UNIT 1 IMPORTANCE OF POST HARVEST MANAGEMENT

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- understand how post harvest management can reduce losses after harvest and increase food availability thereby provides food and nutritional securities;
- state proper post harvest care can add value and provide benefit to the producers and consumers;
- explain efficient post harvest operation can generate employment and bring rural industrialization;
- highlight the role of post harvest technology for better economy of the country through export earning; and
- demonstrate how appropriate post harvest management and processing can utilise unmarketable produce and processing waste for gainful purpose hence reducing pollution and city garbage.

1.1 INTRODUCTION

India is a vast country and a wide range of variety of fruits and vegetables are cultivated in different regions. There has been a phenomenal rise in production of fruits and vegetables in our country since Independence. As per the data for 2000-2001, the production of fruit is about 45.37 million metric tonnes and vegetable about 93.92 million metric tonnes available in India and going to be doubled by 2011 and is considered to be the second largest producer next to china in the world. Unfortunately, unlike other horticulture rich countries, average Indians do not get the basic daily requirement of fruits and vegetables and our Human Development Index is very low. This is because a considerable amount of this valuable produce is lost due to improper post harvest management. High moisture content, living nature and presence of readily utilizable nutrients make fruits and vegetables highly perishable commodities.

Spoilage mainly occurs due to microbial attack, auto-oxidation and insect pest attack. According to a study, at least 25 to 30 percent of the production of fruits and vegetables in the country is lost due to wastage and value destruction. The wastage cost was estimated to be Rs. 67,500 crores each year. Even if 1% of this could be saved by converting them into value added products, there will be a saving of Rs. 67.5 crores annually. Further, the cost of reducing spoilage is much lesser than the production of the same quantity and quality produce. Post harvest management of horticultural produce is therefore the need of the hour in order to feed ever-growing population of the world in general and India in particular. The most important advantage of post harvest management and processing is the reduction of post harvest losses of fruits and vegetables.

1.2 INCREASE FOOD AVAILABILITY

It is well known fact that fruits and vegetables are perishable in nature due to its high moisture content, high rate of physiological activity viz. respiration and ripening, microbial attack, rapid bio-chemical changes such as enzyme activity, softening of the texture and many other biotic and abiotic factors. Harvesting season of almost all fruits and vegetables is very narrow lasting only for 1-2 months. During this short period, availability of that particular fruits and vegetables is abundant but at the end of harvesting season, products availability decreases rapidly and may be completely out of market within 1-2 months. Here, therefore comes the role of Post harvest management of horticultural commodities like proper handling, packaging and storage at safe low temperature, maintenance of cool chain during transportation and marketing, pre and post harvest treatments in order to increase self - life and reduce the overall spoilage etc. These practices make fruits and vegetable available through out the year. Many modern technologies such as refrigerated storage and transportation, Controlled and Modified storage, irradiation, processing into value added products are some of the ways to extend the availability of fruits and vegetables beyond the end of the harvesting season. In this way, the food already produced can be saved for consumption by applying the techniques of post harvest management and indirectly increase food availability. Attention to the concept of post-harvest food loss reduction as a significant means to increase food availability was drawn by the World Food Conference held in Rome in 1974. The seventh session of the U.N. General Assembly in 1975 passed a resolution calling for a 50 percent reduction of post harvest losses by 1985. In the FAO, after consultation with its Governing Body food loss prevention became a priority area and an Action Programme became operational in early 1978. The Food Loss Prevention Programme of FAO till recently focussed mainly on the durable food grains, because of the prominence in daily diet. Only in May 1980, an Expert Consultation on Food Loss Prevention in Perishable Crops mainly covering fruit and vegetables was held in Rome.

1.3 NUTRITIONAL SECURITY

Fruits and vegetables constitute an important part of human's food. Even though they are generally not considered as a staple food yet they help in intake of cereal foods by making them more palatable in nature. Fruit and Vegetables in general, except for a few, are not considered to be the primary source of carbohydrate, protein and fat. However, some of them with storage roots and tubers are rich in carbohydrate, particularly starch, in amounts comparable to the cereal crops, and the leguminous vegetables supply as much as 14 per cent protein, dry seeds supplying still more. The lipid content in most vegetables is less than 0.1 per cent. Most fruit, vegetables and root crops are rich in minerals, carotene (Pro-vitamin A) and vitamin C. Besides, there are some trace elements required by the body like copper, manganese and zinc, which act as coenzymes. These are found in appreciable quantity in fruit and vegetables. The amount of nutrient can vary with fruit and vegetables, cultural practices, stage of maturity, post-harvest handling and storage conditions. Once they are harvested, their composition goes on changing as a result of physiological and biochemical activities, which are natural processes. Fruits and vegetables are the rich source of vitamins, minerals, and trace elements, deficiency of which leads many diseases such as scurvy, beriberi, night blindness etc. In addition, most of the fruits and vegetables are also loaded with antioxidants and fibers. Antioxidant neutralizes free radicals produced in the body that is found a possible cause of cancer and also prevents faster aging. At the same time fiber controls many cardiovascular diseases and movement of foods in the digestive system. Several vitamins and minerals that are scarce in cereals and animal products are present in abundance in fruits and vegetables. Beside this, fruits and vegetables also supply carbohydrates and protein and fulfill the essential nutrients in human diet. Therefore, human health is protected if fruits and vegetables or their processed products are consumed regularly. Fruits and vegetables are therefore considered as protective foods. Further, several vitamins, minerals and phyto-hormones found in fruits and vegetables have now assumed the status of functional food. These substances are capable of providing additional physiological benefit, such as prevention or delaying onset of chronic diseases, as well as meeting nutritional requirements. Keeping in view the nutritional quality of fruits and vegetables, post harvest management of these perishable commodities is the only solution for nutritional security to ever growing population of the country.

1.4 EMPLOYMENT GENERATION

Employment generation of Indian Youth is becoming more and more difficult with increasing in population. It has been observed that job opportunities in government sectors are shrinking day by day and private companies closing fresh recruitment. For rural youth, it becomes more and more difficult to get a good or moderate employment in rural areas as a result unemployed rural youth are rushing towards towns and cities to do any sort of work. This type migration of population from rural to urban area is detrimental to the society. In addition, this situation is creating a big problem in metro cities. Therefore it is the need of the hour that these youth start their own ventures that should not only be remunerative and attractive in nature but also easy to operate. Post harvest handling and processing of fruits and vegetables is one such area that can provide great possibility for employment generation. During harvesting season, people can get employment in harvesting, pre-treatments if any, packaging and transportation of fresh produce to towns and cities. The surplus production and cull fruits and vegetables can be converted into pulps and value added products during the season and later it can be used to prepare various tertiary processed products. All these operations require human resources in large quantity.

A fruit and vegetable processing factory having a capacity of 10qt/month can engage 4-6 people for the whole year. In addition in order to handle freshly produced fruits and vegetables properly grading and packing stations and quality control laboratory have to be developed to keep the pace of development process. Further, as ancillary industries manufacturing units for food processing machinery, packaging materials both for fresh and processed fruit and vegetable products will also develop side by side and generate employment. Other relevant industries and establishments, such as, retail outlets etc, will also provide additional employment. In our country 90% of fruit and vegetable produced are marketed by the farmers compared to only 20% of cereals/food grains production of India.

Employment potential of food processing industries is much higher compared to many other relevant industries. For example per 1,000 crores of investment employment potential in food is 54,000 compared to textiles –48000 and paper –2500. It has been reported that there is a 4 fold indirect employment on investment in food and it provides 60% employment in small towns and rural areas. Our aim is to increase processing from present level of 2% to 10% by 2010 that will involve an investment of Rs.1,40,000 crores generating direct employment 77 lakh and indirect employment 3 crores.

1.5 VALUE ADDITION

Horticultural produce in general and fruits and vegetables in particular generate a large amount of valuable waste such as inedible plant parts as such for human food that end up as garbage. However, if they are gainfully utilised at the proper time they can produce value added products. Vegetables such as cauliflower, peas, leafy vegetables, etc. can be primarily/minimally processed so that inedible parts are removed before being sent on to the metropolitan city markets. They should be unit packed at packing stations situated at appropriate points in every district. This process will reduce the transportation and handling cost of inedible parts and help the consumer by providing a convenience food. The consumers particularly the working women would be willing to pay higher prices because these ready to use products save lots of time, in kitchen besides labour and space. Similarly, bananas should be transported in hands as is done in other countries. Each packing station should have the facility for processing. Physically damaged fruit and vegetables that are without infection but would be spoiled on storage can be made into durable and value added processed products at this point. Utilization of physically damaged fruits and vegetables into value added processed product could considerably reduce the price of main product as a result more processed food products will come within the reach of common people.

Fruits and vegetables are perishable in nature, it can not be stored for longer period. It has been observed that about 25-30% of total production are not fit for fresh marketing and called culled produce. These produce are undersized, oversized and malformed/deformed and physically damaged fruits and vegetables but microbiologically sound at the time of harvest. The produce of this category either sold at throw away prices or left to spoil as such. Thus a huge quantity of horticultural produce in the form of cull fruits and vegetables occurs every year which otherwise could be utilized, if processed into various value added by products. Fruits and vegetable processing units also generate large amount of valuable waste such as peel, stones and other inedible plant parts that are generally not utilsed properly and rejected as such in our country and finally end up as garbage. However, if they are gainfully utilised at the proper time they can become value added products. Some of theses waste are rich source of vital constituents like carbohydrates, protein, fat, minerals, edible fibres, etc. and also constituents of commercial use such as pectin, starch, colours/ pigments, essential oils, sugars, vinegar, alcohol, and many compounds useful in food and beverage industries. In addition the waste may be used as cattle feed that is in short supply in our country. These waste processing not only gives value added products but also reduce the price of the primary processed products that are sold at a premium price in our country beyond the means of the common people. In general, it improves the overall economy of the country. Premature fruit drop due vagaries of climate such dust or hailstorm is also a big problem in India. As a result a substantial quantity of fruits and vegetables are lost before they attend proper maturity stage. These produce can be utilized usefully if processed into value added products such as pulp, pickle, chutney, dried powder etc.

During peak harvesting season a good amount of quality fruits and vegetables are available in abundant quantity resulting in market glut and all of these quality produce can not be marketed in the fresh form. As a result, there is huge spoilage and wastage of fresh fruits and vegetables. This wastage can be reduced if they are timely processed into different value added products or preserved by different methods during harvesting season. Now it can be used throughout the year and can be transported to distant market. Value added products not only palatable but also nutritious and gives economic gain. Nutritional value of these products can be increased many folds through fortification particularly of protein, vitamins and minerals. Processing serves as an outlet for surplus production and therefore acts as price stabilizer. Fruits are generally consumed as fresh but mostly vegetables are cooked before consumption expecting a few ones like cucumbers, tomatoes etc. Value addition also includes peeling, slicing, cutting into pieces, processing and packaging. All such activities increase value of the products.

India has a wide range of indigenous fruits that are underutilized. Most of these fruits are tropical/subtropical in nature and grow even under adverse agro-climatic conditions. A large number of these fruits are known for their therapeutic/medicinal and nutritive value and have excellent flavour and very attractive colour. Some of these fruits are not easy to eat out of hand e.g. baelfruit that has a hard shell, mucilaginous texture and numerous seeds; as a result it is not popular as a dessert fruit. Kokum is not acceptable as a fresh fruit because of its high acidity, only its thick outer rind is used in beverage industry or for culinary purpose in the dried form. Similarly aonla as a fresh fruit is not liked because of its strong astringent taste. All these fruits have a great potentiality to processing into a value added fruit products of commercial importance. So that the growers get a remunerative price and consumers get the opportunity to enjoy the indigenous fruit products. A shrink-wrapped fruit and vegetable fetches more prices compared to non shrink-wrapped ones because of value addition.

It has already been mentioned that less than 2% of production of fruits and vegetables in India goes for processing. As a result, value addition in food sector is low at 7%. The production of fruits and vegetables in our country is now 66% of food grains. It is expected that this figure is likely to be 80% by 2010. With proper infrastructure facility for post harvest handling and processing, value addition will correspondingly go up from 7% to 35 % resulting in increases in GNP.

1.6 EXPORT EARNING

It is known that about 84 different fruits and 63 items of vegetables are traded in world market. In addition a large number of fruit and vegetable products are also marketed. India by virtue of its varied agro-climatic conditions has the advantage of producing most these fruits and vegetables and processing them into products that can be traded in the world market. In order to achieve export potential, following fruits have been identified as having good market potential viz. Mango, Grapes, Banana, Lychee, Exotic fruits Chikoo, Ber, Pomegranate, Amongst vegetables the items identified as having good export potential are - Onion, Potato, Green vegetables. The following two categories of vegetables also has great potentiality: a) Traditional - okra, bitter gourd, chili and other seasonal vegetables; b) Non-traditional - asparagus, celery, broccoli, bell pepper, sweet corn and baby corn; green and lima beans.

India has vast resources of indigenous fruits and vegetables that have established medicinal and therapeutic values apart having high nutritive value, attractive color and excellent flavor viz. aonla, baelfruit, jamun, kokum, phalsa etc. There is always a demand all over the world for new, nutritious, attractive and delicately flavoured products. Also, the trend today is a return to the natural and a preference for the therapy provided by nature. Consumers today are becoming increasingly conscious of the health and nutritional aspects of their food. The tendency is to avoid chemicals and synthetic foods and choose therapy and nutrition through natural resources. The underutilised fruits of India have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. The development of these fruits can considerably contribute to crop diversification, farm income and the improvement of nutrition and also provide valuable exports and additional employment. Therefore, among these indigenous fruit lies an untapped potentiality for processing into value added products that can attract export market. For example, Bael and Aonla are indigenous fruits having highest riboflavin (Vit. B2) and vitamin C respectively. Increased health consciousness in the masses will boost their consumption in India and in International market. Any Aonla products can be exported as they are rich in vitamin- C. Therefore, export of these indigenous fruits and vegetables and their processed products can earn valuable foreign exchange. Though some fruit products, are being manufactured at present on a small scale, inspite of such favourable possibilities no systematic approach has been made to utilise the potential of the indigenous fruits on a large scale mainly because of the lack of the requisite amount of raw material. Organised orcharding and systematic collection of raw material is of utmost importance. Kiwi fruit that was practically unknown in the world market a few years back, is now in the forefront of international fruit trade. The New Zealand Kiwi Fruit Marketing Board highlighted the plus points of Kiwi Fruit such as thirst quenching, highly nutritious, rich in Vitamin -C, good for maintaining health, slimming effect etc. to make it popular among the consumers the world over. There is no reason why we can not achieve similar success. Instead of trying to compete in a market where other countries are already established and far ahead we must break new ground and create markets for our indigenous fruits where no other country can compete with us.

Freezing is rated as the best technique available for food preservation since it maintains the natural properties by reducing post harvest changes and microbial deterioration to the barest minimum without any influence on the original qualities. The rate of freezing plays a great role on the quality of frozen fruits and vegetables; faster freezing rate is required to obtain better quality. Liquid nitrogen is the most common cryogenic substance fused in food freezing. Ultra quick freezing rate, minimum dehydration less, freedom from oxidative changes, minimum freezing damage of freeze sensitive products, maximum quality retention of texture, colour and flavour of sensitive fruits and vegetables during freezing and the inert nature of the freezant are the advantages of liquid nitrogen freezing. A systematic establishment of quick freezing industry can boost export trade of our country. Methods have been standardized under laboratory conditions for the manufacture of cryogenically frozen, crack free, peeled ripe mango slices having excellent retention of quality attributes, well comparable with those of fresh mangoes in ready-to-serve form and cent-per-cent edible portion. This will have a great potentiality in export trade. The problems generally facing the export of fresh mangoes, like short storage life, added bulk of stone and peel, hidden disorders like spongy tissue and stone weevil can be successfully overcome by producing the cryogenically frozen mango slices.

Hardly there is any fruit that is not cultivated in this country. At present only few established fruits and vegetables are exported. Government has already recognized it as one of the major thrust for augmenting the countries export. Lack of proper post harvest management and infrastructure facilities are the major hurdles for export of horticultural produce. Countries like Indonesia, Malaysia, Thailand etc. are far behind in production of fruits and vegetables compared to India but their exports are many folds higher than our country. It is mainly because of good post harvest management practices, quality maintenance through out the marketing channel and basic infrastructure for export

1.7 RURAL INDUSTRIALISATION

Post harvest management and processing of fruits and vegetables is the backbone of the horticulture industry as it takes care of gluts and all possible wastage that occur during handling, storage, distribution and marketing. Most growers are rural people. During peak harvesting season, always there is glut. There is no preservation unit, grading and packinghouse in rural areas. They can not hold their produce, even for few days due to lack of storage facility and they are unable to preserve their produce. This situation forced them to sale their good quality produce at very low price to middleman. Cull fruits and vegetables are generally goes waste or sold at a throw away price. After harvesting season is over, again rural people become jobless. They generally migrate to cities in search of any sort of job. Setting up of small and cottage level preservation factory at village level not only reduces losses due to glut but also provides jobs for rural people. It can always fetch an additional income to the grower and help in stabilizing the prices and providing economic return. Hence, fruit and vegetable processing industry should be encouraged and developed in rural areas, a way of rural industrialisation

1.8 BENEFICIAL TO PRODUCERS AND CONSUMERS

In a country like India, transportation facilities are not so good, rural electrification is also in infancy stage and huge production of horticultural produce occur in different parts of the country particularly in the rural areas and under developed areas. There is always abundance of produce at the production site but scarcity of the same produce at consumption places.

Growers at production site sale their produce at the lowest minimum price due to fear of spoilage. However, the consumers purchase the same commodities at a very high price in cities and urban areas due to involvement of middle man. In this way, both producers and consumers suffer and middle man only get advantage. To overcome this situation, growers should be trained properly about post harvest management, storage and processing of fresh Fruits and vegetables. There must be on farm storage facilities viz. pusa zero energy cool chamber for short duration storage. Cottage and small scale level fruit and vegetable processing unit must be encouraged so that cull fruits and Fruits and vegetables can be converted into value added products, properly stored and processed products can be transported to the places of scarcity during their harvesting season and after the season is over. In this way a glut like situation can be avoided in production areas. Growers will get a good price for their produce and consumer will have to pay a reasonable price only.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the major factors responsible for spoilage of fruits and vegetables?

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2. How post harvest management of fruits and vegetables can increase food availability?

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3. How fruits and vegetables processing industry can revive rural industrialization?

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4. What are the importance and advantages of value addition?

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5. How do you increase export of fresh and processed fruits and vegetables?

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6. Why fruits and vegetables are called as protective foods?

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1.9 LET US SUM UP

Fruits and vegetables are highly perishable in nature that results in rapid spoilage and deterioration in quality. However, proper post harvest management can reduce this spoilage. The cost of reducing spoilage is much lesser than the production on additional land. A good post harvest management reduces spoilage by preserving seasonal surplus and cull fruits and vegetables, which often lie rotting on the roadside. Processing and value addition increases food availability, generates cattle feed by converting factory waste thus reduces garbage accumulation. Growers get remunerative price of their produce and consumers buy it at reasonable price. Many indigenous fruits and vegetables, which are not generally marketed, as fresh can be processed into value added products for export. These products are in demand in national and international market due to its medicinal and therapeutic properties. Fresh as well as processed fruits and vegetables is rich source of vital nutrients like vitamins, minerals, fibers etc. It gives nutritional security forever growing population and protects their health.

1.10 KEY WORDS

Post harvest management : Methods and techniques applied to increase the shelf life and retain quality of horticultural produce either as fresh or processed into different products.

Post harvest losses : Losses of horticultural commodities in quality and quantity after harvesting till consumption.

Food availability : Availability of fruits, vegetables and their processed products beyond their harvesting season or round the year.

Irradiation : Exposure of biological materials to radiation such as X-ray, gama-ray, electron beams etc.

Antioxidants : Substances which prevent oxidative reaction in foods.

1.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - High moisture content.
   - More physiologically active.
   - Soft texture and rich nutrients invites microbes and insect pest.
   - Susceptible to rapid enzymatic oxidation.

2. Your answer should include the following points:

   - Post harvest losses reduction at different stages increases food availability.
   - Processing of surplus fruits and vegetables into value added products.
   - Utilization of cull fruits and vegetables into processed products.
   - Increases shelf-life of fruits and vegetables by improved post harvest management.

3. Your answer should include the following points:

   - Fruits and vegetables processing industry utilizes surplus and cull produce.
   - It provides more employment and occupation for rural people.
   - It saves farmers from distress selling.
   - Ideal in rural areas due to cheap availability of raw material and local labour.

4. Your answer should include the following points:

   - Indigenous fruits and vegetables having medicinal and therapeutic properties.

   - Cull and surplus produce can be utilized for preparation of various products instead of throwing for spoilage.

   - Waste generated during processing can be processed either into animal feed or for use in related industry.

- It generates employment, animal feed and prevents garbage accumulation.

- Earns valuable foreign currency and saves Indian currency paid for import of processed fruits and vegetables products.

- Fulfills Defense requirements.

- Improves overall Indian economy.

5. Your answer should include the following points:

   - Better post harvest infrastructure for export purpose.
   - High tech processing like cryogenic freezing and aseptic packaging.
   - Fresh vegetables rich in anti-oxidant medicinal value.
   - Processing of indigenous tropical fruits rich in nutrient and therapeutic value.

6. Your answer should include the following points:

   - Fruits and vegetables are rich source of vitamins which prevents diseases like scurvy, Beriberi, night blindness etc.

   - They are also rich source of antioxidants neutralizes free radicals formed in human body that causes sometimes cancer and accelerates faster aging.

   - Minerals found in fruits and vegetables take part in various biochemical reactions.

1.12 SOME USEFUL BOOKS

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UNIT 2 CAUSES OF PRE AND POST HARVEST LOSSES OF FRUITS AND VEGETABLES

Structure

2.0 OBJECTIVES

In this unit we will discuss the pre- and post-harvest factors for post-harvest losses of fruits and vegetables.

After going through this unit, you should be able to know the:

- role of cultural practices (irrigation, nutrient deficiency) and maturity index in post-harvest losses of fruits and vegetables;

- infestation of pest and disease and their contribution to post-harvest losses;
- role of environmental factors such as soil condition, climate, frost, hail, pollutants etc. in post-harvest losses; and
- improper handling, storage, transportation and socio-economic factors and their impact in post-harvest losses.

2.1 INTRODUCTION

Fruits and vegetables not only provide nutritional security, but also generate a high income to growers. Better production practices, careful harvesting and proper packaging, storage and transport contribute to the good quality produce. Once a crop is harvested it is impossible to improve its quality. Because of high moisture content, fruits and vegetables are inherently more liable to deteriorate. After harvest, they are also biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which deteriorate the quality of the produce. In India, the post harvest losses of fruits and vegetables is varying from 25-40% /depending upon the kind of produce and its pre and post-harvest practice. This can occur in the field, in packing houses, in storage, during transportation and in the wholesale and retail markets. Severe losses occur because of poor infrastructure, poor pre and post harvest management, marketing of the produce.

Biological causes of deterioration of fruits and vegetables include metabolic changes (respiration, ethylene production and action, compositional changes), mechanical injuries (cuts, bruises, abrasions, etc.), incidence of physiological disorders, and pathological breakdown. The rate of biological deterioration depends on various environmental factors including temperature, relative humidity, and concentrations of ethylene, oxygen, and carbon dioxide.

The loss in food value of fruits and vegetables may be attributed after harvesting through several ways:

- Water content is reduced with time as the continuation of living processes within the produce and as result the commodity gets shrivelled and loses its turgidity.
- Vitamin C content decreases with time after harvest.
- Cooking partially destroys water soluble vitamins B and C.
- Peeling may cause significant loss of food value, since most of the nutrients are in engrossed in epidermis skin especially in potatoes, where the protein content is just adhering to skin.
- Water used in cooking vegetables dissolved minerals and trace elements.

2.2 PRE-HARVEST FACTORS IN POST HARVEST LOSSES

2.2.1 Choice of Cultivars and Planting Materials

The healthy crops will only come from healthy and good quality planting materials. The market quality of the produce is determined by selecting the crops, their cultivars, and the production system. It is well known that some cultivars have better palatability apart from better transport quality and longer shelf life than others. While selecting planting materials following points should be taken into consideration.

What Needs to Do?

- Choose cultivars that will have better quality attributes and as per the demand of the consumers.
- Use clean, healthy, high quality planting materials.
- Grow off-season cultivars of the same crop to extend harvest period.
- Choose cultivars that are well suited to the specific climate, day length, soil and growing conditions.
- Always select seed from the good quality produce or source.

2.2.2 Cultural Practices

Cultural practices can also affect post-harvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, abrasions) is particularly susceptible to post-harvest diseases. For example, mold and decay on pumpkin and squashes caused by the fungus *Rhizoctonia* results from the fruits lying on the ground. Cauliflower curds are susceptible to post-harvest rot caused by the bacteria *Erwinia* if nitrogen is applied as foliar spray. Beets and radishes are susceptible to soil-borne diseases when the soil temperature reaches 80º F. The finger rot in banana and stem end rot in mango caused by *Botryodploidia theobromae* is more severe when temperature is above 30^0C and 20^0 C and bow the growth of the fungus is poor.

Several diseases outbreaks in the field may cause food borne illnesses which have been traced to contamination of produce in the field.

What Measures to Take?

- Follow only recommended practices in terms of variety, season its manure/fertilize doses, irrigation level and the care during growing and after harvesting.

2.2.3 Irrigation

Growing plants need a continuous water supply for both photosynthesis (the process by which plants convert light to chemical energy and produce carbohydrates from carbon dioxide and water) and transpiration (the giving off by a plant of vapour containing waste products). If banana is allowed to mature fully before harvest and harvesting is shortly after rainfall or irrigation, the fruit can easily split during handling operations, allowing micro-organism infection and post-harvest rotting.

Bad effects can be caused by:

- The use of irrigation methods that spray water on foliage or excessive rainfall can increase incidence of disease and fungal infections.
- Excess rain or irrigation during growing and before harvesting can contribute to loss of flavour in many crops and increased susceptibility to bruising and decay in storage, respectively.
- Lack of rain or irrigation during growing can cause low juice content and thick skin in citrus fruit.

- Dry conditions followed by rain or irrigation, give rise to growth cracks or secondary growth in potatoes and growth cracks in tomatoes.

Judicious application of water during the maturity will reduce the post-harvest losses of fruits and vegetables.

2.2.4 Nutrient/Mineral Deficiency

Lack of plant nutrients in the soil can seriously affect the quality of fresh produce at harvest. On the other hand, too much fertilizer can harm the development and post-harvest condition of produce. Crops which contain high levels of nitrogen have poorer keeping quality than the same variety of crop with lower nitrogen levels. The problem of fertilizer balance in soils and its effect on crops is complex and depends also on other conditions such as temperature, moisture, acidity of the soil and reactions among different fertilizer chemicals. Imbalance of fertilizers can result in several physiological disorders which alter the appearance and ultimately consumer's acceptance of the fruit and vegetable produce during post-harvest period.

Nutrient deficiency	**Physiological disorder**
Calcium	blossom end rot in tomato and capsicum, internal browning in Brussels sprout, internal tip burn in cabbage, cavity spot and cracking in carrot, black heart in celery, hollow stem in cabbage, cauliflower and Brussels sprouts, bitter pit in apples, calyx en rot in persimmon, leaf drop in peach etc.
Boron	cracked stem in celery, root split in carrot, brown heart or root canker in beet, browning of curd in cauliflower, lumpiness in papaya, internal necrosis in mango, fruit cracking in pomegranate, russeting and internal cork in apple etc.
Molybdenum	whiptail in cauliflower, yellow spot diseases in oranges
Manganese	marsh spot in peas and beans
Nitrogen	stunted growth or yellow-red discoloration of leaves in green vegetables
Magnesium	Interveinal chlorosis in apple

2.2.5 Other Cultural Practices

- Pruning and thinning – improves sun penetration and ventilation which is important for uniform fruit colour development, increase in fruit size and quality, but yield decreases slightly. Encouraging plants to grow upward on trellises also lowers relative humidity and reduces incidence of disease.

- Weed control – weeds are commonly alternative hosts for crop diseases and pests. Weeds also compete with crops for nutrients and soil moisture and thereby reduce the quality of fruits and vegetables.

- Crop hygiene – decaying plant residues, dead wood and fruit and vegetables wastes are all reservoirs of infection causing post-harvest decay. Their collection and removal are important to keep your crop safe from bacterial and fungal infection.
- Use cultivation practices that are recommended and appropriate for the region and climate.
- Pesticides and herbicides can damage by causing spray burns and leave poisonous residues if used incorrectly.
- Growth-regulating chemicals are used mainly to improve marketability of fruit by controlling the time of fruit set and promote uniform ripening. They require specialist knowledge.

2.2.6 Improper Harvesting

A critical time for growers of fruit and vegetables is the period of decision on when to harvest a crop. Normally fruits and vegetables are harvested when they have developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Confusion may arise because of the word maturity since, in the botanical sense, this refers to the time when the plant has completed its active growth (vegetative growth) and arrived at the stage of flowering and seed production (physiological maturity).

Maturity whether viewed as physiological maturity or harvestable maturity can have a pronounced influence on the quality of fruits and vegetables. Optimum maturity at harvest depends on the market or intended use (storage, fresh consumption and processing). For many vegetables the optimum eating quality is reached at tender stage e.g. leafy vegetables, cucumber, bottle gourd, green peas, beans, okra etc. Delayed harvest will lead to fibre development. The good quality fruits are obtained when harvesting is done at proper stage of maturity. Immature fruits when harvested will give poor quality and erratic ripening. For example the fruits of mango are harvested based on fullness of cheeks, colour in pedicel end whereas banana fruits are harvested based on fullness of fingers and disappearance of angularity on the surface.

Method of harvesting is as important as time of harvesting. Faulty harvesting and rough handling at the farm directly affect market quality. Injury to peel may serve as entry port for the micro-organisms and lead to rotting. For example, banana bunches should be cut leaving 30 cm of stalk.

2.2.7 Post-harvest Physiology

The quality of the harvested fruits and vegetables depend on the condition of growth as well as physiological and biochemical changes they undergo after harvest. Fruit and vegetable cells are still alive after harvest and continue their physiological activity. The post harvest quality and storage life of fruits appear to be controlled by the maturity. If the fruits are harvested at a proper stage of maturity, the quality of the fruits shall be good. Poor quality and uneven ripening are due to early and late harvesting may result in extremely poor shelf life.

Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight, and more rapid deterioration. The respiration rate of a commodity strongly determines its transit and post-harvest life. The higher the storage temperature, the higher the respiration rate will be.

Respiration plays a very significant role in the post harvest life of the fruits. In most of the fruits, the rate of respiration increases rapidly with ripening. The sudden upsurge in respiration is called the 'climacteric rise', which is considered to be the turning point in the life of the fruit. After this the senescence and deterioration of the fruit begin.

Climacteric fruits	**Non-climacteric fruits**
Apple, banana, papaya, mango, guava, jackfruit, fig, sapota, tomato, musk melon, water melon etc.	Litchi, pineapple, grapes, pomegranate, lemon, orange, lime, cucumber etc.

To extend the post harvest life of the fruits its respiration rate should be reduced as far as possible. Thus an understanding of the factors, which influence the rate of respiration, is indispensable to post harvest technologies for manipulating the storage behaviour of fruits and vegetables.

Check Your Progress Exercise 1 ✍

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Match the following:

Nutrient deficiency	**Physiological disorder**
(a) Calcium deficiency	i) marsh spot in peas and beans
(b) Boron deficiency	ii) Inter-veinal chlorosis in apple
(c) Molybdenum deficiency	iii) browning of curd in cauliflower
(d) Manganese deficiency	iv) whiptail in cauliflower
(e) Magnesium deficiency	v) bitter pit in apples

(a)	
(b)	
(c)	
(d)	
(e)	

2. Critically analyse the role of cultural practices in post harvest losses of fruits and vegetables with suitable examples.

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3. Write few basic criteria for selecting cultivars/planting materials for quality produce?

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4. What do you mean by climacteric and non-climacteric fruits?

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2.3 BIOLOGICAL FACTORS

Heavy post-harvest losses are occurred by the invasion of fungi, bacteria, insects and other organisms. Microorganisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism after the harvest and has plenty of nutrients and moisture to support microbial growth. Almost all post-harvest pests originate from field infestations, and if the storage condition is conducive they can multiply on.

2.3.1 Pathological

Plant pathogens cause substantial losses of fruits and vegetables during production. Specific pathogens also resulted in undesirable post-harvest losses. For example, bacterial spots in tomato caused by *Xanthomonas campestris* pv vesicatoria; white mould *(Sclerotinia sclerotiarum)* produces white mycelium in blossom end of cucurbits.

Viral disease like Zucchini Yellow Mosaic virus of summer squash *(Cucurbita pepo)* resulted small distorted fruit and tomato mosaic virus causes discolouration of mature tomato fruits. Black mould rot caused by *Aspergillus niger,* bulb rot by *Fusarium solani* and bacterial rot by *Pseudomonas* sp. infection during cultivation of onion may cause damage during storage. Preharvest infection of fungi, *Botryodiploidia theobromae* and *Glomerella cingulata* cause stem end rot and anthracnose disease, respectively, in mango which usually develop as the fruits ripen. These diseases are also to be effectively controlled before harvest otherwise act as inoculums for post harvest loss.

2.3.2 Entomological

Feeding by different insect generally resulted in distinctly undesirable appearance of the produce. For example, cabbage loopper *(Trichoplusia nii)* create holes in foliage and head becomes unacceptable. Some insects cause primary damage by developing larva that tunnel throughout interior portion of the produce as sweet potato weevil, *Cylas formicarius.* Another form of damage produced through lack of or incomplete pollination resulting in misshapen fruits. For example, cucurbits exhibit small, distorted fruits that are generally shed before reaching harvestable maturity when pollination is inadequate. In the fruits of mango, the insects like fruit flies (*Bactrocera dorsalis*) and mango stone weevil (*Sternochetus mangiferae*) those invaded at the time of flowering, remained inside the fruits till the ripening of fruits. These fruits are unfit for consumption and cause the damage even during storage.

2.4 ENVIRONMENTAL FACTORS

The environmental factors such as soil type, temperature, frost, and rainy weather during growing and at harvest can have an adverse effect on storage life and quality. For example, carrots grown on muck soils do not hold up as well in storage as compared to carrots grown on lighter, upland soils.

2.4.1 Climate

Temperature during growth affects cucumber fruit length and thus repressing development. Likewise, cucumber fruit curvature is increased with increasing temperature. High temperature during pollination resulted in puffiness of fruit in tomato.

2.4.2 Chilling Injury

Chilling injury is often associated with storage but it also occurs prior to harvest. In sweet potato, chilling injury increases rotting and the formation of 'hard-core' a condition where a woody core forms in the storage root. When young cucumber fruits are exposed to chilling temperature, the surface of the fruit is scarred and an undesirable curvature develops. Similarly, when banana fruits are exposed to chilling temperature, there is increase in tannin content, hardening of central placenta, inhibition in starch/sugar conversion and reduction in ascorbic acid content. There is skin pitting, inhibition in conversion of sucrose to reducing sugar in papaya fruits when store in chilling temperature. This type of damage is more acute in other tropical fruits also. Thus, the tropical fruits are to be protected from their chilling in field condition and stored at their appropriate storage temperature.

2.4.3 Frost Damage

Frost occurs through sublimation of water vapour on objects that are below 0^0C. Frost causes damage to the foliage of leafy vegetables as burning symptoms.

2.4.4 High Temperature Stress

Pre-harvest high temperature (during growing) causes losses in post-harvest quality of fruits and vegetables. The losses due to temperature variation vary with species, cultivars, stage of development etc. Direct effects of high temperature stress include damage to cellular membrane, proteins and nucleic acids. Indirect effects include inhibition of pigment formation and degradation. In addition, high temperature causes premature ripening in pumpkin. The oranges grown in the tropics tend to have higher sugar and total solids content than those grown in sub-tropics. However, the tropical grown oranges tend to develop less colour as compared to sub-tropics grown oranges.

2.4.5 Hail Damage

Hail storm size, and its exposure to crop growth stage and duration time are critical factors affecting the degree of damage. Hail damage results in a direct effect on the physical quality of the product, increases the incidence of damage and diseases like bacterial spot (*Xanthomonas campestris* pv. vesicatoria) of sweet pepper.

2.4.6 Soil Condition

The effect of soil on the vegetable produce is largely through its textural properties, drainage, soil reaction and nutrient availability. Soil texture is especially, important for root and tuber crops e.g. hard and compact soil resulted in root forking and stunted growth of carrot and radish.

2.4.7 Pollutants

The toxic elements such as Ag, Cd, Co, Mg, Mn, NI and Zn cause serious damage to vegetables. Air-polllutants such as ozone causes surface blistering of spinach *(Spinacea oleracea* L) leaves, nitrogen dioxide results in marginal and interveinal collapse of lettuce leaves.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Match the following:

Common name	**Scientific name**
a) Cabbage looper	*i) Sternochetus mangiferae*
b) Sweet potato weevil	*ii) Bactrocera dorsalis*
c) Mango stone weevil	*iii) Cylas formicarius*
d) Mango fruit fly	*iv) Trichoplusia nii*

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2. Write the role of environmental factors on post-harvest losses of fruits and vegetables?

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2.5 IMPROPER HANDLING, PACKING, STORAGE AND TRANSPORTATION

2.5.1 During Post-harvest Handling

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept under the shade in the field. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Improper container for packaging capsicum

Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding and other forms of injury. Post-harvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and bruised potatoes may lose three to four times as much weight as non-bruised potatoes.

2.5.2 During Storage

Storage is one of the most important aspects of the post harvest handling of fruits and vegetables. A substantial quantity of fruits and vegetables go waste in our country due to lack of proper storage. The primary purpose of storage is to control the rate of transpiration, respiration, ripening and also any undesirable bio-chemical changes or disease infection. Improper storage resulted in deterioration in fruits and vegetables in following ways:

- Aging due to ripening, softening, and textural and colour changes
- Undesirable metabolic changes and respiratory heat production
- Moisture loss and the wilting
- Spoilage due to invasion by bacteria, fungi, and yeasts and insect pests
- Undesirable growth, such as sprouting of potato

Need and Importance

The field heat of a freshly harvested crop should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to pre cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise, most refrigerated storage rooms have neither the refrigeration capacity nor the forced air movement needed for rapid cooling. Rapid pre-cooling to the product's lowest safe temperature is most critical for crops with both inherently high and low respiration rates commodities.

Crops with high respiration rate	Crops with low respiration rate
Artichokes, Brussels sprouts, green onions, snap beans, asparagus, broccoli, mushrooms, peas, sweet corn etc.	Nuts, apples, grapes, garlic, onions, potatoes (mature), sweet potato etc.

Pre-cooling methods and appropriate storage temperature and relative humidity for fruits and vegetables are important operations just after harvesting of the produce in order to reduce the post harvest losses.

2.5.3 Storage Temperature

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage. Crops such as cucumbers, eggplant, pumpkin, summer squash, okra, and sweet potato are highly sensitive to chilling injury. Similarly, the tropical and sub-tropical fruits like mango, banana, papaya, pineapple etc. are also sensitive to chilling temperature. Moderately sensitive crops are snap bean, muskmelon, sweet pepper, winter squash, tomato, and watermelon. These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomato, squash, sweet pepper that have been over-chilled may be particularly susceptible to decay such as *Alternaria* rot.

2.5.4 Relative Humidity

Relative humidity is also important in the storage of fruits and vegetables. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality-for instance, wilted greens may require excessive trimming, and grapes may drop loose from clusters if their stems dry out. Water loss also leads to saleable weight loss and reduced profit. Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged at higher temperature level.

2.5.5 Storage Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against post-harvest diseases, but also to protect consumers from food borne illnesses. *E. coli*, *Salmonella*, Hepatitis, and *Cyclospera* are among the disease-causing organisms.

2.5.6 Ethylene Evolution

Ethylene, a natural hormone produced by some fruits as they ripen. It promotes additional ripening of produce when exposed to it. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to age too quickly. As the fruits age or ripen, they become more susceptible to diseases. Ethylene "producers" should not be stored with fruits, vegetables that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury.

Bad effects of ethylene during storage include:

- russet spotting of lettuce along the midrib of the leaves;
- loss of green colour in snap bean;
- increased toughness in turnips and asparagus spear;
- bitterness in carrots and parsnip;
- yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- accelerated softening of cucumbers, acorn and summer squash;
- softening and development of off-flavour in watermelon;
- browning and discoloration in eggplant pulp and seed;
- discoloration and off-flavour in sweet potato;
- sprouting of potato; and
- increased ripening and softening of mature green tomato.

Ethylene producers include apple, apricot, avocado, ripening banana, honeydew melons, ripe kiwifruit, nectarines, papayas, peaches, pears, persimmons, plantains, and tomato. By and large, more matured and ripened commodities produce more amount of ethylene production.

In regard to reduce cross-transfer of odours, combinations that should be avoided in storage rooms include:

- apples or pears with celery, cabbage, carrot, potato, or onion
- celery with onion or carrot
- citrus with any of the strongly scented vegetables

Pear and apple acquire an unpleasant, earthy taste and odour when stored with potato. It is recommended that onion, nuts, citrus, and potato each be stored separately.

2.5.7 During Transportation

Transportation through trucks

Inland transportation of horticultural crops is usually by rail or by truck. Overseas transportation is by sea or air. A limited amount of high-valued produce is sometimes transported overland by air. The basic requirements for conditions during transportation are proper control of temperature and humidity and adequate ventilation. In addition, the produce should be immobilized by proper cushioning in packs, packaging and stacking, to avoid excessive movement or vibration. Vibration and impact during transportation may cause severe bruising or other types of mechanical injury.

Plastic crates suitable for packaging tomato

Refrigerated containers and trailers are more often used for long distance shipping, whether by sea, rail or truck. Shipping by refrigerated trucks is not only convenient, but also effective in preserving the quality of product. However, both the initial investment and the operating costs are very high. Another possibility is insulated or properly ventilated trailer trucks. Pre-cooled products can be transported through well-insulated non-refrigerated trucks for many hours without any significant rise in product temperature. There are considerable cost savings without any sacrifice of quality if trucks are only insulated, rather than refrigerated, for short-distance shipping. If the product is not pre-cooled or if the shipping distance is long, a ventilated truck is a better choice than an insulated truck without ventilation and without refrigeration. Ventilation alone does not usually provide a uniform cool temperature, but it may help dissipate excessive field heat and respiration heat, and thus avoid high temperature injury.

2.6 SOCIO-ECONOMIC FACTORS

2.6.1 Marketing Systems

Growers can produce large quantities of good-quality fruits and vegetables, but if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This is further accentuated by lack of communication between producers and receivers, and lack of market information.

Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Advantages of marketing cooperatively include providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies and materials in quantity, providing for proper preparation for market and storage when needed, facilitating transportation to the markets, and acting as a common selling unit for the members, coordinating the marketing program, and distributing profits equitably.

Alternative distribution systems, such as direct selling to the consumer (roadside stands, produce markets in cities, local farmers' markets in the countryside, etc.) should be encouraged. The Farmer's Market system is to be developed for selling their own fruits and vegetables directly to the consumers. Production should be encouraged as close to the major population centres as possible to minimize transportation costs.

Overcrowded market

Wholesale markets in India are in desperate need of improvement in terms of facilities and sanitation. They are overcrowded, unsanitary, and lack adequate facilities for loading, unloading, ripening, consumer packaging, and temporary storage.

2.6.2 Roads

In India, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply during the season. This is true whether for local marketing or export to other countries. Efficient transport system can go a long way not only in reducing post harvest losses of fruits and vegetables but also in stabilizing the price fluctuation of the same commodity available in different parts of the country.

2.6.3 Government Regulations and Legislation

The degree of governmental controls, especially on wholesale and retail prices of fresh fruits and vegetables, varies from one state to another. In many cases, price controls are counterproductive. Although intended for consumer protection, such regulations encourage fraud and provide no incentive for producing high-quality produce or for post harvest quality maintenance due to non-implementation. On the other hand, regulations covering proper handling procedures and public health aspects during marketing are, if enforced properly, very important to the consumer.

2.6.4 Use of Specific Tools and Equipment

Even if growers and handlers of fresh fruits and vegetables were convinced of the merits of using some special tools and/or equipment in harvesting and post harvest handling, they most likely will not be able to find them in the domestic market. This is true of harvesting aids; containers; equipment for cleaning, waxing, and packing; and cooling facilities. Most of these tools are neither manufactured locally nor imported in sufficient quantity to meet demand. Various government regulations not permit direct import by producers of their needs. It is imperative that the tools that will enable handlers to use recommended technology for a given situation be available for them to use. In many cases, such tools can be manufactured locally at much lower costs than those imported.

2.6.5 Awareness among Common People

The human element in post harvest handling of horticultural commodities is extremely important. Most handlers involved directly in harvesting, packaging, transporting, and marketing in developing countries, have limited or no appreciation for the need for, or how to maintain quality. An effective and far-reaching educational (extension) program on these aspects is needed critically and will continue to be essential in the future.

2.6.6 Maintenance of Equipment

In developing countries like India, some good facilities those were built a few years ago are currently "out of order" or not functioning properly because of lack of maintenance and unavailability of spare parts. This problem is especially true of public-sector facilities. Any new project should include in its plan adequate funds for maintenance to ensure its success and extended usefulness.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write in brief how improper storage resulted in deterioration of fruits and vegetables?

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2. What are the bad effects of ethylene during storage?

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3. Describe in brief, the socio-economic factors responsible for post-harvest losses of fruits and vegetables?

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4. Write short notes on following points in 5 sentences:

   i) Judging maturity index of musk melon and banana.
   ii) Post-harvest Physiology of fruits and vegetables.
   iii) Role of insects in post harvest losses of fruits and vegetables with examples.

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2.7 LET US SUM UP

In this unit, we studied association of both pre and post harvest factors with post harvest losses of fruits and vegetables.

Fruits and vegetables are living entities. The quality and marketable life of these commodities depends on both pre and post-harvest factors. The factors which influence the quality include harvest maturity, choice of cultivars/varieties, climate and soil in which it is grown, pre-harvest infection or infestation of micro-organisms and insects, storage conditions etc. The level of damage suffered by the crop during harvesting and handling can also affect the marketable life. Hence in order to maintain a level of freshness of fruits and vegetables from the field to the dinner table presents many challenges. A grower, who can meet these challenges, will be able to expand his or her marketing opportunities and be better able to compete in the marketplace. The causes of losses occur at different times during the production and post harvest cycle of the crop should be clearly understood before taking control measure. If it is clear that loss is due to infection of micro-organisms the control measures will depend on the type of micro-organisms, the time of infection, the reason for the success of the infection and legislation governing possible control measures.

2.8 KEY WORDS

Physiological maturity : It refers to the stage in the development of the fruits and vegetables when maximum growth and maturation have occurred.

Harvest maturity : It refers to the stage of development when plant or plant parts posses the pre-requisites for utilisation by consumers for a purpose.

