick night cooling by radiation and air flow.

5. Square buildings are better than rectangular buildings for better temperature management as rectangular buildings have more wall area per square feet of storage space, so more heat is conducted across the walls. Thus the cooling becomes more costly in rectangular buildings. The shading of the building also reduces the heat load. Using sprinkler systems on the roof of the building also helps in reducing the refrigeration load.

6. Overhanging roof extensions on storage structures are very helpful in shading the walls and ventilation openings during day time and in providing protection from rain. An overhang of at least 1 meter (3 feet) is recommended.

7. The building can be painted with white or silver colour to reflect the solar radiation
and prevent the walls from becoming too hot.

8. Storage facilities should be protected from rodents by different measures as discussed in grain storage section.

9. For refrigerated storage facilities, using outside air for ventilation is wasteful of energy. For these systems, a simple recirculation system can be designed by adding a fan below floor level and by providing a free space at one end of the store room for cool air to return to the inlet vents.

**Ventilated structures**

1. Storage structures can be cooled by ventilating at night when outside air is cool. For best results, air vents should be located at the base of the storage structure. An exhaust fan located at the top of the structure pulls the cool air through the store room. Vents should be closed at sunrise, and remain closed during the heat of the day. A simple, light-proof exhaust vent is a pressure-relief flap.

2. An evaporative cooler located in the peak of a storage structure can cool an entire room of stored produce such as sweet potatoes or other chilling sensitive crops. The vents for outside air should be located at the base of the building so that cool air is circulated throughout the room before it can exit.

3. There should be proper arrangement of floor vents for air circulation.

4. Where electricity is not available, wind-powered turbines can help keep store rooms cool by pulling air up through the building. Vents at the floor level are especially useful for cooling via night air ventilation.

5. The air composition in the storage environment can be manipulated by increasing or decreasing the rate of ventilation (introduction of fresh air) or by using gas absorbers such as potassium permanganate or activated charcoal. Large-scale controlled or modified atmosphere storage requires complex technology and management skills, however, some simple methods are available for handling small volumes of produce. We will discuss about controlled and modified atmosphere storage later in this chapter.

**Evaporatively cooled storage**

The cold storage facility requires high capital investment and huge amount of power for operation. Continuous power is also not available in most rural places, particularly during summer months, when we require the cold storage facility most. Besides, it is not suitable for rural or on-farm storage where most of us would like to store the commodities for only a few days to accumulate sufficient quantities before carrying them to the markets situated far off and in urban areas. Most importantly, the cold store facility is not available in all places. Therefore, a low cost alternative to cold stores can be adopted which is known as evaporatively cooled storage. The basic principle of this storage device is obtained from the traditional earthen pots, which keep the water cool during summer.

A common form of evaporatively cooled storage structure, which is also known as the **zero energy cool chamber**, is made up of side walls in two layers of brick with a gap of 7.5 cm in between (Fig. 2.4). The annular gap is filled with river bed sand. The floor of the structure is made of a single layer of brick spread over 5 cm soil layer on the ground. This is done to prevent moisture seepage through walls and accumulation of water on the floor of the structure. The top cover of the structure is made of 2.5 cm thick layer of wood-wool pads, suitably sandwiched between two layers of welded wire mesh/bamboo splits. There is no
provision for mechanical ventilation. The side walls and the top cover are kept completely wet during the period of storage.

![Fig. 2.4 A zero energy cool chamber](image)

It has been observed that the cool chamber is capable of reducing the inside temperature by up to 15-16°C under dry climatic conditions. However, as the principle is based on evaporative cooling, the system would not work properly in high humidity areas such as in places near the sea or river, as well as in rainy season.

Portable evaporatively cooled storage structures have also been developed with a metallic frame made up of square iron bars, flats and angles. The side walls can be made up of sponge/aspen fibre pad sandwiched between plastic nets as support. The structure also performs satisfactorily as regards to cooling of commodities. The structure is light weight and can be conveniently shifted from one place to another and can be used as temporary storage structures for short term storage or during transportation in trucks/rail cars. They can be installed within a short time at any place to meet immediate demands.

![Fig. 2.5 Portable evaporatively cooled storage chamber for fruits and vegetables](image)

Another simple method for storing small quantities of produce is to use any available container, and create a cool environment for storage by burying the container using insulating materials and soil. For example, we can use a wooden barrel as storage container and straw for insulation.

**Frozen storage**

Another type of low temperature storage is frozen storage, where we keep a temperature less than -10°C or so (That is, in cold stores the temperature is above 0°C and in frozen storage it is less than 0°C). The frozen storages can increase the life of fruits and vegetables for a much longer period than cold stores. Frozen peas, frozen mushroom are some examples of such products available in the market.
Controlled atmosphere (CA) and modified atmosphere (MA) storage

The controlled atmosphere (CA) and modified atmosphere (MA) are excellent devices to increase the shelf life of fruits and vegetables and other respiring commodities.

For many fruits, both respiration and production of ethylene gas (produced naturally by many commodities) increase after harvest, which increase the ripening and accelerate spoilage of the fruit. These activities require oxygen and by controlling the oxygen and carbon dioxide in the atmosphere, we try to extend the shelf life and maintain quality.

The CA storage refers to a storage atmosphere, in which the concentration of normal gases (carbon dioxide, nitrogen and oxygen) are precisely controlled and maintained throughout the storage period. Normally, oxygen is decreased from the standard 21% level in air to 1 - 3% level and carbon dioxide is increased from 0.04% to 1.5-5%, depending on the commodity. Ethylene can also be controlled. CA also helps to retain the flavour, taste, etc. for fruits and vegetables. Sophisticated storage chambers are available for the purpose, which are known as CA chambers.