Pre-cooling : It refers to the process of quick removal of heat just after harvesting of fruits and vegetables by forced air cooling method.

Climacteric fruits : Fruits where there is upsurge in their respiration after the harvest.

Non-climacteric fruits : Fruits where there is no upsurge in their respiration rate after the harvest.

2.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) v b) iii c) iv d) i e) ii

2. Your answer should include the following points:

   - Role of irrigation
   - Role of mineral or nutrient deficiency
   - Other factors such as weed, crop hygiene, plant protection and use of growth regulators etc.

3. Your answer should include the following points:

   The basic criteria are as follows:

   - Choose cultivars that will have better quality attributes and as per the demand of the consumers.
   - Use clean, healthy, high quality planting materials.
   - Grow off-season cultivars of the same crop to extend harvest period.
   - Choose cultivars that are well suited to the specific climate, day length, soil and growing conditions.
   - Always select seed from the good quality produce or source.

4. Your answer should include the following points:

   Definition of climacteric and non-climacteric fruits and write few examples as given in sub-section 2.1.2.2.4.

Check Your Progress Exercise 2

1. A) iv B) iii C) i D) ii

2. Your answer should include the following points:

   i) Climate
   ii) Chilling Injury
   iii) Frost Damage
   iv) High Temperature Stress
   v) Hail Damage
   vi) Soil Condition
   vii) Pollutants

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Storage Temperature
   - Relative Humidity
   - Storage sanitation
   - Ethylene

2. Your answer should include the role of ethylene in fruit deterioration (bad effects) and measures to take as mentioned in Sub-Section 2.1.2.5.2.4

3. Your answer should include the following points:

   - Marketing System
   - Road
   - Government Regulation and Legislation
   - Use of Specific tools and Equipments
   - Awareness among Common People
   - Maintenance of Equipment

4. Your answer should include the following points:

   i) Mention the proper stage of harvesting of both the crops
   ii) Mention the rate of respiration, ethylene evolution etc. during storage
   iii) Write all about insect damage with suitable example as given in Sub-Section 2.1.2.3.2

2.10 SOME USEFUL BOOKS

1. Bose, T.K. and Mitra, S.K. (1st Ed.) (1985) Fruits: Tropical & Sub-tropical, Naya Prokash, Kolkata

2. Bose, T.K., Som, M.G. and Kabir, J. (1st Ed.) (1985) Vegetable Crops, Naya Prokash, Kolkata.

3. Thompson, A.K. (1st Ed.) (1996) Post harvest Technology on fruits and vegetables, Black Well Science Ltd., UK.

UNIT 3 MATURITY INDICES AND HARVESTING PARAMETERS

Structure

3.0 OBJECTIVES

After studying this unit, you should be able to:

- understand what is maturity;
- distinguish between physiological and commercial maturity;
- determine maturity of important fruits and vegetables; and
- know harvesting time methods, and equipment.

3.1 INTRODUCTION

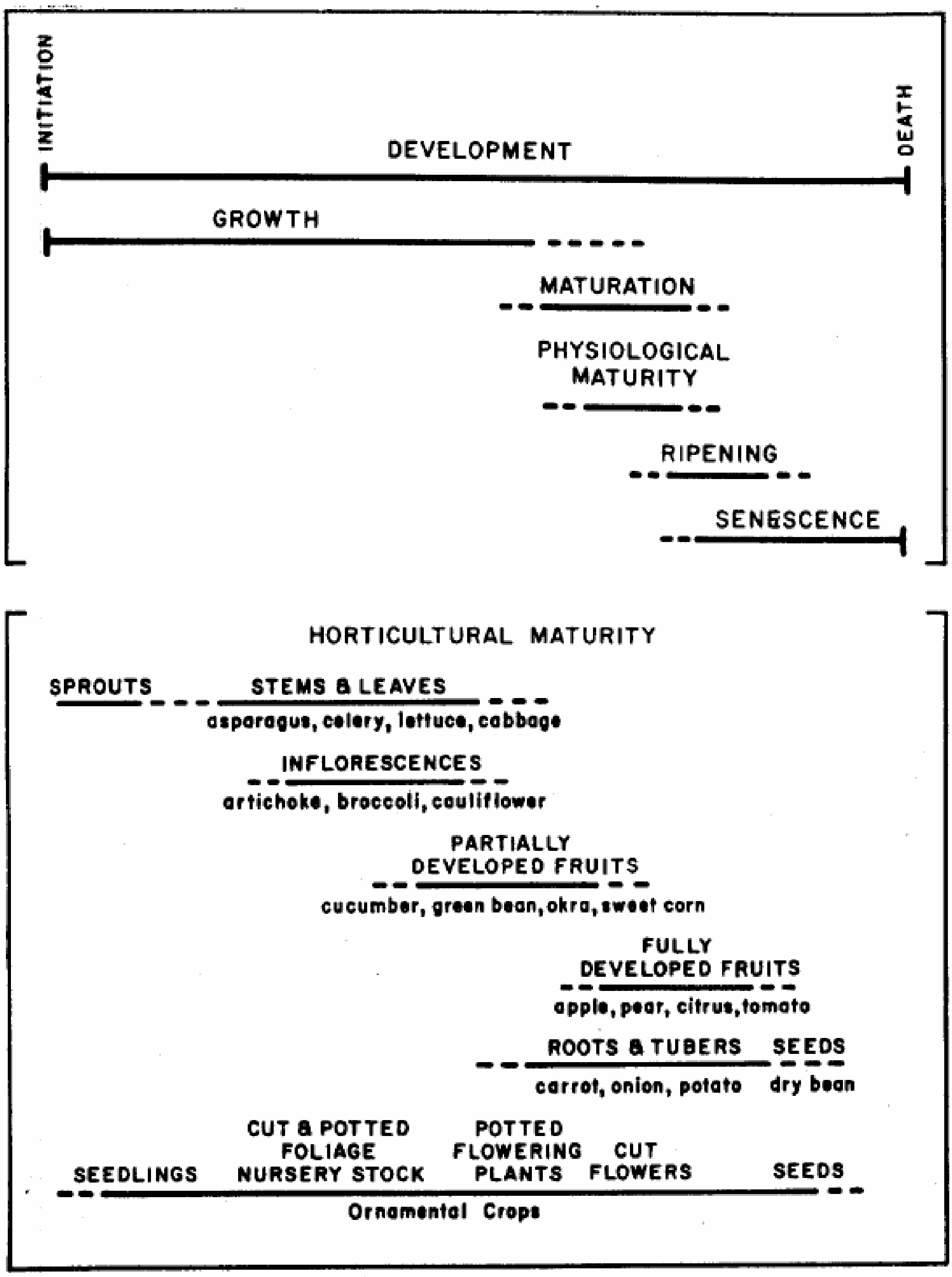
The maturity of fruits and vegetables is an indication of the development of the crop and its progress for becoming a marketable product. Selection of right stage of maturity for harvest is an important aspect, which has considerable influence on storage life and quality and final acceptance by the consumer.

Definition

To most of us 'mature' and 'ripe' means the same thing when describing fruit. But in post-harvest technology mature can be defined as "that stage at which a commodity has reached a sufficient stage of development that after harvesting and post-harvest handling (including ripening, where required), its quality will be at least the minimum acceptable to the ultimate consumer."

Maturity can be of two types – physiological maturity and commercial maturity. Physiological maturity refers to the point in the development of an organ (*e.g.* fruit, leaf) or organism (*e.g.* ornamental plant) when maximum growth has been achieved and the organ or organism has matured to the extent that the next development stage can be completed. In case of fruit, ripening can be considered as the next development stage, preceding the senescence stage.

The commercial or horticultural maturity is the characteristic state of a plant organ required by the consumer. It is concerned with the timing of the harvest to meet particular market requirements. Commercial maturity bears little relation to physiological maturity, and may occur at any stage during development, maturation, ripening or senescence. Examples of commercial maturity include bean sprouts (during early stage of development), cucumber (during maturation) and tomato (during ripening). Chilli can be harvested (commercially mature) at 'green stage' of fruit for 'green chilli' market and at 'red ripe' stage for drying to be used as spice. At both these stages, chilli fruits are commercially or horticulturally mature. The term 'immaturity', 'optimum maturity' and 'over maturity' can be related to these market requirements. To a green chilli market, a red ripe chilli is 'over mature' and to the red ripe chilli market green chilli is 'immature'. Some examples of commercial maturity in relation to physiological age are shown in Figure 3.1



3.2 DETERMINATION OF MATURITY

Determination of the stage of maturity at which a fruit or vegetable should be harvested is important for its subsequent quality, storage and marketable life. Combination of both subjective and objective methods are used to assess maturity of the produce for harvesting. In the former, the appearance; texture, smell, taste comprise the criteria. For the later, the instruments are used to measure colour, ºBrix, sugar, acidity, protein, tannins etc., chemical and physical analyses like determination. These methods can be grouped into physical, chemical, physiological, computation, electronic etc. based on the principles used for measuring the various parameters.

3.2.1 Physical Method

Skin colour

Change of skin colour of many fruits is a valuable guide to maturity. There is gradual loss of intensity of colour from dark green to light green and then development of yellow and/or red pigment (*e.g.* tomato, papaya, litchi, mango). Some fruits like some cultivars of mango, apple, and peach develop red blush colour (i.e. additional colour on the ground colour) as they mature on tree and can be used as maturity index. The assessment of harvest maturity by skin colour changes usually depends on the judgment of the harvester. Colour charts are used for apple, tomato, peach *etc.* Instruments are available for measurement of colour of fruits, and they are mostly used on harvested fruit. On-line commercial colour sorter is used in many crops.

Shape

The shape of fruit and vegetable can change during maturation and this can be used as a criterion to determine harvest maturity For example, some cultivars of banana becomes less angular and more rounded in cross-section. Mango changes shape during maturation on the tree. The shoulder of immature mango fruit slopes away from the fruit stalk and as the maturity advances the shoulder level or becomes raised with the point of attachment with the fruit stalk.

Size

In most crops, size is frequently used to determine when it should be harvested. Sometimes it is related to the market requirement. For example, if a market requires a bottle gourd of 30 cm length, the fruit should not be allowed to grow beyond that limit though the cultivar may be having the potentiality to grow much longer. In banana, the length or width of individual finger can be used to determine harvest maturity. Size also gives rise to volume and is often expressed as weight to determine harvest maturity of many fruits and vegetables like mango, watermelon, pumpkin. When we divide weight by volume it gives density (g/cm^2) and is used as maturity index in potato. The size is also used for grading of many fruits and vegetables and machines have been developed for size grading.

Firmness

As fruits mature and ripen, they soften because of dissolving of pectin comprising the middle lamella of cell wall. This softening can be estimated subjectively by the finger feel of commodity. It can objectively be measured using a fruit hand held pressure tester (also called penetrometer). These testers measure the pressure at which flesh yields to the penetration of a standard diameter plunger inserted to a standard depth. More sophisticated tests can be carried out using machines such as Instron Universal Testing Machine. But these machines are mainly used for experimental studies.

Specific gravity

Specific gravity is the relative gravity or weight of solids or liquids compared to distilled water at 62°F (16.7°C). To determine specific gravity the fruit or vegetable is weighed in air and in distilled water and its weight in air is divided by the loss of weight in water. As fruits mature their specific gravity increases. This parameter is rarely used in practice to determine when to harvest, but can be used as a sampling technique. It is used, however, to grade the produce into different maturity groups after harvesting. To do this, fruits or vegetables are placed in a tank of water, those that float are less mature than those that sink. To increase effectiveness sometimes salt is added to the water at 1% to 2% concentration.

Aroma

Most fruits synthesise volatile chemicals as they ripen. These give the fruit its characteristic flavour and can be used to determine whether fruit is ripe or not.

3.2.2 Chemical Method

Sugars

As the fruit ripens, starch is broken down to sugars. Measurement of sugars can provide an indication of the stage of maturity or ripeness. In practice, the soluble solids, also called degree brix, are measured in the fruit juice. Usually the sugars constitute the major portion of soluble solid of the fruit juice. So measurement of total soluble solid (TSS) can give a reliable estimate of sugar in fruit juice. This is done using a refractometer or a brix hydrometer, which provide quick and easy methods for assessment of ripeness. This can be used in grape, muskmelon, mango etc.

Starch

Measurement of starch content in the developing fruit of pear and apple provides a reliable method for assessing their harvest maturity.

Acidity

The acidity of many types of fruit changes during maturation and ripening. In citrus, mango, pineapple and many other fruits acidity progressively decrease as the fruit matures on the tree. Taking samples of these fruits, extracting the juice and titrating it against a standard alkaline solution give a measure of acidity, which can be related to determine harvest maturity. Normally, acidity is not used singly; it is related to soluble solids, giving what is called sugar acid ratio.

3.2.3 Physiological Method

Climacteric fruits, in which there is a distinct rise in respiration during ripening, can be sampled, kept at a relatively high temperature and respiration rate measured. By doing this, it may be possible to predict the number of days the fruit would have taken to commence the climacteric rise if left on the tree.

3.2.4 Computation Method

The time required between flowering and fruit being ready for harvesting may be measured by 'heat units' or 'degree days' in a particular environment. It has been found that a characteristic number of heat units or degree days is required to mature a crop. Maturity will be advanced under warm conditions or delayed under cooler conditions. The number of degree days to maturity of a particular crop or a variety is determined over a period of several years by obtaining the sum of the difference between the daily mean temperature and a fixed base temperature (commonly the minimum temperature at which growth occurs). For example:

20-15°C (minimum base temp.) × 1 day = 5
25 -15°C = 10 × 2 days = 20; total 25 degree days

Likewise the computation is continued and when the total number of degree days reaches say 1000 for a particular crop it is presumed that the crop is ready for harvest. As maturity approaches the correct stage of the crop may be checked by other means. This method is helpful in planning planting, harvesting and factory management programme for annual processing crops such as pea, tomato *etc*.

3.2.5 Electronic and Other Methods

Electronic principles are used in various machine used in determining the maturity.

Electronic colour sorter

This machine is used in packing houses to sort out fruits on the basis of colour *e.g*. in apple, orange *etc*.

Acoustic and vibration test

The sound of a fruit when tapped with the knuckle of the finger, changes during maturation and ripening. Consumers often use this method for testing when purchasing watermelon. Farmers also use this for determining maturity. Sophisticated machines have been developed to measure the sound of tapping for precise determination of maturity.

Electromagnetic method

Nuclear magnetic resonance (NMR) spectroscopy is used in human pathology to provide images of the inside of the body. Such instrument has been found to be useful in determining maturity by examining internal structure of fruit.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is maturity and how will you differentiate between physiological and commercial maturity?

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2. What are different methods for determining harvest maturity? Describe simple and easy to use methods.

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3.3 MATURITY INDICES OF COMMERCIALLY IMPORTANT FRUITS

Mango

The various criteria recommended for judging maturity are red blush colour development on the shoulders, falling off of one or two ripe fruits from the plant naturally, the specific gravity of fruit ranging from 1.01 to 1.02 and in general fruits attain maturity 90-120 days from the fruit set stage. Sometimes maturity indices like change in pulp colour from white to pale yellow and slowing down of latex flow from the stalk of plucked fruits also serve the purpose.

Banana

The fruits are usually harvested when the ridges on the surface of the skin change from angular to round *i.e.* after the attainment of the ¾ full stage. The maturity of fruits can also be adjudged by some other physical characters and chemical analysis. The physical characters like change in skin colour or development of blush or visually lighter colour is also taken into account to determine the maturity of fruits. In addition, fruits attain the size specific to variety on maturity. However, for long distance transport attainment of ¾ maturity is taken as harvesting index.

Citrus

The fruits are generally harvested when the changes in rind colour take place. The colour break stage (change in colour from green to yellow) is taken as criterion for judging the maturity of lime and lemon. In citrus, total soluble solid (TSS): acid ratio is considered to be a good index for judging maturity, which varies from variety to variety.

Papaya

The fruits should be left on the tree until they mature fully. Usually the fruits are harvested when they are of full size, light green with a tinge of yellow at apical end. On ripening the latex becomes watery from milky.

Pineapple

The fruits are usually harvested when the surface colour is between colour break and quarter yellow for shipment by sea and a half to three-quarter yellow colour for transportation by air. Harvesting for local market and distant market should be done at the full maturity stage and 75-80 per cent maturity stage, respectively. At maturity, the eyelets get flattened.

Grapes

In grapes, the basal berries mature and ripen first and the harvesting of immature berries are never advisable as these do not ripen after harvest. The physical appearance like change in colour from dark green to light green, yellow or red or purple depending upon the type of cultivars, glossyness and softness of berries are also taken as indices for judging maturity. The estimation of TSS: acid ratio is also taken as criteria for judging the maturity. The TSS and acidity of berries are determined by refractometer and titration, respectively.

Sapota

In sapota, various criteria have been suggested for judging the maturity *e.g.* development of a dull orange colour or potato colour, showing light yellow streak instead of a green streak when scratched and disappearance of browny scales on the fruit surface.

Guava

Guava fruits mature 4-5 months after flowering. At maturity the specific gravity varies from 0.95-0.96, while TSS and acid content ranges from 12-13° Brix and 0.36 to 0.41% respectively.

Jackfruit

Several indices are commonly used to determine the optimum time to pick the fruits. A dull, hollow sound is produced when the fruit is tapped by the finger; the fruit spines become well developed and wide spaced; the spines yield to moderate pressure and lastly there is development of aroma. For distant market, fruit should be harvested when still firm and without any aroma.

Pomegranate

The fruits are ready for harvest in 5-6 months after flowering. The fruits are picked when the skin turn slightly yellow and the fruit gives a metallic sound when tapped. Likewise, the ripe fruits give a distinct cracking sound of grain cracking when pressed slightly on the slices.

Apple

Apple may be harvested when a fruit separates easily from the branch, retains firmness of pulp and taste which are desirable. On maturity the skin colour changes from green to yellow or red depending upon the cultivars. The days from complete flowering can also be taken as a criterion to assess the maturity, which varies from 90±4 days in early maturing varieties to 180±5 days in late maturing varieties.

Pear

Pear is harvested when firm and green for canning, while fully mature fruits are harvested for fresh consumption. Days from full flowering, TSS and firmness can also be used for judging the maturity.

Peach

Various criteria have been advised for judging the maturity of peaches like fruit size, shape, firmness, starch content of fruits *etc*. Usually peaches are picked when they are still hard as they can ripen well in storage or in transit.

Plum

Change of ground colour of fruits from green to yellow or red depending upon the varieties, firmness and TSS content of fruits and days from full flowering are used to assess the maturity of fruits.

Strawberry

Strawberries are generally harvested when half to three-fourth of skin develops colour. For distant shipment green or white and still hard berries are harvested.

3.4 MATURITY INDICES OF COMMERCIALLY IMPORTANT VEGETABLES

Broccoli

The best stage of harvesting is before the buds begin to open, the heads remain compact and the yellow petals have not come out. The total length of the stalk and the head can be 15 to 25 cm depending on the variety. The axillary shoots grow and form smaller heads sometime after harvest of the main head. These can also be harvested for marketing.

Cauliflower

Stage of maturity is determined by curd size and its compactness. If harvesting is delayed, the curds become loose and discoloured. If the produce is meant for storage, it is better to harvest when the curds are not fully exposed and still covered with central whorl of leaves.

Cabbage

Solidity and firmness of the heads are the usual maturity characteristics used. Colour of the head is used as an added index. The head turns a lighter shade of green when full development is attained.

Celery

Generally, celery requires blanching, although some growers prefer to sell it green. There is no specific time of harvest for celery though some like to harvest it as early as possible to take advantage of higher price. Blanching of the petioles and stalks and slight enlargement of the heart and inner leaves are used as picking indices.

Carrot

Depending on the variety, the attainment of desired size is the primary consideration. Marketing of roots begins as soon as they attain acceptable size even though they have not attained full size specific to the variety. The roots must be harvested before emergence of the seed stalk.

Cucurbitaceous vegetables

In general, cucurbit fruits mature faster. In such kind of vegetables like summer squash, Indian squash (tinda), bitter gourd, small (gherkin) cucumber and long melon, fruits reach optimum maturity stage within a week or so after fruit set. In other kinds of vegetables like sponge and ridge gourds, bottle gourd, snake gourd, pointed gourd *etc*., picking is done in about 12 to 15 or even 20 days after fruit set. In sponge and ridge gourd the flesh should not turn fibrous. In bittergourd, fruits should not turn yellow or yellowish orange in transit, hence, these are to be harvested at green stage. In musk and watermelon, 30 to 40 days will be required for the fruits to reach harvest maturity.

Picking of fruits at the right edible maturity stage is dependent upon individual kinds and varieties. In salad or slicing cucumber, dark green skin colour should not turn into brownish yellow and white spine colour will also be an useful indication of edible maturity. Over-mature fruits will show carpel separation (development of gap in the flesh) in transverse section.

In muskmelon, there are two groups of cultivars which behave distinctly. In one group, the fruits when mature slips out easily from the vine with little pressure or jerk or if not it will remain separated from the vine next day. This is called full slip stage. Most cultivars including Indian varieties and cantaloupes of the USA behave in this way. The cantaloupes can be picked at ¾ slip stage for long distance transport. There is another group of melon like Honey Dew and Casaba, the fruits of which do not separate at maturity and they have to be picked on the basis of external colour. In some Indian cultivars, green stripes on the skin begin to turn yellow which is an indication of full maturity. Muskmelon is a climacteric fruit which ripens during transit and storage and hence it is harvested before it is fully ripe.

In watermelon, maturity is judged by taking into consideration of several factors: (i) dull sound when the fruit is thumped, in contrast to metallic sound, (ii) withering of tendril at the fruit axil, (iii) ground spot turning yellow, (iv) rind of the ripe melon yields to pressure. Cumulatively all these criteria will help judge correct stage of picking.

Eggplant

Fruits should be picked as soon as they have attained the desired size, before they harden or show streaks of unusual colour. The skin should be bright and glossy and seeds undeveloped.

Tomato

Harvesting depend upon the purpose for which it is grown and time to be taken for reaching the destination. Six maturity stages are recognized. These are mature green, breaker, turning, pink, light red and red. In 'breaker' stage only up to 10% of the fruit surface especially at the blossom end is pink or red and in 'red' stage more than 90% of the fruit surface is red. In India fruits, for a distant market, are harvested at 'breaker' stage and they ripen during transit. For nearby market and for processing, it is better to harvest at a latter stage.

The colour of the fruit can be measured by a colour chart or a colour measuring instrument using light transmittance technique.

Potato

Setting of skin, starch content and leaf senescence are harvest indices. To catch early market and to get high price, potatoes are also harvested before attaining full maturity. These tubers are not fit for storage and should be disposed of quickly.

Garlic and onion

Onions are harvested depending upon the purpose for which the crop is grown. It requires 45 to 90 days from field setting for green onions and 90 to 150 days for bulb depending upon the variety. Onions should be harvested one week after 50% crop shows neck fall. Garlic is ready for harvesting when the tops turn yellowish or brownish and show signs of drying up and bend over.

Okra

Fruits are harvested when they are tender and exhibiting maximum growth rate. At this stage, the blossom end of the fruits, when bent, breaks easily. It takes 7 to 8 days to become ready for harvesting after fruit set. Frequent picking promotes fruit development and increases yield.

Pea

Quality of pea depends on sugar content and tenderness. With increasing maturity and size, sugar declines rapidly with an increase in starch and protein. Thus a high sugar content is an indication of high quality. The appearance of the pod is an added indication of maturity. Since firmness increases with maturity, a tenderometer is used to measure tenderness. Calculation of degree days is also done for mechanical harvesting.

Radish

The crop matures in 3 to 4 weeks in case of quick growing varieties and in 8 to 10 weeks in case of the Chinese varieties. The crop is harvested when the roots are still tender before they become pithy and fibrous.

3.5 HARVESTING

The objective of harvesting is to pick the fruits or vegetables at the proper stage of maturity, with a minimum damage, as rapidly as possible and at a minimum cost. This objective is best achieved by hand harvesting in most fruits and vegetables.

3.5.1 Hand Harvesting

Hand harvesting is the most advantageous method. It offers several advantages:

1. Selection of proper stage of maturity is accurate.
2. Humans can handle fruits and vegetables with minimum damage.
3. Multiple harvesting is possible.
4. Requires less capital investment.

Care in harvesting and handling is necessary to preserve subsequent quality. Bruises and injuries may later show up as black or brown patches, making the commodity unattractive. As far as possible, harvesting should be done during cooler part of the day and the harvested material should immediately be removed to a shady place. Harvesting immediately after rain dew/snow should be avoided as it creates conditions most favourable for multiplication of decay causing pathogens.

a) Fruits

Soft fruits such as strawberry which are borne on low growing plant, are simply removed from the plant and are put into a suitable container. Sometimes they are directly put into the consumer carton for sending to the market. Fruits which are borne on tall or medium tall trees such as mango, citrus, sapota, guava, apple *etc*. are difficult to harvest and the process is time consuming. A long pole with some cutting device and a bag at the end is commonly used. Some improved harvesters have been developed in India by ICAR institutes and SAU'S viz. IARI, New Delhi, IIHR, Bangalore, KKV, Dapoli and CISH, Lucknow. These harvesters have been tested successfully in several crops and have been found to be more efficient and economical than manual harvesting by hand only. It has also been reported that fruits harvested by cutting the fruit stalk rather than twisting and pulling, had lower incidence of rotting during subsequent storage.

b) Vegetables

Most vegetables are hand harvested even in the developed countries. Root crops like potato, onion, garlic, colocasia and tapioca are dug out with the help of fork or spade. Other root crops like radish, turnip, carrot and beet are pulled out of the soil. All damaged roots should be sorted out as early as possible. Fruit vegetables like okra, brinjal *etc*. require some cutting device like krives/siezzer/sickle sickle. Tomato usually does not require such device and pulling by hand can detach the fruits. Muskmelon at full-slip stage does not even require any pulling by hand. At half-slip stages a little jerk may be required in Pumpkin, bottle gourd, bitter gourd, sponge gourd, ridge gourd etc. require some cutting device for harvesting. Cauliflower and cabbage are harvested by cutting the stalk with some sharp tool. Leafy vegetables like amaranth, spinach, spinach beet (Palak), *Trigonella* (Methi) *etc*. may be harvested by picking the leaves or by cutting with sickle depending on the market requirement.

3.5.2 Mechanical Harvesting

Mechanical harvesting has certain advantages:

1. It is a quicker method.
2. Problem associated with labour management is less.

There are certain disadvantages too:

1. It damages perennial crops (e.g. damage to bark by a tree shaker)
2. There may be a lack in processing and handling capacity to handle high rate of harvest.
3. There is less chance of selection of fruits.
4. Damage due to mechanical injury is more.
5. It is more expensive.

a) Fruits

Very little fruit destined for fresh market is harvested by machines because the likely damage could result in rapid deterioration of quality. Fruits for processing may be harvested mechanically. Oranges for juice extraction may be removed from the trees by powerful wind machines being dragged through the orchard followed by collecting oranges from the ground mechanically or manually. Tree shakers are also used. These methods may cause considerable damage to fruits. Grapes can be harvested for wine making using tractor-mounted machines with combing fingers made of rubber which are run up the stems, pulling up the fruit bunches along with leaves. In banana, bunches are cut manually and then conveyed by hanging conveyor rope. Sometimes conveyor belts are also used.

b) Vegetables

Mechanical aids to harvesting vegetables such as cauliflower, cabbage, lettuce involve cutting by hand and placing them on a conveyer of a mobile packing station which is slowly conveyed across the field. Peas for processing are harvested by combine. Tissue damage during harvesting has been reported to develop off flavour due to enzymatic reaction in pea. Mechanical harvesting of French bean may cause breaking of the tips. In potato, mechanical harvester removes the tubers from the soil and by mechanical shaking, soil clods are broken into fine pieces for easy removal of potato from the soil. In developed countries the entire operation of digging and removal of potato is done by machine. In India, in some parts of the country, mainly digging is done by the potato harvester. In some countries, onion is harvested mechanically after cutting the tops mechanically before harvesting. Similar harvester can be used for sweet potato. Harvesters for tapioca and yam have been less successful. Tapioca harvesters for processing are common but the roots must be processed quickly after harvest to avoid deterioration.

Check Your Progress Exercise 2 ✍

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Outline maturity indices of important fruits.

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2. Outline maturity indices of important vegetables.

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3. What are the merits and demerits of hand and mechanical harvesting?

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3.6 LET US SUM UP

In this unit, you have read about maturity of fruits and vegetables, methods of determination of harvest maturity, maturity indices of important fruits and vegetables and their harvesting methods. It has given you an idea about the advantages and disadvantages of hand and machine harvesting. It has also highlighted the simple and commercially followed methods for determining maturity stage for harvesting.

3.7 KEY WORDS

Maturity : It is a phenomenon by which a commodity (fruit or vegetable) reaches a sufficient stage of development that after harvesting and post-harvest handling; its quality will be at least the minimum acceptable to the ultimate consumer.

Physiological maturity : It refers to the point in the development of an organ or organism when maximum growth has been achieved and the organ or organism is ready for the next development stage to be completed.

Horticultural or commercial maturity : It is the characteristic state of a plant organ required by the consumer. It is concerned with the timing of the harvest.

Maturity indices : These are the criteria which are used to determine whether a crop has reached a proper stage for harvesting.

3.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Definition of maturity.
   - Classification of maturity into two types – physiological and commercial and differences between them.

2. Your answer should include the following points:

   - Grouping of methods of determination of maturity into physical, chemical, physiological, computation, electronic and others.
   - Description of methods grouped under physical group.

Check Your Progress Exercise 2

1. Maturity indices of important fruits are to be written.
2. Maturity indices of important vegetables are to be written
3. Merits and demerits of hand and machine harvesting are to be discussed.

3.9 SOME USEFUL BOOKS

1. Kader, A.A. (ed.) (1992) Post-harvest Technology of Horticultural Crops (2nd edition), University of California, Berkley.

2. Thompson, A.K. (2003) Fruits and Vegetables: Harvesting Handling and Storage, Blackwell Publishing, UK.

3. Watada, A.E., Herner, R.C., Kader, A., Romani, R.J. and Staby, G.L. (1984) Terminology for the description of Developmental stages of horticultural Corpp. Hort. Science, 19: 20-21.

4. Wills, R., McGlasson, B., Graham, D. and Joyce, D. (2004) Post-harvest (4th edition), CAB International, U.K.

UNIT 4 PACKAGING OF FRUITS AND VEGETABLES

The main objective of packaging is to keep the fruits, vegetables and root crops in good condition until it is sold and consumed. Good packaging gives more choice to consumers in terms of food availability and encourages the customers to purchase the product. Packaging also enhances the income of rural producers from surplus produce.

Structure

4.0 OBJECTIVES

After studying this unit, you should be able to:

- know the types of post harvest losses;
- select good packaging material for fruits, vegetables and root crops;
- describe different types of packaging material;
- know the types of cushioning material; and
- explain how post-harvest handling and marketing can be improved through better packaging.

4.1 INTRODUCTION

Do you know that India now occupies first place in the world in the production of fruits and vegetables. But increased production of fruits and vegetables will have significance only when they reach the consumer in fresh and palatable condition at a reasonable price. Due to heavy post harvest losses, there is a considerable gap between production and availability of fruits and vegetables to consumers. Post-harvest losses are occurring in the period between harvesting and consumption. The term losses include all types of losses for the farmers, traders and consumers (e.g. weight loss, quality loss, financial loss,

loss of goodwill, loss of marketing opportunities, loss of nutritional value, etc.). Hence there is an urgent need to adopt proper post harvest management practices by adopting improved packaging, handling and efficient transportation methods.

Packaging is

- Assembling the produce in convenient units for transport, distribution, storage, retailing and end use.
- Ensuring safe delivery to the consumer in sound condition at minimum cost.
- It must prevent losses, increase marketability and decrease the handling and transportation cost.

Packaging of fresh fruits, vegetables and root crops is one of the most important steps in the long and complicated journey from grower/farmer to consumer. Packaging extends the shelf-life to local surpluses of food and thus allows the food to be distributed to other areas.

Good packaging has two purposes, which are functional and aesthetic. Functional purpose aim at extending the shelf life to the product by protecting the produce from the hazards of transportation, microbial, insect/ pest damage and physiological and biochemical changes. Aesthetic aspect of packaging aims at attracting the consumer in terms of shape, size, colour and convenience etc of the packaging and identifies the product in the market, which enhances brand loyalty.

Most predominately used packaging materials for fruits, vegetables and root crops are wood followed by jute, bamboo, and corrugated fibre boards. More recently the use of plastics are becoming more convenient due to maximum reusability.

There are mainly two categories of packaging: (i) Retail packaging and (ii) Bulk shipment packaging.

Retail packaging: The materials used for retail or small unit packaging are different in different ecological locations, subject to availability around the producing centres. For example Polyethylene films (HDPE, LDPE), boxes, bags, tray type containers etc.

Bulk Shipment packaging: Corrugated boxes, molded pulp trays, foamed polystyrene trays are used for bulk shipment.

The type of package used depends upon the shape and the perishability of the product. Based on this, there are five main classifications:

Produce	**Common Package Recommended**
Soft fruits	Semi-rigid containers
Hard fruits	Open tray
Stem products	Bags or wrappers
Root vegetables	Polyethylene bags
Green vegetables	Polyethylene or Polystyrene bags

4.2 SELECTION OF PACKAGING MATERIAL

How to select packaging material for a particular commodity? What are the points we should consider to select the packaging material?

Package is selected in accordance with the product characteristics. Now what is the product characteristics based on which the package is selected? They are physical and physico-chemical.

Packaging material is selected on the basis of:

- The commodity itself.
- The systems of production, storage, handling, transportation.
- Cost factor involved in producing packaging material
- Market requirement
- Consumer attitude.
- Requirement of recycling, re-use disposal etc.

The important considerations in selecting packaging material for fruits, vegetables and root crops are:

1. Easy to open and close
2. Easy to fill
3. Easy disposal
4. Easy to recycle
5. Pilfer-proof
6. Eye appeal
7. Should withstand rough handling
8. It must provide adequate ventilation to contents for rapid cooling during transport and storage.
9. It must be readily available.
10. The package should be large enough to hold melons and pumpkins, but should also be suitable to hold smaller produce.
11. It must be cost-effective in terms of the market value of the commodity for which used;
12. Its dimensions and design must be suited to the available transport in order to load neatly, firmly with full capacity.
13. It should be easily transported when empty and occupy less space than when full.

Packages should be of a size, which can be easily handled. The ratio of weight of the container to that of the produce it contains is important. Where transport charges are calculated on a weight basis, heavy packaging can contribute significantly to the final cost of the saleable product. The shape of packages is also significant because of the loading factor, the way the load is positioned on the transport vehicle for maximum capacity and stability. Round baskets hold considerably less produce. A cylindrical basket contains only 78.5 percent by volume compared with a rectangular box occupying the same space.

Suitable packaging for any product requires good ventilation to prevent the build up of heat and carbon dioxide (Heat and carbon dioxide decreases the keeping quality of the produce and leads to development of off-flavour of the produce). The ventilation of produce is very important with adequate air flow through stacked packages. The effectiveness of ventilation during transport also depends upon the air passing through the load. Sacks and net bags must be stacked so that air can circulate through the contents.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the post-harvest loses? How to prevent them?

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2. What are the main criteria for selection of packaging materials?

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4.3 FUNCTIONS AND PROPERTIES OF PACKAGING MATERIAL

What are the primary functions of packaging? Why do we pack a particular commodity in a specific package?

Two main functions of packaging are:

1. To assemble the produce into convenient units for handling.
2. To protect the produce during distribution, storage and marketing.

Packaging materials used serve the following purposes.

1. Serves as an efficient handling unit
2. Protects from mechanical damage
3. Protects against moisture loss
4. Provides clean and sanitary storage
5. To prevent pilferage
6. Provides sales and service motivation
7. Reduces cost of transport and marketing

Need and Importance

The basic functions of packaging are:

a) Containment – protects the loss of produce by holding together a definite quantity as per market requirement.

b) Protection against climate, water vapour, oxygen, light, transport shock, vibration, decay etc.

c) Preserving quality (microbial, freshness & aesthetics attributes)

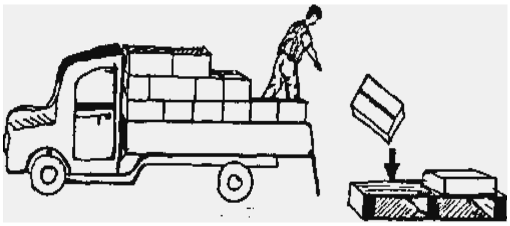
d) Information about the products, producer, content and legal requirements.

Packaging serves as an efficient handling unit to carry produce from field to consumer. It must allow removal of metabolic heat during storage and transport, and may have to contain the perishable produce throughout its ripening process. Proper ventilation is essential for this. Some commodities (e.g. avocados) that are highly sensitive to ethylene (ripening gas) require packages that permit effective ventilation so as to avoid excessive gas build up in transit.

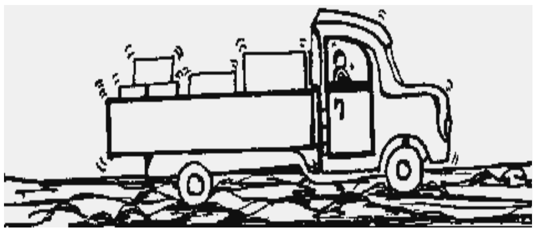
The package should also protect the produce against rotting. Perforated polyethylene liners that allow gas exchange are used for some produce. The special treatments given to certain produces (e.g. sulphur dioxide treatment of grapes and in-package use of ethylene absorbents) must be taken into consideration in package design.

Packages must protect against possible damage. Various kinds of impact and other shocks must be taken into consideration in the design of the package and its fittings to minimize this risk. Impact damage (bruising) result from dropping the individual products or letting the package fall onto a hard surface. Such damage may be avoided by careful handling, use of inserts and improvements in cushioning materials. Damage caused by compressions results from overfilling, and from incorrect and unsuitable packaging.

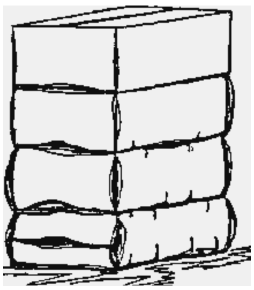
Transportation hazards



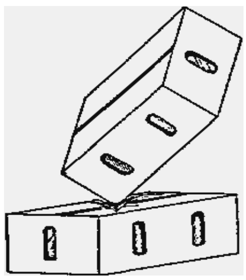
Package falling onto a hard surface



Damage caused by improper filling



Compressions results from overfilling



Damage by puncturing

(Source: FAO)

4.4 PACKAGING MATERIALS FOR FRUITS, VEGETABLES AND ROOT CROPS

There are many different types of package in use throughout the world. Packaging for fresh produce is of several types:

4.4.1 Basket made of woven strips of leaves, bamboo, plastic etc.
4.4.2 Sacks: flexible, made of plastic or jute.
  i) Bags: small size sack
  ii) Nets: sacks made of open mesh
4.4.3 Wooden crates
4.4.4 Fiberboard boxes
  i) Solid fiberboard boxes
  ii) Corrugated fiberboard boxes
4.4.5 Plastic crates
4.4.6 Biodegradable plastics
4.4.7 New innovations in packaging of fruits, vegetables and root crops
4.4.8 Pallet boxes and shipping containers.

4.4.1 Baskets

Baskets are made from woven strips of leaves, plastic and bamboo. Bamboo baskets of different shapes and sizes are used for number of perishable commodities. As the dimensional stability and ability to withstand stacking load is low, they are suitable for head load only and for very short distance transportation only. These packages are not strong enough to withstand rough handling and they are not rigid enough to take the stacking load of more than two or three baskets.

4.4.2 Sacks and Nets

The materials used for sacks and nets may be woven natural fibre (jute, cotton), woven synthetic (polypropylene, polyethylene), knitted natural fabric (cotton), knitted synthetic (polyethylene) or non-woven synthetic (propylene).

Plate 1: Jute bags

Advantages and disadvantages of sacks and nets

The advantages of using sacks and nets are merely financial. The sacks and nets are cheap, have a low weight/volume ratio and, if made of a synthetic material, will not rot. The disadvantages include a low protection against puncturing, compression, vibration and impact injuries such as dropping, difficult stacking, and the need of special stitching equipment. In general, nets are only suitable for hard produce such as coconuts and root crops (potatoes, onions).

4.4.3 Wooden Crates

Commonly used are wire bound crates for citrus/potatoes, wooden trays for tomatoes and wooden field crates.

The advantages of wooden crates are:

1. The crates can be manufactured and repaired locally.
2. Wood is relatively resistant to different weather conditions and water.
3. Wooden crates are often reused and have a higher efficiency for larger fruits, e.g. watermelons.
4. Most crates have good ventilation.

Disadvantages of wooden crates are:

1. Untreated wood can easily become contaminated with fungi and bacteria.
2. Treatment of wooden crates with paint or other chemicals may cause produce deterioration.
3. The material may be too hard or rough for produce like soft fruits, and therefore liners of a soft material may be needed.
4. Manufacturing of wooden crates puts an extra claim on the natural forest resources.

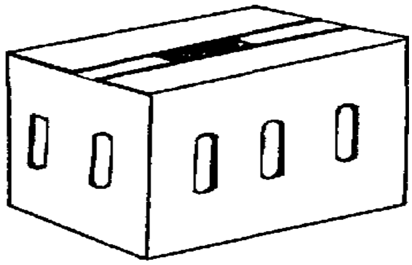
A wooden crate consists of rigid corners with planks nailed or stitched against those corners (e.g. apple or pear crate, field crate).

Plate 2: Wooden crate

4.4.4 Solid and Corrugated Fibreboard Boxes

Fibreboards are of two types viz. CFB (Corrugated Fibre Board) and SFB (Solid Fibre Board). Fibreboard boxes are frequently used because of their low weight, their range of sizes and shapes and their availability.

Solid fibreboard boxes (cartons): The boxes are used for tomato, cucumber and ginger transport. Most of them are printed with attractive colours, a brand name and a label. The information can be stamped on this label after filling the box.



Advantages of solid fibreboard boxes

- Low weight and easy to handle.
- The box can have any design, although it is recommended to use sizes fitting on the standard design of pallets.
- The boxes are delivered flat and assembling boxes can be done locally.
- The box has a low purchase cost.

Disadvantages of solid fibreboard boxes

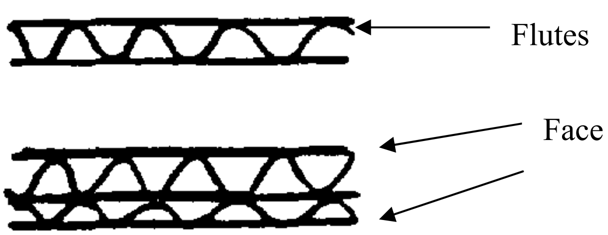
- Moisture and high humidity can seriously weaken the box. Washed produce should be made free from surface moisture before putting it into the box. Empty boxes should be stored in a dry place preferably flat on top of pallets and not for long periods of time.

- The low rigidity causes the lower stacking strength compared to wooden or plastic crates. The fibre-board boxes are easily damaged by rough handling and ropes and too much weight on top of the box can crush the perishable produce inside.

- Ventilation holes are usually small, because large holes would seriously influence the strength of the box. It is advised that the hole surfaces area is kept at least 5 percent of the total surface area of the box. Decreasing the size of the holes by not properly closing telescope boxes or not properly stacking the boxes will decrease heat exchange, resulting in higher temperatures of the produce and increased spoilage. Vertical oblong slots, instead of round holes, have the advantage that the hole stays partly open even when the telescope box lid is not completely closed.

- The boxes are not re-usable.

Corrugated Fiberboard (CFB): Corrugated fiberboard is manufactured in many different styles and weights. Because of its relativity low cost and versatility, it is the popular produce container material and will probably remain so in the near future. The flat surfaces of CFB boxes are known as ‘face’ and the corrugated surfaces are known as ‘flutes’. The strength of CFB primarily depends on the GSM (g/m^2) of kraft paper used, no. of flutes/ meter and the height of the flutes.



The advantages of corrugated fiberboard boxes are:

Low weight, easy to handle, *cushioning* effect due to relatively soft walls. The CFB box can be fabricated to any design, the boxes are delivered flat and assembling of boxes can be done locally. They also have good printability. Above all they are most eco-friendly package due to their *biodegradability*.

Plate 3: Corrugated fibreboard boxes

However, low rigidity and poor stacking strength, high moisture absorbance, and low re-usability are the major disadvantages of CFB boxes. While packaging of fresh horticultural commodities, attention must be given for proper gaseous exchanges by providing required ventilation holes. As a rule, ventilation area should be at least 5 per cent of the total outer surface area of the box. Vertical/ oblong slots are better than round holes. Sometimes coatings with wax or poly linings are also used in CFB boxes in order to make them moisture proof.

4.4.5 Plastic Crates

In general, plastic crates are more expensive than wooden crates or carton boxes, initially but in long run they work out to be cheaper because of their more usability and longer life span. Plastic crates are usually made of high-density polyethylene (HDPE) or polypropylene (PP).

Advantages of plastic crates:

- As a strong, rigid crate, these plastic crates can be used for many journeys, making the cost per journey relatively low.
- Different sizes and shapes are available to suit different customer needs. Colours can be used for marketing purposes.
- The containers are easy to clean and disinfect.

Plastic crates are strong and water resistant and therefore, the containers can be used in humid areas and during hydro cooling.

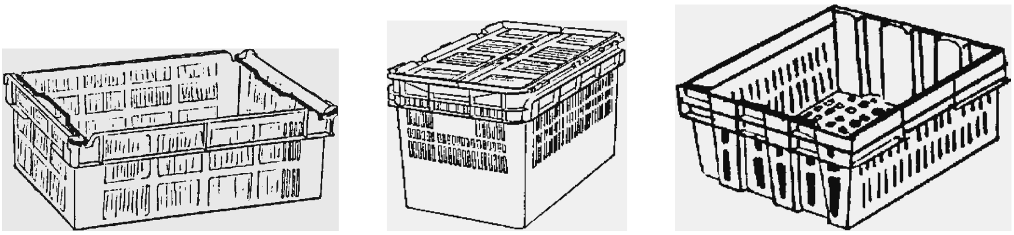
Disadvantages of plastic crates:

- The hard surfaces can damage the produce and it is advised to use liners at the bottom and side.
- The high purchase cost combined with the risk of pilferage could make this type of crate a financial risk.
- Because this crate can be used several times, the extra cost for the return trip should be included in the total running cost.

- The loss of space (40-80 mm on the sides and around 10 mm from the height).

a) *Stacking crates*

Because of the squared design with only the corner slightly rounded, an efficient use of available space is possible.



Plastic Crates (Source: FAO)

4.4.6 Bio-degradable Plastics

Plastic recycling is usually not as straightforward as for the other packaging materials. Many companies/institutions make considerable effort to produce biodegradable packaging. Biodegradable materials can be made from biological, renewable raw materials and from fossil non-renewable raw materials.