In modified atmosphere packaging (MAP), we do not maintain the gas concentration in the storage chamber, but allow the commodities to generate low level of oxygen and high level of carbon dioxide by their respiration, when they are packed in flexible packaging materials usually made up of polyethylene/ plastics. The package is usually permeable to gases and its gas permeabilities should match the product requirements at the storage temperature. Therefore, proper selection of the packaging film is very important and any film can not be used for any type of commodity.

Modified atmosphere packaging is advantageous for fruits and vegetables as the packaging materials are easily available and skill required is low. As the rate of spoilage is slowed down, it allows handling of fruits at a little higher temperatures, which prevents chilling injury and gives uniform ripening. It is very beneficial for chilling sensitive fruits such as mango, banana, papaya, tomato, etc. and most vegetables. As it reduces respiration rates, decreases ethylene production and reduces sensitivity to ethylene action, there is delayed senescence (deterioration) as indicated by retention of chlorophyll, textural quality and sensory quality of fruits.

If we want the modified atmospheres quickly (as it is required for highly perishable commodities), we can take out some air from the package and inject a recommended gas mixture into the package. We can also put oxygen or ethylene absorbers or carbon dioxide emitters to get the effect quickly.

We must remember that, we get the maximum benefit if we use both low temperature and modified atmosphere together (with recommended temperature and as well the gas concentrations). Controlled or modified atmosphere storage should be used as a supplement to, and not as a substitute for, proper temperature and relative humidity management.

Food Packaging
We all know that a properly graded and packaged food increases consumer acceptance and commands higher price in the market. The common examples are the graded and packaged grains, pulses, spices and fruits and vegetables. Different types of packaging materials can be used for different types of commodities and processed products. However, we must bear in mind that the type of package should perform the basic functions of packaging as containment and protection of the product. Further, it should be convenient to handle and attractive.

The main types of packaging materials used in food are the paper and paper boards, many types of plastic films, boxes and containers, foam, textile, glass, etc. Flexible film packaging materials are used for grains, fruits and vegetables. The PET bottles and HDPE bottles are used for fruit drinks, ready to serve beverages, ketchup, yogurt, milk and juices, etc. Glass bottles are also used for different types of drinks, coffee, etc. Textile bags are used for grains or for fruits and vegetable commodities for bulk transportation. Papers and cartons are used for secondary protection of primary film packages and for protection of fruits and vegetables during transit.

The package should be able to protect the food from impact, shock, light, oxygen, etc. depending on the product requirements. Each type of package material has its own advantages and limitations depending on the nature of commodity and consumer needs. Now a day, many types of laminated films and combination of materials are used for different types of packaging applications. If we look around any retail store, we can see such a variety of packaging materials.
Different types of packages and packaging materials

The basic factors that we need to consider for selecting a package material are as follows.

- Product needs
- Distribution needs and wants
- Packaging materials, machinery and production processes
- Consumer needs and wants
- Market needs and wants
- Environmental performance

In addition, it is also important to remember the “four Rs hierarchy” in packaging from the point of view of safeguarding the environment. **They are Reduce, Reuse, Recycle and Recover.** We must try to use less packaging material without compromising on the basic functionalities of packaging. As far as possible, we should try to recycle the packaging materials, particularly the plastics.

The packages can also be classified as primary and secondary packages. The primary packages are those which are in direct contact with the food or beverage, e.g. bottle and cap, carton, plastic pouches, etc. The secondary or transit package contains and collates primary packs- for example, a shrink-wrapped corrugated fibre board tray or case. Similarly there may be a distribution package (shipper or tertiary package), e.g. pallet, roll cage, stretch-wrap to protect the product during distribution and to provide for efficient handling.

The packaging can also be classified as the consumer package (usually of small sizes and eye-catching to attract the consumer) and industrial/ commercial package (where the material is supplied to another processor, for example, a primary processor will supply mango pulp to a plant which prepares mango drinks or squash). The commercial packages are normally big in size and may be less attractive in appearance as they are not put on retail shelves.
Packaging machines

Different types of packaging machines are also available for filling and sealing the materials into rigid and flexible packages. For sealing flexible pouches, hand operated and pedal operated machines are available. The cost can be as low as ₹2000 for hand operated machines to ₹6000 for a pedal operated machines. For liquid and free flowing powders and granules, automatic form, fill and seal machines (commonly known as FFS machines) are also available, the cost of which may start from say ₹2.00 lakhs, only. They can fill the powders or liquids with reasonable accuracy and provide uniform sealing. Different types of equipment for accurate filling of glass containers are also available in the market.
Chapter III

VALUE ADDITION OF FRUITS AND VEGETABLES

When we enter a retail store we see a variety of processed products from fruits and vegetables. They include tomato ketchup, mango pickle, guava jam, orange marmalade, potato chips, garlic powder, frozen peas, and so on. These products are outcomes of the various processing and preservation methods applied on fruits and vegetables.

General methods of preservation and value addition

The common processing and preservation methods of fruits and vegetables have been shown in Fig. 3.1.

Fig. 3.1 General methods of preservation and value addition of fruits and vegetables

Drying and dehydration are the methods of reducing moisture from the food to such a low level that the microorganisms can not grow. Refrigeration and freezing are the lowering of temperature of the food so that the activity of microorganism, and other biochemical reactions are reduced. Similarly canning, sterilisation and pasteurisation are methods of heating the produce for a specific time so as to kill the microorganisms and inactivate enzymes. In chemical preservation methods, we use some chemicals for preservation as we do in preparation of pickles, sauce, etc. In addition to the above methods, fruits and vegetables are also preserved by concentration, fermentation, irradiation, etc.