Traditionally plastics are made from petroleum-based materials that are produced from non-renewable oil (fossil fuels). A further disadvantage is that traditional plastics are not biodegradable.

Polymers of biological origin are now being used as raw materials for plastics. These bioplastics are a new generation of plastics which are claimed to be more environmentally friendly than those made from fossilfuels. Starch - a renewable degradable carbohydrate polymer that can be purified from various sources by environmentally sound processes. It is found in high amount in plants like corn (maize), potatoes, and wheat.

Starch, by itself, has a severe limitation in that it is water soluble, and articles made from starch will swell and deform upon exposure to moisture. Therefore starch is chemically modified or blended with hydrophobic synthetic polymers – which often are not biodegradable.

4.4.7 New Innovations in Packaging of Fruits and Vegetables

Designs and material used for packaging may be different under various condition viz. controlled atmosphere, modified atmosphere, ripening chambers etc. and shipping container.

4.4.8 Pallet Boxes and Shipping Container

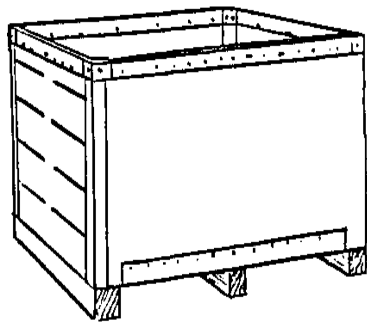
Loading and unloading is one of the very important steps in the post-harvest packaging of fruits, vegetables and root crops. Post-harvest losses can be considerably reduced by using pallets. All the subsequent handling and transportation operation become very easy once the boxes are placed on pallets. Pallets literally form the base on which most fresh produce is delivered to the consumer.

Advantages of a pallet box system:

- Less manual handling and thus reduced cost in loading, filling and unloading.
- More efficient use of available storage as compared to smaller crates.
- Increased speed of mechanical harvest.

Disadvantages of a pallet box system:

- The return volume of most of the pallet boxes is the same as the full load.
- The system requires higher investments in forklift trucks, trailers and handling systems to empty the pallet box.
- Because of the larger volumes, the produce is more easily injured during filling and unloading and the top layers will have made more movements during transport than when packed in smaller boxes.



The material can be printed to give the box a pleasant and recognizable appearance. Also the label can be included in this print.

4.4.9 Packaging Material for Fruits and Vegetable

Generally the fresh produce packed in jute bags or baskets and plastic crates for short distance transportation and CFB boxes and wooden crates for long distance transportation. The fruits and vegetables meant for super market sale are generally packed in polyethylene bags with 200 g and 500 g material.

Gunny bags	Ber, Lemon, Lime, Raw mango, Sand Pear, Sweet Orange, capsicum, cabbage, peas, potato, sweet potato
Bamboo basket	Grape, Guava, Mango, Papaya, lemon, okra, radish, carrot
Earthen Pots	Custard apple, grape
Wooden boxes	Apple, Apricot, Cherry, Litchi, Mango, Mandarin, Pear, Plum, Sapota, tomato, capsicum,
CFB	Apple, Cherry, Grape, Pomegranate and fruits for export, capsicum, chilli
Rigid plastic crates	Loose fruits for public distribution system

Packaging of fruits

1) *Mangoes:* Baskets made of bamboo with paddy as cushioning materials are used as packaging for mangoes in India due to its low cost, but they result in high spoilages of fruits. These a days, corrugated fibre boxes with

different types of cushioning materials like paddy straw, wood wool, vinylite and pliofilms wrappers, paper cuttings, newsprint, tissue paper and polyethylene films etc are used.

2) *Banana:* Conventionally bananas are transported as whole bunches wrapped with banana leaves. Use of polyethylene film bags for wrapping whole bunches for transport is found to be most suitable to reduce wastage. For export purpose bananas are packed in telescopic type corrugated fibre board boxes of different dimensions with good ventilated holes. The banana hands packed into the boxes in the lengthwise manner with their cushion resting on the bottom of the box and fruit finger tips pointing towards the lid. Stacking of these boxes is done lengthwise.

3) *Mandarins:* For long distance transport, wooden packing cases have been recommended. Here corrugated fiber board pieces are uses as liners. CFB boxes are also used with ventilation.

4) *Grapes:* 3 ply corrugated fibreboard boxes which can hold 2 to 4 kg of grapes are generally used for domestic purpose. The boxes are perforated and line with newspapers. The fruits can be protected against decay by placing sulphur treated paper such as ‘Grape guard’.

5) *Apples:* Traditionally apples are packed in wooden cases with newsprint as wrapper and pine needles or paddy straw as filler material. Now-a-days, CFB boxes provided with trays with cavities for holding apples is used. Each tray can hold 20 apples and four such trays can be placed on top of each other in the cartoon.

6) *Guava:* Guava are packed in boxes or baskets with a lining off newspapaer.

7) *Papaya:* The fruits are normally packed in baskets and individual fruits are wrapped in newspaper and the space between the fruits are stuffed with straw or saw dust.

8) *Ber:* Packed in gunny bag, cloth bag, bamboo baskets, wooden, plastic crates.

9) *Phalsa:* packed in baskets in small quantities being very perishable fruit.

10) *Pomegranate:* Usually CFB cartons are used for pomegranate packing.

11) *Bael:* Bael fruits are packed in gunny bags or plastic crates.

12) *Fig:* Fig fruits are packed in ventilated CFB boxes with fresh fig leaves as lining material.

13) *Custard apple:* Packed in earthen pots with grass and custard apple leaves as liners.

Packaging of vegetables

The vegetables are packed and transported in baskets, bags/ sacks or boxes.

1. *Tomatoes:* Tomatoes are usually packed in bamboo basket. Wooden boxes are also used of different size and shape in case of long distance transportation.

2. *Potatoes:* Commonly used packaging materials for potato are fibre mesh sacks, plastic film sacks, burlap bags. Tinted plastic bags are used to reduce light transmission to the tubers. Tubers in the transparent film bags should be protected from direct sunlight to avoid greening of the tubers.
3. *Onions:* Thin Hessian bags or bamboo baskets are used.
4. *Tuber crops:* Cassava tubers are dipped in 1% Mertect and packed in polyethylene bags and sealed to prevent microbial damage.
5. *Brinjal:* Bamboo baskets and gunny bags are used.
6. *Chilli and Capsicum:* Gunny bags, wooden boxes and CFB boxes are used.
7. *Cauliflower:* Generally packaging material are not used in cauliflower in India. Leaves protect the curd from direct exposure to sunlight. They are send in gunny bags to distant market.
8. *Watermelon:* Transported without any packing.
9. *Bottlegourd:* Baskets or crates are used.
10. *Bitter gourd:* Crates, jute bags are generally used and for supermarket sale, polythene bags are used.
11. *Pumpkin:* Baskets and gunny bags are used.
12. *Potato:* Graded and packed in gunny bags.
13. *Spinach:* Spinach is cut above root, washed, trimmed, graded and bunched or bagged.
14. *Cabbage:* Packed in crates and sacks.
15. *Pea:* Baskets, gunny bags and wooden boxes.
16. *French beans:* Wooden baskets, gunny bags.
17. *Okra:* Jute bags, baskets
18. *Muskmelon:* Transported without any individual packing in trucks.
19. *Cucumber:* Baskets, jute bags.

Root crops: Washed, graded and packed in gunny bags.

1. *Radish:* Trimmed, washed and packed in gunny bags.
2. *Carrot:* Packed in polyethylene bags after trimming tops, washing and size grading for super market display.
3. *Beetroot:* Mature roots are detopped, washed, graded and packed in gunny bags. For supermarket sale, packed in polyethylene bags.
4. *Turnip:* Gunny bags.
5. *Potato:* Graded and packed in gunny bags.
6. *Sweet potato:* Jute bags.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the primary functions of packaging material?

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2. What are the packaging materials generally used for fruits, vegetables and root crops?

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3. What are advantages of corrugated fibre board boxes over wooden crates?

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4.5 CUSHIONING MATERIALS AND WRAP

The cushioning material used for packaging fruits and vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds etc. For the cushioning material to be useful, it should dissipate the heat of respiration of the produce. It should be free from infection so that it should not pass on the same to the fruit and vegetables. It is also important that the cushioning materials itself should be physiologically inactive. Moulded pulp tray, honeycomb portion, cell pack are used replacing the cushioning material. Cassia leaves as packaging materials are reported to be most effective in reducing physiological loss in weight (PLW), spoilage, retaining fruit colour and chemical quality.

Damage caused by vibration and abrasion is generally a result of product movement within the package. While the damage may be superficial, it can adversely affect the market value of the commodity. Containers should not be filled either too loosely or too tightly for best results. Loose products may vibrate against each other and cause bruising, while over-packing results in compression bruising. Proper filling along with cushioning can minimize rubbing damage. Overfilling may lose all the benefit provided by suitable cushioning. Adding a simple cardboard liner to a crate will make it less likely to cause abrasion to produce. Shredded newspaper is inexpensive and a lightweight filler for shipping containers (if the ink used for newspaper print is non-toxic). Packaging materials such as trays, cups, wraps, liners and pads may be added to help immobilize the produce.

Plate 4: Use of cushioning material for packing (Source: FAO)

One of the newest trends in produce packaging is the shrink-wrapping of individual produce items. Shrink-wrapping has been used successfully to package apples, mangoes and a variety of tropical fruits. It is reported that seal packaging of individual citrus fruits film doubled the storage life as compared to control without packaging. Packaging of strawberries is done in various types of baskets and film over wraps to improve freshness and shelf-life. Shrink-wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels.

The main advantages of film wrapping of fruits and vegetables are-(i) reduced weight loss extended shelf-life (ii) minimized fruit deformation (iii) reduced chilling injury (iv) reduced decay by preventing secondary infection of fruits packed in the same box.

4.6 PRE-PACKAGING

The term "pre- packaging" covers all packaging of products in consumer units before its presentation to the end consumer. This simple technique involves cleaning, trimming, cutting of the fresh produce and packing the same in unit packages in polyethylene bags. Bean, carrot, brinjal, green chilli, root crops, leafy vegetables, and fruits like orange, lemon, banana, grape can be pre-packaged to obtain 1 to 2 times extension in shelf life in polyethylene bags under normal conditions without any refrigeration. The pre-packed produce presents better consumer appeal, longer shelf life and has considerable handling advantages in transport and marketing. The major facility required at the farm level or in orchards is a packing shed.

Pre-packaging is generally defined as packaging the produce in consumer size units either at producing center before transport or at terminal markets.

Packaging of fresh produce in consumer unit packs protects the produce against the damage and excess moisture loss.

1. It reduces the transportation cost eliminating unwanted and inedible portion of fruits and vegetables.
2. The space required for shipping and storage is less.
3. It has a better eye appeal as the produce is prepackaged in attractive film and the quality of the product can be seen from outside without opening the pack.
4. Pre packaging reduces the shopping time of the consumer as the produce is graded before being packaged.
5. It saves labour costs and produce is easy to handle.

Over-wrapping with plastic films such as polyethylene or PVC, often in the form of shrink-wrap, stretch film or cling film; bags made of paper, perforated polyethylene or polypropylene film, plastic net or cotton mesh; shallow trays of moulded pulp, paperboard, thermoformed plastic or expanded polystyrene, covered with plastic film; baskets, made of peeled wood, moulded pulp, paperboard and thermoformed or injection-moulded plastic, covered with plastic film. Among the different types of packaging films, polyethylene film finds the maximum use. Shelf life of asparagus, brinjal, okra, whole or segmented cauliflower can be increased by pre packaging in perforated or non-ventilated polythene bags.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why cushioning materials are used? What are the common cushioning materials used for fruits and vegetables packaging?

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2. Define pre-packing. Advantages of pre-packing.

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4.7 LET US SUM UP

Adopting improved packaging, handling and transportation methods can successfully avert huge post harvest losses. The product requirements, the marketing system and the personnel preference will determine the type of packaging to use.

4.8 KEY WORDS

Post harvest losses	:	Losses incurred after harvesting till it reaches to the consumer for final consumption. This includes losses occurring during handling, transportation, storage, distribution etc.
Packaging	:	Putting the material in suitable containers for better handling, transportation, and storage.
Fiberboard	:	Board consisting of one or more sheets of fluted or flat paper stuck to a flat sheet of paper or board or between several liners. When fluted sheets are used, it is called corrugated fibre board and when flat paper sheets are used, it is called solid fibre board.
Cushioning material	:	Padding material used in between the package and the product to protect against abrasion, vibration and thereby damage. The most popular cushioning materials are paper shreds, paper liner, cardboard liner, leaves etc.
Pre-packaging	:	Pre-packaging covers all operations include cleaning, trimming, cutting, and packaging in unit packages.

4.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISE

Check Your Progress Exercise 1

1. Post-harvest losses are losses occurring after harvest, loss of weight, quality, nutritive value, financial loss, loss of market and goodwill.

2. Packaging material is selected on the basis of: commodity, the systems of production, storage, handling, transportation, cost factor involved in producing packaging material, market requirement, consumer attitude, requirement of recycling, re-use disposal etc.

Check Your Progress Exercise 2

1. Packaging materials used serve as an efficient handling unit, protects from mechanical damage, protects against moisture loss, provides clean and sanitary storage, sales and service motivation, prevent pilferage, reduces cost of transport and marketing

2. There are many different types of package in use throughout the world. Packaging for fresh produce is of several types: Sacks, wooden crates,

carton or fibreboard boxes, plastic crates, pallet boxes and shipping containers, baskets.

3. The advantages of corrugated fiberboard boxes are: Low weight, easy handling and stacking, cushioning effect due to relatively soft walls, so minimum bruising. CFB box can be fabricated to any design, the boxes are delivered flat and assembling of boxes can be done locally, also have good printability. All they are most eco-friendly package due to their biodegradability, economical transportation

   Disadvantages of wooden crates are: Untreated wood can be contaminated with fungi and bacteria, treatment of wooden crates with paint or other chemicals may cause produce deterioration, material may be too hard or rough for produce like soft fruits, and therefore liners of a soft material may be needed, disposal of the crates after use, manufacturing of wooden crates puts an extra claim on the natural forest resources.

Check Your Progress Exercise 3

1. The cushioning material used for packaging fruits and vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds etc.

2. Pre-packaging is generally defined as packaging the produce in consumer size units either at producing centre before transport or at terminal markets. Packaging of fresh produce in consumer unit packs protects the produce against the damage and excess moisture loss, reduces the transportation cost, the space required for shipping and storage is less, better eye appeal as the produce is pre-packaged in attractive film and the quality of the product can be seen from outside without opening the pack. Pre packaging reduces the shopping time of the consumer as the produce is graded before being packaged and lower labour cost.

4.10 SOME USEFUL BOOKS

1. Cornelis, C.M., Schuur (1988) Packaging for fruits, vegetables and root crops. FAO, Food and Agriculture Organization of United Nations, Bridgetown, Barbados.

2. Er. B. Pantasico (Eds.) (1975) Post harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. AVI Publishing Co.

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5. Wills, R.B.H., McGlasson, W.B., Graham, D., Lee, T.H. and Hall, E.G. (1996) Post Harvest. An introduction to the physiology and handling of fruits and vegetables. CBS Publishers and Distributors, Delhi.

UNIT 5 TRANSPORTATION OF FRESH PRODUCE AND CONTROL OF LOSSES

Structure

5.0 OBJECTIVES

After going through this unit, you should be able to:

- know which mode of transport is suitable for particular condition;
- explain how transportation can influence storage life and the quality of fresh produce;
- discuss proper loading and unloading techniques for different commodities; and
- explain the advantages of Palletisation/ unitization.

5.1 INTRODUCTION

In this unit, we will discuss about transportation of fresh produce. Transport refers to carrying a produce from one place to another. Rapid and reliable transport of fresh fruits and vegetables is of critical importance to successful marketing. The delay in transport not only affects shelf life and the quality of fresh produce, but also reduces its value in the market. Transport is an important link in the handling, storage and distribution of fruits and vegetables. The transport of produce starts from the field to the assembly points or collection centres. From these places, bulk transport is undertaken by retailers, middlemen, wholesalers, processors, exporters and importers at packing stations, storage plants and shipping points. Several modes of transport are used to move fresh fruits and vegetables from farm to final consumer. They include head load, bullock carts, bicycle, rikshaw, autorikshaw, lorry, boat, ship and aeroplane. All these methods have their own advantages and disadvantages. Head load is mostly used for moving small quantities to a nearby market. This mode of transport is usually in practice in interior areas where proper roads are not available. Bullock Carts, Bicycle, rikshaw and autorikshaw are also used for short distance transport, but adequate cushioning should be provided to the transporting material for avoiding impact damage to fruits and vegetables in such mode of transport. Boats are used for inland transport, where as ships carry produce globally. High value products and the most perishables are always air lifted to the destination market. Knowledge of these pros and cons of each mode of transportation will help us to select the suitable mode of transport for an individual commodity.

5.2 PRE-OPERATIONS AND TREATMENTS

5.2.1 Packinghouse Operation

The basic operations in a packinghouse are sorting, sizing, grading and packing. Depending on the kind of produce, additional activities may include degreening, curing, washing, bunching, chemical treatments and pre-cooling. The sequence of activities varies with different crops. These operations are essential preparatory steps for transportation and subsequent marketing.

5.2.2 Curing

Potato, sweet potatoes, taro, onions, garlic and similar crops are cured prior to storage or marketing. Injured or bruised surfaces are allowed to heal by holding for a few days at ambient temperatures. The healing process is necessary so as not to shorten storage life. Periderm formation during healing is favoured by high temperature and high humidity. In sweet potatoes, this condition is most rapid at 30^{o} C with an RH of 95 to 97%. Potato tubers, on the other hand are held above 20^{o} C for about 2 days and then at $8\ ^{o}$ to 15^{o} C for 10 to 12 days at 90 to 95% RH. Another change that occurs during curing is the reduction of moisture content, especially in onions and garlic. Properly cured potato tubers have as much as 50% longer storage potential than those uncured or improperly cured. Curing also reduces rotting. Curing appeared to be generally more effective at ambient temperature than in cold storage.

5.2.3 Degreening

Degreening is the process of decomposing the green pigments in fruits usually by applying ethylene (C_2H_4) or other similar metabolic inducers to give a fruit its characteristic colour as preferred by consumers. It is applicable to bananas, mangoes, citrus and tomatoes. The length of time required to degreen a fruit depends upon the degree of natural colour break and maturity. The lighter the green colour and the more mature a fruit is, the less time is required to reduce the chlorophyll to a desirable level.

The degreening process is carried out in special treating rooms with controlled temperatures and humidity in which low concentrations of C_2H_4 (about 1:50,000) are applied. The C_2H_4 can be supplied either as the chemically pure gas in cylinders or by the old and risky method of using the fumes from the incomplete combustion of kerosene. The room is thoroughly ventilated to keep the CO_2 at levels (below 1%) that will not hinder colouring. The degreening time by this system is 24 to 48 hr. When kerosene fumes are used, the burners are placed outside the degreening room. The fumes enter the room through ducts by forced ventilation. Despite the fire hazard involved, the kerosene fumes produce better coloured fruits than pure C_2H_4, and it is suggested that this may be due to the good ventilation provided in the method. The best degreening temperature is 26°C. It has been found that higher temperatures delay degreening. The RH should be from 85 to 92%. Humidity levels high enough to cause condensation during degreening are associated with slow degreening and increase in decay. Low humidity, although it checks decay, causes excessive shrinkage, shrivelling and peel breakdown.

5.2.4 Pre-cooling

High temperatures are detrimental to the keeping quality of fruits and vegetables. However, elevated produce temperature is inevitable, especially when harvesting is done during hot days. Pre-cooling is a means of removing this field heat. The general aim is to slow down the respiration of the produce, minimize the susceptibility to attack of microorganisms, reduce water loss and ease the load on the cooling system of the transport vehicle or ship's cargo space. Various methods of pre-cooling may be used.

a) Air cooling

The temperature difference between the coolant and the commodities or packages must be reduced fast for pre-cooling to be effective. Cooling may be done fast by the use of coolants such as air, iced water, ice or vacuum. The temperature of the cooling air must not be below 0°C to avoid freezing. Prompt storage is essential to achieve the benefits of pre-cooling.

Pre-coolers using air are cold rooms and tunnels. A cold room has a very intensive air circulation, high refrigerating capacity and fairly low ceilings. The cold room is advantageous for large-scale operations. Pre-cooling tunnels are long, narrow cold rooms in which air circulates at high speed.

In forced air pre-cooling, the pre-cooler forces air through the void spaces of the fruit. The final air temperature is 0 to 1.5°C. Weight loss by forced air cooling is less than 1%. The pre-cooling operation may take 1 to 1 ½ hr.

b) Hydro-cooling

Hydro-cooling quickly extracts field heat from the produce. It has been used with advantage for leafy vegetables to retain texture and freshness. For citrus and some fruits, fungicide in the cooling water may be added to hold decay within tolerable levels. Fruits cooled with water are apparently more susceptible to decay upon warming. Sometimes it may lead to chilling injury (oranges) or damage due to water soaking (citrus). The hydro-cooling equipment consists of a large tank of iced water, a high capacity pump for circulating the water to a sprinkler system, and a conveyor belt for carrying the produce to the sprinkler.

c) Vacuum cooling

Vacuum cooling is the most rapid method of pre-cooling for leafy vegetables. The principle of vacuum cooler is evaporative cooling. At 29.9 in pressure, water evaporates at 100°C. At 0.018 in water will be vaporized at 0°C. There is 1% water loss for every 6°C reduction in temperature, therefore some water must be added to compensate for this loss.

5.2.5 Washing

As consumers demand clean produce, most fruits and vegetables are washed after harvesting. Washing improves the appearance of the produce and reduces the residues of fungicides and insecticides. Washing is not done on soft delicate and perishables fruits like strawberries. Muskmelons, cucumbers, and sweet potatoes are usually cleaned by brushing or wiping dry, rather than by washing.

5.2.6 Drying

Drying removes excess surface water from the fruit or vegetable. This is facilitated by heated air blown on the fruits or vegetables as they pass through sponge roller conveyors. Drying may also be done by a series of rotating brush dryers made of soft bristles. Minimum heat and dryer brush speed should be used to avoid injury to the fruits.

5.2.7 Waxing

Fruits and vegetables have a natural waxy layer on the outer surface, which is partly removed by washing. An extra discontinuous layer of wax is applied to the fruit, which provides the necessary protection against decay organisms. Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present. These can be sealed by wax. Waxing also enhances of the gloss of fruits or vegetables. Appearance is therefore improved, making the produce more acceptable to consumers.

5.2.8 Grading

Fruits and vegetables show considerable variations in quality due to genetic, environmental and agronomic factors. Therefore grading is necessary to get suitable returns commensurate with quality.

Grades are based on soundness, firmness, cleanliness, size, weight, colour, shape, maturity and freedom from foreign matter and diseases, insect damage and mechanical injury. Whatever the classification, the produce must possess the minimum qualifications established by the regulatory agencies.

5.2.9 Sizing

After grading, the produce is sized for uniformity. Hand sizing is useful for small-scale. For large operations, various sizing devices are used, based on either shape or weight of the produce.

For regular-shaped commodities like citrus, sizers are of many types. Longitudinal belt and roll sizers are used for some citrus varieties. Size adjustment can be made quickly from oranges to tangerines to grapefruit. Central longitudinal belt and roll sizers are of many types or variations, such as transverse roll and drop roll. The different sizes drop through the canvas distribution belts and are transported to the packing stations. Perforated belt sizers consist of a belt or chain having certain size holes or meshes in each section. Commodities may be moved about on the sizers. Shaking screens with varying sizes of holes can be used for sizing. Fruits can be vibrated along the screen and collected in different sized holes. For small products such as peas and cherries, a rotating cylinder may be used. The surface of the cylinder contains many holes or slots formed by metal rods. Commodities such as cucumbers, pineapples and large root vegetables are sized by diverging belt or rope grader. For commodities with irregular shapes, sizing is done by weight of the produce.

5.2.10 Disinfestation Treatment

One of the most important pests in crop production are fruit flies. Papayas, mangoes, melons and many other fruits are highly susceptible to fruit fly attacks. Disinfestation treatments do not vary much among fruits. The disinfestation methods for export of papayas include the vapour heat and EDB fumigation treatments. An irradiation treatment needs the government clearance before use.

The vapour-heat treatment, in addition to disinfecting the fruit, controls storage decay, but it is a relatively expensive operation in terms of initial investment for equipment and operational cost. Further, it takes a long time of approximately 15-20 h, and even in properly treated fruits, vapour heat causes a reduction in the aroma of the fruit pulp.

The fumigation treatment is more economical than the vapour-heat treatment. The entire treatment time is only about 4 hr, much less than that required for the vapour-heat method. Furthermore, most of the fruits are not damaged by the treatment, and storage decay is controlled. Cold treatment is also used for this purpose but in case of fruits where there is no injury at low temperature.

5.3 FACTORS AFFECTING TRANSPORTATION OF FRESH PRODUCE

Many opportunities for damage to fruits occur during its transport from field to the destination market. Impact bruises can occur when bins are dropped during loading or unloading. Stacking of overfilled containers may cause compression bruises in fruits and vegetables. Abrasion or vibration bruises may occur when fruits move or vibrate against rough surfaces or each other during transport. Bruises and injury reduce saleability of the fruits and vegetables and reduce the quality and shelf life by enhancing senescence.

The time of harvest or maturity of a product can influence the temperature required during transit. During harvesting and packaging, several factors may affect the physiological behaviour of the commodity during transit. These are (a) maturity at harvest, (b) field temperature and humidity at harvest, (c) mechanical injury, (d) time between harvest and cooling, (e) type and rate of pre-cooling, (f) sanitation of packing facilities and (g) use of brushes, dips, sprays and fumigants.

Factors affecting transportation depend upon

- Product handling
- In-transit temperature and humidity
- Air circulation and ethylene removal
- Compression/abrasion during movement

Poor handling of produce during loading and unloading of transport vehicle results in high post-harvest losses. In our country, containers, rail wagons and road vehicles are loaded by hands, implying that each package is manually lifted and dropped 4-10 times between harvest and consumption. Further, most often casual labours are hired for this work. As casual labours have no or little knowledge of handling fresh fruits and vegetables, the risk of quality deterioration of fruits and vegetables increases.

Each commodity must be transported under optimum conditions of temperature and humidity. Fruits should be protected from high temperature in the field after harvesting. Wherever possible, harvested fruits should be moved to the shade until transport. During transport, speedy handling is done for the protection of the commodity.

Fresh fruits and vegetables in packages have two environments, one inside the package and other one outside. Controlling outside environment does not necessarily control the environment inside the package. Mostly fresh produce is packed in corrugated fibreboard, which is a poor conductor of heat. When the produce generates heat and gives off water, it may affect the packaging material resulting in collapse of carton. When such a package is transferred in cold environment, and if the rate of heat production exceeds the rate of heat transfer, the product will get hotter, and the increased respiration rate will result in higher vapour production. If the walls of package become colder than the air inside the package, moisture given off by the produce can condense on the inside of package walls resulting in collapse of carton. Therefore, circulation of air inside package is important to maintain uniform temperature through out the package. Further, air circulation helps in removal of ethylene from the produce, which is necessary for maintaining the optimum quality of fruits and vegetables.

Packing and mode of transport selected should be such that it causes no or minimum vibration and bruising injury to the product. Vibration and bruising are the major causes of spoilage of fruits and vegetables during transport. To avoid vibration and bruising injury, cushioning material should be used.

Shipping containers

Packaging for shipping and handling requires appropriate engineered containers to protect produce from bruising, vibration and the weight of other stacked containers. The ideal pack consists of a tight fill without a bulge in a lidded container having sufficient stacking strength to protect the contents under all handling conditions. Any shipping container should be designed to meet the specific requirements of the particular fruit or vegetable.

In more developed countries, many shipping containers are used only once, and are not returned to the shipper. In less developed countries, baskets and boxes are often returned for reuse.

Shipping containers should be labelled with large print to specify the commodity, variety, weight or count, grade and source.

Wooden containers can be the strongest and most rigid type of shipping container, but strength depends on the thickness of materials used. Common types include: nailed wooden boxes and crates, wire bound boxes and crates, ply wood boxes, bulk bins or pallet boxes and wooden pallets. Pallets are platform devices used as a base for assembling, storing and handling or shipping other containers in a unit load. The base may be a 2-way or 4-way type to allow entry of types of powered forklift or hand pallet trucks.

Fiberboard (corrugated) cartons are becoming popular for shipping both tropical and subtropical produce. Their light weight and low cost are advantages. However, they have the disadvantage that some types absorb moisture and lose strength and thus stacking height may be limited in areas or in storage where RH is high. The strength of fiberboard cartons may be increased with stronger base materials, with internal dividers, extra liners or by using full telescope type cartons with two outer walls. Strength and moisture resistance may also be aided by resin and paraffin wax coatings. Waxed cartons filled with produce may be hydro-cooled and top iced or have packaged ice enclosed.

Fiberboard cartons are also common for mature green tomatoes and avocados and as master containers for consumer-packaged vegetables, such as cellophane-wrapped cauliflower, trays of tomatoes and polyethylene bags of carrots or other root crops.

Mesh, burlap and multi wall paper bags may be used to ship onions, cabbage and potatoes. Some types of paper bags have special wet strength properties that allow use of package ice for non pre-cooled carrots and sweet corn.

Bulk packs

Bulk boxes or pallet bins occasionally are used as shipping containers for fruits and vegetables going to terminal market warehouses to be repacked in consumer packages. Fruits and vegetables for processing, such as tomatoes, carrots, sweet potatoes, citrus and pineapples are often shipped in bulk boxes. Bulk boxes may be constructed of plywood, sawn lumber, wirebound veneer, fiberboard, wire or combinations of these materials.

The advantages of bulk boxes over field boxes of equivalent capacity, are lower cost, rapid loading of transport vehicles and replacement of costly manual labour. Also with bulk boxes, storage or warehouse facilities can be utilized more fully and properly designed bins easily withstand stacking loads.

Consumer packages

Consumer-sized packages for produce consist only of having a supply of paper or plastic bags available for customers to select, package and weigh their purchases. With such packaging, standard sized units are packed after washing or grading. Each unit is labelled as to commodity, weight or count, brand, source and other information and the consumer units are packed in master shipping containers usually made of fiberboard.

Consumer packages are of the following types: (a) bags made of paper, film or cotton or plastic mesh; (b) trays of moulded pulp, paperboard, plastic or foamed plastic; (c) folding paperboard cartons, sometimes with a clear plastic window or with dividers for individual fruits; and (d) small rectangular or round baskets, punnets or cups of moulded pulp, plastic, veneer or coated or waxed paperboard. Moulded vacuum-formed plastic trays may be made of polystyrene or polypropylene. Foamed plastic trays are usually of polystyrene.

Stacking containers

The nature of the container and the manner of stacking are important factors that influence cooling in storage or transport. An elaborate system for air distribution is useless if poor stacking prevents airflow; air follows the path of least resistance. Generalizations on stacking arrangements are difficult with the large variety of containers in use for different commodities. A distance of 2-3 inches between rows of boxes or cartons is desirable. Rows should be laid out so that the direction of airflow is along rather than across the rows. Loaded pallets or pallet boxes in storage should be formed in straight lines to provide about 4 to 6 in of space between rows.

Special precautions should be taken in stacking containers on pallets so that as much container surface as possible is exposed to moving air to speed cooling. With fiberboard cartons, cooling may be more difficult because, having no bulge or slats, as do many wood containers, they may be stacked too tight. Produce in unventilated cartons cools very slowly and often stays appreciably warmer than the surrounding air during storage. Bulge packed cartons or boxes should not be stacked so that the weight rests on the produce, but should be stacked on their sides; or wood cleats or stripping may be needed to avoid crushing or bruising the products.

5.4 MODES OF TRANSPORT

The mode of transport of fresh horticultural commodity depends on distance to market, perishability and value of product, and the cost of transportation method. Before selection of the mode of transport a consideration must be given to

- Kind, variety, and condition of commodity
- Distance to market
- Price of the commodity
- Transit environment
- Cost of the transport

Different modes of transport used for horticultural crops include:

- Road transport
- Rail transport
- Water transport
- Air transport

Road transport

The most common transport used world wide, and because of its flexibility, door-to-door delivery, fast, easy to load and unload; and general improvement in road conditions its use has been in rise. However, this method is energy intensive, expensive and needs a relatively developed road infrastructure.

In our country land transport is mostly done with open non refrigerated trucks. It results in high losses of produce due to warming. But for short distance transport natural ventilation is always sufficient to prevent losses due to heating. It is advisable to use refrigerated van for long distance transport.

Need and Importance

Transport by road is the most important, and will continue to be the predominant mode of transport in the developing countries. It offers the benefits of great flexibility in operation, suitability for short hauls and possible door-to-door service with all the implied conveniences of loading and unloading. However, it depends upon road conditions, transport service available and organization of transport services. Connecting roads may be inaccessible during rainy months and bridges may become unsafe. Because of inadequate roads, high freight rates may be charged to transporters.

Another difficulty is that in produce transported by public vehicles, handlers and passengers have no regard for the safety and quality of the product. Often, if commodities are carried together with passengers, public vehicles deviate from direct routes to get more passengers, and there is delay in transport.

For more systematic and advanced transport facilities, e.g. refrigerated truck vans, are required. Although, use of modern facilities will increase the cost of the product in the markets, it can be compensated by supply of quality product to the consumers. For short trips, the product can be washed, disinfected, dipped in cold water and immediately placed in ice cold insulated vans. Sometimes the short periods transport can be done in a non-refrigerated but pre-cooled vehicle also. If the distance to the market is such that product temperature would be undesirably high despite provision for pre-cooling and insulation, dispensable refrigerants such as ice, dry ice, eutectic solutions or liquid nitrogen may be used. Application of these refrigerants depends not only on the duration of trip and transport temperature but also on the cost and availability of the refrigerant. If still longer transport time is expected, then the use of mechanical refrigerating machinery in the vehicle should be done.

The fundamental considerations for transport over short and long distances are as follows:

1. In transport of short duration, the product should be protected against mechanical injury and exposure to extreme temperatures. The produce should be moved in a direct and consistent direction as much as possible and should not retrace its tracks.

2. For transport over long distances, there is an added risk of product deterioration due to excessive heating and wilting, inception of decay causing organisms, chilling, softening of succulent commodities or ripening of fruits. Hence, provision for more sophisticated facilities is recognized more than ever and is one of the many urgent problems in the tropics, despite the high capital investments involved.

Rail transport

Although slower than road transport, it can provide vibration free ride at relatively less cost. However, this system of transport is declining significantly due to its less versatility and inaccessibility with production site. For short distances the rail transport is usually completed within 5 hour, which can help in avoiding refrigeration. For long distances, the rail transport is often preferable to road transport provided it is frequent and dependable. Refrigeration is needed and is more easily arranged by rail than by road. Because it is imperative to protect the product during this long shipment, refrigeration principles and practices must be followed.

Water transport

River transport is slow, but it can be used for non-refrigerated commodities. Sea transport is usually used for long distances, and use of refer containers offers a cheap method of transport in comparison to air transport.

Facilities of boats and vessels should be made available for river and sea transport. Frequent and improper commodity handlings often offset any cost advantage of water transport. With the advances in containerization the improvements in the international sea transport are happening. Refrigerated vans or trailers are now being used, which are crane-lifted to the ship, and greatly minimizing dock-to-ship handling.

Air transport

One of the most dramatic developments in the transportation of perishables is airfreight. Air transport is mostly done on passenger airplanes with a little quantities of crop being carried on cargo. Products can be sold in markets thousands of kilometers away only a day after harvest. This transport is relatively fast, making it suitable for very perishable commodities, but cost incurred in transportation is very high.

Use of air transport is very limited despite its speed due to:

a) the high cost per kg,

b) disruption of flight schedules due to bad weather,

c) traffic in handling of produce at air terminals,

d) the distance from the production or consignment centres to the airport and then from the airport to the market upon arrival at destination,

e) uncertain amount of cargo space available on scheduled flights and

With the advent of jet and jumbo planes, however, air transport offers vast possibilities. The lower operating cost per ton/km with even faster schedules has already resulted in an increase in air-transported fruit and vegetables. Prospect of air transport should not be evaluated solely on the basis of reduced operating cost, but also on the gains from premium consumer prices due to better quality of vine- or tree-ripened produce. Airport product-handling facilities and ancillary services are expected to improve as a result of current developments in aviation technology.

5.5 LOADING AND UNLOADING

It is very important to have proper loading and unloading procedure, as both the steps can damage the product integrity and render it unfit for human consumption. The product must be packed in appropriate container. Weak packages and their enclosed contents are more prone to damage during transport. There must be minimum damage to the product during loading and unloading operations.

5.6 PALLETISATION/ UNITIZATION

In advance countries almost all horticultural packages are unitized for handling. The packages must be designed for secure palletisation. The package must withstand expected stresses in the stacking column. If the packages are cross-stacked, their vents must be located on both ends and sides to allow air circulation through all packages on the pallet. The package dimensions must be compatible with pallet dimensions.

Some advantages of palletization include:

a) Savings in handling costs averaging 40 to 45%;

b) reduced handling time;

c) fewer personnel accidents by substituting mechanical or manual handling and lifting;

d) more efficient utilization of storage space;

e) reduced product damage; and

f) uniform stacking of produce.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the different modes of transport used in our country?

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2. Why air circulation during transport is important?

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3. How vibration and bruising injury can be avoided during transport?

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4. In your view what mode of transport should be used for high value fresh horticultural produce for export market and why?

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5. What different modes of transport can be used in for Delhi market?

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6. Why proper loading and unloading procedures are important?

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7. How palletisation helps during transport?

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8. In your view which mode of transport should be used for fresh horticultural produce for export market?

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5.7 LET US SUM UP

Transport of fresh produce is necessary to make sure its availability to the consumers. Although several methods of transport are available, a suitable method is selected based on value of the crop and distance of market. It is of paramount importance to have proper handling before and during transport to avoid any injury to the produce and to have more shelf life.

5.8 KEY WORDS

Transport	:	Movement of the product
Ethylene	:	A colourless flammable gas which stimulates ripening
Respiration	:	Process of hailing oxygen and exhaling carbon-di-oxide
Pre-cooling	:	Process of cooling fruits and vegetables immediately after harvesting
Waxing	:	Coating of fruit surface with food grade paraffin
Refer container	:	Containers used for transport of fruits and vegetables, which can be cooled to refrigerated temperature.
Perishable	:	Commodity having short life cycle
Pelletization	:	Stacking the product in a definite area as a single unit
Unitization	:	Stacking the product in a definite area a single unit

5.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:
   - Road
   - Rail
   - Ship
   - Aeroplane
2. Your answers should include following points:
   - Temperature regulation
   - Ethylene removal
3. Your answers should include following points:
   - Proper cushioning
   - Infrastructure development
4. Your answers should include following points:
   - Air
   - Fast quality deterioration
5. Your answers should include following points:
   - Road
   - Rail
6. Your answers should include following points:
   - Impact injury
   - Quality deterioration
7. Your answers should include following points:
   - Uniform stacking
   - Proper ventilation
   - Avoids injuries
8. Your answers should include following points:
   - Air
   - Sea

5.10 SOME USEFUL BOOKS

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UNIT 6 CLEANING, SELECTION, SORTING, GRADING AND PACKAGING

Structure

6.0 OBJECTIVES

After studying this unit, you should be able to:

- understand different operations in handling of fresh fruits and vegetables;
- learn usefulness of these operations in maintaining quality; and
- know about containers and packing line.

6.1 INTRODUCTION

After harvesting of the crop and before marketing or storage of the produce several operations like cleaning, sorting, grading *etc*. are done. These post-harvest operations increase attractiveness, maintain quality for a longer period and increase storage life. In the developed, countries these operations are done in the packing houses, therefore are called packing house operations. In India these operations are not usually done except in case of fruits of commercial importance. In this chapter, we will learn these operations and their usefulness in post-harvest management of fruits and vegetables.

6.2 CLEANING

Soil and other materials are removed from the surface of fruits and vegetables by washing, brushing or sometimes both to improve their appearance, to prevent wilting and to remove inoculums of pathogen causing post-harvest diseases.

6.2.1 Washing

The produce is washed with clean water usually by putting in a water tank having a continuous flow of water and agitation. Use of chlorinated water containing about 200 ppm of chlorine helps in surface disinfection. If the water is recycled, chlorination is must. This helps in checking spread of the diseases especially bacterial diseases. Washing under a shower with pressurized water is more helpful in removing soil from root vegetables like carrot, radish, turnip *etc*. Rotary drum machine or barrel washer is used for potato and other root vegetables. Brush washers take care of cleaning of individual fruit or vegetable. After washing excess water should be removed. This can be done manually or with a machine.

6.2.2 Dry Cleaning

This is done with the help of machines with brushes and is used in crops that can be adequately cleaned without water. Brushes loosen any leaf or lightly attached particle and give a polishing effect with the option of aspirating afterwards. Aspirators are simple machines consisting of a vibrating mesh belt conveyer which carries the produce across the upward vertical air blast. Any light chaff or leaf is lifted off and removed. Root vegetables often need some degree of abrasion before aspiration. Machines are available with spring or rubber or spiral rollers for this action.

6.3 TRIMMING

Removal of unwanted leaves, stems or roots prior to packaging and storage is done in vegetables like lettuce, cabbage, cauliflower *etc*. It improves attractiveness of the produce and also reduces storage space by eliminating unwanted material.

6.4 SELECTION

The desirable characteristics of a fruit or vegetable are dictated by its intended use. Since the main outlet of fruit and vegetable is usually the fresh market, the acceptability of the produce is determined by consumer preference, attractiveness and organoleptic quality. The same criteria do no necessarily apply to the raw materials for processing. The processor is primarily interested for colour, flavour and texture. The grower is more concerned with least cost of cultivation, high marketable yield and maximum profit.

All these aspects constitute quality of the produce and are important for selection of the commodity. Quality may, therefore, be defined in terms of end use. Important factors in quality for the consumers are (i) appearance including size, shape, and colour (ii) condition and absence of defects, (iii) texture, (iv) flavour and (v) nutritional value.

Overall quality of the fresh produce cannot be improved after harvest. Controlled ripening can improve the colour of the produce like tomato, mango, banana *etc*. or modified storage environment can extend the storage life, but only as much as the pre harvest conditions of the crop allows. Thus the ultimate market quality of the produce will be influenced by the growers as soon as the crop or the variety is selected. If there is no domestic or nearby market for a particular crop and the grower has no facility for allowing distant transportation, there is no point in growing that crop. It is often more profitable for the growers to grow unusual vegetables like lettuce, broccoli, Brussels sprout, cherry tomato, gherkin, yellow or red capsicum *etc*. and fruits like strawberry, Kiwi *etc*. and sending them to metropolitan markets for meeting the requirements of economically higher strata of the society and foreigners. Off-season production of fruits and vegetables also fetch a good return to the grower. Production of vegetables like okra, bittergourd, cucumber *etc*. during winter and capsicum, tomato *etc*. during summer are very remunerative and can fetch higher return in metropolitan cities.

Selection of a particular variety to be grown will depend on a few aspects as discussed below.

a) The variety should match the consumer preferences of the market to be served. This is especially true in case of vegetables like brinjal, tomato and onion, and fruit like banana. In brinjal, shape (round, long, oblong), colour (purple, green, white, variegated) and size (large-round, small-round) determine the preferences among the consumers of different regions. In tomato, sour and juicy varieties are preferred in some areas over non-juicy firm varieties. In some areas white onions are preferred over other types and in some multiplier onion is preferred over the common types. In areas where red bananas are preferred, the yellow ones do not fetch good price.

b) Good seed of genetically pure variety is very important because it will ensure uniform produce of proper maturity at harvest, minimising greatly post harvest problems. This important aspect is very often overlooked.

c) In case of hybrids especially of tomato, long distance transportation could be more remunerative and fetch higher return. Thick skinned (pericarp) hybrids fetch higher prices in the markets located in distant places as they are less susceptible to damage during transit as compared to the varieties with thin pericarp.

d) If the crop is grown for processing, the variety should be selected as per specific requirements of the processing industry. In mango, varieties with more pulp content like Totapuri is preferred for processing. In tomato, varieties with high total soluble solid (TSS) are preferred for manufacture of tomato products. In onion, white varieties with high TSS are required for dehydration.

6.5 SORTING

Sorting is almost entirely a manual operation because human sight and dexterity have not been replaced satisfactorily by machines. Sorting is generally done in a packing house as a part of a cleaning, sorting and sizing on packing line. The purpose of sorting is (i) to remove items which are under size, over or under ripe, misshapen and damaged, and (ii) to meet requirements of a grade established by the centre, state or marketing agreement authority. Sorting improves attractiveness of the produce and reduces the quantity to be handled during subsequent operations like grading, packaging *etc*., by eliminating unwanted materials. By removing the damaged produce before hand, it reduces loss due to post harvest diseases during transport and storage.

Culled fruits and vegetables which do not conform to the specific quality attributes may be utilized for extraction of essential oil and pectin from citrus peel, starch from mango seed kernel and potato, natural colour from grape, *jamun*, p*halsa*, carrot *etc*. They can be effectively utilized for production of animal feed. Some of the fruit and vegetable wastes can be usefully diverted for biogas generation and making field manure.

6.5.1 Sorting Equipment

The produce for sorting generally moves over a belt or roller conveyor. A roller conveyor, which turns the produce as it moves forward, is preferable to a belt because it allows the sorter to see all sides of each item. Each sorter on the line picks out those products, which are not suitable for high marketing. Sufficient light above the sorting table is also essential for high efficiency of the operation.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Why cleaning of horticultural produce is done? What are different methods of cleaning?

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2. What do you mean by selection and sorting? How improvement of quality of the produce to be marketed is brought about by sorting?

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6.6 GRADING

Buying of fruits and vegetables is done on the basis of grade and size. Fruits and vegetables show considerable variation in quality due to genetic, environmental and agronomic factors. Grading is necessary to get suitable returns commensurate with quality. Most countries have their own set of standards for domestic trade. Grades are based on soundness, firmness, cleanliness, size, weight, colour, shape, maturity, freedom from disease, mechanical injury, insect damage *etc*. Usually there are two to three grades for most of the products as extra grade, grade 1 and grade 2. Grading may be done manually or mechanically.

6.6.1 Grading Equipment

Grading machines fit into four main categories depending on the quality to be graded, viz., size, mass, colour and profile. Other machines that have been considered include those which measure a range of acoustic and optical properties, firmness and resilience. Size graders may incorporate an element of shape by which it can select fruits or vegetables with specific shape. Size graders are available in several different forms which have different numbers of contact points and different shaped apertures. The major limitation is that in most graders measurement of the produce is two dimensional and items may be upended to pass through. Other important aspects are utility of the machine to handle different crops, gentle handling of the produce and initial capital cost.