Often a combination of above methods is also used.

Drying and dehydration

*Dried products, if packed properly, have a very good shelf life. They also enjoy good demand in big cities and other countries, where the raw commodity is not grown widely.*

The good examples are dried chilli, peas, spices, aonla, potato chips, etc. Now a day, even dried vegetables like cauliflower and cabbage, dried fruits like pineapples, apples, etc. are
available. Actually, it is one of the most common methods of value addition and storage of fruits and vegetables. As we can store the dried product for longer period, surplus crop in the harvest season can be dried and stored at our level without going for distress sale.

The basic principle behind this method of food preservation is that the moisture present in the commodity helps the spoilage by microorganisms and other biochemical reactions. Hence if the commodity is dried to a low level, the activity of microorganisms is reduced and shelf life of the commodity is increased. Another term which is also used interchangeably for drying is dehydration. Usually when the moisture content of the product is very low, we call that dehydration. Normally dehydration is carried out in mechanical dryers.

Drying of the fruits and vegetables can be carried out under sun or in mechanical dryers. The drying under sun is dependent on weather conditions. Besides, we do not have a control on the drying parameters and hence, sun drying gives inferior quality product. Further, drying outside often contaminates the product and there is loss due to birds, rodents, etc. Dried product often becomes dark in colour.

Fig. 3.2 A hot air mechanical dryer

Fig. 3.3 A small capacity solar dryer

The mechanical dryers give comparatively better quality product as we have a close control on the drying temperature and other conditions. But the mechanical dryers are costly and usually require electrical power. Therefore, mechanical drying is suggested only in case the product is to be sent to the urban markets and high value customers, as it can fetch a better price there.

The mechanical dryers can be batch type and continuous type, and depending on the volume of the commodity handled and the manpower available, the type and size of the mechanical dryer has to be selected.
As a compromise between the mechanical drying and sun drying, we may consider drying of fruits and vegetables in greenhouse type dryers or low tunnel dryers. Such dryers are modifications of the commonly used green houses for crop production. The greenhouses arrest the solar energy and make the inside air hot. Thus, if any commodity is kept inside the greenhouse, it will be heated and moisture will come out of it. But to use the greenhouse for drying the crop, there should be a fresh air inlet at the bottom side and one exhaust port on the opposite side at the top through which the moist air can go out. A fan to blow away the air from the vicinity of the commodity will help to improve the moisture transfer.

Canning, sterilisation and pasteurisation

These are the methods of killing microorganisms originally present in the food by heating at a high temperature (usually more than 100°C, i.e. more than the boiling temperature of water) for a specific time. Sterilisation treatment is more severe than pasteurisation and helps further increase in shelf life, though some flavour of the commodity may be lost. Canned peas, mushrooms, pineapples are available in the market. Most of the spice pastes are also pasteurised at high temperatures to increase their shelf life. Canned products have good demand in international market. The method of canning requires high pressure sterilizers (also known as retorts) to sterilize the contents and other ancillary facilities. The sliced commodities are taken in a can (or a glass bottle/container) along with sugar or salt solution and exposed to very high temperature. The specifically designed canning equipment, exhaust boxes, can seamers, bottle filling and sealing machines, etc. are available.

Preservation by using chemicals

Some chemicals are used along with the recommended methods to prepare products like jam, jelly, marmalade, squash, fruit syrup, pickles, etc. The process followed for each commodity and each type of product will be different and the amount of chemical additives will also be different. There are certain chemicals which are permitted by law as food additives and there are also maximum permissible limits for most of the chemicals. We should strictly follow the rules as the safety and health of the consumer can not be ignored.

Preparation of pickles, jams, jellies, etc. are examples of food processing by addition of chemical preservatives. The acetic acid, citric acid, vinegar, potassium metabisulphite are the examples of preservatives which increase the storability of fruits and vegetables. Even the common salt and sugar are good preservatives. Remember that we add sugar for the preparation of jam and jelly. The different chemical methods for food preservation are given in Table 8.1.

<table>
<thead>
<tr>
<th>Method of preservation</th>
<th>Examples of food products</th>
</tr>
</thead>
<tbody>
<tr>
<td>By addition of acid such as vinegar or lactic acid</td>
<td>Pickled vegetables, fruits</td>
</tr>
<tr>
<td>By salting or brining</td>
<td>vegetable/fruit pickles</td>
</tr>
<tr>
<td>By addition of sugar and heating</td>
<td>Fruit preserves, jams, jellies, marmalades, etc.</td>
</tr>
<tr>
<td>By addition of chemical preservatives</td>
<td>Using water soluble salts of SO₂, benzoic acid, sorbic acid and a few like H₂O₂, etc. which are permitted as harmless in foods</td>
</tr>
</tbody>
</table>
By means of substances of bacterial origin such as tylosin, resin, etc., which are permitted to a limited extent in some cases as harmless additives.

The preservatives that are commonly added to the food are classified as either class I or class II preservatives. For the class I preservatives, there is no limit to the amount at which it can be applied.

Table 8.2 Usually accepted chemical food preservatives

<table>
<thead>
<tr>
<th>Agent</th>
<th>Acceptable Daily intake (mg/Kg body weight)</th>
<th>Commonly used levels (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Citric acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Sodium Diacetate</td>
<td>15</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Sodium benzoate</td>
<td>5</td>
<td>0.03-0.2</td>
</tr>
<tr>
<td>Sodium propionate</td>
<td>10</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Potassium sorbate</td>
<td>25</td>
<td>0.05-0.2</td>
</tr>
<tr>
<td>Methyl paraben</td>
<td>10</td>
<td>0.05-0.1</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.2</td>
<td>0.01-0.02</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>0.7</td>
<td>0.005-0.2</td>
</tr>
</tbody>
</table>

(Source: FDA, 1991)

Table 8.3 Some food products commonly stored by chemical preservatives

<table>
<thead>
<tr>
<th>Agent</th>
<th>Food products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citric acid</td>
<td>fruit juices; jams; other sugar preserves</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>vegetable pickles; other vegetable products</td>
</tr>
<tr>
<td>Sodium benzoate</td>
<td>vegetable pickles; preserves; jams; jellies; semi-processed products</td>
</tr>
<tr>
<td>Sodium propionate</td>
<td>fruits; vegetables</td>
</tr>
<tr>
<td>Potassium sorbate</td>
<td>fruits; vegetables; pickled products; jams, jellies</td>
</tr>
<tr>
<td>Methyl paraben</td>
<td>fruit products; pickles; preserves</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>fruit juices; dried / dehydrated fruits and vegetables; semi-processed products</td>
</tr>
</tbody>
</table>

The sulphur dioxide, carbon dioxide and chlorine are some gaseous preservatives.

*Food acidification is one important way of preventing deterioration by creating an unfavourable medium for development of micro-organisms. This acidification can be obtained by two ways: natural acidification and artificial acidification.*

The natural acidification is achieved by a predominant lactic fermentation. In fact, preservation of food by fermentation has been practised since time immemorial, and the fermented vegetables still enjoy a good market potential, mainly because of their nutritional...
and gastronomic qualities. Preservation by lactic fermentation is also called biochemical preservation. In contrast to other methods as heat processing, chilling, etc., where we intend to slow down the microbial activity, in food fermentation, we encourage the multiplication of some specific micro-organisms and their metabolic activities in foods. Table 8.4 gives the some industrial fermentation agents used in food processing industries.

**Table 7.4 Some industrial fermentation agents used in food industries**

<table>
<thead>
<tr>
<th>Microbial agent</th>
<th>Examples of application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw commodity</td>
</tr>
<tr>
<td>I. Lactic acid bacteria</td>
<td>cucumbers</td>
</tr>
<tr>
<td></td>
<td>cabbage</td>
</tr>
<tr>
<td></td>
<td>turnips</td>
</tr>
<tr>
<td></td>
<td>lettuce</td>
</tr>
<tr>
<td></td>
<td>cabbage</td>
</tr>
<tr>
<td></td>
<td>vegetables and milk</td>
</tr>
<tr>
<td></td>
<td>turnips, radish, cabbage</td>
</tr>
<tr>
<td>II. Lactic acid bacteria with other micro-organisms</td>
<td>with yeasts</td>
</tr>
<tr>
<td></td>
<td>with moulds</td>
</tr>
<tr>
<td>III. Acetic acid bacteria</td>
<td>sugary or starchy products, wine, cider or any alcoholic material</td>
</tr>
<tr>
<td>IV. Yeasts</td>
<td>fruit</td>
</tr>
</tbody>
</table>

The following points should be kept in mind while modifying foods with chemical preservatives.

- Proper dosage of the chemical food preservatives is important, and anything extra becomes harmful or unacceptable.
- "Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.
- Only the chemicals which have been recognised as being without harmful effects on human beings' by national and international authorities are to be used.

**Other methods.** In addition to the above methods, fruits and vegetables are also preserved by concentration, irradiation, etc.
**Value added products from different commodities**

In fact there is no commodity to which value can not be added. From any commodity, a number of value added products can be prepared. A product profile for different types of fruits and vegetables are given in the Tables 8.5 to 8.8.

**Table 8.5 Value added products from some fruits**

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Processed products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>Pickles, chutneys, amchur, slices in brine, flavour concentrates, slices in syrup, pulp, jams, toffee, fruit bar, custard powder, ready to serve (RTS) beverage, nectar, squash, frozen mango pulp and slices</td>
</tr>
<tr>
<td>Banana</td>
<td>Puree, banana figs, chips and wafers, fruit bars, squash, starch, banana powder, clarified banana juice</td>
</tr>
<tr>
<td>Cashew apple</td>
<td>Cashew apple juice, RTS beverage, feni, candy, mixed jam, canning, chutney, pickles, vinegar</td>
</tr>
<tr>
<td>Cashew nut</td>
<td>Salted and roasted cashew nuts</td>
</tr>
<tr>
<td>Guava</td>
<td>Juices, nectar, jam, jellies, canned products</td>
</tr>
<tr>
<td>Jackfruit-raw</td>
<td>Pickles, dehydrated cubes, canned</td>
</tr>
<tr>
<td>Jackfruit-ripe</td>
<td>Nectar, fruit bar, jam, etc.</td>
</tr>
<tr>
<td>Pineapple</td>
<td>Squash, slices in syrup canned product, deserts, fruit salads, dried rings, candies</td>
</tr>
<tr>
<td>Lemon/ lime</td>
<td>Squash, cordial, juice, marmalade, RTS</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Juice, health formulations from seeds</td>
</tr>
<tr>
<td>Wood apple (Bael)</td>
<td>Pulp, canned pulp, nectar, squash, fruit slab, toffee, powder</td>
</tr>
<tr>
<td>Coconut</td>
<td>Desiccated coconut, sweetened and toasted product, jam, syrup, coconut milk, oil, cake, flour, coconut water, toddy, etc.</td>
</tr>
<tr>
<td>Litchi</td>
<td>RTS, squash</td>
</tr>
</tbody>
</table>