Different types of available graders suitable for individual crop are discussed below:

Screen grader

In this machine the produce is conveyed along with a series of belts having holes of different sizes. Any item smaller than the hole size of the belt drops down onto a chute or crosswise conveyor below. The machine will have two or three belts with holes of different sizes. The first belt will have smallest holes to remove the smaller sizes first. The size of mesh (hole) increases with subsequent belts and the largest fraction would be the carry-over from the larger mesh belt. The shape of the hole in the belt is usually square, but hexagonal are also available. This is usually a harsh method and is not suitable for fruits like apple, peach etc., which require gentle handling. Continuous shaking of the belt provides easy cleaning of the holes and faster movement of the produce.

Barrel screen grader

These graders have cylindrical screens in place of flat belt screens as in screen grader. A typical barrel grader will have three cylindrical screens. The smaller holes are at the upper end of the sloping barrel and the larger holes are at the lower end. The barrel is tilted at about 5^o so that the produce passes down by gravity. This type of grader is suitable for onion, carrot, beet, citrus, gladiolus bulbs *etc*.

Diverging belt grader

The grader operates on the basic principle of diverging elements. The produce is conveyed along a narrow channel, the width of which increases gradually as it travels along until it is so wide that the produce drops through the gap by gravity on a belt or chute below. The smaller ones drop through first and the larger ones are carried further. Graders working on this principle are available for different crops.

Roller grader

This is working on the principle of diverging elements where the produce is conveyed by a series of rollers which get wider and wider as it moves along. The smaller fruits or vegetables drop down first and the larger ones are carried forward. The main drawback of this machine is that it cannot differentiate between a longer and a shorter produce. It is suitable for spherical shaped fruits like orange, apple, tomato *etc*.

Link grader

It works almost in the same way as that of the roller grader. But instead of rollers, it carries the produce between the links which move along diverging rails. It gives more precise grading than the roller grader.

Iris grader

This is the grader where round hole mechanism has been used, and instead of having only two links, it has a set of elements arranged in an iris with a central hole. The irises pick up one fruit each at the entry point of the machine and then move along a track. The irises widen as they move along providing increasing diameter of the hole to the fruit. The fruits while passing through the holes drop at the appropriate place.

Mass grader

This is different from other grades where the produce is graded on the basis of weight, whereas most fruits and vegetables are bought and sold by both size and weight.

6.6.2 Optical Methods of Grading

Several crops are bought on the basis of colour, for e.g. tomato, pepper and apple. The usual colour to be sensed is green, yellow and red, which can be readily sensed by photoelectric techniques by the grader. The principle of operation is that light is taken from at least two sources at the fruit or vegetable and the reflected light is received by photoelectric cells. A reflector behind the item shows one of its colours, for e.g. a red apple might have a red reflector. In this case, the sensor or photoelectric cell would not recognise any difference between the apple and the reflector. If a green apple comes, it will receive a different reflected signal and the green one will be removed mechanically from the lot.

6.6.3 Manual Inspection and Grading

In spite of advances in the development of sophisticated equipment for grading, majority of fruits and vegetables are graded manually by hand and eye, even in the developed countries. Some fruits and vegetables have unusual physical characteristics, which demand manual grading. For example, grapes and bananas have unusual shape and invariably sold in bunches or clusters. Machine grading is not possible in such cases. Bananas are to be carefully graded in terms of ripeness, colour, length and blemishes, all of which are carried out manually.

Manual inspection is usually done by workers who sit along side a moving flat belt or preferably a series of rollers so that the produce is turned over continually in order to see each side of it. The workers inspect and group the produce into different grades.

6.7 PACKAGING

Assembling of the produce into convenient units for handling is called packaging, and it provides protection to the produce during transport, storage and marketing. Sometimes the produce is enclosed in smaller individual packages of consumer units (Wraps, bags, trays etc.), which is called as pre-packaging and then the individual units are put into the bigger container.

6.7.1 Pre-packaging

Many materials are used as pre-packages for different produce *e.g.* plastic films like polyethylene, polypropylene, polyvinyl chloride and polystyrene, nylon net bag, paper bag, pulp tray, open-weaven hessian bag *etc*. Plastic films have heat shrink characteristics and can be used for shrink wrapping under controlled temperature and tension in a specialized machine. They may be used separately or as wrap over moulded polystyrene or pulp trays. The produce in a package (usually consumer unit) should be of comparable weight, size, maturity and grade. Some packaging involves enclosing a single product unit (a curd of cauliflower or a head of cabbage), while in other packaging, several product units are enclosed in a single consumer unit (radish, carrot). Packaging is done manually or by a machine. However, such additional packaging increases cost. Therefore, it must be compensated by reduced wastage and increased selling price. A given quantity (count or weight) of individual packages is then packed in a larger container for transportation and distribution. Such containers may be bags, wooden boxes, bamboo (or other plant twig) basket, corrugated fibreboard boxes, plastic crates *etc*.

6.7.2 Qualities of a Package

Modern packages and packaging should meet the following requirements.

i) They should be strong enough to protect the contents during handling and transport.

ii) They should stabilize and secure the product against movement within the package during handling.

iii) The packages should maintain shape and strength under high humidity and when wet.

iv) They must facilitate rapid cooling of contents and/or offer a degree of insulation from external heat or cold.

v) They should have sufficient permeability (in case of plastic films) to gases and vapours produced during respiration by the contents.

vi) The packages should be cost effective and attractive and amenable for containing details of printing the label.

vii) The material of construction must not contain chemicals which could be transferred to the produce and be toxic to human being.

viii) The security of the package or its ease of opening and closing might be important in some marketing situation.

ix) The package might be required to aid retail presentation.

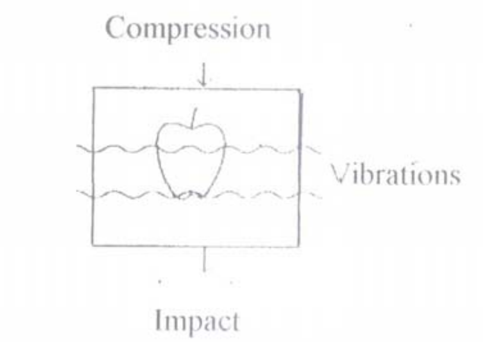
x) The package might need to be designed for ease of disposal, re-use or recycling.

It is becoming important to standardize the size and shape of the packages for unitization (*e.g.* use of pallets) and mechanical handling (*e.g.* fork lifting). An optimum length to width of the package is about 1.5:1.0. As per recommendations by the International Labour Organisation, 30 litre (about 20 kg of produce) and 15 litre packages are becoming standard for fruits and 36 litre packages for some vegetables.

6.7.3 Prevention of Mechanical Damage

- Four different causes of mechanical injury are

  - cuts
  - compression
  - impacts
  - vibrations (rubs)



- **Cuts:** Handle produce carefully. Avoid cuts.

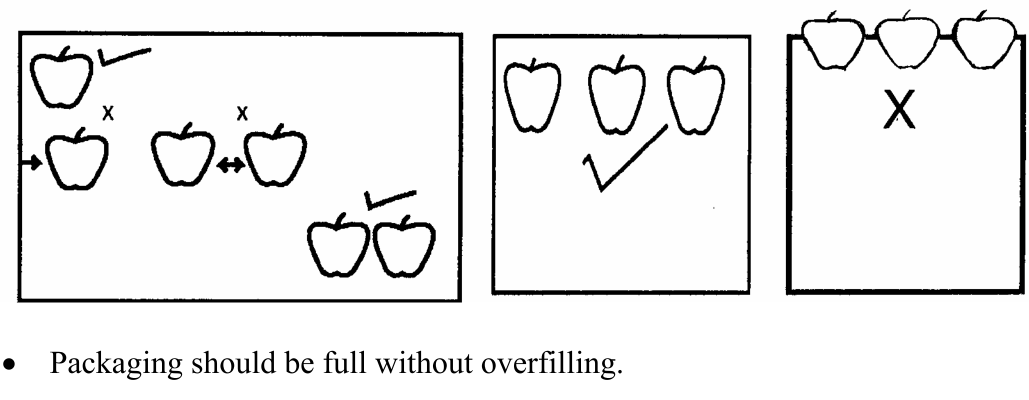
- **Compression:** Except certain so called 'hard' vegetables such as pumpkin, potato or onions, the package must be strong enough to carry the stacking loads, otherwise there will varying degree of compression bruising.

- **Impact:** Dropping of packages or impact shock in transport

- **Vibrations:** Common during transport, causes abrasions ranging from light rub marks to removal of not only skin but also some of the flesh. All these injuries turn brown during exposure of the material to air. The produce is disfigured and its market value is reduced. These injuries are avenues of infection, increase respiration, enhance the rate of deterioration and cause immediate loss of edible material because of the need to trim damaged portions.

Avoiding vibration injury

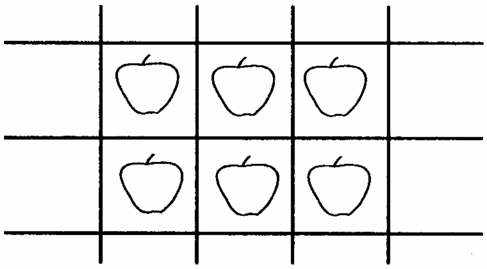
- Individual specimen should not move with respect to each other or the walls of the package.



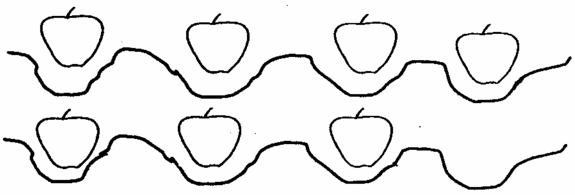
- Packaging should be full without overfilling.

- Packing too tightly increases compression and impact bruising.

- Individual wrapping.
- Isolating each piece as in cell pack.



- Tray packing



6.7.4 Some Important Aspects

There are some other important considerations in packaging which are given below:

- Cushioning materials are provided to absorb vibration and compression during transport and to prevent movement of the produce in pack or packaged units within the container. Various cushioning materials such as paper shreds, thermocole, dry grass, paddy straw *etc*. used as bottom pads or between layers of fruits and vegetables are effective in absorbing impact and reducing bruising of the produce. The cushioning material (i) should have ability to dissipate the heat of respiration of the produce, (ii) should be free from infection which is likely to be passed on to the produce, (iii) should not injure the soft fruit, and (iv) should be physiologically inactive.

- Water loss of the produce in packages can be reduced by using plastic films with ventilating holes as pre-packaging or consumer packaging material. Ventilating holes (small perforations) prevent condensation of moisture inside packages and also allow some gas exchange for respiration, thereby preventing anaerobic respiration which otherwise would have caused off-flavour development. Polyethylene film lined corrugated fibreboard boxes with ventilating holes serve as a good container of pre-packaged units for fruits and vegetables.

- Fruits on ripening release ethylene gas which causes ripening of other fruits in the package. If early ripening is not desired, it is necessary to remove ethylene developed within the packages as quickly as possible. This is done by ethylene scrubber using blocks or sachets of high surface area materials *e.g.* foam, blotting paper *etc*. impregnated with potassium permanganate solution. Potassium permanganate oxidises ethylene to carbon dioxide and water. Some commercially formulated material like Purafil is available for scrubbing ethylene from the packages.

6.7.5 Packing Line

The method of packaging depends on the type of the produce, size of the package and operation time. High value crops such as avocado, peach, apple and kiwi fruit are often packed by hand. Hand packing helps in proper orientation of fruits in a box and thus improves overall protection and appearance. Large scale operations are often done in a packing machine. The automatic machines are arranged in multiples up to about 10 along a belt conveyor. The produce is fed into the reception hopper from where it is elevated and distributed to different machines. A gate linked to each filling station deflects the produce down a chute and into a tilted, waiting box. As the box becomes full, it lowers gradually and the preset weighing machine closes off the feed gate. The box is then carried on a short roller conveyor onto a further main conveyor with all boxes from other machines. Each box takes about one minute to fill and needs no supervision. The boxes then pass through an automatic box sealing and printing machine. Though this is a convenient method of packaging, it causes damage to sensitive fruits. It is, therefore, popular for more robust fruits like citrus and for fruits for local market. Automatic pallet loading by palletizer may then follow, or else the boxes may be manually stacked for transport.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by grading?

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2. What is packaging and what are qualities of a good package?

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3. How water loss from and anaerobic respiration of the produce and ethylene accumulation inside the package are prevented by proper packaging techniques?

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6.8 LET US SUM UP

In this unit, you have read about post harvest operations like cleaning, trimming, selection, sorting, grading and packaging of horticultural produce. It has given you an idea of different machines used for grading and packaging.

6.9 KEY WORDS

Cleaning	:	Removal of soil and other materials from the surface of the produce by brushing or washing.
Sorting	:	Removal of under size, over or under ripe, misshapen and damaged products from the lot to meet requirements of a grade.
Grading	:	Grouping of the produce into different lots on the basis of size, weight, colour, shape, maturity.
Packaging	:	Assembling of the produce into convenient units and it provides protection to the produce during transport, storage and marketing.

6.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Purpose and methods of cleaning of horticultural produce

2. Your answer should include the following points:

   - Definition of selection and sorting
   - Improvement of the produce by sorting

Check Your Progress Exercise 2

1. Your answer should include:

   - Grading and its importance

2. Your answer should include:

   - Definition of packaging
   - Qualities of a good package

3. Your answer should include:

   - Methods which help in preventing water loss and anaerobic respiration of the packaged produce
   - Use of ethylene scrubber

6.11 SOME USEFUL BOOKS

1. Kader, A.A. (ed.) (1992) Post-harvest Technology of Horticultural Crops (2nd edition), University of California, Berkley.

2. Thompson, A.K. (2003) Fruits and Vegetables: Harvesting Handling and Storage, Blackwell Publishing, U.K.

3. Wills, R., McGlasson, B., Graham, D. and Joyce, D. (2004) Post-harvest (4th edition), CAB International, U.K.

UNIT 7 TREATMENTS: PRE-COOLING, CURING, INHIBITION OF SPROUTING AND FUNGICIDE APPLICATION AND RIPENING

Structure

7.0 OBJECTIVES

This unit shall analyze the problems related to checking post harvest losses of fruits and vegetables. Here the issues of appropriate post harvest treatments with particular reference to curing, pre-cooling, checking sprouting and rotting of fresh fruits and vegetables will be discussed.

After studying this unit, you should be able to:

- cooling requirement of horticultural crops and pre-cooling techniques;
- concepts of curing;
- effects of sprouting and its inhibition;
- waxing and surface coating of fruits and vegetables;
- post harvest disease management and fungicide application; and
- control of ripening.

7.1 INTRODUCTION

Ever since the civilization of mankind, efforts have been directed towards accumulating and storing foods when they are in plenty in order to meet needs during the days of scarcity. In case of food grains not much problem was faced due to nature's noble way of reducing the moisture level as the grains mature and further drying after harvest. However, in case of fruits and vegetables, long term storage in their fresh form was not possible (until development of modern methods) primarily due to their high degree of perishability owing to high moisture content of these commodities at the time of harvest.

Storage of fruits and vegetables in their fresh form prolongs their usefulness and in some cases improves their quality. It also checks market glut, helps in orderly marketing, increases financial gain to both the producers and consumer and preserves quality of produce for much longer time. Horticultural produce like fruits, vegetables and cut flowers are living respiring tissues separated from the parent plant. Therefore, the aim of storage is to control various physiological and biochemical processes viz. respiration, transpiration and other metabolic activities to keep produce in maximum usable form. Hence pre-treatments viz. Curing, Pre-Cooling, Inhibition of sprouting and fungicide application plays an important role to prolong the storage life of horticultural produce.

7.2 IMPORTANCE AND METHODS OF PRE-COOLING

Pre-cooling is the process of rapid removal of field heat/respiratory heat usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before cold storage or before processing depending on the commodity. This is the first step of good temperature management. The primary advantages of pre-cooling are: (a) Inhibition of the growth of decay causing organisms, (b) restriction of the enzyme activities, (c) reduction of water loss, (d) reduction in rate of respiration and C_2H_4 liberation and (e) rapid wound healing. The production and action of ethylene from harvested fruits, vegetables and flowers are temperature dependent. Harvested produce kept at 25^0 C with 30% RH shows a tendency of 36 times more water loss as compared to that stored at 0^0C with 90% RH. Hence pre-cooling serves as an essential practice in any successful cool chain management of horticultural produce. The two most important factors in pre-cooling are temperature and time, i.e. fruit or vegetable must be cooled in the shortest possible time. Product cooling follows a logarithmic function, with initial rapid cooling followed by a slower rate. Since it is difficult to remove all the field heat, pre-cooling to $7/8^{th}$ of the recommended storage temperature is advisable. The product can then be placed in storage where the remaining $1/8^{th}$ of the heat can be gradually removed with less energy cost. If several products are being handled, then a system must be selected that is compatible to all of them. Highly perishable products, which have a high respiratory rate, e.g., asparagus, broccoli, spinach and sweet corn, need fast cooling and require high refrigeration capacity and fast pre-cooling methods.

In order to predict the end point of pre-cooling, it is essential to know the “half-cooling time”. Half-cooling time is the time required to reduce the temperature difference between commodities and the coolant by one-half. This is independent of the initial temperature of the commodity.

The speed of cooling depends upon the following factors: (i) Accessibility of product to the refrigerating medium. (ii) Difference in temperature between the product and refrigerating medium. (iii) Velocity of refrigerating medium and (iv) Type of cooling medium. The shape, density, and surface area/volume ratio of the fruit or vegetable and the type of container are important in determining the appropriate type of cooling medium, i.e. air, water or ice.

Some products do not tolerate exposure to water. In general, the greater the amount of packaging the slower the cooling rate. If the packaging is exposed to water, packaging in paper-based material is not recommended unless it is waxed.

There are basically five methods of pre-cooling used for horticultural commodities. These are (i) Room/air cooling, (ii) Water/hydro cooling, (iii) Forced air-cooling, (iv) Vacuum cooling, and (v) Package icing.

7.2.1 Room/Air Cooling

In room / air-cooling heat transfer takes place by means of conduction. Produce is placed in an insulated room equipped with refrigeration units. This method can be used in most commodities, but it is slow compared with other options. Containers should be stacked in such a way in the room so that cold air can freely move around them, with adequate space between stacks. The cost of room / air-cooling is a relatively low.

7.2.2 Hydrocooling

By hydrocooling, the product is cooled by immersing in cold water or by showering cold water on it. Heat transfer in hydrocooling takes place by both conduction and convection mechanism. It is faster than air-cooling and does not dehydrate the product. It can be used if the product is not damaged by exposure to water. The critical factors for effective hydrocooling are water sanitation and use of water-tolerant packaging that makes it more expensive. Hydrocooling has the advantage over other pre-cooling methods in a sense that it helps to clean the produce thereby reducing the primary inoculum load. The water is normally cooled by mechanical refrigeration but if this is not available an alternate source of cold water could be clean one source of water.

7.2.3 Forced-Air/Pressure Cooling

This method is a modification of room cooling in which pre-cooling is achieved by "pulling" cold air through the stacked product (Figure 7.1). In a properly designed forced-air system, the evaporator coils in the refrigeration system have more surface area than conventional coils, allowing for more rapid heat removal. Although the cooling rate depends on the air temperature and the rate of airflow, this method is usually 75-90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached. If mechanical refrigeration is not available, passing it through a water soaked pad that will remove heat can cool the air by evaporative cooling. Since evaporative cooling will cool the air to only 1-2°C above the wet bulb temperature of the air, it is most appropriate in dry climates and for chilling-sensitive products. Another alternative to mechanical refrigeration is to pre-cool the produce only at night when the air is colder. The main disadvantage of forced air-cooling system is desiccation of the produce due to very high velocity of air. To reduce this effect the cold air is humidified using appropriate air handlers.

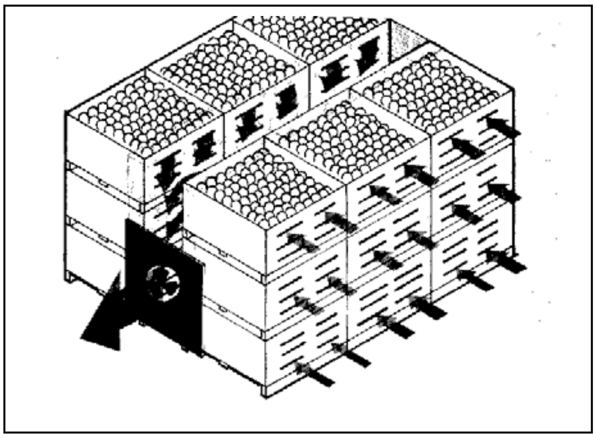

Figure 7.1: Technique of forced air cooling

7.2.4 Vacuum Cooling

This is the most rapid and energy efficient form of pre-cooling. Here the cooling is achieved by the latent heat of vaporization of water. Packaged product is placed inside an airtight chamber and the air is evacuated, which lowers the pressure and the boiling point of water. At a reduced pressure of 4.6 mm Hg, water on the surface of the product rapidly evaporates, which removes the field heat. Although this method can cool product in less than 30 minutes, it is only efficient on products with a high surface area/volume ratio. Crops having a relatively thick waxy cuticle e.g. tomatoes, grapes etc. are not suitable for vacuum cooling. Vacuum coolers are in limited use because they are expensive to purchase and operate and can only be used on a limited range of products.

7.2.5 Package-Icing

It is commonly applied to boxes of produce by placing a layer of crushed ice directly on top of the crop. The ice melts and the cold water runs down through the produce and is cooled. The main use of top icing is for road transport and it can be applied shortly after harvest to begin pre-cooling as soon as possible. By this method product is cooled faster than forced-air but the product must tolerate contact with water and ice. Although the easiest method is to add flaked ice on the top of the container, greater contact with the product can be achieved by injecting slurry of water and ice into the package. Care must be taken to ensure complete distribution in the package. Containers must be water-tolerant with holes for water drainage.

7.2.6 Alternate Methods of Pre-cooling

Several alternate methods of pre-cooling can be practiced in order to achieve the partial goal of pre-cooling in places where procurement and installation of expensive pre-cooling equipment are difficult. Some of the examples of the system could be (i) Radiant cooling by use of solar collector during night, (ii) High altitude cooling by utilizing naturally cool surrounding (about 10 c fall in temperature is recorded in every 1000m higher altitude.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.

   i) By pre-cooling the heat is removed from the produce at very slow rate.

   ii) Rapid removal of field heat is called pre-cooling.

   iii) One of the primary advantages of pre-cooling is inhibition of the growth of decay causing organisms.

   iv) Relative humidity of the cooling medium plays a great role in pre-cooling.

2. What are the various methods of pre-cooling of fruits and vegetables? What is half-cooling time?

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7.3 ROLE AND METHODS OF DRYING AND CURING

One of the most important methods of reducing post-harvest losses in many root crops such as yam and sweet potato and also for onions, is the use of surface drying and curing processes. Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms. In contrast, the curing of onions, and garlic is mainly a drying process where excess moisture is removed from the outer skin and neck of the onion. At the same time, by exposing the onion to higher temperatures, the colour of the skin gets darkened and natural fungicidal compounds accumulate in the skin. Both processes together ensure the formation of protecting layer which greatly reduces water loss and serves as a physical and chemical barrier to infection.

Let us examine the mechanism involved in curing:

In most of the root and tuber crops suberization is the key process of curing. "Suberin" – a group of fatty acids imparts initial protection to water loss and infection to the harvested produce. The next important mechanism is the formation of periderm which is located below the suberized cells and formed by layer of meristematic cells. This is also called 'cork cambium' since it produces new cells that seals off the damaged areas. In the curing process deposition of suberin (suberization) in the parenchymatous cells (periderm) takes place simultaneously. The speed of suberization depends on: temperature, relative humidity and use of chemical sprout suppressant. Few cases showing the relation of temperature and humidity to the period of suberization are given below:

Factor	Effect
Curing Temperature $\geq$ 21°C	I day for suberization
Curing Temperature = 15°C	2 days for suberization
Curing Temperature = 10°C	5-8 days for suberization
Curing Temperature = 2.5°C	> 8 days for suberization
High R.H.	Better suberization
Low R.H.	Poor suberization
Use of chemical sprout suppressant	Inhibit suberization

The term curing is also sometimes used for citrus fruits. Generally, lemons are cured at 56º to 58º F (13.33–14.4º C) and 85-90% relative humidity. Green fruits may be held for 4 months or more, while the peel becomes yellow and thinner, the pulp juicier (6-80%) and the proportion of soluble solids higher (7-24%).

7.4 EFFECTS OF SPROUTING AND ITS INHIBITION

Roots, tubers and bulb crops have one common feature i.e. inflated storage organs. Containing a substantial amount of carbohydrate, protein and vitamins and minerals. Like many other fruits and vegetables, they remain active after harvest and carry out all the vital physiological and metabolic processes until its death. The high respiration rate of these crops after harvest not only brings about the compositional changes but also builds up temperature around it which in turn creates favourable conditions for the growth of microorganisms already present on these commodity. Although, these crops are not considered to be highly perishable, the severe problem of sprouting and rooting in storage limits their successful marketing.

Now, let us analyze the typical case of onion and potato. Commodities like onion and potato have buds that enter a dormant state at maturity. In this dormant stage, the plant can survive periods unfavourable to plant growth. This coincides with the appropriate stage of harvesting of these produce for orderly marketing for several months by storing them under appropriate conditions. The duration of post harvest dormancy in potato is commonly known as 'rest period'. The rest period is influenced by pre-harvest factors, maturity and variety. This is not dependent on temperature of the storage chamber in which the commodities are stored. Once the rest period ends, the sprouting begins and this is dependent on temperature of the storage environment. Sprouting of potato occurs rarely below 4°C, but storage at this temperature results in conversion of starch to sugars making the potatoes sweet. The sweetening of potato is not desirable from the point of view of processing or fresh marketing. Presence of sugars in potato adversely affect the quality of potato chips. Moreover, the consumers do not prefer the potatoes that are sweet in taste for even culinary purposes. Again, if the potatoes are stored at temperature above 4°C sprout growth will begin after 2-3 months storage. Sprouts are the new growths and comprise of highly active tissues. Therefore, sprouted potatoes quickly loose moisture, gets shrivelled and become prone to several microbial infection. Thus sprouting results in a huge post harvest losses. Apart from physical loss due to sprouting, the quality of sprouted potatoes became poor due to high respiratory utilization of substrates. Hence the control of sprouting becomes a first step in successful marketing of potato after harvest.

We will explain you the various methods of inhibition of sprouting. They are two common practices can suppress the sprouting. i.e. Use of chemical sprout suppressant either applied in the field i.e. pre-harvest application or after the harvest of the produce i.e. post harvest application and ii) Use of ionizing radiation. Maleic Hydrazide (MH-40), Nonylalcohol, 3-chloroisopropyl – N – phenylcarbamate (CIPC), Isopropyl phenylcarbamate (IPPC), methyl napthaleneacetic acid (MENA) and 2,3,4,6 tetrachloronitrobenzene (TCNB) are commonly used as sprout inhibitors. However, legal restrictions on usage of these chemical and their residual toxicity limit their use based on the legislation prevailing in a particular country. Out of these, MH is predominantly used as pre-harvest spray to control the sprouting of onion during storage.

As onions mature, tops begin to fall and dry. Sprout inhibitors are applied when onions are intended for long term storage. They are applied when tops are about 50% down, and there are 5 to 8 green leaves per bulb to absorb and translocate the sprout inhibitor. These are not applied when temperatures exceed 26-29°C to avoid crystallization on leaf surfaces. Use of a spray adjuvant is suggested. Avoid early sprays before maturity to reduce spongy onions. Maleic hydrazide (Royal MH-30) @ 0.9 Kg ai/Acre is most commonly used. Apply in sufficient water to insure adequate coverage. Most of the other chemicals are normally used as post harvest application. One should remember the fact that CIPC is one of the very stong sprout inhibitor used as post harvest application for long term storage of potato. It is applied as dust, water dip, vapour or thermofogging formulation. A normal dosage of 50 ml per one metric ton of potato is normally recommended. Potatoes become safe for consumption after about 30 days after treatment with CIPC depending on the temperature of storage. The most important advantage of CIPC treatment is the economy in saving electrical energy in cold storage since the potatoes could be safely stored at higher temperature of 10^{o}C without any sprouting or quality deterioration. Since CIPC interferes with the periderm formation, we must take care of its application only after proper curing. So far we have learnt about the chemical sprout suppressant.

Now let us learn about the use of ionizing radiation treatment to control sprouting in onion and potato. Under the present situation, use of gama irradiation @ 0.02- 0.15 kGY has been widely accepted by many countries for successful sprout inhibition of onion and potato without affecting the other quality attributes. However, the major limitation for use of irradiation is the high cost of specialized equipment, training and further more the consumer acceptability due to the fear of induced radioactivity and formation of harmful radiolysis products in irradiated produce. The report of world health organization (WHO, 1981) clearly concluded that irradiation to any food commodity to an overall average dose of 10 kGY had no toxicological hazards.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the main causes of spoilage of root, bulb and tuber crops?

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2. Explain how sprouting affects the quality of potato.

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3. What are the various methods of inhibition of sprouting of potato?

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4. Why irradiation treatments are not commercially used in India for checking sprouting of potato and onion during storage?

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7.5 WAXING AND SURFACE COATING

Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process. An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in the following objectives:

- Replacement of natural wax
- To reduce the water loss during shipment and storage
- To give a cosmetic appeal
- To cover up the minute injuries caused during post-harvest handling
- To use as a carrier of fungicide/inhibitor for better shelf life and
- To protect against decay organisms.

Sugarcane wax, carnuaba wax, shellac and various resins are common types of waxes used for-the preparation of wax-emulsion. Recently, sucrose polyester waxes are gaining popularity due to their water solubility and biodegradibility. Waxes are generally applied by foaming, spraying, dipping brushing and foaming. Foaming is a very satisfactory method since it leaves a very thin coating.

Apart from the above mentioned objectives use of surface coating and waxing creates a modified atmospheric condition between the cuticle and the coating material which reduces the physiological and metabolic activities in certain fruits. Some of the common surface coating materials used are: Semperfresh, Sta-Fresh, Citrashine, Waxol, etc.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.

   i) Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process.

   ii) An extra discontinuous layer of wax is applied to reduce the water loss during shipment and storage and to give a cosmetic appeal to the consumer.

   iii) Commonly used candles are normally used for waxing of fruits.

2. Write six important objectives of waxing or surface coating of fruits and vegetables.

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7.6 POST HARVEST DISEASE MANAGEMENT AND FUNGICIDE APPLICATION

Different types of micro-organisms can cause spoilage in storage houses. However, bacteria and fungi are the most common. Bacteria are generally propagated by direct contact between perishable goods or with contaminated surfaces, or else with the water used during treatment before or after storage**.** Some of these bacteria can be pathogenic for human as well, for e.g. as *Listeria monocytogenes.* Vegetables are mostly spoiled by bacteria due to their high pH (4.5-7.0) whereas many fruits particularly the acidic fruits (pH < 4.5) inhibits the growth of bacteria but encourage fungal spoilage. A relative humidity less than 94 to 95 % is considered low enough for growth of bacteria. Majority of the soft rots causing bacteria have their optimum temperature for growth around 30°C. The following are the major bacterial species that infect the fruits and vegetables.

Sl. No.	Commodity	Disease	Causal organism
1.	Potato	Soft rot	*Erwinia cartovora* *Bacillus subtilis* *Clostridium sp*
2.	Onion	Rot	*Pseudomonas capacia*
3.	Cabbage, Lettuce	Rot	*Pseudomonas cicorii*
4.	Cauliflower, cabbage, tomato, bean, radish	Bacterial rot	*Xanthomonas spp*
5.	Mango, plum, cherry, peach	Bacterial rot	*Xanthomonas campestris*
6.	Pineapple, papaya, Guava	Bacterial rot	*Ewrinia spp*
7.	Apples and pear	Bacterial rot	*Pseudomonas spp*

Bacteria like Erwinia and Xanthomonas are mainly disseminated by leafhoppers.

Control of bacterial diseases: Chlorine compounds added to water as chorine gas or as hypochlorite solution could be used to kill bacteria rapidly. In commercial practice, 2 per cent Na-hypochlorite or 50 to 100 mg of chlorine or 1-1.5 g/litre chlorine dioxide are frequently used to control the bacteria. Low temperature storage is considered to be the best method for controlling the bacterial diseases.

Several fungal rots are considered to be of major importance causing severe post harvest losses to fruits and vegetables. The fungus forms acervulli from which single celled conidia arise. Acervulus is a clamp or cushion of conidia bearing on hyphae called conidiophore. The conidium on germination produces aspersorium, which helps in adhering of conidia to the skin. When the hyphae from the germinating conidia penetrate the surface of the fruits (unripe) these cause rotting. Hyphae that arise from aspersoria when the fruits start ripening can colonise the tissue and cause rot. This dormancy of aspersoria has been attributed to phytoalexin production or non-availability of nutrients in unripe fruits. This process of existence of fungal organism in the dormant form called latent or quiescent infection. Some of the examples of quiescent infections are mentioned below.

Sl.No.	Commodity	Causal organism
1.	Apple	*Gloeosporium perennans,* *Diplodia perniciosa,* *Nectria galligena*
2.	Citrus	*Colletotrichum gloeosporoides*
3.	Mango	*Colletotrichum gloeosporoides*
4.	Strawberry	*Botrytis cinerea*

In quiescent infections the development of fungus is stopped at the stage of aspersoriaor colonization.

Control of Quiescent infection in fruits:

i) Strict sanitation in pack house to reduce conidial rot

ii) Avoidance of injury

iii) Post harvest dips with systemic fungicides

a) Benlate @ 100 ppm
b) Benomyl @ 100-400 ppm
c) Thiabendazole @ 200 ppm

iv) Pre-cooling or cool chain management

The other fungal diseases include:

Finger rot of banana: this is caused by Botryodiplodia theobromae. The infection starts from the tip of the finger. The infected fruits soon become soft and brown. An aqueous dip in Thiabendazole @ 200-500 ppm for few seconds can control the disease.

The next important disease of banana is the crown rot caused by several organisms viz, *Cremonium spp, Botryodiplodia theobromae, Ceratocystis paradoxa, Colletotrichum musae, Fusarium pallidoroseum, Verticillium theobromae* etc. Treating with any of the systemic fungicides mentioned above could do successful control of this disease.

Dark brown spots with concentric rings on ripe banana may be due to Monilial disease caused by *Monilia fructigena or M. lexa*. Benomyl dip @ 0.2% or Thiabendazole @1200-2400 ppm dip could successfully control the disease.

Two major diseases of mango observed during post harvest stage are: I) anthracnose: caused by Glomerella cingulata (conidial stage *Colletotrichum gloeosporoides*). The symptoms appear on ripe fruits as black spots or streaks. Hot benomyl dip @0.1% at 52°C could successfully control the disease. The stem end rot of mango is associated with Botryodiplodia theobromae and or Aspergillus niger. Typical lesion of black to brown spots extending the stem is the major symptom of the disease. Thiabendazole @ 0.1% is the best control measure of this disease. Among the other pathogen Penicillium expansum is responsible for causing diseases to many fruits and vegetables e.g. apples, citrus etc.

Three major fungal organisms are mostly associated with post harvest diseases of vegetables. These are: (i) Fusarium spp causing rots in tinda, bean, cowpea, chilli, tomato, cauliflower, potato, cucumber, pointed gourd and pumpkin. (ii) Geotrichum diseases caused by Geotrichum candidum in tomato, pointed gourd, watermelon and muskmelon. As a thumb rule, the foods containing lactic acid are attacked by this fungus and (iii) Pithium diseases caused by Pithium spp. that attack okra and cucurbits. The following are the time temperature combinations for control of the fungal organisms:

Organism	**Temperature (°C)**	**Time/duration**
Botryodiplodia. Gloeosporium, Colletotrichum, Rhizopus	43-49 (Papaya)	20
Colletotrichum, Diplodia, Aspergillus, Bortyodiolodia, Rhizopus	47-55 (Mango)	10-20
Monilia, Rhizopus	49-84 (peaches)	1.5-3.5
Alternaria, Geotrichum	48-57 (Tomatoes)	5-10

The development of mould on walls or ceilings of the storage chamber may indicate insufficient insulation or a perforated or poorly installed vapour seal. Many of these organisms feed on perishable goods and organic matter. In the absence of nutrient sources, they can survive on other materials, such as wood and plastic. When they attack organic matter, bacteria and fungi can give off foul odours (ethylene and other volatile substances) that can change the taste or accelerate the maturation of stored fruit and vegetables. Although it is difficult to completely eliminate these micro-organisms, preventive measures and an appropriate clean-up plan can control their proliferation and greatly reduce the infection rate of perishable goods in storage houses. Micro-organisms, which are present in the storage house, also on fruit and vegetables, can be eliminated with an appropriate clean-up plan. The presence of any residue of plant material in the storage chamber can allow bacteria and fungus spores to survive between two storage periods. For a clean-up plan to be effective, it must follow certain steps in a specific order. These steps are cleaning, disinfecting, rinsing and drying. The techniques and products used to carry out each step must be adapted to treatment systems and storage facilities, whose main components.

Floors, walls, ceiling, doors and structural beams; refrigeration systems electrical fixtures; water and air pipes and channels and their components (drains, grill); wooden and plastic containers reused for storage of fruit and vegetables; pallets used to handle containers; machinery used in the storage house; waste containers.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.
   i) Fruits are mainly spoiled by bacteria whereas the vegetables are spoiled be fungi.
   ii) Soft rot of potato during storage is caused by *Pseudomonas spp.*
   iii) Anthracnose and stem end rot are the two major post harvest diseases of mango.
2. Write five important steps in controlling the quiescent infection in fruit crops.

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7.7 CONTROL OF RIPENING

Ripening is a dramatic event in the life of a fruit. It transforms a physiologically mature but inedible plant organ into a visually attractive taste and smell sensation. Ripening marks the completion of development of a fruit and the commencement of senescence, and it is normally an **irreversible** event. Ripening is the result of a complex changes, many of these probably occurring independently of one another. The changes that may occur during the ripening of freshly fruit are: Seed maturation, Colour changes, abscission (detachment from parent plant), Changes in respiratory and ethylene evolution rates, alteration in tissue/cell permeability, softening, changes in organic acids, Protein changes, production of flavour volatiles and development of wax on the skin.

On the basis of the respiratory pattern and ripening behaviour fruits are classified into two classes viz. **climacteric fruits** and **non-climacteric fruits**. As a thumb rule, the fruits which are harvested at optimum maturity and undergo ripening after harvest are grouped under Climacteric fruits; whereas another group of fruits that ripen on the tree itself and does not undergo much change after harvest or undergo further ripening are grouped under non-climacteric fruits. You observe the rise in respiration during ripening of the climacteric fruits but you don't find such trend in non-climacteric fruits. Some of the examples of both the groups of fruits are mentioned below:

Climacteric fruits are:

Apple, Apricot, Avocado, Banana, Blueberry, Fig, Kiwi fruit, Mango, Papaya, Passion fruit, Peach, Pear, Persimon, Plum, Muskmelon, Watermelon and tomato.

While Non-climacteric fruits are:

Cherry, Cucumber, Grapes, Lemon, Pineapple, Mandarins, Strawberry etc.

Climacteric and non-climacteric fruits may be further differentiated by their response to applied ethylene and by their pattern of ethylene production during ripening. It has been clearly established that all fruit produces minute qualities of ethylene during development. However, on ripening, climacteric fruits produce much larger amounts of ethylene than non-climacteric ones. Ethylene, applied at a concentration as low as 0.1−1.0 micro litres per litre for one day, is normally sufficient to hasten full ripening of climacteric fruits. However, the magnitude of climacteric is relatively independent of the concentration of applied ethylene. In contrast, applied ethylene merely increases the respiration of non-climacteric fruits, the magnitude of the increase being dependent on the concentration of ethylene. There are two different systems of introduction of ethylene in the ripening room. These are:

a) ***Shot system:*** Accurately measured quantity of ethylene is introduced into the ripening room at regular intervals using a gauge which registers the discharge of ethylene in cft/min. thorough ventilation is essential.

b) ***Trickle system:*** In this system the ethylene is introduced into the room continuously, rather than intermittently, as done in the shot system.

There are three major sources of obtaining ethylene for use in the ripening room:

i) Ethylene generators: In this a liquid (probably ethanol) produces ethylene when heated in the presence of a catalyst. This is used widely for supplying ethylene in the ripening room.

ii) Ethephon: It is commercially available as Ethrel or CEPA. To release l cft of C_2H_4 requires about 7 fluid ounces of active ingredient of ethrel. The solution of ethrel should be alkaline in order to release ethylene from ethrel. The ratio of Caustic soda: ethrel is approximately 3g: 20ml for effective release of ethylene.

iii) Ripe gas: This is compressed ethylene gas in mixed with CO_2 available in compressed cylinders. The normal concentration of ethylene in the ripe gas is 6% and CO_2 is used to make it non-inflammable.

Temperature and RH management of the storage rooms are the major factors responsible for control of ripening of fruits. The commodity should be stored at appropriate temperature and RH condition for extending its green life. These stored commodities can be ripened artificially by proper combination of temperature, RH and ethylene concentration in the ripening room. Besides temperature and RH management use of Controlled Atmosphere or Modified Atmosphere packaging or storage are proved to be successful in delaying the ripening of many fruits and vegetables and thereby extending the green life for orderly marketing practices.

The ideal condition for ripening by using ethylene in some important fruits and vegetables are mentioned below:

Fruit	Temperature (°C)	Ethylene Treatment (ppm)	Time (hours)
Avocado	18-21	10	24-72
Banana	15-21	10	24
Cantaloupe	18-21	Nil	
Honeydew melon	1821	10	24
Kiwi fruit	18-21	10	24
Mango	29-31	10	24
Papaya	21-27	Nil	
Pear	15-18	10	24
Pershimon	18-21	10	24
Tomato	13-22	10	Continuous

Ethylene is a colourless gaseous hydrocarbon with a faint sweetish smell having molecular weight 28.05; its boiling point at 760mmHg is −103.7°C. The flammable limits ranges from any composition between 3.10 to 32.00 %. It is a plant growth substance and a key to ripening of fruits and Vegetables. Its production is increased during leaf fall, flower senescence and fruit ripening. In addition, stress factors such as wounding, flooding, chilling, disease, high temperatures and drought seem to induce ethylene biosynthesis.

Threshold limit for ethylene action in various fruits varies from the type of commodity, but in most cases it ranges between 0.1−1.0 ppm. The duration of exposure may vary from 12 h to 72 h for initiation of ripening but full ripening may take several days. The effectiveness of ethylene in achieving proper and more uniform ripening depends on three important factors viz. (i) stage of maturity, (ii) temperature and RH in the ripening room, and (iii) concentration and duration of exposure to ethylene. In general, the ripening of fruits occur at 18-25^{0}C, 90-95% RH with 10-100 ppm ethylene and 24-72 h exposure depending on the commodity. Ethylene can be applied through ethylene generator using ethanol or by use of ethrel/ ethephon (2-chloroethyl phosphonic acid). One must remember the fact that ripening of fruits can be initiated by many other hydrocarbons viz. acetylene, propylene etc. But the efficacy of ethylene is considered to be 100 times more than acetylene. Calcium carbide was used for ripening fruits in India as a commercial practice. However, due to its deleterious effects on human health, it has been banned in India for use in ripening.

While storing fruits and vegetables care should be taken in such a way that the actively ethylene producing commodities should not be stored along with other fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life and specific symptoms of injury. Some examples of ethylene effects include: (i) Russet spotting of lettuce along the midrib of the leaves, (ii) loss of green colour in snap beans, (iii) increased toughness in turnips and asparagus spears, (iv) bitterness in carrots and parsnips, (v) yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower, (vi) accelerated softening of cucumbers, acorn and summer squash, (vii) softening and development of off-flavour in watermelons,

(viii) browning and discoloration in eggplant pulp and seed, (ix) discoloration and off-flavour in sweet potatoes, (x) sprouting of potatoes, (xi) increased ripening and softening of mature green tomatoes and (xii) shattering of raspberries and blackberries.

7.7.1 Biological Effects of Ethylene

Some of the very important biological effects of ethylene observed in plant tissues are mentioned below:

- **Respiration –** Ethylene increases the rate of respiration in both climacteric and non-climacteric fruits
- **Ripening** – The change in fruit physiology from maturation to ripening is initiated when cellular quantities of ethylene reach a threshold level
- **Flavour** – Ethylene exposure results in development of bitter taste in carrot and beetroot
- **Toxicity** – Pea pods exposed to 0.2 to 20 ppm ethylene developed *pisatin* (a phenolic phytoalexin), which is anti-fungal compound.
- **Colour** – Ethylene exposure cause rapid breakdown of chlorophyll, increase in carotenoid and lycopene content, so colour of petals of cut flowers can be affected by ethylene.
- **Disease –** High decay was observed in presence of ethylene in celery, brinjal, cabbage, and strawberries. Ethylene stimulated spore germination of fungi, which cause rotting.
- **Sprouting –** Ethylene has an opposite effect on dormancy and stimulates the activity of other growth regulators such as gibberellins.
- **Growth –** Ethylene can stimulate the growth of harvested crops which lead to undesirable effects e.g. loss of compactness foe to increase in inter node growth in Brussels sprout.
- **Texture –** Sweet potato and asparagus develop hard texture due to increase in fiber production. In orange and pineapple softening is hastened with ethylene levels of 1.0 ppm in the store.
- **Abscission –** Fruit stalk abscission increases in the presence of ethylene.
- **Floral senescence –** Hastening of senescence of cut flowers takes place when exposed to ethylene. Sleepiness in carnation is due to presence of ethylene causing the buds failure to open. Petal abscission and blueing of rose is also due to presence of ethylene.

Besides all these deleterious effects ethylene is highly beneficial and recommended for artificial ripening and degreening of fruits without posing any health hazard. Ethylene exposed fruits show more ascorbic acid content than unexposed fruit. Hence for the purpose of extending the storage life (green life) the removal of ethylene from the storage atmosphere plays a critical role for orderly marketing. However application of ethylene finds a good place on removal from store and during marketing.

Ethylene from the storage chamber can be removed by the following means: (i) elimination of source i.e. IC-engines, (ii) ventilation (iii) use of chemical scrubbing system e.g. $KMnO_4$ impregnated vermiculite / celite blocks (purafil), ozone, brominated or activated charcoal (iv) use of bacterial system e.g. *Mycobacterium* (v) hyobaric storage (vi) controlled atmosphere storage and (vii) by use of specific antiethylene compounds e.g. Silver nitrate. (Hydroxy quinolene citrate)HQC, HQS (H Hydroxy quinolene sulfate), Rhizotoxin and its analogues.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks with appropriate word (s).

   i) On the basis of the respiratory pattern and ripening behaviour fruits are classified into two classes viz.___________ fruits and _______________ fruits.

   ii) Ripening marks the completion of fruit _______________ and the commencement of ___________and it is normally an _____________ event.

2. What are the different methods of artificial ripening of fruits? Explain in detail.

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3. Mention the different methods of removal of ethylene from the storage room

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7.8 LET US SUM UP

We should clearly remember that the fruits, vegetables and flowers after harvest remain alive and undergo high rate of physiological and metabolic activities i.e. increased rate of respiration, transpiration. Hence pre-treatments viz. Curing, Pre-Cooling, Inhibition of sprouting and fungicide application play a very crucial role to prolong the storage life of horticultural produce.

Pre-cooling is the process of rapid removal of field heat/respiratory heat, usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before storage or before processing depending on the commodity. This is the first step of good temperature management.

Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms. In contrast, the curing of onions, and garlic is mainly a drying process where excess moisture is removed from the outer skin and neck of the onion. Sprouting results in a huge post harvest losses. Apart from physical loss due to sprouting, the quality of sprouted potatoes became poor due to high respiratory utilization of substrates. Hence the control of sprouting becomes a first step in successful marketing of potato after harvest

Vegetables are mostly spoiled by bacteria due to their high pH (4.5-7.0) whereas many fruits particularly the acidic fruits (pH < 4.5) inhibits the growth of bacteria but encourage fungal spoilage. A relative humidity less than 94 to 95% is considered low enough for growth of bacteria. Majority of the soft rots causing bacteria have their optimum temperature for growth around 30°C.

Ripening marks the completion of development of a fruit and the commencement of senescence, and it is normally an **irreversible** event. Temperature and RH management of the storage rooms are the major factors responsible for control of ripening of fruits.

Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process. An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in the following objectives: Replacement of natural wax; to reduce the water loss during shipment and storage, to give a cosmetic appeal to the consumer, to cover up the minute injuries caused during post-harvest handling, to use as a carrier of fungicide/inhibitor for better shelf life and to protect against decay organisms.

7.9 KEY WORDS

Curing : Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms.

Pre-cooling : Pre-cooling is the process of rapid removal of field heat/respiratory heat usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before storage or before processing depending on the commodity.

Sprouting : Commodities like onion and potato have buds that enter a dormant state at maturity. The duration of post harvest dormancy in potato is commonly known as ‘rest period’. Once the rest period ends, the sprouting begins. This process of breaking the dormancy is known as sprouting.

Latent infection : The process of existence of fungal organism in the dormant form called latent or quiescent infection.

Climacteric fruits : As a thumb rule the fruits which are harvested at optimum maturity and undergo ripening after harvest are grouped under Climacteric fruits.

Non-climacteric fruits: Group of fruits that ripen on the tree itself and does not undergo much change after harvest or undergo further ripening are grouped under non-climacteric fruits.

Ripening : Ripening is a dramatic event in the life of a fruit. It transforms a physiologically mature but inedible plant organ into a visually attractive taste and smell sensation.

Waxing/surface coating : An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in order to replace natural wax lost during washing, reduce the water loss, give a cosmetic appeal, cover up the minute injuries, use as a carrier of fungicide and protect against decay organisms.

7.10 ANSWERS TO CHECK YOUR PROGRESS EXCERCISES

✍

Check Your Progress Exercise 1

1. i) × ii) √ iii) √ iv) √
2. See sec 7.2. Your answer should include hydro cooling, room cooling, forced air cooling, package icing, vacuum cooling, alternate cooling. Definition of half-cooling time.

Check Your Progress Exercise 2

1. Your answer should include sprouting, rooting, rotting; See sec. 7.4.
2. See sec 7.4, Your answer should include increase in sweetness, loss in marketability, shrivelling, increased respiratory rate and aggravate rotting
3. See Sec. 7.4, your answer should include i) Use of chemical sprout suppressant as pre-harvest application or post harvest application and ii) Use of gama irradiation @ 0.02- 0.15 kGY. Maleic Hydrazide (MH-40) 3-chloroisopropyl–N–phenylcarbamate (CIPC), Isopropyl phenylcarbamate (IPPC), methyl napthaleneacetic acid (MENA) and 2,3,4,6 tetrachloronitrobenzene (TCNB).
4. See Sec. 7.4 , your answer should include high cost of specialized equipment, training , consumer acceptability due to the fear of induced radioactivity and formation of harmful radiolysis products in irradiated produce.

Check Your Progress Exercise 3

1. i) √ ii) √ iii) ×

2. See Sec. 7.5.

Check Your Progress Exercise 4

1. i) × ii) × iii) √

2. See Sec. 7.5. Your answer should include: sanitation of pack house, avoidance of injury, post harvest dips with systemic fungicides, pre-cooling or cool chain management.

Check Your Progress Exercise 5

1. i) Climacteric, Non-climacteric; ii) development , senescence

2. See Sec. 7.6, your answer should include use of ethrel, ethylene gas and calcium carbide, different methods of application of ethylene, temperature effect etc.

3. See Sec. 7.5, your answer should include (i) elimination of source i.e. IC-engines, (ii) ventilation (iii) use of chemical scrubbing system e.g. $KMnO_4$ impregnated vermiculite/celite blocks (purafil), ozone, brominated or activated charcoal (iv) use of bacterial system e.g. *Mycobacterium* (v) hyobaric storage (vi) controlled atmosphere storage and (vii) by use of specific antiethylene compounds

7.11 SOME USEFUL BOOKS

1. Burton, W.G. (1982) Post-harvest physiology of food crops. London and New York: Longman. 339 pp.

2. Dennis, C. (1983) Post-harvest pathology of fruits and vegetables. London: Academic Press. 264 pp.

3. Pantastico, Er. B. (ed.) (1975) Post-harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. Westport, CT: A VI Publ. Co. 560 pp.

4. Wills, R.H.H., Lee, T.H., Graham, De., McGlasson, W.B. and Hall, E.G. (1981) Post-harvest: An introduction to the physiology and handling of fruit and vegetables. Westport, CT: A VI Publ. Co. 163 pp.

UNIT 10 MARKET AND MARKET MECHANIZATION

Structure

10.0 OBJECTIVES

After reading this unit, you should be able to understand:

- concept of markets;
- what role markets play in economic development?;
- various classifications of markets and marketing channels;
- various types of market functions that are performed in the marketing and role of market middlemen;
- marketing efficiency and how to measure marketing efficiency; and
- what is meant by market mechanization, its role and scope?

10.1 INTRODUCTION

In the traditional subsistent society, most of the people earned their livelihood from land and had little left for marketing. This marketable surplus was exchanged locally only. The distance between producers and consumers was less. Small quantities of commodities were transported as head loads to places of demand. There were limited varieties of commodities brought to market. The commodities were normally sold in raw form and seasonally only. Roads were not developed and time was not properly valued. All the marketing services were performed manually. However, slowly and slowly market centres developed where bulk of commodities started flowing in. The urbanization further helped in establishing big markets. However, with a larger proportion of commodities moving to urban markets and more proportions available for commercial markets, certain kinds of problems, characteristic to the stage of development, also became apparent.

With the stage of development, the income of the people increased the demand for better markets and better marketing services also increased. A wide range of variety of commodities also developed. Those producers who could meet the consumers' demands, gained. The part of gain was further invested for improving marketing facilities and services. Government also helped in establishing the modern markets.

However, there were many problems too. With the increase in population and further increase in income and urbanization, the demand for fast marketing services increased. The limited supply of increased marketing services could not keep the pace with demand. Thus the need for the mechanization of the markets was felt to meet the demand, promptly.

Transportation in the market itself became fast. Well developed countries today have mechanical grading, packing, stitching and loading and unloading of the commodities in the market places. The weighing machines immediately weighs the commodities accurately even to fractions. A similar mechanized system is needed to move manufactured inputs to farm from urban areas where they are produced.

10.2 CONCEPT AND DEFINITIONS

In any market oriented economy, the production is mainly for sale to the consumers. The direct sale of the producer to the consumer can bring higher price to him. But the search of consumers for direct sale is normally costly. The direct sale to consumers is not possible by every producer especially when producer faces shortage of labour and time. The market place serves a better outlet, in such situation, where more amounts can be sold with less labour and time. It is in this context that the formal markets with modern facilities, especially for agricultural produce are of paramount importance in agricultural countries like India.

Traditionally, a "market" was a physical place where buyers and sellers gathered to exchange goods. A market includes any area/place where the people assemble for sale and purchase of the commodities that satisfy their demand. Thus, it is an area in which the demand and supply forces operate.

Economists describe a market as a collection of buyers and sellers who transact over a particular product. But marketers view the sellers as constituting the industry and the buyers as constituting the market. Business people often use the term markets to cover various groupings of customers such as product markets (the shoe market); demographic markets (the youth market); and geographic markets (the Indian market).

The traditional boundary of the market in terms of place is now relaxed. We can distinguish between a marketplace and a market space. The marketplace is physical, as one goes shopping in a store; market space is digital, as when one goes shopping on the Internet. Many observers believe that an increasing amount of purchasing will shift from the marketplace. Today, each nation's economy and the global economy consist of complex interacting sets of markets linked through exchange processes.

Thus, the term market means not a particular market place in which things are bought and sold but the whole of any region in which buyers and sellers are in such a free intercourse with one another that the prices of the same good tend to equality, easily and quickly. Therefore, a market is defined in terms of existence of fundamental forces of supply and demand and is not necessarily confined to a place.

Some necessary conditions for a market to exist are:

- Reference of the commodity
- Existence of buyers as well as sellers
- Existence of business relationship between buyers and sellers.
- Medium of exchange.

Thus, market is an arena for organizing and facilitating business activities and for answering the economic questions: What to produce, how much to produce and how to distribute? The marketing on the other hand is performance of all business activities involved in flow of goods and services associated with inputs and output from initial point of production to ultimate consumers.

10.3 ROLE OF MARKETS

The markets provide most convenient outlet for producers and consumers. These provide livelihood to various people who perform different kinds of activities /functions. Since, the commodity prices are principal factors affecting the level of living of both producers and consumers in developing counties, it is often desirable to measure the returns to the farmers and also lower cost to consumers in order to raise their standard of living. Well organized/ regulated and managed market does not permit malpractices.

Free markets play a very important role in the development of a country by providing the right direction to the resources' use and fulfil the demand of all types of consumers and producers of variety of goods. They operate to make a variety of products to targeted consumers at various places in desired form and conditions and deliver to those who are willing to pay reasonably.

Well developed marketing system in rural areas will further add to increase the market for industrial goods. Thus, a good marketing system acts as a motivating force for development of a country. The market demand will signal the, production and the employment and profitability.

It is important to note that an efficient, viable marketing system can not be realized without institutions which provide financing , assume risk, aid exchange by impartially mediating set weight and measures, grades and standards and help to disseminate market facts.

10.4 TYPES OF MARKETS

Markets are of various types and can be divided on various bases. Some of the basis on which, agricultural markets can be classified are given below:

Classification of Markets:

10.4.1 On the Basis of Location

On the basis of the place or location or operation, markets are of the following types:

a) *Village markets:* A market which is located in a small village, where major transactions take place among the buyers and sellers of a village, is called a village market.

b) *Primary wholesale markets:* These markets are located in big towns near the centres of production of agricultural commodities. In these markets, a major part of the produce is brought for sale by the producers-farmers themselves. Transactions in these markets usually take place between the farmers and traders.

c) *Secondary wholesale markets:* These markets are located generally in district headquarters or important trade centres or near railway junctions. The major transactions of commodities take place between the village traders and wholesalers. The bulk of arrival in this market is from other markets.

d) *Terminal markets:* The terminal markets are those in which goods produced are finally either sold to the consumers/processors or assembled for export. Such markets are located either in cities or near sea ports.

e) *Seaboard markets:* These markets are located near seashore. These are mainly for exports/imports. Such markets are Mumbai, Kolkata and Chennai.

10.4.2 On the Basis of Area Covered

On the basis of the area from which buyers and sellers usually come for transactions, markets may be classified into the following four classes:

a) *Local or village markets:* This covers a village/local area. In this type of market the buying and selling activities are confined among the buyers and sellers drawn from the same village or nearby villages. The village markets exist mostly for perishable commodities in small lots, e.g., egg market, local milk market or vegetable market.

b) *Regional markets:* Regional market is one in which buyers and sellers for a commodity are drawn from a larger area than the local markets. Regional markets in India usually exist for food grains such as Moga market for wheat.

c) *National markets:* A market in which buyers and sellers are at the. National level. National markets are found for durable goods like spices, jute and tea.

d) *World market:* The buyers and sellers are drawn from the whole world. These are the biggest markets from the area point of view. These markets exist in the commodities which have a worldwide demand and/or supply, such as coffee, machinery, gold, silver, etc.

10.4.3 On the Basis of Time Span

The markets can be classified on the basis of the duration for which they work.

a) *Short-period markets:* The markets which are held only for a few hours are called short-period markets. The highly perishable commodity/ products assemble at a place near village or city to market the produce like fish, vegetables and in these markets, the prices of commodities are governed mainly by the extent of demand for, rather than by the supply of, the commodity.

   There are weekly markets in many places where all commodities including agricultural commodities are sold at a particular day in a week.

b) *Long-period markets:* These markets are held for a longer period than the short-period markets. The commodities traded in these markets are less perishable and can be stored for longer time. These are food grains and oi1seeds. The prices are governed both by the supply and demand forces.

c) *Secular markets:* These markets are of a permanent nature. The commodities traded in these markets are durable in nature and can be stored for many years. Examples are markets for machinery, manufactured goods.

10.4.4 On the Basis of Volume of Transactions

The markets on the basis of volume of transactions at a time can be divided into two.

a) *Wholesale markets:* A wholesale market is one in which commodities are bought and sold in large quantities or in bulk. The farm produce from far off places is normally sold to wholesaler here. However, transactions take place between traders also.

b) *Retail markets:* Transactions in these markets take place between retailers and final consumers. The retailer purchase in wholesale market and sell in small lots to the consumers as per their requirements. These markets are very near to the consumers.

10.4.5 On the Basis of Nature of Transactions

The markets can also be classified on the basis of nature of transaction. These markets are of two types

a) *Spot or cash markets:* A market in which goods are exchanged for money on the spot is called the spot or cash market.

b) *Forward markets:* A market in which the purchase and sale of a commodity takes place at time 't' but the exchange of the commodity takes place on some specified date in future i.e., time t + 1. Sometimes even on the specified date in the future (t + 1), there may not be any exchange of the commodity. Instead, the difference in the purchase and sale prices are paid or taken.

10.4.6 On the Basis of Degree of Competition

The market can be classified on the basis of competition of exchange of commodity between buyers and sellers. On the basis of competition, markets may be classified into the following categories:

Perfect Markets: A perfect market is one in which the following conditions are satisfied:

i) Large number of buyers and sellers exist.

ii) All the buyers and sellers in the market have perfect knowledge of prices.

iii) Prices of homogeneous goods at any time are uniform over a geographical area, plus or minus the cost of getting supplies from surplus to deficit areas.

iv) The prices are uniform at any place over periods of time, plus or minus the cost of storage from one period to another.

v) The prices of different forms of a product are uniform, plus or minus the cost of converting the product from one form to another.

vi) There is free entry and exit of the buyers and sellers.

Imperfect Markets: The markets in which perfect competition conditions lack are characterized as imperfect markets. The following situations, each based on the degree of imperfection, are normally identified:

a) *Monopoly market:* Pure Monopoly is a market situation in which there is only one seller of a commodity. He exercises sole control over the quantity or price of the commodity. In this market, the price of a commodity is generally higher than in other markets. But when there is only one buyer of a product, the market is termed as a Monopsony market.

b) *Duopoly market:* A duopoly market is one which has only two sellers of a commodity. They mutually agree to charge a common price which is higher than the hypothetical price in a perfect market. The market situation in which there are only two buyers of a commodity is known as the duopsony market.

c) *Oligopoly market:* A market in which there are more than two but still a few sellers of a commodity is termed as an oligopoly market. A market having a few (more than two) buyers is known as oligopsony market.

d) Monopolistic competition: When a large number of sellers deal in heterogeneous or differentiated form of a commodity, the situation is called monopolistic competition. The difference is made conspicuous by different trade marks on the product. Different prices prevail for the same basic product. Examples of monopolistic competition faced by farmers may be drawn from the input markets. For example, they have to choose between various makes of insecticides, pump sets, fertilizers and equipment.

10.4.7 Classification of the Market on the Basis of Public Intervention

Based on the extent of public intervention, markets may be placed in anyone of the following two classes:

a) *Regulated markets:* Markets in which business is done in accordance with the rules and regulations framed by the statutory market organization. Standards, grades and charges in such markets are fixed.

b) *Unregulated markets:* There are no official rules, regulation and public controls. The market rules etc. are made by the private parties only, in these markets.

10.5 MARKETING FUNCTIONS

Each of marketing function is a major specialized activity performed in accomplishing the marketing process. The list of the marketing functions differs among the writers. However, we shall follow a fairly widely accepted classification of functions, as follows:

A. Exchange functions:

1. Buying (assembling)
2. Selling

B. Physical functions:

1. Storage
2. Transportation
3. Processing

C. Facilitating functions:

1. Standardization
2. Financing
3. Risk-bearing
4. Market intelligence

The ***exchange functions*** are the activities involved in the transfer of title to goods. They represent the point at which price is determined during marketing. These functions are never performed in our economy without a judgment of value, usually expressed at least partially as a price, being placed on the goods. Both the buying and selling functions have as their primary objective, the negotiation of favourable terms of exchange.

The ***buying*** *function* is largely, one of seeking out the sources of supply, assembling of products, and the activities associated with purchase. This function can be either the assembling of the raw products from the production areas or the assembling of finished products into the hands of other middlemen in order to meet the demands of the ultimate consumer.

The ***selling*** *function* includes most of the physical arrangements of display of goods. Advertising and other promotional devices to influence or create demands are also part of the selling function. The decision like proper unit of sale, the proper packages, the best marketing channel, the proper time and place to approach potential buyers can be included in the selling function.

The ***physical functions*** are those activities that involve handling, movement, and physical change of the actual commodity itself. They are involved in solving the problems of when, what, and where, in marketing process.

The *storage function* is primarily concerned with making goods available at the desired time. The owners of a product hold large quantities of raw materials until they are needed for further processing. It may be the holding of supplies of finished goods as the inventories of processor, wholesalers and retailers.

The *transportation function* is primarily concerned with making goods available at the proper place. Adequate performance of this function requires the weighing of alternatives of routes and modes of transportation as they affect transportation costs. It includes the activities involved in preparation for shipment, also.

The *processing* function is often excluded in the list of marketing functions because it is a form-changing activity. However, in the broad view of agricultural marketing this activity cannot be omitted. The processing function would include all those essential manufacturing activities that change the basic form of the product, such as converting fresh peas into canned or frozen peas, or wheat into flour and finally into bread.

The ***facilitating*** f**unctions** are those that help in smooth performance of the exchange and physical functions. These activities are not directly involved in either the exchange of title or the physical handling of products. However, without them, the modern marketing system would not be possible. These functions serve as the grease that makes the wheels of the marketing machine go round.

The *standardization function* is the establishment and maintenance of uniform measurements. These may be measurements of both quality and quantity. This function simplifies buying and selling, because it makes the sale by sample and description, possible. It, therefore, is one of the activities that make possible mass selling. Effective standardization is basic to an efficient pricing process. A consumer directed system assumes that the consumer will make his wants known largely through price differentials. These differentials must then be passed back through the marketing channel so that marketing agencies and producers can know what is wanted. Well-defined units of quality and quantity of a commodity can fetch a better price. Standardization also simplifies grouping of similar lots of commodities at producing points. After their establishment, the use of standards must be policed. Such activities as quality control in processing plants and inspections to maintain the standards in the marketing channel can be considered part of this function. In addition, certain aspects of the packaging activity are a standardization procedure of units of sale as well as being part of the merchandising activity of the selling function.

The *financing function* is the advancing of money to carry out the various aspects of marketing. The capital is tied up between the time of the first sale of raw products and the sale of finished goods to the ultimate consumer. Someone must finance this holding of goods. The period may vary from 3 months for perishable and more than six months for semi perishable products. Financing may be from various lending agencies or owner's capital resources. In either instance, it is a necessary activity in modern marketing.

The *risk-bearing function* is the accepting the risk of loss in the marketing of a product. These risks are physical risks and market risks. The physical risks are those that occur from destruction or deterioration of the product itself by fire, accident, wind, earthquakes, cold, and heat. Market risks are those that occur because of the changes in value of a product as it is marketed. An unfavourable movement in prices might result in high inventory losses. A change in consumer taste might reduce the desirability of the product. A change in competitors marketing situation might result in a loss of customers. All these risks in varying degrees must be borne in the marketing of a product. Risk-bearing may take a more conventional form, such as the use of insurance companies in the case of physical risks or utilizes the future exchanges in the case of price risks. Or, as is often true, the entrepreneur himself may bear the risk without the aid of any of these specialized agencies. The function of risk-bearing is often confused with the function of finance. Their differences can be kept clear, however, if it is remembered that the need for financing arises because of the time lag between the purchase and sale of products, thus the need for risk-bearing arises because of the possibility of loss during the holding period (unlike the function of financing which is because of time lag between purchases and sales).

The *market intelligence function* involves collecting, interpreting, and disseminating the large variety of data necessary for the smooth operation of the marketing processes. Efficient marketing cannot operate in an information vacuum. An effective pricing mechanism depends on well-informed buyers and sellers. Successful decisions on how much to pay for commodities or what kind of pricing policy to use in the sale require a large amount of market knowledge. Adequate storage programs, an efficient transportation service, and an adequate standardization program, all depend to a considerable extent on good information. As with other functions, this function may be performed by those who specialize in its performance. On the other hand, everyone in the marketing process who buys and sells products, evaluates available market data and therefore tries to perform this function efficiently.

10.6 MARKETING CHANNELS

Marketing channels may be defined as alternative route of product flow from producer to consumers. Or, we may define marketing channels as the set of various agents/ firms/ individuals that take title or assist in transferring goods/services as it moves from producer to the final consumer.

The analysis of marketing channels is intended to provide a systematic knowledge of the flow of goods and services from their origin (producer) to their final destination (consumer). This knowledge is acquired by studying the "participants" in the process, i.e., those who perform physical marketing functions in order to obtain economic benefits. In carrying out these functions, marketing agents achieve both personal and social goals. They earn a (personal) financial reward by performing an activity desired by society. They add value to product and in doing so help satisfy customers' needs. The price the consumer pays for the goods (the physical commodity) and services (e.g., storage, transportation, bulk-bearing, grading) rendered, compensates the marketing agent for his efforts. This price also serves as a signal to all the actors in the marketing channel, i.e., producers, rural assemblers, transporters, wholesalers, and retailers etc.

Producers and consumers are part of all marketing channels. The number of intermediaries in between these two will indicate the length of channel. For example:

Zero level – producer → consumer

One level – producer → whole seller → consumer

Three level – producer → miller → whole seller → consumer

The following marketing channels for general food grains in India.

Some common marketing channels for wheat have been identified as follows:

a) Farmer to consumer;
b) Farmer to retailer or village trader to consumer;
c) Farmer to wholesaler to retailer to consumer;
d) Farmer to village trader to wholesaler to retailer to consumer;
e) Farmer to co-operative marketing society to retailer to consumer;
f) Farmer to a government agency (FCI, etc.) to fair price shop-owner to consumer;
g) Farmer to wholesaler to flour miller to retailer to consumer.

The channels of paddy-rice and pulses are broadly the same, except that rice millers or dal millers come into the picture before the produce reaches retailers or consumers.

10.7 THE PERFECT MARKET CONCEPT

The general nature of these market structures is familiar- perfect knowledge, no lag, large no. of firms, stadardised or homogenous products, and no exercise of monopoly powers. Actually the requirements for a perfect market are some what less restrictive. The essential conditions are:

1. Large no. of buyers and sellers are there in the market
2. Perfect knowledge by all buyers and sellers
3. Each buyer and seller acts in an economically "rational" way, disregarding any influence of his actions on price, and
4. Free entry in all directions.

Of course, all markets in real life operate with some degree of imperfect knowledge and with lags and frictions, and some have important elements of monopoly. In spite of this, the concept of the perfect market is important. Its abstraction permits us to focus attention on and to understand the general nature of many market forces. It is a fair approximation to reality in some markets and, perhaps, especially for many agricultural markets. It has some "normative" values associated with the concept of economic efficiency and so, may be useful in economic planning. Finally, it provides an essential background for understanding imperfect markets.

10.8 ROLE OF MIDDLEMAN

Middlemen are those individuals who specialize in various marketing functions involved in sale and purchase of goods as the commodity moves from producers to consumers. They may operate as individual, partner proprietors, co-operatives or non cooperative corporations. The activities and functions that most people visualize as "agricultural marketing" are those related to the movement of commodities from primary producers through to ultimate consumers. Some farm commodities move directly to ultimate consumers, but most of products require some additional sorting, grading, storing, and processing before they are ready for consumption. Transportation and handling takes place as commodities move from one stage to another in the marketing system. Storing and processing may take place at several different stages. This involves expenditure. In fact, marketing process is expensive. Nearly 40 percent of costs are the marketing costs. In case of perishables, the marketing cost is very high.

Many people in developing countries see the activities being performed by middlemen, add little value but charge heavily. It is reported in many studies that there are excessive "hands" in the marketing process, but most recognize that the marketing functions of transporting, storing, and processing, and the provision of place, time, and form utility, are essential – whoever performs them.

Often, marketers or middlemen are looked upon as parasites in the economy. They do, however perform essential functions and the system should permit equitable earnings for those performing needed services. Thus, The marketing systems provide a livelihood for people who perform the various marketing activities, and should yield reasonable returns to the capital and management skills devoted to them. Transportation and storage provide place and time utility--bringing goods to the people where and when they want it. Processing increases form utility—preserving the life of commodities like food and making them available in more convenient ways. It matters little who performs these kinds of functions—the farmer himself or his wife who sells their commodities in the market place, his cooperative association or a marketing board, the trucker or miller or baker. All have a right to expect payment for their services and some return on their investment in facilities needed to perform the services. As marketing organizations grow in size, requiring more capital and specialized management, returns on investment and payment for management skills become increasingly important in the interest of efficient market performance.

In India, various middlemen, in agricultural marketing, who perform marketing activities in between producers and consumers can be classified as

I. Agent Middlemen
   1. Brokers
   2. Commission agents

II. Merchant middlemen
   1. Wholesale traders
   2. Retailers

III. Speculative middlemen

IV. Processors and manufacturers

V. Facilitative middleman.
   1. Hamals/Labour
   2. Weighmen
   3. Transporters
   4. Graders
   5. Communication agencies
   6. Advertising agencies

Their description is as follows:

I) *Agent Middlemen:* These are those individuals/agencies which act as representatives of their clients like traders or producers. They earn their income through sale of their specialised services. They charge commission/ brokerage in sale or purchase activities. These are of two types namely brokers and commission agents. The difference between two is very little.

1. *Brokers:* These agents work for a commission on behalf of other participants. They operate at all levels in marketing chain. Typically, they work for a flat rate or percentage (of the selling price)/ commission. They charge brokerage from buyers/sellers or both depending on services provided by them. They bring together the sellers and buyers. They do not work in regulated markets and where the sale is through open auction method. They do not have establishments in the markets.

2. *Commission agents:* They are usually granted broad powers by those who send commodities to him. They normally take over physical handling of products, arrange for the terms of sale, deduct their fee from the sale proceeds and remit the balance to sellers/farm producer. They also advance loan to the farmers/itinerant traders on the condition that produce to be sold will be routed through them. Commission agents are of two types namely Kuchha Arhtya and Pucca Arhtya. Pucca Arhtyas normally acts on behalf of wholesalers/traders/ processors/oil millers who purchase the quantity in bulk through these commission agents. They have their shop, godown and also some times guest house of their own for the farmers in the markets, they act as 'A' class traders.

II) *Merchant Middlemen:* These are those individuals who purchase and sell the products on their own and bear the market risk. These are mainly of two types:

1. *Wholesalers:* These traders purchase in bulk either at their own in the market or from producers/ itinerant traders or through commission agents. They sell to the retailers/processors or dispatch to other markets also. They bear the market risk.

2. *Retailers:* Retailers are those traders who normally purchase from the wholesalers either on cash or credit. They divide up large amount of produce purchased and sell it to consumers in small units. They also bear the market risk.

   Itinerant traders/village merchants are also in this category who purchase the produce from those producers/farmers, who do not want to go to markets for various reasons, and sell produce in the nearby market on some profit. They keep them aware of daily market prices.

III)*Speculative Middlemen:* These **are** those who speculate and take advantage of price movement in the market. Speculative middlemen seek out and specialize in taking price risks and usually do not handle and merchandise. They often attempt to earn their profits from short-run fluctuations in prices. Purchases and sales are usually made at the same level in the marketing channel. For example, a speculator merchant may buy a product/commodity today and sell it back either today or tomorrow in the same market. They may buy and sell commodities in futures several times within the same day. They are professional risk takers unlike merchant middlemen.

IV) Processors and Manufacturers: These undertake processing activities and thus add form utility in raw or semi-finished products. They many times, use their own buying agents in the producing areas. This group may undertake processing or manufacturing and then wholesaling of their finished products to retailers. Many processors attempt to reach the ultimate consumer through advertising.

The restaurant most often is a retailing establishment in that it sells to final consumers. However, some of these businesses operate as wholesalers, preparing food in large quantities and selling to other retail outlets. And of course these businesses are, because of their preparation and cooking activities, processors.

V) Facilitative Organizations: These organizations aid the various middlemen in performing their tasks. They do not directly participate in the marketing processes either as merchants, agents, processors or speculators. One group of these organizations furnishes the physical facilities for the handling of products. They also aid in grading, arranging and transmitting payment etc.

1. *Hamal/labour:* These load/ unload the products from vehicles and move them in the markets. They receive their incomes from their physical labour use.

2. *Weighmen:* The weighmen weigh the products in the market and get payment for that.

3. *Transporters:* These move commodities from production point and transport those to consuming points.

4. *Graders:* These facilitate in making the products uniform for better pricing. They charge for their labour used in grading.

5. *Communication agencies:* They help in providing information on various aspects of marketing, including price and arrival information in a market or at different markets.

10.9 MARKETING EFFICIENCY

Marketing efficiency is a degree of market performance. Marketing efficiency is the ratio of market output (satisfaction) to marketing input (cost of resources). An increase in this ratio represents an improvement in the efficiency. The reduction in the cost for same level of satisfaction or an increase in the satisfaction at a given cost results in the improvement in the efficiency. Clark, defined marketing efficiency as having following three components:

i) The effectiveness with which a marketing service is performed.

ii) The cost at which the service is performed.

iii) The effect of this cost and the method of performing the service.

10.9.1 Types of Marketing Efficiency

Traditional efficiency of the marketing system has been looked at two angles:

a) *Pricing efficiency or allocative efficiency*

   The pricing efficiency is concerned with improving the operation of buying, selling, and pricing aspects of marketing process, so that it remains responsive to the consumers' directions. The best measure of the consumer satisfaction obtained, from marketing systems output, is what the consumers are willing to pay for it in the market place. If markets are operating efficiently, the prices of the different commodities are related to space, time and form. The prices should not differ among geographical regions, transportation cost and storage cost. Similarly it should not exceed more than the cost of processing. If it differs more than that, then the pricing efficiency is low.

   Therefore, pricing or economic efficiency relates to functional deficiency or degree of competition or monopoly. Government needs to police the conduct to prohibit collusion or any other act that hurts the competitive performance.

b) *Operating or technical efficiency*

   It indicates use of technology in providing marketing services. In contrast to pricing or economic efficiency, operational or technical efficiency assumes that the output of goods and services is given and focuses on reducing the costs of providing them. For example more efficient use of machine for sorting and grading will reduce the cost of grading. If these costs are lowered, keeping the services at the same level, bulk transport using efficient mode of transport, will reduce the operational cost. Both of above two types of efficiencies reinforce each other for better efficiency.

For example, if in market A cost of say grading is Rs 1.00 per kg and in market B cost of grading is Rs 1.20 per kg, then market A is operating efficiently in respect of grading.

10.9.2 Methods to Measure Marketing Efficiency

Both types of above efficiencies can be reflected in terms of value added and the costs. The marketing services provided will add to the value and the cost involved in providing the service. Thus we can work out the index of output to input for any of the market in order to assess the marketing efficiency. However it is very difficult to assess the services provided in value terms. In other words, it is difficult to assess the value added by an activity during the marketing. However, evaluation of cost is relatively easy.

Index of marketing,

$$E = O/I$$

Where E is the index of marketing efficiency, O is the output (value added or the services provided) and I is the input cost.

Total value added in a marketing system can be taken as the difference in the price of product paid by the consumer and the price received by the producer. If we want to compare the efficiency for two different markets located at a distance, we need to work out this index for both market and see which of the two is an efficient market. Obviously, wherever the index will be more, that market will be efficient comparatively, provided, same type of services are provided. The difference in output and also in input may be due to difference in the technology used or the market competition itself. We also need to find the imperfection in competition. In imperfect market, the prices of output are more due to undue profit charges.

A modified version of marketing efficiency (ME) as given by Shepherd is given below:

$$ME = (V - I)/I$$

Where V is Price paid by consumer, I is the input cost. In this method the difficulty in value added by marketing services is overcome. However, the formula remains the same if approximation is used for value added.

We compare the efficiency of different markets, marketing channels using this method.

10.10 MARKET MECHANISATION – CONCEPT, ROLE AND SCOPE

Mechanization of marketing operations has become popular in almost every human activity. However, the pace of mechanization in India in respect of marketing is slow. Mechanization in crop production has been spectacular especially on large farms. It has also saved farmers from the drudgery of farm operations. Mechanical market operations differ for different commodities. In view of urgency, the farmers have now become commercial minded and therefore the production has also increased. The marketable and marketed surplus of all types of crops has increased. This has created over crowding and congestion in the markets, especially those of food grains.

10.10.1 Role

Higher marketed and marketable surplus of almost all agricultural commodities including fruits and vegetables has expanded the arrivals in the markets. But Indian markets are normally congested. High arrivals have made them more congested especially when commodities do not move faster due to slow and time consuming marketing operation. Mechanisation of various marketing operations in such situation (like that in crop production) is the only answer for swift movement and clearing the markets. The role can be easily seen through followings:

1. The precision in operation by manual labour is not possible. This calls for mechanization so that more uniform goods are available to consumer. This will also facilitate other marketing operations.

2. The operations by manual labour are very costly. But the mechanical operations perform these various activities at reasonable cost. This will help the consumer more.

3. Fast transport of commodities from very far-off places is possible through rail and highways. This will also help the farmers in taking advantage of higher price in a particular market.

4. Drudgery of marketing operation drastically reduces.

10.10.2 Scope

Market mechanization in India is very slow and need special attention for providing variety of services. Today, variety of services with swiftness and that too at low cost are extremely important. All of these could be achieved, provided we go for mechanization. The mechanization for different commodities may differ. The perishable commodities like fruits and vegetables need different kind of mechanization compared to food grains.

Sorting, grading weighing, bagging, stitching and use of conveyor will be very effective in improving operations in the markets. While time saving mechanization is important in perishable commodities like fruits and vegetable etc. less costly operation are needed for non-perishable commodities which are dealt in bulk. Mechanical operations at all marketing stages including mixing of chemicals in the commodities kept in storage (if needed) will reduce the cost tremendously. Thus, there is tremendous scope for marketing mechanization which will enable the marketing functionaries to provide the marketing services with swiftness, at low cost and well in time. It will also help in decongestion of the agricultural markets to a large extent.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. a) Define a market.

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b) What are the necessary condition for market to exist?

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c) What is the role of markets in farm economy in India?

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2. a) Classify the markets on the basis of location.

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b) Write in brief the concept of perfect market.

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3. a) What is meant by marketing channels?

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b) Write various marketing channels of vegetables in nearby market in your area/ district.

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4. a) Write briefly the marketing functions.

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b) Why these functions are important?

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5. a) Explain briefly operational and technical marketing efficiencies.

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b) How the marketing efficiency can be measured?

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6. a) What is meant by market mechanization?

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b) Explain its role in improving the agricultural marketing in India.

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10.11 LET US SUM UP

Markets are very important in smooth conduct of buying and selling operations of any goods and services. These markets play a very important role by giving, directions to the resource use. In fact, a perfect market situation maximizes the welfare of producers as well as consumers'.

Market Prices are the signals that direct and coordinate the decisions of producers, consumers and food marketing firms. These prices are the result of supply and demand forces operating within the framework of an open exchange freely competitive marketplace. There is a tendency for farm prices to return to the supply and demand equilibrium point when disturbed. Shifts in the supply and demand, results in new equilibrium prices.

Competition plays a key role in harnessing the rivalry and the profit- seeking of the marketplace in order that it may serve the public interest. The competitive state of the agricultural markets disciplines firms' conduct, behaviour and practices; encourage new technologies and products; and regulates prices and profit level.

10.12 KEY WORDS

Market : Market is an arena for organizing and facilitating business activities and for answering the economic questions: What to produce, how much to produce and how to distribute.

Marketing : Marketing is performance of all business activities involved in flow of goods and services associated with inputs and output from initial point of production to ultimate consumers.

Perfect Market : A market characterized with large no. of buyers and sellers all engaged in sale and purchase of homogenous products with perfect knowledge of market prices and quantities and no discrimination. Perfect competition is a market structure having above characteristics.

Marketing functions : These are specialized business activities necessary to the marketing process.

Marketing channels : Alternative routes of product flow from producer to the consumers.

Brokers : An agent middleman who facilitate trade but does not physically handle the produce. He is paid fee by the sellers or buyers.

Marketing efficiency : A ration of market output (satisfaction) to marketing inputs (cost of performing functions). An increase in this ratio represents improved efficiency, a decrease indicates decrease in efficiency.

Market Mechanization : Performing various marketing functions including loading and unloading using mechanical means is market mechanization.

10.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) Your answer should include definition of market.

   b) The conditions included are existence of commodity, buyers and sellers and medium of exchange.

   c) Your answer should indicate/explain how the market gives direction to produce more beneficial commodities, through price.

2. a) Your answer should include the explanation village, primary, secondary, terminal and sea board markets.

   b) Your answer should include the definition of perfect market and also the conditions for perfect market

3. a) Your answer to this question should include definition of marketing channels (routes through which agricultural produce passes from farmers to ultimate consumers.

   b) Explain the various marketing channels of commodity sale to consumer such as

   Farmer –-> co-operatives –->wholesaler –-> retailers –->- consumer

   Farmers –-> consumer

   Farmers –-> Commission agent & or –-> wholesaler –-> consumer etc.

   From your own experience you should write which of the channels in prevalent in your nearby market.

4. a) The answer to this should includes exchange function, physical function and facilitating function along with sub functions of each of these.

   b) Your answer should include the help in smooth sale and purchases (as valuation becomes easier), both farmers/intermediaries and exporters gain through this and gives income and employment.

5. a) Your answer should include operational and technical efficiencies along with examples.

   b) The answer should include formula for marketing efficiency index including revised version of marketing efficiency.

6. a) The answer should include the meaning/definition of market mechanization with some example.

   b) Under this you should explain fastness, economic, uniformity and better pricing through mechanization.

10.14 SOME USEFUL BOOKS

1. Acharya, S.S. and Agarwal, N.L. (1999) Agricultural Marketing in India. OXFORD & IBH, Co. Pvt. Ltd., New Delhi.
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3. Jobber, David (1998) Principals and Practices of Marketing. McGraw-Hill Publishing Company, London.
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5. Ramaswamy, V.S. and Namakumari, S. (1999) Marketing Management Planning, Implementation and Control. MACMILLAN India Limited, Delhi.
6. Saxena, Ranjan (1997) Marketing Management. Tata McGraw Hill, New Delhi.

UNIT 11 MARKET INFORMATION SYSTEM

Structure

11.0 OBJECTIVES

After reading this unit, you should be able to:

- explain concept of market information system;
- describe importance of Marketing information system to various people engaged in marketing;
- know why information system is needed and what is the existing marketing information system in India;
- explain difference in marketing information and marketing intelligence;
- know various agencies providing marketing information in India, lacunae in marketing information system and how it can be improved; and
- describe components of marketing environment and various sub-systems of marketing information system.

11.1 INTRODUCTION

In traditional subsistence economy the farmers had little marketed and marketable surplus which they sold in the local markets only. They knew their customers first hand. They knew consumers' preference and their paying capacity etc. by being around them. Today, the consumers are wide spread in domestic and international markets with better paying capacity. This has offered a good market opportunity to the farmers. The remarkable development of roads, transport and communication have further added to the market opportunity. An agricultural commodity producer located in a corner of the country can plan the sale of his agricultural products through out the country or even globally. But for better prices he must have knowledge of potential buyers and prices in various markets. This information provides him opportunities for high sale prices and greater profit. In fact, we can say that market knowledge is the power for higher income even to the small farmer or a tiny producer. Thus, a farmer / manufacturer can harvest rich returns if he is able to take right marketing decisions, given the market information. All producers, manufacturers, and all other marketing intermediaries, include the organizations providing marketing facilities, utilise marketing information to run the business more profitability. However, Market information requirement of various groups of people engaged in marketing may vary.

Farmers, businessmen, administrators, and legislators have come to rely more and more on statistics to tell them what's happening, to show where their economic problems are, and to assist them in finding answers or serving as a guideline both for current activities and planning ahead.

11.2 CONCEPT AND DEFINITION

Marketing information system is system of collecting and analysing information related to marketing of goods and services. It consists of people, equipment, and procedures to gather, sort, analyse, evaluate, and distribute pertinent, timely and accurate information for use by marketing decision makers. A marketing information system collects the information on various related aspects of marketing environment such as marketing channels, competitors, prices, arrivals, grades, standards etc.. For international marketing it collects information on prices, quality, standard, grades and legal aspects for products sale in importing countries.

It combines this external information with his own business information including his capacity and capability (internal) to take the right decision on what, where, when and how to sell (from farmer's point of view or any other seller's/manufacturer's point of view).

Market information may be defined as a information on all marketing aspects important from selling or buying point of view. It includes all facts, estimates, opinions and other information which affect the marketing of goods and services.

Authentic market information is the life blood for profitable marketing/sales. Market information agencies judge the pulse of Market (whether price is high and sale is active or sluggish?), measure the temperature of markets (prices whether rising or fallings?), and monitor the market's pressure (whether supplies are adequate, short or in glut?). The market's history is recorded in statistical data series, and agencies offer a prognosis or estimate of the markets' future health.

Market information is a facilitating marketing function, and market intelligence is essential to a smooth and efficiently operating marketing system. Accurate and timely market information facilitates market decision, regulates the competitive market process and lubricates the marketing machinery.

All those who produce, buy and sell agricultural products are continuously amassing, revising and using market information on prices, supplies, demand, and other market conditions.

11.3 IMPORTANCE AND NEED OF MARKETING INFORMATION SYSTEM

11.3.1 Importance

After learning the definition you should be able to understand the role and need of MIS to various groups of people engaged in marketing. Information for management of commercial farming is very important from profit point of view. In fact, to manage a business very profitably is to plan and manage its future, but to plan and manage future is to manage the relevant information. Its importance for various group of people can be judged from the following:

a) *Farmer-producers:* Market information helps in improving decision-making power of the farmer. A farmer is required to decide when, where and through whom he should sell his produce and buy inputs. Price information helps him to take these decisions.

b) *Market middlemen:* Market middlemen also need market information to plan the purchase, storage and sale of particular commodity. On the basis of market information/ data, they project their estimates and take decisions about whether to sell immediately or to stock goods for some time, whether to sell into the local market or go in for import or export, whether to sell in their original form or processed form. The loss/failure of business can partly be attributed to either the non-availability of market information or its inadequate availability, analysis and interpretation of market information. Co-operative marketing societies operating as commission agents make use of market information for advising their members so that they may take decisions on when to sell their product.

   Processors make use of market information and plan their purchases so that they may run their plant continuously and profitably. They can also work out the inventory of a product that should be maintained for a particular period of time.

c) *General economy:* In fact, market information is also beneficial for whole economy. There is always need for a competitive market process for all commodities. The competitive process contributes to the operational efficiency of production and marketing. However, a perfectly competitive system is difficult to obtain; but the availability of market information contributes towards the competitive situation. In the absence of this system, different prices will prevail, leading to the profiteering by specialized agencies. The business of forward trading is based on the availability of market information.

d) *Government:* Market information is essential for the government in framing its agricultural production policies, in the regulation of markets, buffer stocking, import-export, prices, mechanization and control policies.

11.3.2 Need of Marketing Information System

During the past century three developments have taken place that necessitated need for more and better marketing information system.

a) *Markets expanded from local to national and international marketing*. The fast infrastructure development has remarkably expanded the market. The producers can take the advantage of this expanded market. When the commercial farmers expand their business or area of operation to meet demand, they need more formal system for collecting market information and analyzing it. The WTO has opened a new chapter for developing countries for export of agricultural products in global market provided developed countries do follow the code of conduct and help in establishing fair trading system.

b) *Change from buyers needs to buyer wants*. As the income of the buyers increase they become more choosy and need variety of goods. In fact, today, consumers need more diversified food basket. The increase in number of buyer also result in large opportunities. However, seller find it harder to predict buyers response to different features. Obviously more detailed information on consumers' wants can help the business enterprises.

c) *Change from price to non-price competition*. As sellers increase the use of branding, products differentiation, advertising and sales promotion, they require more information on effectiveness of these marketing tools.

Marketing information need can be assessed through the following questions:

- What type of decision you are normally required to take?
- What type of information you need to take these decisions?
- What type of information do you regularly get?
- What additional type of information you need?
- What information you want daily, weekly, monthly and annually?
- What five most important improvements can be made in the present marketing information system?
- What information do you need for export of specific product?

Both government and non government organizations are engaged in collecting and disseminating the information world wide. Better endowed Farmers/Traders/ firms collect the market information through their own resources.

A rational farmer or trader will try to maximize his profit through sale by integrating all the markets information. Market information pertaining to a set of markets helps the users in taking decision on what, where, when and how to sell. An intelligent farmer/trader monitors the movement of price as well as demand and supply of different agricultural commodities overtime and across various markets including international markets and then takes the decision to the best of his advantage under national and international macro environment. Such market information on commercial agricultural products normally consists of different products, grades, standards, factors affecting market forces, prices in different markets for different grades and the competitors of similar products. Thus, this will include information on all the micro and macro, socio-economic and political factors that affects the decision-making in agricultural trade.

The role of the marketing information system is to assess the information needs of farmers and traders, develop the needed information and distribute the information in time to the various clienteles i.e. farmers, processors, traders and consumers. The needed information can be developed through collection of information by survey, marketing intelligence activities, marketing research and marketing decision support analysis.

Different countries have developed marketing information systems with variations depending on the amount of money invested in the system. Those systems are also related to planning priorities, and the type of commodity produced. Most countries in Asia operate a marketing information service with the express aim of promoting efficient marketing and raising farm incomes. The form it takes varies according to the level of economic development, and especially the extent to which agriculture has changed from subsistence to commercial farming.