**Table 8.6 Value added products from vegetables**

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Processed products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Juice, puree, paste, ketchup, sauce, chutney, cocktail, powder</td>
</tr>
<tr>
<td>Papaya</td>
<td>Papain, pectin, tutti-frutti, papaya powder, ripe papaya drinks, desserts, fruit salads, garnishes</td>
</tr>
<tr>
<td>Potato</td>
<td>Chips, wafers, granules, flakes, flour, snacks, dehydrated, starch</td>
</tr>
<tr>
<td>Bean</td>
<td>Canned product, dehydrated product</td>
</tr>
<tr>
<td>Beet</td>
<td>Canned product, dehydrated product</td>
</tr>
<tr>
<td>Name of the vegetable</td>
<td>Processed products</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Canned product, dehydrated product, pickles</td>
</tr>
<tr>
<td>Cabbages</td>
<td>Canned product, dehydrated product, sauerkraut</td>
</tr>
<tr>
<td>Carrot</td>
<td>Canned product, dehydrated product, carotene</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>Canned product, dehydrated product, powder (spray dried), soup mixes, freeze drying</td>
</tr>
<tr>
<td>Okra</td>
<td>Canned product, dehydrated product</td>
</tr>
<tr>
<td>Pea</td>
<td>Canned product, dehydrated product, green peas</td>
</tr>
<tr>
<td>Spinach</td>
<td>Canned product, dehydrated product</td>
</tr>
<tr>
<td>Onion</td>
<td>Dehydrated onion flakes and granules, powder, paste</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>Canned product, dehydrated product, RTS, etc.</td>
</tr>
<tr>
<td>Chilli</td>
<td>Dried powder, masala powder, Capsain, pigments, concentrates</td>
</tr>
<tr>
<td>Drum stick</td>
<td>Pickles, water purifiers, pectin</td>
</tr>
</tbody>
</table>

**Table 8.7 Value added products from some spices**

<table>
<thead>
<tr>
<th>Name of the spice</th>
<th>Processed products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginger</td>
<td>Dehydrated flakes, powder, masala powder, paste, ginger oil, oleoresin, candy, RTS</td>
</tr>
<tr>
<td>Garlic</td>
<td>Garlic paste, masala powder, flakes, granules, garlic salt, oleoresin, active principles</td>
</tr>
<tr>
<td>Turmeric</td>
<td>Turmeric powder, masala powder, curcumin</td>
</tr>
<tr>
<td>Black pepper</td>
<td>Canned berries, pepper powder</td>
</tr>
<tr>
<td>Bay leaves (Tej patta)</td>
<td>Masala powder, flavour concentrates</td>
</tr>
<tr>
<td>Curry leaves</td>
<td>Chutneys, flavour concentrates</td>
</tr>
<tr>
<td>Coriander seeds</td>
<td>Masala powder</td>
</tr>
<tr>
<td>Coriander leaves</td>
<td>Chutneys, flavour concentrates</td>
</tr>
<tr>
<td>Tamarind</td>
<td>De-seeded tamarind, pulp, concentrates</td>
</tr>
</tbody>
</table>
Table 8.8  Value added products from some aromatic & medicinal plants

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Processed products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aloe Vera</td>
<td>Juices, traditional medicines, active principles for medicinal uses</td>
</tr>
<tr>
<td>Coleus aromatica</td>
<td>Flavour enhancer, traditional medicines</td>
</tr>
<tr>
<td>Annapurna</td>
<td>Flavour enhancer, flavour concentrates</td>
</tr>
<tr>
<td>Stevea</td>
<td>Traditional medicines, sugar free sweetener</td>
</tr>
<tr>
<td>Jamun</td>
<td>Dried and powdered seeds to be used as anti-diabetic, anthocyanine, vinegar, RTS</td>
</tr>
<tr>
<td>Aonla</td>
<td>Aonla in syrup, health drink in triphala, salted and dried aonla, ascorbic acid</td>
</tr>
<tr>
<td>Lemon grass (Dhanwantari)</td>
<td>Aromatic oil, traditional medicines, mosquito repellant, citral</td>
</tr>
</tbody>
</table>

The above lists are just indicative and we can add many more commodities and products to those lists. It is also important to mention here that most of the fruits, vegetables and spices are very good sources of nutraceuticals and medicinal compounds, and are being used for extraction of nutraceuticals and other active ingredients.

It is not possible to explain in details the preparation methods of these products in this text. Hence in the following section we will discuss about preparation of some specific types of value added products. The principles can be also applied to other commodities after due consideration of the nature of the commodity.

**Preparation of dried fruits and vegetables**

As we have discussed earlier, drying and reduction of moisture content of the fruits and vegetables is an important method of food preservation. The basic steps in the preparation of the dried fruits and vegetables are shown in Fig. 3.4.

As we see from the sequence of operations, depending on the type of fruit/vegetable, the operations as washing, peeling, slicing, pulping, blanching, dipping in acid/treatment with sulphur dioxide or syruiping are carried out.