11.3.3 Need for Marketing Information In India

India has varied agro-climatic conditions which enables it to produce all kinds of agricultural crops in various parts of the country at different period of times in an year. But, the forward linkage is India is very poor and the farmers sell the produce in nearby/local markets or in the village itself. Many a times heavy supplies come to the local market which leads to low price and thus low profit while price in other/distant markets is high. This high price in other markets can be a fortune for any farmer. But the farmers not have the information on such prices. The local market traders also exploit the poor farmers through various mal practices.

National marketing information systems usually provide price information through the mass media, such as newspapers and radio. However, it is not clear how useful such information is to the farmers. It is believed that information is either not available or available in different forms.

The need for market information on agricultural products and markets is more important in agricultural economy like India where large amount is produced by crores of small and marginal farmers. Their income depends on the sale proceeds of agricultural commodities. Thus, marketing information will help Indian farmers and other market functionaries make profit oriented decisions through what, how, when and where to market produce and what price to expect under prevailing conditions. The farmers who understand market trends and market opportunities have a better chance of getting potential returns and success. As a matter of fact, marketing information plays a vital role in the functioning of the whole market system. Helping farmers in India through market information ensure that produce goes to markets where there is a demand for it. It shortens marketing channels and cuts down on transport costs. It helps ensure that each marketing transaction is a fair one, and that all participants share the risks and benefits. However, this does not happen if marketing information is distributed unequally, as is generally the case in India where large number of small size farmers sell to local traders or to the markets with few traders for various reasons especially lack of resources and market information. The farmers then end up bearing the greater part of the risk, while the dealers end up with the greater part of the profits.

Recent advances in information technology will help small farmers, large farmers or traders with the marketing information they need to make right decision. However, farmers may not benefit from sophisticated facilities, if the system is poorly managed or not designed for their needs in terms of infrastructure. It is not enough for marketing information to be collected: it must also be disseminated in a form accessible to clients and adapted in their decisions.

In many marketing information systems, regional data is transmitted to a central national facility where it is processed and amalgamated with similar data from all over the country. The result is useful to those working for central government agencies, who need to know what is happening over the whole country. It is of less value to the farmers or consumers in the rural areas. Farmers are interested mainly in prices in local markets where they sell their goods. Big traders, Associations/ houses take advantage of such national and international marketing information.

11.3.4 Central Scheme for Marketing Information in India

In India, the Directorate of Marketing and Inspection (DMI) headed by the Agricultural Marketing Advisor, Department of Agriculture & Co-operation (DAC) implements agricultural marketing policies and programmes of the Government of India. It undertakes:

- Standardisation, grading and quality control of agricultural and allied produce
- Market research and surveys
- Provides technical support in regulation, planning and designing of physical markets.
- Training of personnel in agricultural marketing in the country
- Promotion of cold storages
- Administration of Meat Food Products Order
- Marketing extension, consumer education etc.
- Market Information network.

It also liaise with the State Agricultural Marketing Boards and Directorates for Agricultural Marketing Development in the country, which have been established to ensure proper planning and development of agricultural marketing including implementation of State Marketing Legislations which define local market practices, market charges payable to various functionaries, license the functionaries and promote the development of orderly marketing. The dissemination of market information is common function of Agricultural Produce Marketing committee (APMC), which is performed through displaying of the prices prevailing in the market on the notice boards and broadcasting through All-India Radio, etc. This information is also supplied to State & Central Government from important markets. The statistics of arrival, sales & prices etc. are generally maintained by APMCs of various markets in India.

By and large the States and Union Territories are providing some market information in one form or the other for the benefits of market users like producers, traders and consumers. However, the information is collected and disseminated by use of conventional methods which cause delay in communicating the information to different target groups, adversely affecting its utility. The farmers are also not able to know about the prices prevailing in other markets. Many Market Committees still disseminate information in respect of their own markets only. The farmers are, therefore, left with no alternative but to dispose of their produce in the nearest market, even at throw away prices, because of either not available or delayed market information.

Therefore there is an urgent need to bring improvement in the present marketing information system by linking all APMCs, State marketing Board and State Directorates of Agricultural Marketing and DMI of Ministry of Agriculture. It is felt that investment on network of about 7000 Whole sale Agricultural Produce Markets in the country will facilitate globalisation of Indian farmers. In view of this importance, the Department of Agriculture and Co-operation in Ministry of Agriculture Government of India (GOI), under DMI, has sanctioned a Central Sector Scheme named as Agricultural Marketing Information Network (AGMARK-NET) at an estimated project cost of 10 crores to link at present 770 agricultural markets besides 40 Agricultural Marketing Boards/Directorates in the beginning during 2000-02. The objectives of this Scheme are:

- To establish a nation-wide information network for speedy collection and dissemination of market information for its efficient utilisation.
- To computerise data on market fee, market charges, total arrivals, arrivals by agencies, prices (variety wise / quality wise), storage, dispatches with destination, mode of transportation, costs, sold and unsold stocks, sources of supply with destination, method of sale, payment, weighment, grading facilities, quantities graded, market personnel (trained/ untrained), market functionaries, market finance, development programmes, infrastructure facilities, constitution/composition of Market Committee, income and expenditure and other activities of the Agriculture Produce Market Committees, State Marketing Boards and Departments.
- To ensure flow of regular and reliable data to producers, traders and consumers to derive maximum benefit of their sales and purchases.
- To increase the efficiency in marketing by effecting improvement in the existing market information system

11.4 TYPES OF MARKET INFORMATION

Market information is of two types:

i) *Market intelligence:* Marketing intelligence is different from regular marketing information or marketing research data. It may form part of marketing information system but it is special in the sense that it gives strategic information in a flash and is quite often related to competitors' activities. The nature of the marketing job necessitates a good intelligence system. Broadly, marketing intelligence furnishes information on changes in market conditions, changes in customers' requirement, emerging strategies of competitors and emerging opportunities in the business Marketing intelligence may be gathered by marketing executives directly or through field sales managers. Occasionally, it is also purchased from external agencies which provide marketing intelligence services. In what so whatever manner it is collected, it is essential to have a reliable and efficient system for gathering and using the intelligence. If there is too much delay in the process, the marketing intelligence loses its significance.

If it is gathered and used properly, marketing intelligence will serve as a pathfinder.

ii) *Market news:* This term refers to current information about prices, arrivals and changes in market conditions. This information tips the farmers to take decisions about when and where to sell his produce. The availability of market news in time and with speed is of utmost value. Sometimes, a person/trader who gets the first market news has a substantial advantage over his fellow-traders who receive it late. Market news quickly becomes obsolete and requires frequent up dating.

11.5 AGENCIES PROVIDING MARKET INFORMATION

The collected information has no meaning until it reaches the persons who need it. The agencies/ sources through which market information is disseminated are:

a) *Personal contacts:* This is the most important source of dissemination of market information. Information is given orally, i.e., by one businessman to another businessman, by a businessman to a farmer, or by one farmer to other farmer.

b) *Post and telephone:* Businessmen get information from other markets on the telephones. Commission agents convey the information on the prices of different commodities to their client-farmers on postcards. They fill the rates on these postcards and post them daily or some time at intervals.

c) *Newspapers:* The newspapers in English, Hindi and regional languages publish the wholesale prices of important agricultural commodities in the selected markets of the country/State. In addition, the Economic Times and the Financial Express contain a lot of information on the various aspects of marketing including prices.

d) *Magazines:* Magazines, such as the Eastern Economist, Commerce and Capital, are important weekly trade journals, which collect information on trade.

e) *Government agencies' reports:* The regulated markets, the Agriculture Marketing Department in the States, the Directorates of Economics and Statistics in the States, the Directorate of Marketing and Inspection, Government of India, and the Directorate of Economics and statistics, Ministry of Food and Agriculture, Government of India are some of the government agencies which disseminate the collected market information through their regular publications and broadcasts on All India Radio.

f) *Price bulletins:* These are issued daily, weekly, or every month. The important bulletins through which price information is disseminated are: Bulletin of Agricultural Prices (Weekly), Agricultural Situation in India (Monthly), Agricultural Prices in India (Annual), and Bulletin on Food Statistics (Annual). The monthly situation and outlook ports are published by the Directorate of Marketing and Inspection, Government of India.

g) *Radio and television:* The information on the market situation in respect of prices and arrivals of commodities in major markets are regularly telecasted. Almost all channels now have the slot for market information. Several State Governments and National Information Centres of the

Government of India have initiated interlinking the markets with NIC-NET with view to ensure the quick flow and accessibility of market information on prices and arrivals. The information on this is also available on internet.

h) *Through internet:* Internet has become a main source of market information. All the world major markets' grade-wise prices and arrivals of various commodities on different days are available. Even the origin wise and variety-wise information is also available through internet. Directorate of Marketing and Information (DMI) has been pioneering in this aspect.

i) Krishi channel: Recently a new Television Channel dedicated to agriculture has been proposed. The channel will cover production and marketing including international trade issues. The farmers have high hopes from it. This will also extend the marketing information in future.

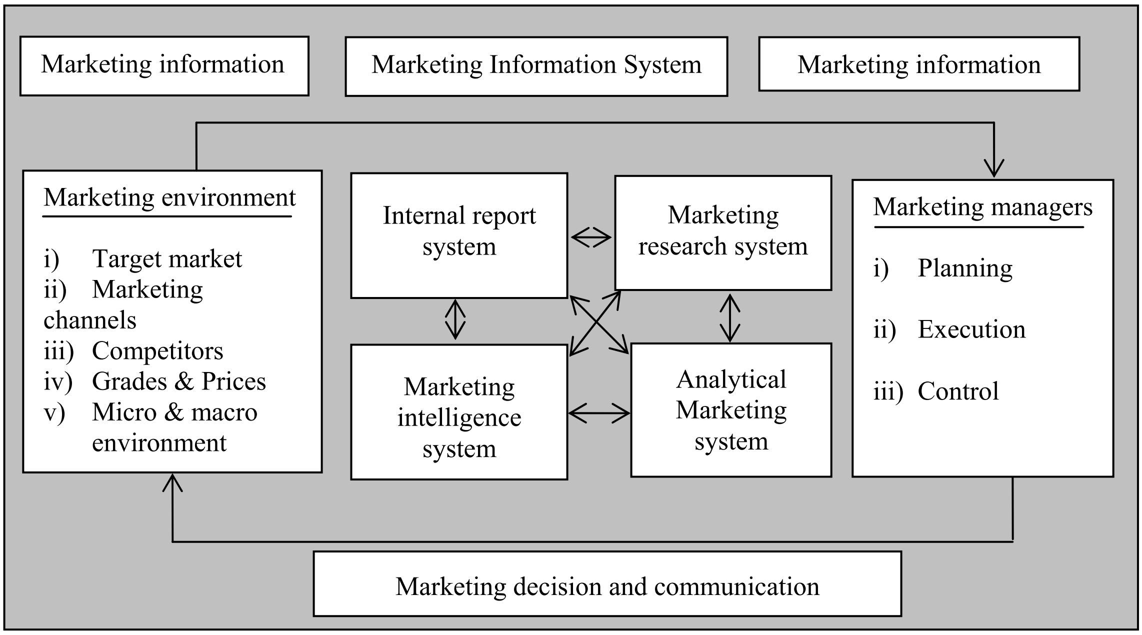
j) Kisan call centres: Kisan Call Centres will be spread throughout the country in various states/zones. These will have direct link with experts on various agricultural aspects including agricultural marketing, in State Agricultural Universities/ Research Institutes or a panel of experts at these centres only. Any farmer can seek information/ ask any question related to agriculture at any time by dialling 1551, a toll free number. The solution to his problem will be suggested on line or with in 24 hrs depending upon question and experts availability.

11.6 COMPONENTS OF MARKETING INFORMATION SYSTEM

Instead of a plethora of unrelated data on market information one needs pin pointed information which farmers/traders/firms combines various inputs with internal information and presents integrated report for him. Thus every farmer or trader must organize a rich flow of information or they must search for relevant information. Conceptually in a competitive world they must study the information need and design marketing information system to meet its demand. The various components of marketing environment are

- Target market
- Marketing channels
- Competitors
- Publics
- Microenvironment forces and
- Macro environment forces.

They must collect and monitor marketing environment and market trend information and analyze through four subsystems making up the Marketing Information System. These subsystems are presented in the following diagram.



Let us take a closer look at above four subsystems.

i) *Internal report system:* Every farm/firm manager produce internal report showing their current production, sales, cost, inventory, profit and capabilities. They plan the information need and design to collect it.

ii) *Market intelligence system:* This system provides the farm/firm/coy with happenings data in the commercial environment. The farm manager get the information through reading newspaper, reports, internet, telephone/ mobiles, telegraph, suppliers, distributors, specialist, panel of experts, even purchase the intelligent from outside, or keep their own staff to get information. Farmers normally need the information of standard/grades, prices, transport, channels, strategies, legal system, institutions and competitiveness.

iii) *Marketing research system:* It is the systematic design, collection, analysis and reporting of data and finding relevant information specific to situation facing the firm. The managers either get the data analyzed or study the specific situation himself. They measure market potential based on various marketing components and analyze it to take decision.

iv) *Analytical marketing system:* It consists of advanced techniques for analyzing marketing data and problems. The data is available in the farm records/firms data bank. Farm/firm manager try to find out major variables (and their significance) which affect the sales potential. They thus find the potential markets and the segment of the markets through analytical system. Then they plan for marketing of produce. They choose the mode of transport, distributor and channels.

Based on analysis of market information they can plan and execute the plan, monitor and keep control over the business.

11.6.1 Steps Involved in Designing MIS

- Identifying the broad information requirement of the organization.
- Classifying the information requirement and identifying whether it is for planning purposes or control purpose.

- Evaluating the cost of collecting and processing the information.
- Comparing the cost verses benefits.
- Decoding the frequency and timing of collection of information.
- Identifying the sources of information.
- Designing the mechanism/procedure for gathering, processing, storing and retrieval of information.
- Analyzing and interpreting the information and disseminating it to the right persons at the right time and in the right manner.
- Monitoring, maintaining, reviewing and improving the system.

11.6.2 Marketing Information Benefits

Various benefits that flow from marketing information are listed below:

- It helps marketing planning by making available reliable information on the external environment and the internal realities of the company.
- It helps effective tapping of marketing opportunities and provides effective defence against emerging marketing threats.
- It helps early spotting of changing trends; it provides market intelligence to the firm.
- It facilitates the development of action programmes for achieving goals.
- It helps the farmer/trader adjust their products and services to the needs and tastes of customers.
- It helps the farmer/trader control their marketing activities.

The quality of marketing decisions are decided to a great extent by the quality of marketing information available to the decision maker.

11.6.3 Criteria for Evaluating Market Information

For maximum benefits, the market information must meet a number of criteria. Some of those are described below:

1. *Comprehensive information:* The information must cover all agricultural commodities and markets including international markets. A reasonable and comprehensive information includes prices, price trends, production, supply movements, stocks, and demand conditions at each level of the market for a product. Providing such a mass of information, especially under the constantly changing conditions is a formidable and expensive task.

2. *Accuracy and trustworthiness:* Information must be accurate and trustworthy. However by nature, market information can never be 100 per cent accurate, but it must be an honest market appraisal in order to earn the trust of information users. Constant efforts are made to improve the accuracy of market information and news services.

3. *Usability:* Information also must be relevant and in usable form. It is not enough to simply collect a number of reports. Information must be collected, packaged, and disseminated with the user's interests in mind.

Much market information goes unused because it is not in usable form. In such case the efforts made in collecting the information go waste.

4. *Confidentiality:* The information should be confidential to whom it is collected. The information revealed under this situation of confidentiality will be more correct and may assist in drawing policy implications. The names of firms, to whom the market information is collected, should not be leaked out.

5. *Timeliness:* Market information must be timely, in the sense of being relevant to current decisions, and must be speedily transmitted to users. Much market information is unusable. Futures market traders require minute-to-minute market information.

6. *Accessibility:* Each interested party like farmers, consumers, government officials and marketing agencies should have equal access to all the information relevant to the bargaining and marketing processes.

7. *Relevance and clarity:* Market information must be relevant and clear.

8. *Objectivity:* It should convey objective message.

9. *Strategic value:* It should be conceived and used as a marketing decision support system.

10. *Economic:* It must be economical. In other words it should be cost effective

11.7 LACUNAE IN MARKET INFORMATION

Although sellers need pin pointed marketing information. However, such information is normally highly subjective. The major lacunae in existing market information are as follow:

- Lack of information of the right kind. Sometimes right kind of information is not available and is very difficult to under stand by the illiterate farmers in India. The market reports are also incomplete and bulky many times and do not serve any purpose.
- The available information are not in desired form. Most of the information pertains to wholesale marketing. One also needs information of prices at retail level or quality or pack size.
- Lack in timely dissemination of market information. Most of the time, the news reported is so late that it is of no use. Inadequacies of information especially on phyto-sanitary aspects under changing global scenario prevents wider access to international market by Indian Exporters.
- Reliability of the information is very poor. The biasly collected and disseminated information further adds to woe.

11.8 HOW MARKETING INFORMATION CAN BE IMPROVED

Following are some of the suggestions for improvement in the existing market information system, so that the marketing system for agricultural commodities becomes orderly, efficient and effective in helping the agencies involved in marketing:

- Uniform units should be quoted. A standardized system of quoting the prices of the different varieties, grades and weight of the commodity should be followed instead of many time quoted in the local units, so that the prices may be compared over time and space.

- The prices announced on FM/AM/ local AIR should cover more local markets rather than important secondary and terminal markets located in far off areas. The frequency of, and time allotted for the announcement should be increased so that the farmers may benefit from the information. The broadcast time should be such that the farmers can listen to the announcement and take decisions about consignment of the produce to the market.

- Prices should be displayed on notice boards at important public places like hospitals, schools, panchayat ghars, etc.

- The staff posted for the collection of market news should be knowledgeable and trained. There must be thorough and frequent check to ensure that guess work, manipulation and bias are excluded.

- Market news should have no place for rumours: Rumours are harmful for the cultivators.

- Market news provided should be as fresh as possible so that it may create confidence and trust among the users.

- A correct and intelligent interpretation of market information should be made and announced. This is very important, for farmers may not be able to interpret correctly.

- There must be proper-coordination between market intelligence and policy making departments so that the later may better understand the problem and can make such adjustments in the information as may be called for.

- In many markets, a price range is reported instead of a single price. This is so because of the variation in quality and the large number of transactions taking place in the market. The range is very wide, and may not serve the purpose of the users. Therefore, the price range should not be very wide or ambiguous.

- The users of market information should be trained from time to time as the development takes place. This will help them to take the best advantage of market information.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. a) Define a market information system.

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b) Explain its role in increasing the income of the farmers and exporters.

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2. a) Explain various agencies/sources through which the market information in India is available.

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b) Which one is the best for farmers in your view and why?

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3. a) Outline various steps for designing marketing information system.

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b) Enumerate MIS benefits.

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4. a) What is the lacunae in marketing information system?

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b) How MIS can be improved?

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5. a) What are the components of marketing environment?

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b) Explain the various sub-systems of market information system.

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6. a) Why marketing information system is needed?

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b) How MIS can be evaluated?

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11.9 LET US SUM UP

Marketing information is extremely important in commercial agriculture. Its importance has further increased as a result of opening of WTO chapter in the history. The farmers/ Traders in India increase income and employment by strategic planning for domestic marketing. Their income will increase through external trade especially in commodities in which it has comparative advantage. Small farmers can take a collective venture for their benefit through the group action or through co-operatives. Thus, marketing information is a powerful tool for enhancing the income of producers, processor, traders or any other firm.

11.10 KEY WORDS

Market information (MI)	:	is the information/data on various marketing aspects that is necessary for taking decision for profitable selling of the products.
Marketing information system (MIS)	:	Marketing information system is system of collecting and analysing information related to marketing of goods and services.
Directorate of marketing and inspection (DMI)	:	An organisation of Government of India under ministry of agriculture that looks after various aspects of agricultural marketing.
APMC (Agricultural produce marketing committees)	:	It is committee that looks after functioning and facilities in the defined marketing area (normally a whole sale market area).
Agmarknet	:	It is a market information network which has linked large no. of agricultural markets in India.
Market intelligence	:	Marketing intelligence furnishes information on changes in market conditions, changes in customers' requirement, emerging strategies of competitors and emerging opportunities in the business that helps in furtherance of seller's objective.
KCC (Krishi call centres)	:	These are specially created centres which provide information on calling them.
Components of MIS	:	Components are the sub-systems of MIS which collect and analyse the market information that helps in sellers decisions to plan, execute and control.
Lacunae of MIS	:	Shortcomings of MIS.
Price bulletins	:	These are special publications giving information on prices of various commodities prevailing in various markets.
Micro environment	:	Marketing environment relates to individual market/commodity such as existing traders, practices, standards, grades, rules and regulation etc.
Macro environment	:	Macro environment will include legal aspects, phyto-sanitary aspects, grades, preference and practices in a state markets /country markets.

11.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) Your answer should include MIS definition.

   b) Your answer should include how Marketing Information is able to increase income of the farmers (both for domestic and international marketing) as well as exporters by taking right decision based on objective judgement.

2. a) Your answer should include news paper, telephone, posts, magazines, bulletins, display boards, internet as agencies/sources of marketing information.

   b) Answer to question of best agency/sources will be based on your own judgement but you should explain why the agency or source suggested by you is best.

3. a) Answer to this question should include; what information is required, what sources of information are available, mechanism to collect, analyse, process and interpret collected information, sources-wise costs comparison, evaluation of adopted MIS.

   b) While answering benefits of MIS you should explain how it helps in planning, tapping opportunities, meeting trend of preferences of consumers, catching to needs for goods and services controlling of marketing activities and increasing the income of farmers/ intermediaries and the welfare of the consumers.

4. a) Your answer should include the points; inadequacy of information, lack of right information, unavailability of information in desired form, authenticity of marketing information.

   b) Your answer should includes suggestion on uniformity in quoting and displaying prices, quality, grade and variety wise prices in local markets, recruiting knowledgeable staff, reliability of information and proper co-ordination.

5. a) Components of marketing environment will include target market, marketing channels, competitors, grades & prices and other micro and macro environment.

   b) Your answer should include internal reporting system, marketing research system, marketing intelligence system and analytical marketing system including their functions.

6. a) Your answer should include usefulness of MIS to various marketing functionaries including farmers and exporters.

b) Your answer should include evaluation in terms of fulfilment of required information, timeliness, relevance, clarity, accuracy, trustworthiness, strategic value and cost effectiveness.

11.12 SOME USEFUL BOOKS

1. Acharya, S.S. and Agarwal, N.L. (1999) Agricultural Marketing in India. OXFORD & IBH, Co. Pvt. Ltd., New Delhi.

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4. Parsad, Jagdish and Prasad, Arvind (1995) Indian Agricultural Marketing: Emerging Trend and Prospects: Mitall Publication, New Delhi.

5. Ramaswamy, V.S. and Namakumari, S. (1999) Marketing Management Planning, Implementation and Control. MACMILLAN India Limited, Delhi.

6. Saxena, Ranjan (1997) Marketing Management. Tata McGraw Hill Publication. New Delhi.

UNIT 8 FACTORS AFFECTING STORAGE LIFE

Structure

8.0 OBJECTIVES

After going through this unit, you should be able to:

- know why low temperature is helpful in increasing storage life;
- tell the role of relative humidity in the maintenance of product quality;
- differentiate between climacteric and non-climacteric fruits; and
- explain the effect of low O_2 and high CO_2 concentration on fruits.

8.1 INTRODUCTION

Storage of fruits and vegetables is one of the most important aspects of post harvest management. It is estimated that about 30 percent of fruits and vegetables produced annually is lost in India due to inadequate post harvest management. Reduction in post harvest losses could increase the availability of fruits and vegetables without increasing production. One of the reasons for the post harvest losses of fruits and vegetables is lack of proper storage facilities. Refrigerated cool store is considered to be the best method for storing fruits and vegetables. But this method is not only highly energy intensive but also involves huge capital investment. The Expert, Consultation on Food Loss Prevention in perishable crops held at FAO, Rome in May 1980 recommended that the use of proper temperature management includes simple and low cost cooling system and the use of evaporative cooling for storage of fruits and vegetables.

Storage of fresh fruits and vegetables prolongs their usefulness and in some cases improves their quality: it also checks market glut, provides wide selections of fruits and vegetables throughout the year, helps in orderly marketing, increases financial gain to the producers, and preserves the quality of the commodities. The principal aim of storage is to control the rate of transpiration, respiration and disease infection and to preserve the commodity in its most usable form for consumers.

Storage life may be prolonged by proper control of post-harvest diseases, regulation of the atmosphere, chemical treatments, irradiation and refrigeration. To date, refrigeration is the only known economical method for long term storage of fresh fruits and vegetables; all the other methods of regulating ripening and deterioration are at best only supplemental to low temperature. In fact, other quality maintaining methods will not work satisfactorily without refrigeration. In a hot tropical climate, CA storage, waxing and use of polyethylene bags are not advisable if not combined with refrigeration, as deterioration would be fast due to rapid build up of heat and CO_2.

Storage life of the fresh horticultural product is affected by many factors; most important of them are temperature and relative humidity. Fresh fruits and vegetables are living tissues and continue to respire after harvest. Storage temperature is the most important environmental factor affecting the senescence of fruits and vegetables because it regulates the rate of all associated physiological and biochemical processes. Many physiological processes are affected by temperature after harvest. Changes in quantity and quality affect horticultural crops between harvest and consumption. While some of the changes are desirable, most are not. Senescence is the final stage in the development of plant organs during which a number of changes take place that lead to breakdown and death of the plant cells, and storage life of produce is terminated.

8.2 PRINCIPLES OF STORAGE

8.2.1 Control of Undesirable Plant Processes

Since all fruits and vegetables are living tissues, the tendency after harvest is a continuation of all life processes. The aim of storage is to minimize the rate at which these processes take place. Thus, proper and adequate storage conditions must be supplied to the product; otherwise, the following undesirable plant processes may occur.

Sprouting

This can be a serious cause of deterioration, especially in onions, ginger, garlic sweet potatoes and potatoes. Sprouting is related to dormancy and rest. Dormancy is a condition of quiescence due to some internal or external factors. Rest is a phenomenon in which sprouting does not occur in spite of a favourable environment. Of the crops mentioned above, only sweet potatoes have no state of rest.

Elongation of Existing Structures

This process may be exemplified by products such as asparagus, carrot, beet and kohlrabi.

Rooting

Rooting may be initiated by a condition of elevated humidities, which may result in rapid decay, shrivelling and exhaustion of food reserves, especially in roots and tubers.

Seed Germination

During storage, seed germination within mature fruits is favoured. This process is observed in tomatoes, papaya and pod bearing vegetables. In most cases this may not be objectionable, but is detrimental in canning of whole tomatoes.

Greening

Exposure of potatoes to light during storage may produce green tissues. These portions contain solanine, which has some toxic properties. Thus, during storage, light should be minimized.

Toughening

Green beans and sweet corn may toughen when storage is unduly prolonged due to the development of spongy tissues.

Tropic Response

Response to gravity and light may cause bending of tissues. Products of uneven shapes are difficult to package. Appearance of the product, when offered for sale is also affected.

8.2.2 Control of Transpiration

Of the environmental factors, temperature, RH and vapour pressure difference (VPD) are important in transpiration. Low temperature, high RH and small VPD are necessary to minimize shrinkage of the product. A 5% loss in weight of a fruit is enough to produce shrivelling which makes it unattractive for sale. In using high RH during storage, care must be taken not to allow the development of surface moulds and other decay organisms due to condensation of moisture on the surface of the products. It can be controlled by proper packaging, use of protective coatings and by keeping the refrigerant as close as possible to the desired air temperature.

8.2.3 Control of Respiration

The basic principle in cold storage is the retarding effect of low temperature on respiration. Respiration is a breakdown process and means to minimize this process should be provided. Controlled atmosphere storage has proved to be a good commercial supplement to refrigeration. Its feasibility in the tropics should be explored.

Ventilation is indirectly related to respiration. Usually, the heat generated by respiration accumulates at the centre of the storeroom, and if provisions are not made for its exit, the rate of respiration of the stored products will be increased. It will be noted that since respiration and storage life are intimately related, whatever factors affect one will also influence the other.

8.3 TYPES OF STORAGE OPERATION

The enormous increase of fruit and vegetable production, owing to larger acreage and high yielding varieties, requires sufficient storage space. Accordingly, storage operations have been developed into a skilful job with a wide range of variations depending on the existing facilities and the nature, kind and quantity of products.

Storage operations may be either temporary, short term or long term. Temporary storage operation is needed for highly perishable products which require immediate marketing. It may be installed with or without refrigeration. This is extremely important for road side stands, market gardens, railway stations, shipping yards and retail stores. Mid term storage operation is aimed at checking the market glut without much deterioration in quality. This may extend from 1 to 6 wk, depending on the need. Mango, banana, papaya, cabbage, brinjal, tomatoes, cauliflower and beans are transferred to short term storage rooms when their quality is still good, and held there until a reasonable market price is attained. They are constantly inspected. Crops like apples, oranges, pomelos, pears, squash, potatoes, colocasia, sweet potatoes, carrots, onions, garlics and pumpkins are stored for a longer period of time. Long term storage operation is principally influenced by economic factors. The products are stored during their peak periods of production and marketed continuously during the rest of the year when producers and dealers can obtain reasonably high prices.

Storage operation may be classified as either natural or artificial. Artificial storage operation may be divided further into 4 types: (a) mechanical or structural, (b) controlled atmosphere, (c) chemical and (d) radiation. Natural storage operation keeps the products in situ without any artificial treatment. The aim is to let the fruit or vegetable mature and ripen on the plant for as long as possible. Harvesting is therefore delayed. Artificial storage operation, on the other hand, attempts to provide all possible artificial storage conditions to prolong the usability of the product.

8.3.1 Natural Storage

In India, particularly in West Bengal, vegetables like potato, yam, sweet potato, garlic and ginger are kept in situ for several months after they attain maturity. These are removed keeping in view the market rate. Staggering the harvest is easy and economical because it does not involve any extra expenditure and fabrication for storing. The vegetables are generally, removed before the rainy season to prevent rotting and sprouting.

8.3.2 Artificial Storage

Vegetables are stored in pits and trenches by mounting soil on the surface. Pits are used for storing beets, potatoes, carrots, turnips, cabbage, parsnips, sweet potatoes etc. Except for cabbage and parsnips, the vegetables are first covered with hay, straw or litter and then with soil to protect the surface from water leakage and freezing.

The small trenches should be dug at right angles to each other to facilitate ventilation. Wooden planks or boards are often placed above. The soil, about 4 to 5 in thick is filled with hay or straw and the products are piled inside the trench. A similar cover of straw or hay is placed above the commodity and plastered with mud. Several small trenches are better than one or two large ones. When a trench is opened all the stored products should be removed at a time. The location of the trenches should be on well drained high land. There should be no surface drain near the trench.

Untopped beets are stored underground, 12 to 16 inches deep in regions of mild winter. At the start of severe cold, 2 adjacent rows are placed in covered with soil. In this way, beets, which are neither too young nor too mature, can be kept for 5 to 6 months. In British Columbia, a cover of 4 to 5 inches is enough, but in the southern states, from 8 to 10 in is usually necessary.

Underground field storage offers the advantage of being convenient for the grower, as it can be done anywhere at anytime. Space is not restricted. It is most suitable for short term storage operations. However, many disadvantages render this type of storage unfavourable. It is expensive in terms of labour charges from digging the pit to removal of the product. Weather and soil conditions influence the operation. Heavy losses may occur since climatic conditions cannot be controlled. Deterioration can be faster for vegetables not removed before cold and wet weather.

8.3.3 Low Cost Storage Structures

Low cost storage system has a great significance in our country since other advanced storage systems work ought to be extremely expensive. Most of the low cost storage structures are built by taking the advantage of natural cooling.

i) Clamps

The clamps are commonly used for potatoes, turnips, beet etc. and vary in design. An area of land at the side of the field which is not prone to water logging is selected. The width can be any convenient size but normally it ranges between 3'-7'5" and it can be any suitable length. These dimensions are marked out and the vegetables piled on the ground. Occasionally straw is put on the ground before keeping the vegetables. The height of the pile should be about 1/3 of its width. The pile is covered with whole wheat or rice straw to about 6-8" thick, when compressed. In colder climates, more straw and soil may be added.

ii) Cellar

These are underground or partly underground structures usually below a house. They are used for years as storage for fruits and vegetables. The cellar temperature is approximately equal to the average annual air temperature. Cool under ground spaces work well for storing already cooled produce but not for removing field heat.

iii) Night time cooling

In some parts of our country there are significant differences between night and day temperatures allowing night time ventilation to be a good source of cool temperature.

iv) High altitude cooling

High altitude can be a source of cold. As a thumb rule air temperature decreases by 10°C for every 1 km increase in altitude.

v) **Zero energy cool chambers**

It is based on the principle of evaporative cooling. Evaporative cooling is not only one of the simplest and cheapest methods but also does not involve any conventional energy source or power to operate. Evaporative cooling is widely used for comfort cooling of living and working spaces in hot, dry climates and has considerable potential for pre-cooling and even storage of fruits and vegetables in such climates.

The basic principles are evaporation of water produces considerable cooling effect and the faster the evaporation, the greater the cooling. Evaporative cooling occurs when air that is not already saturated with water vapour is blown across any wet surface. Thus an evaporative cooler consists of a wet porous bed through which air is drawn, cooled and humidified by evaporation of water. Theoretically the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature.

8.3.4 Ventilated Storage

a) **Above ground warehouse:** This is a common type of structure built above the surface of the ground and extensively used by rural farmers in the Indian peninsula. A dwelling house may be used for this purpose. The nature and type of construction depend on the area and nature of the product to be stored. In cold regions, greater insulation is needed, whereas in warm areas proper ventilation is essential. A storage structure for sweet potatoes differs from that for onions, leafy vegetables, crucifers or mangoes.

This structure has the following advantages over the other types: (a) special construction is not needed, since a dwelling house will satisfy the conditions provided it is provided with necessary fittings suited for the particular type of fruits or vegetables; (b) products are easily handled during storage and removal; (c) grading, storing and packing of fruits and vegetables are facilitated.

b) **Controlled atmosphere storage:** Artificial atmospheres have been maintained in storage rooms in several ways. The respiration by the fruits increases the concentration of CO_2 and decreases the O_2 in the room. Proper levels are maintained by CO_2 absorbers, usually NaOH. Water is also used for absorbing CO_2 from CA storage when the concentration becomes too high. This method was less expensive and less noxious than with NaOH.

8.3.5 Refrigerated Storage

Although costly, the advantages of refrigerated or low temperature storage are well known. The following general principles should be considered during planning the refrigerated warehouse.

Site selection: The site of a storage plant should be selected bearing in mind its accessibility to highways, production areas, shipping points and distribution centres. Availability of fuel, telephone systems, electricity, water and sewer should also be considered. The site should be levelled so that costs of excavations and steep driveways are minimized.

Utilization of space and equipment: Mechanical product handling and newer methods of construction tend to give single story design greater capacity per rupee of investment than multi story refrigerated warehouse. In a one-story structure, high ceilings are provided; thus ducts, refrigeration units, pipes, sprinklers and other overhead obstructions should be placed so that they do not interfere with the use of vertical space. Small columns on wide centres permit palletized storage with comparatively little lost space.

Insulation requirement: A good insulating material must have low thermal conductivity, permanence, ease of application, reasonable cost and moisture-resisting qualities. The best insulating medium possible is two silver-coated surfaces separated by a perfect vacuum. This is used in small units (e.g. Thermos bottles) but is impractical in a larger scale. Still air is the second best insulator, but in practice this is not realized because of convection currents carrying heat. Other insulating materials include granulated cork, charcoal, cellular ebonite, glass fiber, kapok, cane fiber boards, silicate cotton (slag wool), cellular plastics, balsa wood, saw dust, rice husk and coconut fibers. However, they are not as efficient as slab cork. Usually they absorb moisture readily, causing decreased resistance to heat flow and structural deterioration.

To protect the insulator against entry of water vapour, a vapour barrier is needed. Since this travels inward, from the warmer to the colder side, the vapour seal should be placed on the outer surface of the insulator. Plastic film, metal foil, rigid metal sheets or hot mastics will provide adequate vapour seals.

Insulation is not usually placed on floors if the ground water level is more than 12 ft below the floor surface. Dry ground is a fairly effective insulator. Insulation thickness varies with the average and extreme temperatures of the location and temperature of the room. For cold storage of fruits and vegetables in the tropics, 4 to 5 in of cork insulator are sufficient.

Ventilation: Storage rooms should be provided with a forced air distribution system, which will allow uniform airflow throughout the pile of commodities. Air should circulate from the centre of the room outward to the walls, down through and between the rows of commodity and back up through the centre of the room. This is made possible by providing ducts or blowers and proper stacking of containers to permit airflow in a pre determined direction.

Refrigeration doors: Doors should permit easy access in and out of the room and at the same time minimizes undue loss of refrigeration. Bumper doors (or air doors) are convenient because they are self-closing and can easily be opened by dumping them with a fork lift truck. A hinge-insulated door opening should have at least 12 inch clearance on both sides of a pallet. The recent tendency is to use 10 feet as the standard height to accommodate all types of stacking lift trucks.

8.4 FACTORS AFFECTING STORAGE LIFE

8.4.1 Temperature

All fresh commodities contain water in their tissues and therefore are subjected to desiccation, which makes them susceptible for deterioration by other factors, such as microbial infection. Further elevated temperature influences the deterioration rate of harvested commodities. For each increment of 10°C, the rate of deterioration increases by two-to-three fold. Exposure to undesirable temperature results in many physiological disorders. Temperature also influences the effect of ethylene, reduced O_2 and elevated CO_2. Temperature can also influence the incidence or severity of pathogens.

8.4.2 Relative Humidity

In addition to temperature, relative humidity (RH) is the other factor which influences water loss from the product. It is important to maintain the RH level to optimum as lower RH may cause desiccation of the product, and higher RH may lead to condensation of water on fruit surface which may invite a host of problems.

8.4.3 Atmospheric Composition

Reduction of O_2 and elevation of CO_2 can either delay or accelerate the deterioration of fresh horticultural produce. The extent of these effects depends on commodity, cultivar, physiological age, O_2 and CO_2 level, temperature and duration of holding.

8.4.4 Physiological State-Respiration Rate and Ethylene Evolution

Respiration rate and ethylene evolution are major factors determining the storage life of harvested commodity. Respiration is the process by which stored complex materials are broken into simple products and energy is released. While respiration is essential to maintain the state of living of the produce, it causes deterioration due to losses in food reserves, food value, flavour, and dry weight. Further, a good amount of energy is released during respiration. The rate of deterioration of harvested produce is generally proportional to their respiration rate.

Ethylene is the natural ripening and senescence hormone, which is physiologically active at very low concentration (0.1 ppm). While all the plants produce ethylene, its production varies greatly. Generally ethylene production rate increases with maturity at harvest, physical injury, disease incidence, increased temperature and water stress. It can be controlled by storing at low temperatures and reduced O_2 and elevated CO_2 atmosphere.

8.4.5 Initial Infection and Physical Condition of Produce

The produce should be in good condition before storage. Harvesting should be done in a manner that it doesn’t cause impact, bruising or injury to the product. Bruising may stimulate respiration and enhance ethylene production that accelerates ripening and associated changes. The bruised or cut sites may invite microbial infection, which ultimately reduces the life of the product.

8.4.6 Pre-harvest Factors

The prevailing climatic conditions and cultural practices determine the quality of the produce. The incidence of infection at the time of harvest will determine the storage life of a commodity. A sizable proportion of stored produce is spoiled by these infections.

Storage life partly reflects the cultural and environmental conditions to which the produce is exposed before harvesting. The environmental factors include temperature, RH, light, soil texture, wind, elevation, and rain fall; whereas cultural factors are mineral nutrition, soil management, pruning, thinning, chemical spray, rootstocks, planting density and irrigation.

I) Climatic influences

Temperature: The metabolism and composition of the fruit are affected by temperature. Tomatoes grown at high night temperature have higher respiration rates than those, which grow at lower night temperature and ultimately have lower shelf life.

Light: The duration, intensity and quality of light affect the quality of fruit and vegetable at harvest and have influence on the shelf life. In tomatoes leaf shading of fruits produces a deep red colour, and the fruits exposed to the sun are lighter in weight with thinner rind. Such fruits are more susceptible to mechanical damage and have higher transpiration rate; and lower shelf life.

Water supply: Water supply to plant during growth also affects the storage life. Fruits and vegetables grown under water deficit condition may not develop properly and will have shorter shelf life. Similarly under water logged conditions may cause development of water soaked areas on commodity reducing the storage life.

Wind: Wind may damage the leaves of the vegetables or cause abrasions on fruit surface, which reduces their shelf life. High wind velocity may have a deleterious effect on plant growth.

II) Cultural practices

Several factors before harvest affect quality of horticultural crops after harvest. The quality of the seed or the plant material is an important factor that controls the fruit produced. Besides this genetic makeup of plant also determines the quality of the product. All cultural practices have direct effect on final quality of the produce.

Seeding or planting period: Many species are very sensitive to environmental conditions, so optimum quality of produce cannot be expected when crop is grown under adverse conditions.

Planting density: Planting density can affect both quality and quantity of produce. In high density planting competition among plants is increased which reduces light availability, and thus may decrease its quality. Low density planting leads to large sized fruits with good colour. But larger fruits are commonly more susceptible to physiological disorders.

Environmental conditions during growth: High temperature, light intensity, wind rain, hail, storm and snowfall are the environmental conditions that may influence the quality of the produce.

Irrigation: Irregular watering usually reduces fruit size, increases splitting and physiological disorders, and it reduces water content in fruit or plant.

Fertilization: Poor fertilization increases chances of physiological disorders due to deficiency of some minerals, or excess may lead to toxicity of some minerals. Nutrition of the plant is the most studied factor affecting the quality of harvested produce and its storage life. Many physiological disorders are the result of depleted nutrient status or nutrient toxicity in the soil. High level of nitrogen promotes stem end rind breakdown in citrus, and cracking in sweet potato, where as deficiency of nitrogen causes stunted growth. Deficiency of potassium leads to black spot in potatoes. Calcium deficiency causes reduction in firmness besides causing cavity spot in carrots. Besides the major nutrients, micronutrient deficiency also affects product storage life. Fruits of citrus become hard and grow to irregular shape and contain brown gummy discoloration in the albedo if grown in boron deficient soil.

Pruning: Pruning reduces the load in plants, and leads to good fruit development in the plant. Fruits from well pruned tree can be expected to have more storage life than unpruned tree due to proper growth and development.

Thinning: Thinning reduces the competition between fruit trees, and therefore promotes a good balance between the vegetative parts and fruit, which results in improvement of quality.

Disease and insect control measures: Incidences of pathogens and insects have negative effect on fruit quality. Poor management of plant protection programs has the potential of not only reducing yield, but quality also.

Hormone and growth regulators used during growing season: Many hormones and growth regulators are sprayed during growth season to improve the quality of fruit/vegetables.

Chemical sprays: Chemical sprays during pre-harvest are done for control of weeds, insects and pests, and control of nematodes. Timely and adequate concentrations of these sprays improve the quality of the produce.

Rootstock: The effect of genetic material on storage potential after harvest is well documented. Different cultivars of same fruit vary in their storage requirement and storage life.

Other cultural practices: Any factor that affects plant growth also influences the quality of harvested produce. Age of the tree also influences the size and quality of the fruit, as in orange the older trees have smaller fruits with thin rinds, but high TSS. Further interactions among different levels of climatic and cultural factors during growth may affect the fruit quality and its storage potential.

8.4.7 Harvesting and Handling Practices

These likewise influence storage behaviour and quality. Merely dropping the fruit to the ground from a height of only a few inches will cause an outburst of CO_2 production, which may not be immediately counteracted by low temperature storage. Bruises, punctures, scratches and other mechanical injuries can be expected to produce even greater damage. Hence, careful handling and prompt storage should be practiced.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How temperature affects the respiration rate of the product?

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2. What is the effect of lowering oxygen content in maintaining quality of fresh produce?

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3. How relative humidity affects the quality of fresh produce?

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4. What is the effect of low temperature storage on fruit quality?

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5. What is the relationship between respiration and deterioration of quality of fresh horticultural product?

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6. Differentiate between climacteric and non-climacteric fruits.

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7. What is senescence?

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8. How bruising during harvesting affects the storage life of the horticultural commodity?

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8.5 LET US SUM UP

Being a live tissue, fruits and vegetables continue to perform metabolic activities even after harvesting, which is the major cause of their spoilage. Therefore proper storage after harvest is necessary to maintain the product quality after harvest. The product should be stored under optimum conditions of temperature to reduce its respiration and ethylene production, which leads to senescence. Maintaining proper humidity and alteration of product environment during storage also helps in extending the storage life of fresh produce.

8.6 KEY WORDS

Relative humidity	**:**	The relative amount of moisture in the atmosphere
Desiccation	**:**	Removal of water from the surface
Harvesting	**:**	Detaching the edible portion from the plant
Impact	**:**	To hit with force against a hard surface
Bruising	**:**	To injure the surface without breaking the skin, but causing Discoloration.
Microbial infection	**:**	Growth of microorganism on a product
Ethylene	**:**	A gas which stimulates ripening
Respiration	**:**	Process of inhaling oxygen and exhaling carbon-di-oxide

8.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:

   - Rate of chemical and biochemical reactions
   - Severity of pathogen infection

2. Your answers should include following points:

   - Temperature regulation
   - Ethylene removal

3. Your answers should include following points:

   - Desiccation
   - Pathogen infection

4. Your answers should include following points:

   - Reduced respiration
   - Reduced ethylene production

- Low pathogen incidence
- Enhanced shelf life

5. Your answers should include following points:

   - Loss of storage material
   - Ethylene production
   - Heat production

6. Your answers should include following points:

   - Respiration
   - Ethylene production

7. Your answers should include following points:

   - Death of tissues
   - Termination of metabolic activities

8. Your answers should include following points:

   - Enhanced ethylene production
   - Site for pathogen attack
   - Blackening of surface

8.8 SOME USEFUL BOOKS

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UNIT 9 STORAGE STRUCTURE

Structure

9.0 OBJECTIVES

After reading this unit, you should be able to:

- explain orderly marketing of fruits and vegetables thereby increase the period of availability;
- understand the role of temperature, humidity and atmospheric gases during storage;
- state different high-tech and low cost traditional storage techniques;
- demonstrate the principle of evaporative cooling and the role of Zero Energy Cool Chamber; and
- highlight the importance of refrigerated/cool stores for the benefit of the producers and consumers.

9.1 INTRODUCTION

Storage of fruits and vegetables is very much essential, because of their highly perishable nature. Their storage can be extended by various treatments applied to them after harvest. The most important of these is temperature management. Orderly marketing of these perishable commodities requires some storage facility in order to balance day to day fluctuation between product harvest and their sale.

Fruits and vegetables are grown in many parts of the country but not uniformly. During harvesting season, availability is abundant in one region but generally scarcity in other parts. The season lasts for few days to few weeks and this situation creates a glut in growing area and the growers do not get a remunerative price of their valuable produce. As a result, they encounter more spoilage and force to undertake distress selling at the instance of unscrupulous traders. Considerable difference exists in marketing of perishable fruits and vegetables and that of durable cereal grains. Consumers generally prefer to buy a small / requisite quantity of vegetables daily or once/twice a week because of their perishable nature. While in case of other items of food viz. cereals, pulses, vegetable oil, spices etc are normally procured once in a month as they are durable in nature primarily because they contain less moisture compared to fruits and vegetables. In order to extend marketing of these perishable commodities beyond the end of harvest season, proper storage of fruits and vegetables become essential.

A proper storage system reduces physiological activity of horticultural commodities by maintaining lowest safe temperature that will not cause chilling or freezing injury. It also reduces growth of spoilage causing microorganisms. With some commodities, the storage facility may also be used to apply special treatments like curing of tuber and other fruits and vegetables. For example potatoes and sweet potatoes are held at high temperature and high relative humidity for few hours/days to cure wounds sustained during harvest, drying of scaly leaves of onion and garlic, and degreening of oranges and lemons and application etherals for uniform ripening before marketing or shipment.

9.2 REFRIGERATED/COOL STORAGE

Fruits and vegetables if stored at low temperature remain fresh and nutritious for a longer time. Low temperature reduces physiological activity rate of the product like respiration, transpiration, ethylene production and other biochemical reactions responsible for rapid ripening and senescence. It also minimizes attack of pest and diseases and prevents product dryness with the help of humidifier in the storage room. Refrigerated storage is one such type of storage structure where temperature can be brought down with the help of mechanical refrigeration. This system doesn't produce cooling but removes heat from the storage that we feel is cooled. Refrigeration cycle in the compression system is by far the most popular and most widely used system of refrigeration. It consists of four important units namely compressor, condenser, cooling coil and expansion valves.

A good refrigerant changes into vapour phase upon heating and in liquid state upon cooling. The refrigerant (Fereon-12) or ammonia takes out the heat from the room and changes into vapour. The expansion valve controls the amount of refrigerant. The expanded gas is then compressed in compressor and thus the heat is removed from the compressed gas by means of running water or circulating cool air over the cooling coils containing the hot gas. The hot gas changes into liquid in condenser. Once the refrigerant is returned to the liquid state, it is again ready to be admitted through the expansion or the pressure-reducing device on to the evaporation. This cycle of actions in the compression system is repeated continuously so long as the compressor is in operation and with such a system accurate temperature control is possible. The ideal condition in the cool store is the lowest minimum temperature that does not cause chilling injuries to the produce.

Table 9.1: Recommended cool store temperature and relative humidity of some important fruits

Fruit	Temperature °c	Relative humidity%	Storage (days)
Apple	-0.1- +4	90-95	30-50
Banana	13-15	85-90	30-45
Grape	+1 -	90-95	60-90
Guava	5-10	90	14-21
Lemon	10-14	90	60-150
Lime	9-10	90	30-60
Litchi	1.5	90-95	21-35
Mango	13.3	85-90	15-25
Orange	4-6	85-90	45-80
Papaya	12.2	85-90	7-21
Pineapple	10-13	90	21-28
Sapota	12.2	85-90	14-21

Source: Hardenburg, R.E.; Watada, A.E. and Wang, C.Y. (1990)

Table 9.2: Recommended cool store temperature and relative humidity of some important vegetables

Fruit	Temperature °c	Relative humidity%	Storage (days)
Broccoli	0	95-100	10-14
Cabbage	0	98-100	21-42
Carrot	0	98-100	210-270
Cauliflower	0	95-98	21-27
Cucumber	10-13	95	10-14
Eggplant / Brinjal	8-12	90-95	7
Green peas	0	95-98	7-14
Melons	10-15	90	14-21
Okra	7-10	90-95	7-10
Onion	0	65-70	180-240
Potato	3-8	90-95	150-300
Tomato (Ripe)	8-10	90-95	4-7

Source: Hardenburg, R.E.; Watada, A.E. and Wang, C.Y. (1990)

9.3 CONTROL/MODIFIED ATMOSPHERE STORAGE

It is an advance technology for storage of fruits and vegetables. In these systems, storage environment is different than the normal. Controlled atmosphere (CA) storage utilizes the correct amount of gas combination during storage. In CA, oxygen is reduced from 21% to 2-5% and CO_2 is increased from 0.03 to 1-5%. These results slow down of physiological activity of fruits and vegetables such as rate of respiration, ethylene production and other bio-chemical reactions. The reduced rate of these activities actually decreases the ripening and senescence process considerably. Construction and running of CA storage needs special attention such as it should be gas tight, mechanical refrigeration should be attached to maintain a temperature of 30-32 ^{0}F. Nitrogen and CO_2 gas are introduced into the storage and excess CO_2 must be removed by dry hydrated lime because high CO_2 is not tolerated by many commodities. No doubt, CA storage has many advantages but few harmful effects have also been recorded. For example, Initiation of black heart in potatoes, brown stains on lettuce, irregular ripening of banana, pear, tomato and development of off-flavour at very low O_2 concentration.

Modified atmosphere inside the package develops due to the respiration of fruits and vegetables. Inside the package O_2 decreases and CO_2 increases with the uptake of O_2 and release of CO_2. In MA storage, a very low degree of control gas concentration is possible. However, a desired gas combination can also be obtained by placing absorbers and adsorbers of O_2, CO_2 and ethylene. The MA and CA differ mainly in degree of control of gas concentration. Advances in the design and manufacturing of polymeric films with wide range of gas permeability increased the efficiency of MA storage.

9.4 ICE BANK COOLER

In efficient cooling system cooled air passes over the stored fruits and vegetables at a very high velocity as a result desiccation of the crop takes place. In order to avoid this, various methods of humidifying the cooling air have been developed. A recent development in refrigeration is the Ice Bank Cooling system with positive ventilation. The system positively directs ice cold air through the boxes or crates containing fresh fruits and vegetables. In this way quicker cooling is possible and large amount of heat can be removed in a relatively short period of time. In this system, a bank of ice is built up with the help of a small refrigeration plant. The ice is accumulated on extended surface plate, which are suspended in a tank of water. The water surrounding the ice is pumped to the top of a cooling tower and falls through the tower passing over the extended surface, giving a large surface area of heat exchange. The air leaving the tower maintains high relative humidity. Once initial cooling is complete the store maintains a temperature of 0.5 - 0.8^{o}C and relative humidity of 98 per cent. In view of the continuous humid cool air circulated through the stored commodities this system of storage is found very useful for storage of fresh horticultural produce. This will be preceding step for cool storage of fruits and vegetables.

9.5 HYPOBARIC STORAGE

Fruits and vegetables can be stored under less than atmospheric pressure. This technology is called hypobaric storage. Fruits were held at about 0.2 to 0.5 atmospheric pressure at 59 to 75°F and humidified air was passed through the chamber in order to maintain humidity and to remove ethylene and other volatile compounds given off by the fruits and vegetables. There is reduction of ethylene in the fruit tissues and O_2 in the chamber. As a result, products respiration and ethylene production decreases which results increased shelf - life. Many volatile compounds evolved by the produce and from other sources may accumulate in the storage atmosphere. Ethylene is the most important volatile compound accumulated in the storage room. Its accumulation above certain level may reduce storage life. Therefore, its removal becomes necessary. Hypobaric storage is a form of controlled atmosphere storage in which the produce is stored in partial vacuum. In hypobaric storage system, the commodity is placed in a vacuum tight and refrigerated container and air is evacuated by a vacuum pump to the desired low pressure. This is a very expensive method and used in case of high value commodities.

9.6 LOW COST STORAGE

Low cost storage structures are the best alternative for rural areas and in all such places where electric facility is not available. It is easy to install and run by unskilled people. These low cost storage systems have a great significance in our country since other advanced storage techniques work out to be extremely expensive. Most of the low cost storage structures are build by taking the advantage of natural cooling and all of them are not only environment friendly but also energy saving.

Clamps

These have been used from time immemorial as a traditional method of storage. The clamps vary in design and commonly used for potatoes, turnips, beet etc. An area of land at the side of the field that is not susceptive to water logging is selected. The width can be any convenient one but normally it ranges between 3' – 7. 5' and it can be any suitable length. These dimensions are marked out and the vegetables piled on the ground. Occasionally straw is put on the ground before the vegetables. The height of the pile should be about 1/3 of its width. The pile is covered with unbroken what or rice straw to about 6.8" thick, when fully compressed, laid upright from ground to ridge and capped at the top with bent over straws. About 2 weeks after the clamp is covered with a layer of soil, usually in the order of 6-8" thick when compressed. In colder climates more straw and soil may be added.

Pits

Normally pits or trenches are dug at the edges of the field where the crop is grown. One should remember that the site of pits or trenches in the field should be at higher points particularly in high rainfall regions. These are lined with straw or any other organic matter before filling with the commodities to be stored and then covered with a layer of organic matter and then with a layer of soil. Sometimes wooden boards are placed on the surface before the soil is put on. Some times lack of ventilation may cause rotting problems. This can be avoided by providing ventilation hole at the top in such away that it allows only air to pass out but no rain to penetrate.

Cellar

These were underground or partly underground structures usually below a house. This location provides good insulation as a result they are protected from excessively low temperatures in cold climates. They were used for years as storage for fruits and vegetables. The crops are usually spread out thinly on shelves in order to ensure good air circulation. The doors of the cellars are generally kept open at night to ensure that the temperature in store remains low. It has often been observed that the cellar humidity remains low that may induce desiccation. In order to avoid such situation precaution is taken to keep the floor of the store wet. As a general rule, the cellar temperature is approximately equal to the average annual air temperature. Cool under ground spaces work well for storing already cooled produce but not for removing field heat.

Night time cooling

This is also called as air cooled storage system. This method actually should consist of an insulating room from all the sides with air inlet and out let for exchange of air. During night open these pores and allow the cool air to come inside. By putting an exhaust fan at out let will increase the efficiency of nighttime cooling. It will facilitate more sucking of cool air inside for faster air circulation and rapid cooling. During daytime both inlet and outlet are kept closed. The trapped cool air will keep the produce cool. The relative humidity can also be maintained by sprinkling water on the floor or by providing mechanical humidifier. Fruits and vegetables can be stored for few days to a few weeks depending on the out side temperature. In some parts of the world, there are significant differences between night and day temperatures allowing night time ventilation as an efficient system of storage of fruits and vegetables. In hilly areas also night temperature falls as high as 15 to 20°C. Low night temperature can be used to reduce field heat simply by harvesting the produce during early morning hours.

Well water

In some areas, well water can be an effective source of cold. The temperatures of the ground at depths greater than about 2m (5feet) below the surface is equal to the average annual temperature. Well water temperatures are usually very near to this.

Naturally formed ice

This is an old method of refrigeration and very useful for cold countries where water of lakes, ponds are frozen in winter season. The ice is harvested and stored in insulated houses and used for pre-cooling, storage and transportation of horticultural commodities. Before the development of mechanical refrigeration, refrigeration was provided by ice formed naturally in shallow ponds during winter. The ice was insulated from spring and summer heat with straw and transported to cities as needed. But the cost of transportation was found very high as compared to electrical cost for refrigeration. Generally one Kg of ice takes 325 Kilo Joules of energy for complete melting. The heat comes form the commodities and its immediate surroundings that results cooling. But this method requires a large quantity of ice and creates problem of disposal of melt water. However, cooling facilities in climates where winter ice making is feasible can store for summer use. In case of few fruits and vegetables, it is best suited for transportation along with ice.

High altitude cooling

High altitude can also be a source of cold. As a thumb rule, air temperature decreases by 10°C (18°F) every 1Km increase in altitude. It is not possible to bring this air down to ground level because it naturally heats up as it drops in altitude. However, in some cases it may be possible to store the commodity at high altitude in mountainous areas.

Underground storage

Cellars, abandoned mines, and other underground storage have been used for years for storage of fruits and vegetables. The temperature inside storage is approximately equal to the average annual air temperature. It should be noted that cool underground spaces work well for already cooled produce but not for removing field heat. The soil has a poor ability to transfer heat. Once the cold is depleted from an area it will not regenerate rapidly. Use of soil at the top for insulating the underground pit is important in order to avoid run-off and rain water to enter into the pit. A small tube is generally inserted inside the pit for gaseous exchange.

Ventilated storage/onion storage structure

The conventional storage structures used in India for onion are primarily made of bamboo or similar plant material with a thatch on top. All attempts are made to provide side and bottom ventilation, but unfortunately due to indiscriminate piling of onion heat pockets develop because of improper ventilation of onion stack. As a result of inadequate ventilation, spoilage is accelerated. Therefore, air movement is essential for onion storage. Considerable reduction of spoilage of onion could be achieved by modifying the existing storage structure and introducing pile ventilation with the help of perforated bamboo pipes. It was observed that storage of onion in perforated plastic crates stacked in a ventilated room/shed could reduce the storage losses due to spoilage to a considerable extent. The big size cool chamber can be used as an ideal onion storage structure if the water is withdrawn from the system.

9.7 EVAPORATIVE COOLING/PUSA ZERO ENERGY COOL CHAMBER

Evaporative cooling is Nature's very own method. The ancient Egyptians used a primitive form of evaporative cooling, dating back to about 2500 BC and so did the Mughals a few centuries ago. Evaporation of water produces a considerable cooling effect and the faster the evaporation the greater is the cooling. Evaporative cooling occurs when air, that is not already saturated with water vapour, is blown across any wet surface. Thus evaporative coolers consist of a wet porous bet through which air is drawn and is cooled and humidified by evaporation of water. Theoretically, the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature. Evaporative cooling is widely used for comfort cooling of living and working spaces in hot, dry climates and it has a considerable potential for pre-cooling and even storage of fruits. The principles of evaporative cooling can be gainfully utilized for storage of fresh produce, particularly in rural India, as it can be constructed even in a remote village.

This is a low cost storage structure, based on the principle of evaporative cooling. The most important advantage of this low cost technology lies in the fact that it requires very minimal electricity or power to operate and all the construction material of cool chamber are available easily and cheaply. It can be installed by low skill persons as it does not require any specialised skill. Only the place / site should have a permanent source of water. The raw material required for the construction of cool chamber are bricks river bed sand, bamboo, khaskhas, rice straw (or any material of similar nature), gunny bags/cloths etc. Its construction is also very simple. First of all floor is made with a single layer of bricks and the side wall are made with a double layer of bricks leaving a cavity of approximately 7.6 cm space in between the two layers of bricks. This cavity is filled with river bed sand free from stones and other materials. The top cover is made with khaskhas or gunny bags in a bamboo frame structure. About 400 bricks are required to built a cool chamber for 1 quintal of fruits or vegetables. After construction, wall, floor sand and top cover should be wetted fully by water. Once the chamber is fully saturated with water, sprinkling of water once in the morning and once in the evening is enough to maintain the temperature and humidity. These cool chambers can reduce the temperature by 17-18°C during the peak summer months and maintain a very high humidity of about 95 per cent throughout the year even when the atmospheric relative humidity falls below 20 per cent. The improved system of watering by single drip in zero energy cool chamber was found to be efficient in maintaining slightly lower temperature compared to the conventional system. It also helped in saving considerable amount of water and labour. Few precautions should be taken to run this chamber successfully, that there should be a permanent source of water, it should be constructed under shade and the site should not be prone to water logging condition. Spray recommended insecticide/ fungicides before storage. The shelf life of fruits and vegetables could be increased from a few days to few weeks in these chambers.

Commercial size cool chamber

The low cost big size cool chamber has been designed and constructed with the double brick wall having cavity filled with riverbed sand. The bottom of the chamber is provided with four ducts that are submerged in wet sand. The floor of the chamber is made of wooden planks with provision of the entry of fresh air through the duct. An exhaust fan has been provided at the top for ventilation purpose. The trial with big size cool chamber showed that it could bring down the temperature by 8-10°C. The study revealed that the temperature could be brought down efficiently by judicious operation of the exhaust fan.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Why do we need storage of fruits and vegetables?

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2. What are the different types of low cost storage systems other than Pusa Zero Energy Cool Chamber?

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3. Write the utility of Pusa Zero Energy Cool Chamber (PUSAZECC).

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4. What are the high-tech. storage systems?

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5. Write different components of refrigerated storage?

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6. How CA differs from MA storage?

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9.8 LET US SUM UP

Storage of fruits and vegetables is essential to extend the period of availability for orderly marketing, pricestablization, spoilage reduction and distribution to the places of scarcity. Many biotic and abiotic factors effects the storage life of fruits and vegetables after harvesting. In order to control these factors many, high-tech storage systems are developed such as refrigerated storage, Controlled/Modified atmosphere storage, Hypobaric storage etc. However, such high-tech storage are costly, requires power to operate and skilled persons which a small farmer can not afford. On the other hand, low cost storage systems are found very useful for on farm. Pusa Zero Energy Cool Chamber is one such low cost storage system. It requires very low or minimal electricity or power to operate nor any skilled person to operate, maintains low temperature and high humidity. Small and marginal farmers can adopt this low cost storage to store his daily harvesting instead of selling to middlemen at cheapest rate. In addition commercial size cool chamber can be constructed in a in village hat for storage purpose.

9.9 KEY WORDS

Evaporative cooling	**:**	Evaporative cooling occurs when air that is not saturated with water vapour is blown across any wet surface.
Zero energy cool chamber	**:**	Low cost storage structure for storage of horticultural perishable.
Relative humidity	**:**	Ratio of weight of water vapour present in the air and the weight of water vapour required to fully saturate the air, expressed in percentage.
Processing	**:**	Sterilizing process by the application of heat.

9.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - It regulates market price and facilitates orderly marketing of fruits and vegetables.
   - Increases availability of fruits and vegetables during off-season.
   - Extend the shelf-life of fruits and vegetables beyond the harvesting season.
   - Increases the marketing period of fruits and vegetables.
   - Beneficial to both the producers and the consumers.

2. Your answer should include the following points:

   - Underground storage such cellars, abandoned mines, caves etc.

- Cooling by naturally formed ice
- High altitude cooling
- Night time cooling
- Storage in clamps

3. Your answer should include the following points:

   - It does not require any electricity or power to operate.
   - All the construction material of cool chamber are available easily and cheaply.
   - Any person can install it at any place/site (with a permanent source of water).
   - It maintains high humidity and low temperature which is essential to preserve freshness and prevents desiccation of horticultural produce during storage.
   - It increases shelf-life of fruits and vegetables and preserve their nutritional quality.

4. Your answer should include the following points:

   - Refrigerated storage
   - Controlled atmosphere storage.
   - Modified atmosphere storage.
   - Hypobaric storage
   - Ice Bank cooler

5. Your answer should include the following points:

   - Expansion valve
   - Compressor
   - Condenser
   - Cooling coil
   - Refrigerant

6. Your answer should include the following points:

   - CA maintains required level of gases in the storage, which is not possible in MA.
   - In CA required amount of gases are maintained by injecting or removing but not in MA.
   - In MA respiration of fruits or vegetables modifies gases composition.
   - Packing of fruits and vegetables in a polyethylene pouch is an example of MA.
   - CA requires airtight room with refrigeration and gases controlling facility.

9.11 SOME USEFUL BOOKS

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5. Wills, R.B.H.; Lee, T.H.; Graham, D.; McGlasson, W.B. and Hall, E.G. (1989) Post-harvest: An introduction to the physiology and handling of Fruits and Vegetables, New York: Van Nostrand.

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UNIT 12 MINIMAL PROCESSING

Structure

12.0 OBJECTIVES

After reading this unit, you should be able to understand:

- consumer and market trends in the market that have favoured minimal processing, its advantages;
- key requirements of minimal processing; and
- quality maintenance in Minimal processing.

12.1 INTRODUCTION

The present day food processing industry is moving with a fast pace. The food market today is more competitive, consumer driven and technologically advanced. Compared with the market place of 25 years ago, it has more processed fruit and vegetable products and more innovative packaging. New development in scientific research, consumer demands, taste preferences and technological advances in food processing are some important factors affecting the food industry and new product development**.** Progress in scientific research and food biotechnology also has played a tremendous impact. The present day consumer is more health and quality conscious and more averse to traditional chemical preservatives. The way he perceives the food is also changing. This has had a dramatic impact on food processing technologies. Food processors are exploring new processing and preservation technologies to suit the changing needs of consumers. This has left processors with less flexibility in choosing preservatives and preservation methods. Newer methods of processing and packaging material are being tried to suit to the changing needs of consumers. Minimal processing is one such technology that has arisen because of the changing needs and need for fresh and quality products. Minimal processing (MP) in layman's language are precut fruits and vegetables which are packed in suitable packaging material that permits suitable shelf-life and fresh like characters. Before we see what is minimal processing, let us see its background and examine some factors that have changed the consumers and in turn the food industry.

Background of minimal processing

Need for minimal processing in the present day can be traced back to factors like changed life styles, demographic patterns and more working women and more income. Let us se them in detail.

Changing life styles and demographic patterns

The present day families are nuclear and more fragmented compared to then the families of earlier days. The joint family system has broken apart and nowadays more nuclear families are seen. Smaller families have different needs then joint families. The concept of unitized packaging instead of bulk packaging has arisen due to this change in family structure. This is in turn putting more demands on food processing industry. Smaller families can easily opt for ready to meals then joint or big families. Have you observed that the demand for bakery segment foods has been rising because consumers are asking for more take away meals and snacks rather than traditionally home-cooked set meals. Pizzas, burgers, patties and other confectionary items have put bakeries as major business sectors. These items are becoming increasingly popular among youngsters and college going students.

Apart from this there are changes in life styles and populations too. There are more working women in cities. They have less time for kitchen. Thus more demand for convenient food items. Also we have more older people in population. This group has different food requirements then the younger population.

More working women and more incomes

Since both men and women are working and there are dual incomes in the families. This is probably the reason for more eating out habits seen nowadays. This has also made the present consumer more adventurous who likes to try more different types of product. Consumer in metropolitan cities has developed taste for Chinese, Mexican, Italian, apart from our traditional south Indian and Gujrati foods. The present day scenario was very different from market place twenty years ago.

Need for convenience and quality

Convenience and Quality are the buzz words in the market place. You will ask me what is ‘Convenience’, and how does it relate to processing of food. Observe some common examples around you. Pizzas, burgers, patties are some examples of convenient bakery take away foods in the market. They are convenient because you don’t have to cook them simply buy them and eat them. Lets see more examples from fruits and vegetables. Have you observed that your subjiwala who sells green leafy vegetables such as palak, mustard and fenugreek now also keeps a small machine to cut them? Earlier this was never seen. Our mothers and grandmothers would spent hours together in cleaning and cutting such leafy vegetables. He now delivers convenience to you by cutting the leafy vegetables at this end. In cities, majority of women are working. She has less time for food preparation, and thus prefer to have precut vegetables. Why only working women even housewives like to have precut vegetables since it saves time and labour. Let us observe some more examples. Have you observed peeled and sliced pineapple rings and fleshy axils of pomegranate being sold in the busy market place? They are the most appropriate examples of convenience. You would often such things around busy office complexes. It is easier to eat an apple fruit than a pineapple which needs to be peeled, cored and sliced. What if the fruit is sold in form of sliced rings. It becomes more convenient to eat. Similar is the case with pomegranate, which needs to be peeled and fleshy arils, be removed from white placental tissue. Such convenience has become essential because of busy part and parcel of the urban lifestyle. Precut fruits and vegetables fulfil convenience and provides fresh like characters. With this background in mind, it will be easy for you to understand what minimal processing is. Now let us come to our main topic minimal processing.

Consumer and market trends

1. More health conscious
2. More working women in cities, less kitchen time, more eating out habits
3. More ageing and diverse population
4. Low fat, sodium and reduced calorie requirement
5. High requirement of Vitamin/mineral fortified food

Industry response to consumer trends

1. Increase in products with low fat and calories e.g. low fat butter, cheese spreads
2. Increase in availability of low calorie sweetner (asparatame, acesulfame) and diet colas
3. Introduction of foods with added health benefits (margarines, sport bar, fortified drinks) Choices in many categories such as dairy salad dress, frozen meals, snacks)
4. Increased availability of convenient foods breakfast bar, meal kits and ready to eat to meals, yoghurt cups, sprouted cereals and pulses, drinkable soup and frozen dinners.
5. Exploring newer methods of processing e.g. microwave and aseptic processing

Let us group these changes and see their consequences in a graphic form

Changes		Consequences
	→ Convenience →	**More** snacking, portability food service, relaxation foods, less cooking skill
More obesity, older consumers, health awareness (food/fitlink), safety concerns, alternative health solutions	→ Health →	**More** functional foods, natural/organic less junk foods
More older consumers, balanced health approach income polarization, change in leisure time	→ Indulgence →	**More** large portion sizes snacks, sweetness in flavouring, premium brands
More travel, immigration**,** media fragmentation, segment fragmentation, sophisticated consumers	→ Novelty →	**More** brand switching, fun foods, ethnic and brand foods

12.2 ADVANTAGES OF MINIMAL PROCESSING (MP)

In scientific language, MP is defined as these procedures such as washing, sorting, trimming, peeling, slicing or chopping that does not affect the freshness of the product. The result of such operations is a convenient fresh product that can be prepared and consumed in less time. Minimal processing is also called Light Processing. It may be defined in another form. Any fruit or vegetable or combination thereof that has been physically altered from its original form but remain in a fresh state. Since it includes pre-processing unit operations such as cutting, slicing and dicing, it is also called as 'Light Processing'.

Why has there been demand for such type of processing? What are its advantages over the other methods:

1. Consumers are increasingly demanding convenient, ready to use and ready to eat fruit and vegetables with a fresh like quality and containing only natural ingredients. They can easily go for meal preparation.

2. Delivers fresh like characteristics. Peeled, cut/shredded fruits and vegetables if delivered in time, offer fresh like characters.

3. Not only general consumers, the catering industry also wants to purchase fruits and vegetables that are sliced, grated or shredded. This is primarily for the reasons of expense, labour and hygiene.

4. Pre-packaging allows for more efficient portion control.
5. Solid waste disposal problems are reduced.
6. Demand on limited refrigerated storage spaces are reduced.
7. Supply of a variety of ready-to-eat items that exhibit excellent uniformity of quality and identity is available over many weeks.

Minimal processing is different from conventional processing

Conventional processing is different from minimal processing. While conventional food processing methods extend shelf-life of fruits and vegetables, minimal processing renders products highly perishable, requiring chilled storage to ensure a reasonable shelf-life. Preparation steps such as cutting, peeling renders them susceptible to wilting and desiccation. In conventional processing such as canning and freezing, many of these problems are prevented or controlled by heat inactivation or freezing or use of protective packaging materials or through application of food additives. Several chemicals are used for this purpose. Another important point of difference is that since no heat is applied to maintain fresh like characters, use of preservatives becomes mandatory here.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. The market place in food processing sector has changed in the last 25 years. Analyze the major factors.

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2. What has been the major consumer trend influencing the food processing industry?

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3. Name some convenient food products available in the market.

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4. Can you cite some examples of some minimally processed products available in the market?

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5. What is Minimal Processing?

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6. What are the alternate terms used for minimal processing?

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7. What are the main reasons for demand of MP produce?

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8. How is minimal processing different from conventional processing?

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12.3 PERISHABILITY OF MP

MP produce are highly perishable. They deteriorate fast because of physiological ageing, bio-chemical changes and microbial spoilage, which may result in the degradation of the colour, texture and flavour of the produce. Major deterioration factors are enzymes, ethylene and increased respiratory activity.

Enzymes

During peeling and grating operations, many cells are ruptured and intracellular products such as oxidizing enzymes are liberated. These enzymes are responsible for deterioration. The most important enzyme with regard to MP is polyphenol oxidase (PPO), which causes browning. Enzymatic browning requires presence of different components: oxygen, an oxidizing enzyme and a suitable substrate. To prevent browning, at-least one of these components must be removed from the system. Another important enzyme is lipo-oxidase which causes the formation of numerous bad smelling aldehydes and ketones.

Ethylene Production

Ethylene is a gas which is produced when fruits and vegetables respire. This gas is also called as the ripening harmone, and plays an important role in ripening of fruits. Cutting and peeling both release ethylene. It may be partially responsible for bringing about physiological changes in sliced fruit, such as softening.

Increase in respiration activity

Depending upon the produce and cutting grade and temperature, respiration activity of minimally processed increases 1.2-7.0 fold or even more. Increased respiration leads to anaerobic conditions and increased rate of spoilage.

12.4 FACTORS AFFECTING QUALITY

The main factors affecting the quality of minimally processed produce are harvesting operations, raw material, preparation procedures (trimming, cutting, peeling, shredding, processing conditions and Good manufacturing practices) In fact you can also study them under major unit operations of minimally processed produce.

Harvesting

Harvesting is a fundamental unit operation required for the production of minimally processed produce. Most of the raw material for fresh cut produce is cultivated under contracts that specify the cultivars and cultivation techniques in western countries (including sowing time, pesticide, fertilizer applications, and harvest conditions). Following points should also be borne in mind with regard to harvesting.

- Harvesting should be done preferably in the morning hours because of the cooler temperature.
- Pre-cooling to 1^{o}C, as soon as possible to extend potential shelf-life.
- Processing within 2 days of harvesting.

Raw material

Not all types of vegetables may be suitable for MP. Say, for example, onions, carrots and cabbage may be highly suitable for MP. Vegetables that can be washed and peeled easily are more suitable. Vegetables like tomato, calocasia and okra may not be best suited. Again, it is important to understand that not all varieties of a particular vegetable may be used for preparation. The correct choice of variety is particularly important in case of carrot, potato and onions. For example, carrot varieties that give the most juicy grated product cannot be used in the production of grated products that need to have a shelf-life of several day. Poor colour, flavour and microorganisms can create become problems if the selection of the variety is not proper. Main criteria in assessing suitability of cultivars to minimal processing are:

1. Processing yield (30-50%).
2. Low sensitivity to physiological disorders and microbial diseases.
3. Mechanical resistance to damage
4. Resistance to elevated carbon dioxide and/or low oxygen.
5. High sugar content because sugar may be responsible for energy stress.
6. Low respiration rate

Trimming

Trimming is an important unit operation sought after in vegetables especially in salad mixes. All unwanted parts of plants including outer green leaves are removed manually. This can be done using stainless steel knives, or ceramic blades. Cutting or bruising plant tissues with browning capability results in a brown discoloration. Using very sharp blades and chill storage can reduce browning.

Peeling, cutting and shredding

Some vegetables or fruits such as potatoes, carrots or apple require peeling. Peeling should be as gentle as possible. There are several methods of peeling, for example, hand peeling, steam, or lye peeling or industrial peeling using rotating carborundum drums. The ideal method is hand peeling using sharp knife. Peeling increases the respiration rate. Cutting and shredding must be performed with knives or blades that are as sharp as possible, these being made from stainless steel. Sharp blades are always better than blunt and dull blades. Blunt blades and knives impair the retention of quality because these rupture cells and release tissue fluid to a great extent. Mats and blades that are used in slicing operations can be disinfected with 1% hypochlorite solution. Cutting of vegetables should be preferably done under water. Because the internal liquid of injured cell is removed by water flow, browning is markedly compared to any commercial cutting technique.

Cleaning/washing/drying

Fruits and vegetables, after harvesting are covered with soil, mud or sand, they should be carefully cleaned before processing. Usually, a second washing is performed after peeling and/or cutting. For example, cabbage must be washed after shredding, however, carrot must be washed before grating. Washing after peeling and/or cutting removes microorganisms and tissue fluids, thus, reducing microbial growth and enzymatic oxidation during subsequent storage. Washing is done in ice-cold water (< 5^oC). Washing the produce in flowing or air-bubbling water is preferable to simplify dipping it in water. Both the microbiological and the sensory qualities of washing water must be good and its temperature is low, preferably < 5^oC. The recommended quantity of water that should be used is 5-10 l/kg of product before peeling and/or cutting and 3 l/kg after peeling and/or cutting. Preservatives can be used in the washing water to reduce microbial numbers and retard enzymatic activity, thereby improving both the shelf-life and sensory quality of the product. Chlorine is the most common preservative that is used in MP. Chlorine or citric acid (100-200 mg/l) is effective in the washing water before or after peeling to extend shelf-life. The effectiveness of chlorine can be enhanced by using a low pH, high temperature, pure water and correct contact time. The optimum chlorine concentration is 100 mg/l at a contact time of 12-13 seconds. Use of chlorine is banned in some European countries such as Belgium, Germany and Holland. The last step of washing operation is rinsing with tap water containing less than 0.5 ppm active chlorine. This step is used when chlorine is used at a concentration of higher than 1 ppm. Careful washing with water containing 100 mg chlorine/litre and subsequent rinsing improved the sensory shelf-life of minimally processed vegetables by several days, up to 7-8 days. Excessive free water on leaf surface leads to rapid bacterial spoilage.

Draining

Washing water should be gently removed from the product. Centrifugation seems to be the best method. It is important to choose the centrifugation time and rate carefully.

Dipping in anti-browning agents: Browning inhibition

Browning is the main quality problem in pre-peeled or cut fruits and vegetables. What happens to the apple slices and peeled potato, if you leave them open in air. You will find that after sometimes, the outer tissues start getting brown. This browning is basically a type of enzymatic browning, caused due to action of enzyme known as polyphenol oxidase (PPO). Oxidation of phenols in the presence of PPO causes these tissues to brown. Dipping the tissues in water or in salt water can reduce browning to some extent but cannot totally eliminate browning. The traditional preservative used to prevent browning are sulphites. Potassium metabisulphite is the most common preservative that has been used to control browning, however, its uses has some disadvantages. Recently, there have been reports regarding their harmful side effects for people with asthma. It is for this reason the US Food and Drug Administration (FDA) has partly restricted the use of sulphites in 1990, and since then there is increasing interest in substitutes for sulphites. In India, however, they continued to be used. Citric acid (CA) combined with ascorbic acid (AA) alone or in combination with potassium sorbate in case of potato, or Hexyl-resorcinol in the case of apple, seem to be promising alternatives for sulphites, particularly when hand peeling is used. Potatoes when heated for 5-20 min in a solution containing 1% ascorbic acid and 2% citric acid at 45-55^{o}C, cooled and then dipped for 5 min in a browning inhibitor solution containing 4% ascorbic acid. The combined treatment inhibits potato discolouration for 14 days at 4^{o}C, compared with 3-6 days with the browning inhibitor treatment alone.

12.5 PACKAGING AND STORAGE OF MINIMAL PROCESSED FRUITS AND VEGETABLES

12.5.1 Modified-Atmosphere Packaging and Edible Coatings

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

MAP is being used commercially for minimally processed lettuce, carrots and cabbage although current design is not sufficient to prevent the onset of fermentation under normal marketing conditions. In these cases, fermentation alters the flavour and quality of the product. This approach will not work for products such as broccoli that produce offensive off-flavour.

Packaging films such as combinations of ethylene vinyl acetate with oriented polypropylene and low density polyethylene have proved useful as these combinations have significantly high gas permeability. The shelf-life of shredded cabbage and grated carrots packed in these composites is 7-8 days at 5^{o}C. This is 2 days higher than oriented polypropylene which is generally used in the vegetable industry.

Edible coatings are another possible packaging method for extending the post-harvest storage life of minimally processed foods. Use of edible coatings is made from lipid resins, polysaccharides and proteins. In addition, plasticizers such as polyhydrin, alcohol, waxes and oils are added to improve flexibility and elongation of polymeric substances. Can you cite an example of edible coatings in your daily routine? The medicine capsules that you take when you fall sick, is a good example of an edible coating. Coatings serve dual functions. They serve as carrier of antimicrobial agents and retard loss of desirable flavour, volatiles and water vapour and restricts exchange of CO_2 and O_2 creating a modified atmosphere.

The packing room must be clean and refrigerated at 1-2°C and must be separated from the washing section. Most of MP are packed in bags of polypropylene (25-40 um thick). Oriented polypropylene (OPP) is preferred to polyethylene mostly for its brightness, crispness and suitability for machine packing. The permanence of this film is suitable for packaging fresh cut endive and lettuce provided that distribution temperature does not exceed 10°C. This film generates a modified atmosphere within bag that prevents necrosis of salad leaves. Salads (including lettuce), that are highly sensitive to oxidation are flushed with nitrogen so that residual oxygen within package range from 1-3%.

Temperature management after packaging is very essential, for minimizing the damaging effects of mechanical injury. Low temperature storage reduces metabolic reactions. It has a tremendous effect on respiration rates, and affects permeability of gases through packaging films and also slows down microbial growth. To ensure high quality products it is recommended that fresh cut products be kept at temperatures just above freezing. Usually 4-6°C temperature is recommended for storage of fresh precut produce.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why are MP perishable?

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2. What are main enzymes responsible for colour and flavour changes in MP?

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3. List some key requirements of minimally processed products for assuming quality.

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4. Shelf-life of MP strictly depends upon maintenance of low temperature during storage. Justify

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5. What is optimum dose for chlorination for minimal processed vegetables?

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6. What is referred to second washing in minimal processing? Why is it important?

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7. List some precautions with respect to washing of pre-cut produce.

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8. What type of packaging material is most appropriate for MP?

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9. Which of microorganisms can cause spoilage in fresh cut fruit & vegetables stored at low temperature?

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10. Identify some main criteria in assessing suitability of cultivars to MP.

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11. Name some vegetables that are highly suitable for MP.

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12. How can you improve the effectiveness of chlorine for washing?

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13. What precautions/points should be followed for peeling of fruit and vegetables for MP.

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14. Mention some strategies to prevent browning in MP fruit and vegetables.

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15. MAP is not recommended for which vegetable and why?

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12.5.2 Some General Processing Conditions, GMP's and Key Requirements of MP

Have you noticed that there was no mention of heating step in MP. It is for this reason that they must be handled and stored at refrigerated temperature at < 5°C to achieve a sufficient shelf-life and ensure microbiological safety. Shelf-life of minimally processed fruits and vegetables strictly depends upon maintenance of low temperature during storage. However, there are certain microorganisms which can also grow under low temperature conditions. Can you name any of such microorganisms? Pathogens such as *Listeria, Monocytogenes, Yersinia enterocolilica* and *Salmonella* can survive and even proliferate at low temperature. Such microorganisms are known as Psychrotrophic. So maintenance of hygienic conditions throughout the processing chain is the crux of MP. This becomes all the more important since no thermal heat processing is used. Following hygienic codes of practices or GMPs (Good manufacturing practices) are key requirements for MP and the best way to eliminate or keep away microorganisms.Lets see some points

The key requirements in the minimal processing of fruit and vegetables.

- Good quality raw materials (correct variety, correct cultivation, harvesting and storage conditions.
- Strict hygiene and good manufacturing practices, use of hazard analysis and critical control point principles.
- Low temperatures during processing.
- Careful cleaning and/or washing before and after peeling.
- Good quality water (sensory, microbiology, pH) for washing.
- Use of mild additives in washing water for disinfect ion for the prevention of browning.
- Gentle spin drying following washing.
- Gentle peeling.
- Gentle cutting, slicing and/or shredding.
- Correct packaging materials and packaging methods.
- Correct temperature and humidity during distribution and retailing.

We have seen that MP are extremely perishable. In order to extend their shelf-life we should follow certain guidelines which are aimed at reducing biological, physical and chemical hazards. Guidelines propose conditions under which raw materials are grown as well as processing and distribution guidelines. Let us see some of these guidelines.

Forward only movement

Generally raw material is considered to be unclean product. I think by this time you know why is this so? Raw material is unclean because it may be loaded with surface microorganisms which if not cleaned can cause contamination. Keeping this in mind, raw material should be separated from the clean finished product. This requires that there should be no crossing over in the processing line between the raw material and clean products.

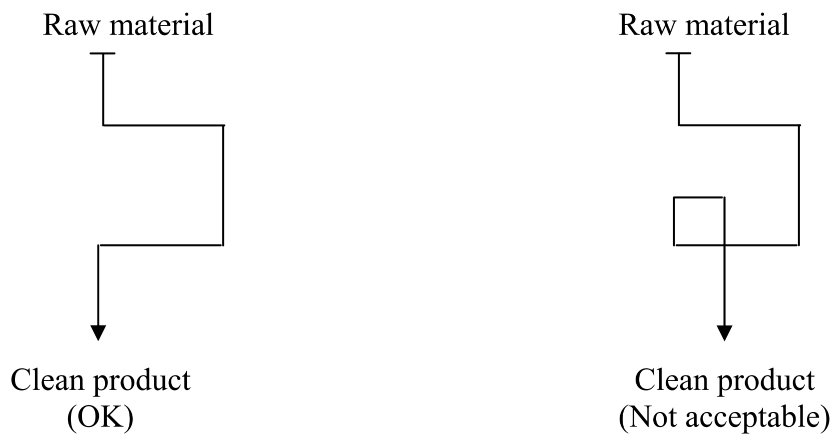

Figure 12.1: Principle of forward-only movement

Separation of the trimming room, washing room and the packing room

In order to prevent cross contamination, the different processing rooms must be delimited by walls in order to progressively increase cleanliness from the trimming room to the packaging section

Trimming room →	Washing disinfecting rinsing →	Packaging

Figure 12.2: Segmentation of processing line

Temperature control

Fresh-packed products must be immediately stored at 4°C and maintained at 0-4°C until delivered to consumers.

Air flow	→	→	Positive Pressure	
	12°C	WASHING	4°C	
Raw material	Trimming pre-washing		Packing	Carton expedition

Figure 12.3: Temperature gradient and air flow in the processing unit

The following are therefore recommended:

1. Limit exposure to temperatures above 10°C

2. Refrigerate the product at 0-2^{o}C before packing in order to be at the right temperature during the operation.
3. Maintain this temperature during storage.

The temperature gradient and flow of products run counter-currently. Temperature in the trimming and disinfecting rooms must not exceed 12^{o}C and must not exceed 4^{o}C in the packing room and ware house.

Air Flow

Ventilation systems are designed to maintain the required temperature and prevent both condensation and circulation of dust. The air current must flow from the packing to the trimming room.

Wastes

Waste materials are evacuated from the facility to avoid any cross-contamination (Figure 12.4). The equipment and machinery used for non-edible material and waste must be clearly identified and never used for edible product. Moreover, they should be easy to wash and sanitized.

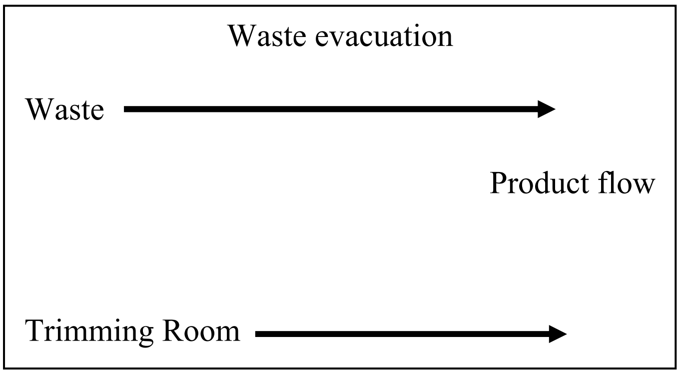

Figure 12.4: Waste disposal

Cleaning, equipment, material and utensil

Washing should be performed by any method of combination of methods involving mechanical action (scrubbing, brushing, water, jet spraying) or chemical cleaning (acidic or alkali detergent). A detergent or disinfecting detergent should be applied so as to permit the elimination of dirt and bacterial biofilms. Efficient rinsing with potable water should eliminate the detached particles and detergent residues.

Sanitation

Product safety is the very critical sanitation issue of the minimal processing plant. Processing of the product and employee practices are some of the factors influencing the plant sanitation. These include, sanitary layout of processing facility, processing rooms with positive airflow and sanitary design of processing equipment. Washing the premises and machines with steam or chemicals. Good manufacturing practices (GMP's) and hygiene are pre-requisites to ensuring quality in minimally processed foods.

Hygenic procedures for operators

Personnel should know the hygienic procedure (International Code of Practices, general principles of food hygiene) and wear protective clothing and foot-wear specific to the area.

Quality assurance programs

An effective quality assurance system throughout the handling steps between harvest and retail display is required to provide a consistent good quality supply of fresh-cut fruits and vegetables to the consumers and to protect the reputation of a given marketing label. Quality assurance starts in the field with selection of proper time to harvest for maximum quality. Exposure of commodity to temperatures, relative humidities, and/or concentration of oxygen and ethylene outside its optimum ranges accelerates loss of quality. The loss of flavour and nutritional quality occurs at the faster rate then appearance factors. That's why quality assurance programs should be based on quality attributes and not on appearance factor as is often the case.

Following is a list of handling steps and associated quality assurance functions:

1. Training workers on proper maturity and quality selection, careful handling, and produce protection from sun exposure during harvesting operations

2. Checking product maturity, quality, and temperature upon arrival at the processing plant

3. Implementing an effective sanitation program to reduce microbial load

4. Checking packaging materials and shipping containers to ensure they meet specifications

5. Training workers on proper processing and packaging operations

6. Inspecting a random sample of the packed product to ensure that it meets grade specification

7. Monitoring product temperature to assure completion of the cooling process before shipment

8. Inspecting all transport vehicles before loading for functionality and cleanliness

9. Training workers on proper loading and placement of temperature-recording devices in each load

10. Keeping records of all shipments as part of the "trace-back" system

11. Checking product quality upon receipt and moving it quickly to the appropriate storage area

12. Shipping product from distribution centre to retain markets without delay and on a first-in/first-out basis unless its condition necessitates a different order

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is referred to 'Forward only' movement in MP?

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2. Name some inhibitors that can inhibit the activity of PPO.

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12.6 LET US SUM UP

A characteristics feature of minimal processing is an integrated approach where raw materials is an integrated approach, where raw materials, handling, processing, packaging and distribution must all be properly considered to make shelf-life extension possible. New cultivars need to be selected and created or hybrids adapted to meet the specific requirements of minimal processing**.** The equipment used in unit operations, such as peeling, and shredding, needs further developments so it can process produce more gently. Further for maintaining quality in minimal processing requires anti-browning agents such as acidulants (citric acid), reducing agents like ascorbic acid. All these combined with proper packaging material and low temperature will result into a shelf stable product.

12.7 KEY WORDS

Minimal processing : is defined as these procedures such as washing, sorting, trimming, peeling, slicing or chopping that does not affect the freshness of the product.

Good manufacturing practices : refers to hygienic code of practice which are to be followed to maintain quality in food processing unit.

Modified atmosphere packaging : It involves modifying the atmosphere around the food product inside the wrapper. This allows chemical, enzymatic or microbiological reactions to be controlled and therefore reduces or eliminates the main processes of deterioration in the product

12.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Availability of more processed fruits and vegetables.
   - Innovative packaging.
   - Consumer demands (demand for convenient and quality products, dual incomes).
   - Taste preferences.
   - Technological advances in food processing.