*Syruiping (addition of sugar solution) is done particularly for sour fruits so that they become sweet while losing some moisture to the sugar solution. Usually the fruit slices are kept in sugar solution for 4-6 hours and then dried. The product is also known as osmo-dried fruits. Salt solution is used for vegetables, in place of syrup for getting osmo-dried vegetables.*

Then drying is carried out either under sun/ solar dryer or mechanical dryer. Subsequently packing, labelling and storing operations are carried out.

In the following table we will also discuss about the special care to be taken before and during the drying of fruits and vegetables.
Fig. 8.4 Process flow chart for preparation of dried fruits and vegetables

<table>
<thead>
<tr>
<th>Unit operation</th>
<th>Special care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>Check for full maturity, but the commodity should not be over ripe. Harvest carefully to reduce bruising, etc.</td>
</tr>
<tr>
<td>Washing</td>
<td>Clean water should be used.</td>
</tr>
<tr>
<td>Sorting / grading</td>
<td>Uniform maturity is important to get similar drying time for all pieces. Sorting can be done by hand.</td>
</tr>
<tr>
<td>Peeling</td>
<td>Peeling of the commodity, in addition to removing the inedible portions, also improves drying rate. All traces of peel should be removed.</td>
</tr>
<tr>
<td>Process</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cutting / slicing / coring</td>
<td>The operation also helps in faster blanching, sulphur dioxide treatment and drying. We have to check for uniform size pieces.</td>
</tr>
<tr>
<td>Pulping</td>
<td>Pulping is required if we want to dry fruit leather. The pulp should be uniform, and no fruit pieces should be visible. Small scale pulpers are preferable, however, hand pulping is also done.</td>
</tr>
<tr>
<td>Blanching</td>
<td>The operation is mostly used for vegetables. We should check blancher water temperature, time of heating and concentration of any salts added. Care is needed to prevent blanched foods from being recontaminated before drying.</td>
</tr>
<tr>
<td>Acid dipping</td>
<td>The operation is sometimes used for light coloured fruits and vegetables to prevent browning. It is usually done by dipping in 1.5-2% citric acid, lemon or lime juice for 5-10 minutes. The acid concentration is to be checked, particularly if the same acid is recycled for the next batch.</td>
</tr>
<tr>
<td>Treatment with SO$_2$</td>
<td>The treatment is usually practised for fruits to reduce browning during drying. The weight of sulphur or concentration of sulphite and time of treatment are to be checked. We should be careful while handling SO$_2$ as it causes coughing and eye irritation.</td>
</tr>
<tr>
<td>Syruping</td>
<td>Used for crystallised, osmo-dried fruits or to make peels for marmalade. Generally the fruit is boiled in 60% sugar syrup for 10-15 minutes and then soaked in the same syrup for 12-18 hours. The syrup concentration and temperature are to be checked.</td>
</tr>
<tr>
<td>Drying</td>
<td>Generally fruits and vegetables are dried at 40-60°C. In case of pulp drying, suitable metal tray or polyethylene sheet are to be taken. In a mechanical dryer, the drying air temperature, and air velocity are controlled. The size of the fruit pieces also affect the rate of drying. Also check for mould growth and insect contamination.</td>
</tr>
<tr>
<td>Packing</td>
<td>The package should be moisture proof, or else the produce will again absorb moisture and spoil. The fill weight and sealing are to be regulated.</td>
</tr>
<tr>
<td>Labelling</td>
<td>Correct label for type of product is to be used. The label should give complete information about the product that a consumer wants. It should also be attractive.</td>
</tr>
<tr>
<td>Storage</td>
<td>The storage atmosphere should not be damp and exposed to direct sunlight. Proper stack height is to be maintained. For fragile products, secondary packaging as cardboard boxes may be practised</td>
</tr>
</tbody>
</table>
The fruit pulps can also be dried into form of leather. The common example is the dried mango pulp. In this case, the prepared pulp is transferred to aluminium trays previously coated with glycerine. The trays are placed in the dryer. After drying, the dried pulp (leather) is removed and cut into uniform sizes and then packed.

The different equipment required for the purpose will be as follows.

- Wash tanks or special washers
- Sorting and grading equipment
- Knives, peelers, small peeling machines, slicing and dicing machines
- Blanching/ smoking equipment/ sulphuring cabinet or food grade plastic tank
- Pulpers, liquidisers, steamers, or at a large scale, pulper-finishers
- Boiling pan, heat source, wire basket or steamer
- Weighing scales or scoops
- Boiling pan, heater, food-grade tank, muslin cloth filter
- Sun-drying yard/ solar dryer or any type of suitable dryer
- Electric heat sealer for plastic bags sealing

With the above knowledge, we can standardize the sequence of operation for drying of any specific commodity. As an example we discuss below the preparation methods of dried onions, dried tomatoes and dried cabbages in Figs. 8.6-8.8.
Preparation of tomato sauce

Tomato sauce is a product which has consumer demand at all times of the year. This is also an effective way to preserve tomato and channelize the production in glut season for additional income. The flow chart for the preparation of tomato sauce is shown in Fig. 3.9 and the details of the unit operations in Table 8.10.
Fig. 3.9 Process chart for tomato sauce

Table 8.10 Care during preparation of tomato sauce

<table>
<thead>
<tr>
<th>Unit operation</th>
<th>Special care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>We should check for full maturity, but the fruit should not be over ripe (of the plum tomato variety). It has to be picked carefully to avoid bruising and puncturing, etc. Transportation should also be done carefully to avoid damage.</td>
</tr>
<tr>
<td>Sorting / grading</td>
<td>It helps to get product with uniform quality. Hand sorting can be done to have similar colour while discarding the under-ripe, mouldy or discoloured fruits.</td>
</tr>
<tr>
<td>Heating / Peeling</td>
<td>Tomatoes are placed in wire basket and heated in boiling water for 10 minutes. They are then removed and peeled by hand. Alternatively a pulper-finisher can be used. We have to maintain proper temperature and time of heating.</td>
</tr>
<tr>
<td>Pulping or chopping</td>
<td>If heat peeled, the chopping has to be done finely by hand. The pulp should be uniform.</td>
</tr>
</tbody>
</table>
Filtering | Filtering is done to get proper homogeneous pulp after discarding seeds. the filter or mesh screen is not required if pulper-finisher used. We have to ensure that all seeds are removed.  
Mixing | A typical formulation for 1 kg of tomatoes is 10 g salt, 200 ml vinegar and 80 g sugar. Herbs and spices, such as 1 g each of cinnamon, ground cloves, allspice, and cayenne pepper are placed into a tied muslin bag and this is submerged in the pulp. We have to check the correct formulation.  
Heating | The mixture is heated to 80-90°C until thick, usually within 20 min. Vinegar is added towards the end of the boiling to replenish the amount of acetic acid that is lost by evaporation. The time and temperature are the important parameters that are to be used. The total soluble solids (TSS) or degree brix can also be measured with a small apparatus known as brix meter or refractometer (Degree brix is a scale to define the total soluble solids in a solution.)  
Filling and sealing | The filling is to be done while the product is hot. The bottles have to be sterilised before. Sealing is done correctly. The weight of the product is to be checked.  
Cooling, labelling and storage | The storage should be done in racks, in a cool dry atmosphere, away from sunlight  

The basic equipment required for the purpose are as follows.

- Wash tanks or special washers
- Boiling pan, wire basket (pulper-finisher optional)
- Mesh screen
- Weighing scales or scoops, muslin bag
- Boiling pan, heat source, scales or scoops, refractometer or brix meter
- Funnel or paste filler, scales
- Stainless steel boiling pan
- Label applicator (optional)

**Preparation of miscellaneous products as squash, jam, jellies, pickles, etc.**

We will study the preparation of some other types of products as squash, pickles, syrups etc. fruits and vegetables with the help of flow charts.
Fig. 3.10 Flow chart for squashes and cordials

Fig. 3.11 Flow chart for preparation of pickles
Fig. 3.12 Process chart for chutney (e.g. mango chutney)

Fig. 3.13 Processing of Pineapple rings in syrup
Processing of fruit juices

The processing operations for fruit juice are shown in Fig. 3.15. Different types of pressing machines as basket press and hydraulic press, pulping machines, homogenisers, etc. are available for preparation and processing of fruit juices. Small additional equipment like brix meter can help determining the total soluble solid in a fruit syrup during processing and controlling the processing steps. In addition, the bottle filling machines, bottle sealing machines, rinsing machines, exhaust boxes, etc. are used in fruit juice industries.
<table>
<thead>
<tr>
<th>Pulper</th>
<th>Basket press</th>
<th>Hydraulic juice press</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable agitators</td>
<td>Filter centrifuges</td>
<td>Double jacketed' pan for larger scale boiling</td>
</tr>
<tr>
<td>Citrus fruit juice extractor</td>
<td>Batch type mixer</td>
<td>Fruit cutters suitable for small scale production</td>
</tr>
</tbody>
</table>

Fig. 3.16 Different types of equipments used for processing of food products
<table>
<thead>
<tr>
<th>Bottle rinser</th>
<th>Bottle washer</th>
<th>Vacuum filling m/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric filling machine</td>
<td>Semi-automatic liquid filler</td>
<td>Gravity filler</td>
</tr>
<tr>
<td>Bottle capper</td>
<td>Pressure cooker/canner for sterilisation</td>
<td>Bottle cooling system</td>
</tr>
</tbody>
</table>

Fig. 3.17 Different types of equipment used for bottle washing, filling and sealing
Minimal processing

Now a day in the retail stores, fresh fruits and vegetables with minimum of processing are also available and a group of consumers have special preference for that. Though minimal processing has a broad definition, but the normal operations that we carry on fruits and vegetables are cleaning and trimming, peeling, slicing, packaging and storage under refrigeration. The minimally processed food contribute to convenience of the consumer and particularly helpful for the working women.
The last words……

Basic considerations for starting a food processing enterprise

Suppose you want to establish a mango processing industry in a particular area, what type of questions would immediately come to your mind?

The first set of questions you would ask yourself is:

- Is sufficient quantity of good quality raw material available in the locality, or what will be the transportation cost for bringing raw material from another locality to the proposed processing site?
- Whether the auxiliary facilities such as electricity, water, labour, etc. are available in the locality?
- Is there any other associated facility (and/or problems) for establishment of industry in the particular place?

The answers to all these questions should be favourable for you to proceed. These are some of the factors, which affect the site selection for any type of manufacturing industry. In fact many such factors influence the site selection for any industry. If we don’t give a realistic consideration to all these factors, we may face problems in running the enterprise in subsequent time.

In general, a proper site for a food processing plant should have the following features.

1. There should be availability of adequate quantities of good quality raw materials in the nearby locality. This is particularly important for fruits and vegetables, as these are perishable commodities and deteriorate in very long distance transport.

2. The food processing plants require a huge amount of water for processing, cleaning and other operations. Hence the area should have a good source of quality water supply, or there should be a good water table so that we can ensure adequate supply of water throughout the year.

3. There should not be any problem for availability of electrical power in the area. A standby generator will help in maintaining operation during power failures.

4. There should exist proper transport facilities for the movement of raw materials and finished products.

5. There should be easy availability of labour in the area.

Consultation with officials of the neighboring plants on the various nature of locations in the area and attitude of the local community can be helpful on all the above aspects. After we have selected an area or region for locating the plant, the next job is to select a specific site. The final site selection requires a careful scrutiny of experts. Some such points of consideration are as follows.

1. We should shortlist some probable sites and test their soil condition. If the soil doesn’t have good bearing capacity, there will be more investment on foundation costs.

2. Good natural drainage is another desirable feature.
3. The environment should be as far as possible clean and free from debris and dust. The site should be at a considerable distance from other industries, which may affect adversely the quality of processed product by spreading smoke, disagreeable odours, etc.

4. There should also be facilities for disposal of the waste, as this is being a matter of growing concern these days.

5. If the site is located near a stream or other body of water, we should check the flood history.

6. And last, but not the least, there should be scope for future expansion of the establishment.

Then we have to decide on the amount of commodity, we want to process in a season or per day basis. As fruits and vegetables are usually seasonal commodities, we can also think of different types of commodities, that we would like to process in different times of the year. This will help us in planning for the capacity of the equipment and storage space for raw and finished products.

Next task is to identify the different unit operations and activities that are to be carried out in the establishment. After we identify the type of activities, the selection of equipment is to be done. The equipment size and capacity is usually based on the capacity of processing. In addition, the equipment can also be classified as manual, semi-automatic or fully automatic machines. The costs of these machines and the quality of final product also vary greatly. The selection of type of equipment will also depend on the target consumers. So we have to carefully choose the type of processing as well as packaging equipment after consultation with experts. The equipment should be obtained from reputed manufacturers after duly considering their past history on equipment quality and service aspects along with the cost.

Proper layout of the equipment is also very important as it affects the efficiency of operations, and in a long run the viability of the complete system. In general, a good plant layout will permit simple and forward movement for the product and containers through the plant. Expert guidance should be taken in this regard.

There are several laws and regulations regarding the establishment of food processing industries and the quality of processed foods. A certified product ensures quality and safety of the food and has better acceptability in national and international market. For commercial processing and marketing, we have to obtain a permission from the Food Safety and Standards Authority of India (FSSAI). The FSSAI has been established under Food Safety and Standards Act (FSS act), 2006, for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption. Ministry of Health and Family Welfare, Government of India is the administrative ministry for the implementation of FSS act. The Food Inspectors of the respective areas are usually the contact authorities for obtaining such permission. In addition, we have to obtain permission from the District industries centre. The permission from the Directorate of Industries and Boilers is required if we will install a boiler of a higher capacity. For certain industries, the NOC from the Pollution Control Board is also required.

For export purpose, we have to additionally abide by the standards prescribed by the destination countries., which we are not going to discuss in details in this book. For
international marketing, there are further controls as the Hazard Analysis and Critical Control Points (HACCP), Codex Alimentarius Commission, etc.

**Unique features of food processing enterprises**

The processing operations of commodities differ as they are different in their characteristics and because their end uses also differ. We have discussed how the grains differ from the fruits and vegetables. Different fruits and vegetables also individually differ in their physical, biochemical and other characteristics. Even for the same fruit, the characteristics differ with their variety, agronomical practices, etc. Thus the processing also differs from each other. Hence, technologies as well as equipment have a wide range depending on the requirement of the processor and consumer.

In general, the agro processing enterprises are unique and unlike other sectors because of three characteristics of the raw materials. These are, seasonality, perishability, variability.

**Seasonality**

The supply of agri-commodities is seasonal, usually the raw material supply is confined to one or two brief periods during the year, but the demand for finished product is constant throughout the year. Unlike other industries, our agro-processing enterprise must content with a supply and demand imbalance and problems of inventory management, production scheduling, and coordination among the production, processing and marketing segments of the farm to consumer chain.

**Perishability**

Our raw materials (or the raw materials for food processing enterprises) are biological in nature and the normal shelf life is very less. For this reason, they require greater speed and care in handling and storage. Proper care is needed to protect the nutritional value and other characteristics. We should take proper care that the quality of commodity is not spoiled before it reaches the food processing plant or the place where primary processing operations are carried out.

**Variability**

Another important concern is the variability in the quantity and quality of raw material. Quantity is uncertain because of weather changes or damage to crop from disease/pest. Quality varies because of changes in pre- and post-harvest conditions. But in other type industries we do not see such variations in quality of raw materials.

These variations put additional pressure on agro-based enterprise’s production scheduling and quality control operations, as well as on post harvest management of agricultural produce.

**Scope and opportunities of food processing in India**

Anyway, all of us will agree that even if the challenge is there, there is a huge scope of developing food processing industry in India mainly because of following reasons.

**Production.** India is a leading producer of agri-commodities in the world and still has vast untapped potential of growing more agricultural produce. Thus automatically there is a potential of processing and export.

**Market size.** India is also a huge consumer base and the country presently has a largely untapped domestic market from among over one billion consumers of whom 300-500 million consume processed and packaged foods.
Export. Despite being one of the largest food producer in the world, our share in export is very small. It is because of inappropriate product quality and insufficient infrastructure to produce good quality. Thus, there is a great scope of improving our processed food industry and increasing export.

The theme is that our country has huge opportunity for growth in terms of food processing and post harvest management, and while stepping in to the field of food processing and post harvest management, we should take proper care of safety, hygiene, regulations, etc. to get the maximum benefit from our investment and labour.
**Further reading**