2. Your answer should include the following points:

   - Demand for convenient and high quality processed products.
   - More working women in cities and less time for kitchen

3. Your answer should include the following points:

   - Bakery goods, pizzas, burgers, French fries, confectionary items.
   - Fruit and vegetable juices tetra packs take away colas, instant juice concentrates.
   - Frozen foods, frozen vegetables, peas, beans, cauliflowers etc.
   - Sauces ketchups, concentrate purees, yoghurts, curds etc.

4. Your answer should include the following points:

   - Pre-cut salads and fruit slices.
   - Sprouted pulses.
     Shelled peas.

5. Minimal processing is defined as procedures such as washing, sorting, trimming, peeling, slicing/chopping that does not affect the freshness of product.

6. MP is also known as

   - Light processing
   - Precut produce

7. Need for fresh like characters.

   - Need for convenience.
   - Need for quality.
     Fresh produce gives health

8. MP is different from conventional processing in following manner:

   - No heat used.
   - Product has limited shelf life (4-21 days).
   - Chilled/refrigerated storage is must during transportation & retailing.
   - Produce is more close to fresh ones.

Check Your Progress Exercise 2

1. MP are perishable because

   - Cutting/shredding renders produce susceptible to desiccation/wilting, biochemical and microbial spoilage.
   - Fast degradation of colour, flavour and texture because of ethylene liberation, increased respiratory activity and enzymatic changes.

2. Main enzymes responsible for colour and flavour changes are:

   - Polyphenol oxidase causes browning.
   - Lipo-oxidase causes bad smelling odours

3. Your answer should include the following points:

   Key requirements for minimal processing

   - Good quality raw material.
   - Strict hygiene and use of GMPs.
   - Low temperature during processing.
   - Good quality water.
   - Gentle spin drying.
   - Gentle peeling, slicing and shredding.
   - Correct packaging material and packaging methods.

4. Low temperature lowers down metabolic activities and helps to extend shelf-life.

   - Delays microbial spoilage.
   - Name some microorganisms.
   - Salmonella sp.
   - Listeria sp.
   - Monocytogenes sp.
   - Yersinea sp.

5. The optimum chlorine concentration is 100 mg/l at a contact time of 12-13 seconds.

6. Your answer should include the following points:

   Second washing is performed after peeling/cutting/shredding/dicing. It is done in ice-cold water (> 5^{o}C). It is important because it:

   - Removes tissue fluids and microorganisms.
   - Reduces enzymatic oxidation.
   - Low temperature seals the cut/damaged surfaces.
   - Washing before peeling and after cutting/shredding/dicing.

- Second washing in ice-cold water (> 5^{o}C).
- Use of preservatives in washing water containing 100 mg chlorine/l.
- Rinsing with tap water after washing.

7. Your answer should include the following points:

- Washing before peeling and after cutting/shredding/dicing.
- Second washing in ice-cold water (> 5^{o}C).
- Use of preservatives in washing water containing 100 mg chlorine/l.
- Rinsing with tap water after washing.

8. Your answer should include the following points:

- Oriented polypropylene.
- LDP – Low density polyethylene.
- Ethylene vinyl acetate.

9. Main Micro-organisms are:

- L. monocytogenes.
- Acromonas hydrophila

10. Your answer should include the following points:

Main criteria in assessing suitability of cultivars to MP.

- Processing yield (30-50%).
- Mechanical resistance to damage.
- Resistance to elevated CO_2 or low oxygen.
- Low respiration rate.

11. Your answer should include the following points:

- Onions
- Carrots
- Cabbage

12. Your answer should include the following points:

- Low pH
- High temperature
- Correct contact

13. Your answer should include the following points:

- Gentle rather than harsh peeling
- Peeling with sharp knives
- Disinfection with 1% hypochlorite solution
- Cutting or peeling done under water

14. Your answer should include the following points:

- Placing the tissues in water immediately after cutting
- Use of potassium metasulphite
- Citric acid combined with ascorbic acid alone or in combination with potassium sorbate.

15. Your answer should include the following points:

    MAP is not recommended for:

    - Broccoli
    - Cauliflower
    - Onions

    Because they emanate offensive odours during storage.

Check Your Progress Exercise 3

1. *Forward only movement*

   Forward only movement refers to complete separation of raw material from clean finished product. This requires that there is no crossing over in the processing line between raw material and clean products.

2. Your answer should include the following points:

   - Sodium chloride
   - 4-Hexyl resorcinol
   - Ascorbic acid
   - Sporix and cyclodextrins.

12.9 SOME USEFUL BOOKS

1. Lamikanra, Olsuola (2002) Fresh Cut Fruit and Vegetable Science, CRC Press.

2. Ohlsso, Thomas and Bengtsson, Nils (2004) Minimal Processing Technologies in Food Industry CHIPS.

3. Pulle, Mervyn (2004) Food Processing Insights into Food Manufacturing Food Technology, Part 4, Part 4KBS publishers.

4. Singh, R.P. and Oliveira, F.A.R (1994) Minimal Processing of Foods and Process Optimization, CRC.

5. Wiley, R.C. (1994) Minimally Processed Refrigerated Processed Fruits and Vegetables, CRC.

UNIT 13 PROCESSING BY HEAT APPLICATION

Structure

13.0 OBJECTIVES

After reading this unit, you should be able to:

- define types of heat applications;
- describe the role of heat application during processing and product preparation;
- state the effect of heat application on quality of food, microorganisms and enzymes; and
- discuss the effect of heat in combination with time, temperature, pH or acidity.

13.1 INTRODUCTION

Fruits and vegetables are living entities and highly perishable horticulture produce. Enzymes and microorganisms can easily spoil these commodities. In order to keep fruits and vegetables for a longer period, they are protected by several means. Heat application is one of the most important methods of preservation of fruits and vegetables. The main purpose of processing of fruits and vegetables by application of heat is to inactivate enzymes and killing of microorganisms. Heat can be applied in different forms such as blanching, pasteurization and sterilization. Heat application influences the texture and composition of fruits and vegetables, and microorganisms and enzymes. Heat application plays a great role during various unit operations of processing of fruits and vegetables viz., peeling, preparation of juice and pulp; syrup and brine, during blanching, exhausting, pasteurization or sterilization. There are certain factors like time, temperature; pH and acidity in combination with heat application will affect the quality of the processed products. There are several types of processed products, generally preserved by heat application such as jam, jelly, juices, sauces, candies, canned and bottled products etc. Heat processing has advantages such as to improve eating quality and availability of some nutrients and a simple control of processing conditions.

13.2 EFFECT OF HEAT ON TEXTURE AND COMPOSITION

Carbohydrates, proteins, fats, vitamins, minerals and fibre are the major dietary constituents of fresh vegetables in addition to a large quantity of water. Fruits are held in high public regard as sources of wholesome food and are valued for their taste, aroma and texture. Fresh fruits appeal virtually to all the senses, smell, taste, touch, sight and even sound as when one bites into crunchy apple. Vitamins and minerals are the major contributions of fruits to the human diet. Although some fruits are also considered good energy sources and some may contribute notable amount of fat (e.g. Avocados and nuts), sugar (e.g. Dates and figs) and proteins (e.g. tucuma). Fruits may play an important role in the diet by supplying fibre.

Heat processing is one of the most important methods for extending the storage life of fruit and vegetable products. Because of this extended life, the processed products are made available throughout the year. This has increased the availability of nutrients to the consumer. However, heat processing also has a detrimental effect on nutrients since there is thermal degradation of nutrients. Therefore, heat processing makes it possible to extend and increase availability of a food product to the consumer, but the food product may have a lower nutrient content compared to the fresh food product. This is a great challenge to the food processing industry is to minimize the loss of nutrients during thermal processing.

Heat processes are used in terms of blanching, pasteurization and sterilization. The primary objective of heat processing is to increase the palatability of the food and to increase the storage life of food product besides minimizing food-borne diseases. For example, the cooking, which includes roasting, boiling, frying etc. The heat processes viz. blanching, pasteurization and sterilization has already dealt in Para 2.5 and 2.6 in a greater details, here we are discussing their effect on texture and composition of fruits and vegetables.

Heat processing generally includes the terms blanching, pasteurization and sterilization and their principal purpose is given here.

Blanching is a heat process frequently applied to fruit and vegetables prior to freezing, drying or canning. The objective of the blanching process depends on the subsequent treatment of the foodstuffs. The adequacy of the blanching operation is enzyme inactivation. Generally, if enzymes are inactivated, the heat treatment was sufficient to accomplish the objectives of blanching prior to canning.

Pasteurization is a heat process meant to inactivate part, but not all, of the vegetative microorganisms present in the food product. Since the food is not sterile, the pasteurization must also be used in conjunction with other preservation techniques like fermentation, refrigeration, and maintenance of anaerobic conditions.

Sterile is a term, which used to a condition in which no viable microorganisms are present. A viable organism being one that is able to reproduce under conditions optimum for its growth. Sterilization is a term used to apply to a heat process that produces a sterile condition in food product. Some microorganisms and their spores are extremely heat resistant and cannot be destroyed completely. Severe heat treatment can only make the food sterile, but it will influence the organoleptic and nutritive value of food. Therefore, the sterilization process is also used in conjunction with other preservation techniques, such as packaging and control of storage temperature. Thus, the remaining dormant microorganisms or their spores will not grow in the environment of the food under the storage. Foods that have been thermally processed and meet this requirement are said to be "commercially sterile".

Heat processing may change not only the chemical composition of the food but also its structure by softening tissues, releasing or tying up moisture, destroying or forming colloidal suspensions, gels or emulsions. Protein may become denatured and therefore more available to some organisms than it was in the native state. Starch or protein may become gelated, releasing moisture and becoming more easily decomposed. For the same reasons, cooked food usually is more easily decomposed than the original fresh food.

Preservation is a convenient method of storing fruit for use in periods when the fresh products are not available. The characteristics of fruit are usually altered to such an extent during processing that the processed products do not necessarily resemble the fresh products. If processed and stored properly, the nutritive value of these processed fruit is comparable to that of the fresh products.

The thermal processes viz. blanching, pasteurization and commercial sterilization have to be optimized for nutrient retention, given in the box below:

Process	Method of optimization
Blanching	Thermal losses, leaching losses, oxidative degradation, damage to product
Pasteurization	HTST if heat resistant enzymes are not present
Commercial	Convection – heating foods and aseptic processing.
Sterilization	HTST until heat-resistant enzymes become important
Conduction	heating foods; not necessarily HTST; difficult but not impossible calculation.

Effect of blanching on nutrients

The effect of blanching on food nutrients is generally considered based on thermal, leaching and oxidative losses. Blanching is done either by dipping in hot water or exposing to steam. In water blanching the loss of water –soluble vitamins increases with contact time, and fat – soluble vitamins are relatively unaffected. Steam Blanching results in greater retention of water – soluble nutrients than water blanching. There is a slight improvement in ascorbic acid retention with IQB (individual quick blanch) as compared to conventional steam blanching. In conclusion, blanching can significantly reduce the nutrient content of foods. The extent of losses of nutrient is dependent on the blanching method and the product.

Effect of pasteurization on nutrients

The foods having a low pH (mostly below 4.5) are generally pasteurized. Some food products, which receive pasteurization, are summarized in the box given below:

Food Products preserved by Pasteurization treatments

Sl. No.	Product Pasteurized	Temperature (^oC)
1.	Carbonated Beverages	60-65
2.	Non Alcoholic fruit drinks	65-70
3.	Dill Pickles, Carbonated fruit juices	70-75
4.	Apple juice (Holding process) grape juice, raspberries, strawberries in syrups in cans or jars	75-80
5.	Processed and pickled vegetables, wine (U.S.), desiccated coconut	80-85
6.	Apple juice (flash process), canned olives, citrus juices, peeled tomatoes (pH 4.1)	85-90
7.	Tomato puree, citrus juices (flash process) tomato juice, peeled tomatoes (pH 4.5), Jam	90-95
8.	Wine (flash process), fruit puree, fruit juices, canned fruits (internal can temp.)	95-100

Source: Shapton et al. (1971)

Since most of the heat – labile nutrients are relatively stable in acid conditions; nutrients losses in those products are relatively minor. Although thermal losses during pasteurization may be small, oxidative losses can be high.

We have already discussed that HT ST (High Temperature Short Time) process results in greater nutrients retention for those nutrients affected by the pasteurization process. They are primarily thiamin, vitamin C and vitamin B 12. The nutrients that are more sensitive to high temperature are generally the same ones that are of concern during storage. It would be reasonable that the lower the storage temperature, the slower the rate of nutrient degradation.

Effect of commercial sterilization

The destruction of nutrients the thermal process is dependent on i) time-temperature treatment used as the basis of the process and ii) rate of heat transfer into the product. The commercial developments have focused primarily on increasing the rate of heat transfer into the product. Hence, agitated retorts such as the orbitort, steritort, flame sterilizer and hydrostatic cooker have been developed.

In addition to increasing the rate of heat transfer, however, there also has been a gradual shift to higher processing temperature. This results in adaptation of HTST process for greater nutrient retention in those products heating primarily by convection. It has been observed (Ammerman 1957) that retention of vitamin C in tomato juice is improved when processing is conducted at a HTST condition.

The HTST process is particularly adaptable to aseptic processing. In this system, processing temperatures in excess of 149^{o}C are used for very short periods i.e. order of seconds. Under these conditions nutrient retention may be greatly enhanced. HTST aseptic canning also results in a significant improvement in organoleptic qualities i.e. colour, taste and aroma. In an evaluation of HTST aseptic processing, it was found that thiamin retention was significantly greater in HTST products than in conventionally canned and retorted products. Based on existing literature available, nutrient losses range from 0 to 91 percent, depending on the nutrient and product.

It is a misconception to think that commercially sterile products remain unchanged during storage. This is not the truth. Organoleptic and nutrient changes do occur during storage, the extent of the changes being dependent on the time and temperature of storage. It has been observed that low temperature storage results in an improvement in nutrient retention.

In conclusion, it is evident that there is a significant loss of nutrients during canning and that these losses increase during storage. Altering heat processing and storage conditions to maximize nutrient retention is an important and necessary consideration for the fruit and vegetable processing industry.

13.3 EFFECT OF HEAT ON MICROORGANISMS AND ENZYMES

Generally the food spoilage takes place at any temperature between –5^{o} and 70^{o}C. Since microorganisms differ so widely in their optimal, minimal and maximal temperature for growth, it is obvious that the temperature at which a food is held will have a great influence on the kind, rate and amount of microbial induced change that will take place. Even a small change in temperature may favour an entirely different kind of organism and result in different type of spoilage. For example, moulds and yeasts generally do not grow well above 35 to 37°C, hence not important in foods held at high temperatures. But moulds and yeasts grow well at ordinary room temperatures and many of them grow fairly well at low temperatures. Most bacteria grow best at ordinary temperatures. Some (thermopiles) grow well at high temperatures and others (psychrotopes) at chilling temperatures. The heat, which kills microorganisms and inactivate enzymes is supposed to be denaturation of the proteins. The heat treatment varies depending upon the different factors such as kind of organism, its state and the environment during heating. Depending upon the heat treatment employed, only part of the vegetative cells, most or all of them may be killed. There are known certain terms of heat treatment given below:

Heat Processing – Use of high temperature to destroy enzymes and microorganisms that could reduce quality and /or safety of food.

UHT – A very severe heat treatment, very short in time.

Pasteurization – A mild heat treatment used primarily to destroy pathogenic organisms but it also destroys enzymes and reduces microbial load. Requires an addition preservation method to extend shelf life (for example – refrigeration, drying).

Commercial sterilization – A severe heat treatment that destroys pathogenic and many microorganisms that could spoil food. Extends shelf life, room temperature stable.

Sterilization – A very severe heat treatment that destroys all microorganisms.

Details of these heat treatments can be seen in other Para of this unit.

Factors affecting heat resistance

There are certain factors, which are known to affect the heat resistance of cells or spores of microorganisms. This point must be kept in mind when microorganisms are compared and when heat treatments for destruction of an organism are considered. The main known factors are listed below:

1. The temperature – time relationship – The time for killing cells or spores under a given environment decreases as the temperature is increased.

2. Initial Concentration of Spores – the more the spores present, the greater is the heat treatment required to kill all of them.

3. Environment of Vegetative spores –

   i) *Medium of growth:* Nutrients in the growth medium influences the heat resistance. The better the medium for growth, the more resistant the spores cell.

   ii) *Temperature of incubation*: In general, resistance increases as the incubation temperature is raised toward the optimum for the organisms.

   iii) *State of growth and age:* Very young immature spores are less resistant than mature ones.

   iv) *Desiccation:* Certain spores are harder to kill by heat than those kept moist.

4. Composition of substrate also influences the thermal death time of the microorganisms.

   i) Moist heat is a much more effective killing agent than dry heat.

   ii) *pH:* In general microbial cells or spores are most heat – resistant in a substrate near neutrality. (See more details in 2.7 Para)

   iii) *Other constituents:* Common salt and sugar also protect some organisms or spores. The colloidal materials, especially proteins and fats, are protective against heat.

Heat resistance of microorganisms

The heat resistance of microorganisms usually is expresses in terms of their thermal death time. The thermal death time (TDT), which is defined as the time it takes at a certain temperature to kill a stated number of organisms (or spores) under specified conditions.

Most of the yeasts, moulds and their spores are killed by moist heat at 60°C, but some species are considerably more heat resistance, but may not survive 100°C. The bacterial vegetative cells are easily killed at 80-90°C. But resistance of bacterial spores at 100°C may vary from less than 1 minute to over 20 Hours.

Heat resistance of enzymes

The most food enzymes are destroyed at 80°C, some may with stand higher temperatures, especially if high temperature – short –time heating is employed. Generally the effect of heat is intended for preservations of food i.e. to kill bacteria and inactivate enzymes. For example, the pasteurization of milk, fruit juice and beverages and the sterilization of canned foods. The main aim is to deliver the required microbial kill with as little damage to the structure and consumption of the food products as possible.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Named constituents of fruits and vegetables.

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2. What is the primary objective of heat processing?

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3. What are the methods of optimization of heat process?

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4. Define different terms of heat treatments.

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5. List the factors affecting heat resistance.

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13.4 ROLE OF HEAT APPLICATION – PEELING, JUICE PROCESSING, SYRUP/BRINE PREPARATION & FILLING

13.4.1 Use of Heat in Peeling of Fruits and Vegetables

Generally fruits and vegetables are peeled by hand, mechanical means, use of heat and lye solution. Heat in various forms is applied in last two methods of peeling. Heat is generally used in the form of boiling water, steam, roasting by a direct gas flame and heating in steam under pressure.

Peaches, tomatoes, beetroots are either immersed in boiling water or exposed to live steam until it loosen skin or cracked or peel is separated from the flesh easily, and then cool by spraying or immersion in cold water. The loose/ cracked or separated skin is easily slipped from the fruit by hand or by spraying water.

Sweet potatoes are steamed under pressure to soften the skin and are peeled by hand. Sometimes peeling of carrots, beets, potatoes and apples and some other vegetables can be done by heating under pressure to a very high temperature for a few seconds then releasing the pressure. This method of peeling can be a continuous or batch type process.

Pimientos and onions are flame-peeled in a continuous natural gas-heated chamber at very high temperature (1568°C). Then they are washed in sprays of water. Uniform size of the produce gives better results.

Heat is also used during lye peeling. It makes the lye solution more effective than cold lye. Lye is a solution of alkali such as sodium hydroxide. Its strength and time of immersion of the commodities depends upon type and nature of fruits and vegetables and thickness of their skin. Lye peeling is used on peaches, sweet potatoes, apricots and carrots. Sometimes the sodium carbonate-sodium hydroxide mixture is also used, is called canners alkali. The lye solution having 1.5 to 2 percent sodium hydroxide is used for peeling of fruits. For vegetables 10 to 15 percent sodium hydroxide solution is used. The time of immersion in lye solution for fruits varies from ½ to 2 minutes and 6-8 minutes for vegetables. The boiling dilute lye solution causes the separation of the outer skin of the fruits from the flesh. In case of sweet potatoes the action of lye solution is upon the cutin.

13.4.2 Use of Heat in Juice and Pulp Processing

Use of heat application helps in clarification and preservation of fruit juices and beverages. Fruit juices after pasteurization will become clear during storage. The length of storage required depends upon the type of juice and other conditions. For example the pomegranate juice will become clear within twenty four hours, after pasteurization where as grape juice requires several months for setting solids and it can be enhanced by refrigerated low temperatures.

The heat treatment is used to pasteurize the fruit juices and it means the destruction of all microorganisms capable of increasing in the juice of causing spoilage. It doesn't kill the spore forming bacteria such as *Bacillus subtilis* and *Bacillus mesentericus* but these spore bearing bacteria cannot grow in acid fruit juices. However, pasteurization should be done at such a temperature and for such a time that yeast and moulds are destroyed. For example yeast is killed in a few minutes by heating juice at 60-66°C. But resistant mould spores require a temperature of 80^0C for 20 minutes; however, carbonated juices can be pasteurized safely at 66°C. Thus, we can conclude that the fruit juices must be pasteurized at lower temperature (71-74°C).

The presence of carbon dioxide generally does not reduce the death temperature of fruit juice microorganisms such as yeast, mould spores, and bacteria. But it prevents the growth of surviving mould spores. However, it has been observed that carbonated and heavily inoculated fruit juice heated for 30 minutes at 65°C, which prevents subsequent development of mould spores.

The bulk juices are pasteurized either as continuous or batch type process. The continuous pasteurization is done in a tubular or plate type heat exchangers. Hot water or steam is used as heating medium. The batch type pasteurization is done in steam-jacketed kettle or in a tank equipped with steam coils. In these vessels, the juice is placed and heated to the desired temperature. This system has some disadvantages such as the small portion of juice may be over heated or exposed to air and cause oxidation during pasteurization and injury to colour and flavour on prolong heating.

Heating can also be done by electricity. The fruit juices are passed between carbon electrodes. The juice is heated instantaneously to the desired temperature when ordinary alternating current (110 Volts 60cycle) is passed in the electrodes. Heat is generated by passage of current against the resistance of juice, without heating the electrodes.

The fruit juices are also preserved by flash pasteurization and cooling. The prolong heating results in considerable injury to the flavour and colour of the products. Hence, the fruit juices are heated at higher temperatures and rapidly cooled and then under aseptic conditions filled into sterile containers such as bottles and sealing by sterile cork or caps. Great care must be taken to avoid the infecting juice with mould or yeast. For example the juice is heated to about 82 to 90°C for a few seconds only, the juice suffers very less injury to colour or flavour. In some instances the citrus, apple or tomato juice is flash pasteurized momentarily at 116°C or higher, but cooled to 98°C (tomato juice) and 88°C to other juices before filling into the container. This treatment will inactivate enzymes also. Now a day's pasteurization is generally done by "hot-fill-hold-cool" method. In this method the hot sterile bottles or cans usually filled hot directly from bulk or continuous pasteurizer, sealed and given no further heating but cooled in the air and water, respectively.

Heat should also be used to sterilize bottles, cans, and bottle caps otherwise they may cause infection in bottled beverages.

13.4.3 Syrup/Brine Preparation and Filling

The syrups are added to fruits and brines are added to vegetables during canning. These additives improve the flavour; fill the spaces between the pieces of canned fruits and vegetables and aid in the transfer of heat during the processing.

For making syrup, cane sugar, liquid glucose or invert sugar is used but usually cane sugar is employed. The sugar is dissolved in small quantity of water to yield heavy syrup (60-65^{0}Brix). The cane sugar and water are heated together until a clear syrup is obtained. Heat treatment is provided through steam. Tanks with steam heated coils or steam jacketed kettle is used for the preparation of the syrup. Sugar syrup is clarified by passing through cloth. Then it is diluted to the desired degree Brix depending on the nature and grades of the fruit. Here the heating helps in dissolving sugar in the water and quick filtration before it is cooled. Hot syrup is filled into cans containing fruit pieces, which helps in reducing time of exhausting.

Dilute brines of 1 to 2 percent common salt are used during canning of vegetables. Salt used for canning should be at least 99 % sodium chloride (NaCl) and lower purity less than 98 % should not be used. Salt is dissolved in water by heating, after proper filtration is filled into the cans containing prepared vegetables before exhausting. Hot brine is used for filling into the cans.

13.5 BLANCHING AND EXHAUSTING

13.5.1 Blanching

Blanching is a unit operation applied to fruits and vegetables prior to canning, drying or freezing. Blanching is a mild type of heat processing. It involves heating food to preset temperature for preset time. It is usually done in water or steam at a temperature less than 100°C. Prepared fruits and vegetables is kept in hot water or exposed to steam and then cool rapidly to ambient temperature.

Blanching is used to destroy microorganism and enzymatic activity in fruits and vegetables. Blanching caused inactivation of enzymes in canning, freezing and dehydration, because freezing and dehydration are insufficient to inactivate enzymes. Sometimes canning process may allow sufficient time for enzymatic activity. And under blanching may increase the enzymatic activity. There are four types of enzymes such as lipoxygenase, polyphenololase, polygalacturonase and chlorophyllase, which causes loss of quality in fruits and vegetables, must be inactivated. The enzymes such as catalase and peroxidase are heat resistant, which need appropriate time and temperature to inactivate them.

Blanching also reduces the number of microorganisms. Blanching of fruits and vegetables in steam has the advantages such as less loss of water-soluble constituents, less volume of waste, easy to clean and sterilize. But it has some disadvantages i.e. higher capital costs, uneven blanching, and low efficiency. Generally hot water blanchers are used because of lower capital costs and better energy efficiency. But it has some disadvantages like loss of water-soluble constituents, risk of contamination and higher cost of water and disposal of effluent than steam blanchers.

Blanching of green leafy vegetables especially spinach at boiling point causes loss of green colour but lower temperature (77°C), it retains the natural green colour, even when heated at higher temperature (121°C) during sterilization. At lower temperature time the enzyme chlorophyllage remains active for little time and convert chlorophyll to a phyllin, which retain green colour.

13.5.2 Exhausting

Exhausting is a mild type of heat processing. It is one of the unit operations involved during canning of foods. Exhausting, generally remove air and gases from cans. It can be done either by application of heat. In this method, the cans are passed through a tank of hot water or exhaust box under steam. The temperature of water is generally ranged between 82^0C to 100^0C and the center of the can should reach a temperature of about 79^0C. The time of exhausting varies from 6 to 10 minutes, depending upon the nature of the commodities. Generally, exhausting of the cans is preferred at lower temperature for a longer time to ensure to uniform heating of the contents, without softening of the produce. Exhausting at high temperature should be avoided, otherwise it will be formed more volume of water vapour, which may produce greater vacuum in the can.

Exhausting help in avoiding the corrosion of the tin plate and pin holing during storage, minimizing discolouration by preventing oxidation, better retention of vitamin C, prevents bulging of cans when stored at high altitude. It also helps in reducing chemical reaction between containers and food and prevents development of expressive pressure and strain during sterilization of cans.

13.6 PASTEURISATION AND STERILISATION

13.6.1 Pasteurization

Pasteurization is a mild type of heat processing. In this method, the heat treatment is performed below 100°C, which kills some selective but not all of the microorganisms present. Heating is done in form of hot water, steam, dry heat or electric currents. The food products are cooled rapidly to ambient temperature after heat treatment.

The main function of pasteurization is to inactivate enzymes, kill non-spore forming bacteria, yeasts and moulds. Pasteurisation is used in combination of other preservation methods such as fermentation (pickles), refrigeration and anaerobic conditions as the food products are not sterile. Pasteurization is generally used in fruit juices, where the environment is not suited for the growth of spoilage causing microorganisms.

The severity of pasteurisation depends on pH of the food products. In low acid ($pH>4.5$) foods, the destruction of pathogenic bacteria, whereas in high acid foods ($pH<4.5$), the destruction of spoilage microorganisms and inactivation of enzymes are essentially the requirement.

Heating to 100^oC mostly preserves the fruit juices or slightly below for a sufficient time to kill spoilage microorganisms are called pasteurization. Generally, the fruit juice is hermetically sealed in cans or glass bottles before being pasteurized. The juice would not spoil as long as the cans or bottles remain sealed against the entry of spoilage microorganisms from outside. Some spores and spore forming bacteria like *Bacillus subtilis* and *Bacillus mesentericus* can survive the process. But these organisms are highly sensitive to acid products and cannot grow in acid fruit juices and beverages. Generally, the fruit juices are pasteurized at about 85^0C for 25 to 30 minutes depending upon the nature of the juice and the size of the containers. In this process most of the bacteria, mould, spores and yeasts are readily killed.

Fruit juices are pasteurized by two methods. First by heating the juice at a low temperature for a long period, and secondly by heating the juice at high temperature for a short time (HTST). Pasteurisation is governed by the temperature and its types & methodology. For example under 'Holding' pasteurisation also called Bottle method, the prepared and finished juice is filled into glass bottles leaving proper head space. The bottles are then sealed airtight and pasteurized. The headspace is left in the bottle for the expansion of the juice during heating. In over-flow method of pasteurization, the fruit juice is heated to a temperature about 2.5^0C higher than the pasteurisation temperature. The hot juice is filled into hot sterilized bottles upto brim and sealed by crown corking. A care is taken that the temperature of the juice does not fall below pasteurisation temperature during filling and sealing.

In flash pasteurization the juice is heated rapidly to a temperature of 5.5^0C higher than pasteurisation temperature for one minute and filled into bottles and canes, sealed air-tight under cover of steam and then cooled. The steam will sterilize the seal. The flash pasteurisation has some advantages, that it helps in minimizing loss in flavour, retention of vitamins, it effects economy in time and space, keep the juice uniformly cloudy, heats the juice uniformly, which reduces to a minimum any cooked taste of the juice. Flash pasteurisation is a type of higher temperature and short time (HTST) heating system.

Some liquid foods are pasteurized after packaging. Food packaged in glass containers is generally pasteurized with hot water. The unpackaged foods such as fruit juices and beverages of low viscosity are pasteurized in continuous operation using plate heat exchangers.

13.6.2 Sterilization

Sterilization is a process of heat application above 100°C, which is employed to deprive microorganisms of their ability to multiply. We can obtain this sterilization temperature by using steam under pressure. The boiling point of water can be raised if the water and steam are enclosed in a strong retort (autoclave). In this retort, temperature increases with increase in steam pressure. The temperature at sea level is 100°C without pressure but at 0.7kg/cm2 steam pressure the temperature of 121°C or above may be easily obtained. At these high temperatures the spores of the heat resistant bacteria are quickly killed. The longer is the heat treatment time at lethal temperatures, the larger is the number of killed microorganisms. At higher temperature, the shorter is the time required to kill microorganisms and lower is heat-included damage to food products.

Theoretically, absolute sterility does not exist. In commercial practice not all cans of food are sterile. However, they usually do not spoil because conditions in the container are not favourable for the growth of concerned microorganisms. The pH may be too low or absence of oxygen. Therefore, the term processing is highly suitable than the term 'sterilization' applied to canned foods.

The foods products low in acid and often high in protein and contain spore-forming bacteria are difficult to sterilize. The acidity of fruits and tomatoes greatly lower the death or sterilizing temperature, which usually explains why acid fruits are easily sterilized.

The purpose of sterilization is the destruction of all pathogenic, spoilage causing organisms and non-pathogenic microorganisms. This process will make the treated product safely preserved at room temperature. Thus, the food products with safe preservation at room temperature are generally defined as commercially sterile.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe types of heat treatments.

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2. What is the difference between pasteurization and flash pasteurization?

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3. Explain sterility and commercial sterilization.

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13.7 COMBINATION OF TIME, TEMPERATURE, pH/ ACIDITY

13.7.1 Time and Temperature

The food is generally decomposed by the presence of microorganisms and can be prevented by killing them. The heat preservation is one of the most important methods of killing / inactivation of microorganism as well as enzymes which are already present in the food. Heat application kills the microorganisms because of denaturation of proteins. Different microorganisms have different heat resistance. This can be shown by their thermal death time (TDT) at a particular temperature. For example the TDT of *Lactobacillus bulgaricus* is 30 min. at 71°C; *Escherichia coli* is 20-30 min. at 57.3°C and *Streptococcus thermophylus* is 15 min. at 70-75°C. Thus it is the combination of time and temperature required to kill the specified microorganisms. In a set of given conditions, with increase of temperature the time required to kill cells or spores decreases.

The canning is one of the major methods of food preservation based on destruction of microorganisms by heat treatment and prevention of recontamination. The heat treatment in respect of time and temperature is governed by the nature of food product and size of the container. Thus we can enlist below certain factors, which affect the heat resistance of cells or spores.

i) Initial concentration of spores
ii) The time-temperature relationship
iii) The type and nature of microorganisms
iv) Composition of substrates such as moisture content, pH or acidity, fat, protein, pectin, etc.

The heat treatment based on temperature can be grouped as

i) Pasteurization (heating below 100°C)
ii) Blanching (heating at about 100°C)
iii) Sterilization (heating above 100°C)

You can find more details in Para 13.5 and 13.6.

We can see a time and temperature combination during canning process. The canned food is most sterile when packed; hence the filled cans are exposed to temperature-time profile sufficient to give a safe product. In this process the heat is applied externally which will be the cause of product to lag the surface and bulk product temperatures. Therefore it is essential to estimate the temperature at the slowest heating point. It will also ensure that a product is not over processed. For example canned low acid foods having the pH greater than 4.5 is generally processed at a reference temperature of 121.1°C for 3 minutes at its slowest heating point. Thus, we can consider this thermal process of canned food as safe. If the temperature of thermal process varies, then time will also vary and it can be seen, from the literature. The time – temperature profile as follows: 1.2 min at 125°C; 3.9 min at 120°C; 12.2 min at 115°C; 38.7 min at 110°C; 122.2 min at 105°C and 386.5 min at 100°C.

13.7.2 pH or Acidity

The processing temperature is generally governed by the pH or acidity of food product. The food having a lower pH than 4.6 or higher acidity is generally given low temperature heat treatment. While, food having a higher pH than 4.6 or lower acidity is given high temperature heat treatment.

Food product can be classified based on pH or acidity as follows:

1. *Low acid, pH 5.0 and higher:* This class includes mostly non-acid vegetables and some fruits such as peas, beans, corn, asparagus and bael

fruit, papaya etc. All types of microorganisms including Clostridium botulinum can spoil these products.

2. *Medium acid, pH 5.0-4.5:* Vegetable mixtures, soups, which has partially acidic ingredients. All types of microorganisms also spoil these. The flat sour producing microbes is of importance.

3. *Acid, pH 4.5-3.7:* This group includes tomatoes, pears, pineapple, figs etc. These products can be spoiled by non-spoiling aciduric types, butyric anaerobic and thermophilic anaerobic.

4. *High acid, pH 3.7 and below:* This class includes citrus juices, grape fruits, rhubarb, berries, pickles and sauerkraut.

The bacterial spores are easily destroyed in fruits at pH 3.0 than in vegetables at pH 5.0 and above. These microbial spores do not grow at pH below 4.5. Hence, pH 4.5 has been considered as dividing line between acid and non-acid foods. It is usually practice in canning process. A canned food product, having a pH below 4.5, can be processed at boiling water (100°C). But the food having pH above 4.5 is processed under pressure 0.7 to 1.0 kg/cm^2 to raise the temperature more than 100°C.

The heat inactivation of enzymes in food products is generally governed by time of heat application as well as by pH. Lowering of pH by addition of acids, control enzymatic browning. Acids, which are naturally found in plant tissues such as citric, malic, and ascorbic acids help in reducing enzymatic browning.

13.8 ROLE OF HEAT APPLICATION DURING PRODUCT PREPARATION

Preparation of jam, jelly, juices, sauces, candies etc require a substantial amount of heating. This heat treatment is essential for safe preservation of these products, is being discussed below.

13.8.1 Use of Heat in Jam and Jelly Production

Let us **define** the jam and jelly, marmalade and preserves, and then we will discuss how heat is essential during their preparation.

Jam: Jam is prepared by boiling whole fruit pulp with cane sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. As per FPO specification 45 parts of fruit to each 55 parts of sugar, is used for preparation of jam.

Jelly: Jelly is prepared by boiling fruit with water, expressing as water (pectin) extract), adding sugar, and concentrating to such consistency that gelatinization takes place on cooling. The best jelly is clear, sparkling, transparent and of attractive colour. It should retain the shape when removed from container or glass bottle.

Marmalade: Marmalade is a clear jelly in which shreds of peel are suspended. It is generally prepared from citrus fruits.

Preserves: cooking prepared fruit in sugar syrup until the concentration of sugar reaches 55 to 70 percent makes Fruit preserves. In this product, fruits retain its shape and are crisp rather than soft. Here also 45 parts of fruit for each 55 parts of sugar is employed.

Heat in Jam and Jelly Production

Jams

Jams may be made from all varieties of fruits. Good, fully matured fruits are selected, washed, peeled. Thin skinned fruits do not require peeling such as Apricots, plums etc but stone can be removed by machine. Fruits should be boiled in a small quantity of water and steamed and passed through pulper and finisher to get the desired texture pulp. Hence, heating is required to boiling or cooking the fruit to make into pulp. Cane sugar or sucrose is added to the pulp in equal ratio for most of the fruits. But for sweet fruits of low acidity such as ripe peaches, sweet prunes and grapes less than equal weight and sugar is required.

Boiling is an important heat treatment in the preparation of jam, jelly, marmalade and fruit preserves. Boiling or cooking is desirable, it causes intimate mixing of the fruit pulp and sugar. It partially concentrates the product by evaporation of excess moisture. Boiling is again dependent upon the firmness of fruits. Soft fruits in small lots can be concentrated to desired consistency as rapidly as possible. Other hard fruits are more resistant to heat application, may be boiled more slowly. Steam-jacketed stainless steal kettles are commonly used in commercial practice. Vacuum pan is also used to minimize heat damage to the product. Most jam should be concentrated to boiling temperature of 103 to 105^0C. The end points of jams boiling vary with fruit varieties, amount of sugar and some other factors. However, the finished jam should show 65 to 68 percent soluble solids as determined by refractometer.

Jelly

The pectin, acid and sugar are essential to the preparation of a normal fruit jelly, out of which pectin is the most important. To make a jelly of excellent consistency, pectin, acid, sugar and water must be in the proper portion. If the fruit is deficient in any one of the constituents, which can be added from outside source. However, we should take proper care in selection of fruits. Fruits rich in pectin, acid and sugars and fully ripe are selected to impart good flavour and texture to the finish product.

The pectin is precipitated as a hydrated colloid that forms a network of fibrils throughout the mass, binding the sugar into the gel. The concentration of sugar makes the texture stiffer. Acid causes the jelly to be the firmer by toughening the fibrils. This is the reason that these constituents must be in the right proportion viz. pectin 1%, sugar 60 to 65%, fruit acid 1% and water 33 to 38%.

Washed fruits are cut into slices or crushed. Very juicy fruits like berries, do not require water, simply they crushed and heated to the boiling point for 2 to 3 minutes and juice or pectin extracted pressed out. Firmer the fruits like apple, guava, oranges are cut or crushed and water is added half to equal volume of the fruits. They are required to be heated to 20 min. Citrus fruits require two to three volume of water for each volume of fruits and require to be heated for 30 to 60 min.

After addition of water, the fruit is boiled and then slowly put on simmering fire for the sufficient time (as mentioned above) to extract pectin, acid and sugars. A clear fruit extract is filtered and tested for pectin content by alcoholic test. The equal amount of juice and alcohol is taken in a centrifuge tube, mixed well, centrifuging, and reading the volume of the sediment. The viscosity of the juice varies with the pectin content hence, the viscosity test by any standard method may be used as a guide for pectin content.

Then fruit extract, sugar, acid are taken in an appropriate proportion. The whole mass is boiled to the end point.

Boiling is one of the important steps in jelly preparation. The boiling dissolve sugar, causes mixing of sugar, acid and pectin to form jelly. During heat treatment certain organic compounds coagulates, which can be skimmed from the surface and their removal make jelly clearer. The principal purpose of boiling is to increase the concentration of sugar to the point where jellying will occur. End point can be measured accurately by use of a thermometer. The thermometer is inserted in the boiling juice. If the juice contains the proper portion of sugar, acid and pectin, the boiling point of the liquid will be a few degrees higher above the boiling point. At sea level the boiling point will be 104 to 105^0C and corresponding to a concentration of 65 to 68 percent total solids in the jelly after cooling. This can be also measured by refractometer.

Marmalade

Marmalade preparation is similar to jelly with the difference that it contains pieces of fruit peel suspended there in. The principles of jelly making, apply also to the preparation of marmalade.

Preserves

Fruit preserves should retain the form of original fruit, either whole or cut fruit in clear sugar syrup of higher concentration. Fruit should not be overcooked or caramelized.

Preserves are processed by three different methods viz. open-kettle one-period process, the slow open-kettle process and by vacuum cooking of preserves. Heat treatment is the essential part of these cooking and it influences the quality of the finished products. These three methods are briefly discussed below:

Open kettle one period process: This is a simple method of preserve making and usually employed by housewives. In this process fruit is boiled in steam-jacketed kettles with sugar or in syrup until fruit is impregnated with thick or heavy density syrup. Soft fruits and berries should be boiled for short time. But the firm fruits like peach, pears, aonla require a long period to impregnated them with the syrup. Here, the end point can easily be determined by refractometer at 68 percent soluble solids or by a thermometer, which shows the boiling point about 104 to 105°C at sea level. It is a rapid method with low cost operation, but may result in serious injury to flavour and colour of the finished product.

The slow open-kettle process: In this process the fruit is heated for short time on successive days in sugar syrup of progressively increasing sugar concentration. This will avoid undue injury, to the colour and flavour of the preserves. Initially fruit is boiled enough in syrup containing about 40 percent sugar. Then the mixture kept aside for 24 hours and then further boiled for 3-4 minutes with the addition of 10 percent more sugar. This step is repeated until the product has the desired consistency and then placed in the final containers and sterilized.

Vacuum cooking of preserves: The vacuum cooked preserves are of superior quality in respect of flavour and colour then the preserves made in an open cooker.

The fruit preserves filled into glass jars or can at 88 to 96^{0}C and in commercial practice are generally pasteurized.

Candies: Candied fruits or candies are prepared essentially of slowly impregnating the fruit with sugar syrup until the sugar concentration in fruit is so high enough to prevent spoiling. Repeated boiling and storage in syrups of progressively increasing concentration of sugar generally accomplish this. The fruit is washed and dried to remove excessive sugar from surface. Then it is coated with glaze of sugar and glucose syrup, called glazed or candies. We have learned that heat treatment is essential part of the preparation these products.

13.8.2 Use of Heat in Ketchup and Sauce Production

Tomato ketchup:– Tomato ketchup (catsup, catchup) can be defined that it is a clean, sound product made from strained tomato juice, with spices, sugar, salt, vinegar, onion and garlic etc. It should contain not less than 12 percent tomato solids and 28 percent total solids.

Sauce: It can be defined that the sauce is a clean, sound product made from properly prepared fruits/ tomatoes / peppers with spices, salt, sugar, ginger, onion, garlic etc. It should contain total solids from 12 to 25 per cent.

For preparation of tomato ketchup the first step to prepare tomato juice or pulp for which fully ripe, red coloured fruits are taken. Heat application plays an important role in juice extraction from tomatoes particularly in hot break method. Tomatoes are cut or sliced and immediately heated to boil in their own juice for 3 to 5 minutes to facilitate juicing or pulping. The heat treatments help in the following ways:

1. The pectin present in the skin and seeds can be incorporated into the juice otherwise juice may separate into liquid and pulp.

2. Heat treatment inactivates/destroy the pectate enzymes otherwise hydrolyse the natural pectin present in tomatoes and resulting the thin juice.

3. Boiling tomatoes release the pectin and it thickens the pulp.

4. Boiling sterilizes the tomato juice partly, thereby controlling to some extent the growth of microorganisms, which may cause fermentation etc in the juice.

5. It also inactivates some oxidative enzymes, resulting better retention of vitamin C.

6. The cooking also releases the red colour present in the tomato skin.

7. Heat treatment yield higher juice recovery than cold method.

The tomato ketchup can be made from tomato juice or its concentrate or paste. Here we can say that for preparation of juice concentrate, paste or ketchup the original tomato juice has to be concentrated by application of heat. Thus, heat treatment evaporates water resulting in concentration of juice. The concentration of tomato juice is carried in two ways i.e. by open cooking and cooking under vacuum.

In the **open cooking** – the tomato juice is cooked or boiled in aluminium vessel (Patila), at smaller scale. In large scale, the juice is heated mostly in stainless steel steam jacket – kettle to the desired consistency, which can be measured either by refractometer or specific gravity hydrometer. The open cooking is generally employed, but it has some disadvantages. During cooking the product is exposed to the oxygen in the air, which may destroy vitamin C and makes the juice brown. Sometimes edible oil is added to prevent foaming, boiling, over sticking or burning. It also helps in lessening oxidation.

In **vacuum cooking –** All the above defects are removed in vacuum cooking. In this method the juice is placed in vacuum pan and heated. Under vacuum, boiling takes at reduced temperature of 71°C. This method results in the superior quality of finished product with better retention of vitamin C and colour than open cooking. In the end vacuum is broken and the juice is sterilized by heating to 100°C for about 10 minutes.

Sauce can be made from Soyabean, mushroom, apple and mixtures of various other fruits. Thin sauce is mainly consists of vinegar extract of various flavouring materials like spices and herbs for example Soya sauce, Worcestershire sauce. Thick sauce is highly viscous and contains fruit pulp and more sugar. Their cooking is similar to tomato ketchup.

Similarly fruit juices such as apple juice, pineapple juice, orange juice etc. are also concentrated which can be seen in other blocks and all needed heat treatment.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How heat application works during peeling.

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2 Describe the use of heat application during fruit juice processing.

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3. Explain that the heat processing is greatly influenced by the pH or acidity of the product.

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4. Describe the important role played by heat application in the preservation of jam and jellies.

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13.9 LET US SUM UP

Fruits and vegetables are generally preserved by heat application. Heat treatments are in terms of blanching, pasteurization and sterilization, which also affect the fruit and vegetable compositions, microorganisms and enzyme activity. Heat treatment protects the processed food products from spoilage causing bacteria, moulds and yeasts as well as enzymatic changes.

Heat treatment also made processed food palatable but reduces some of the nutrients. If appropriate time – temperature used and storage at low temperature helps in reducing the nutrient losses. It also enhances their storage life.

Appropriateness of the factors such as salt, sugar, fat, and protein, besides time – temperature and storage temperature also influences the quality and nutrients retention in the processed products.

Heat treatment in various forms is employed during canning process, for peeling, blanching, syrup or brine preparation, filling, exhausting, sterilization etc.

Heat is also applied during product preparation so that jam, jelly, and marmalade etc are set properly. Heat application is also employed in processing of juice and beverage.

Thus appropriate time – temperature depending upon the product and presence of microorganisms and enzymes can manufacture processed products of good quality with proper retention of nutrients.

13.10 KEY WORDS

Pasteurization : process of heating food product to a specific temperature for a specific time to kill the most heat resistant vegetative pathogen.

Sterilization : A process to heat food product to a specific temperature for a specific time to kill the most heat resistant spore-forming organism.

D-value : It is also called "decimal reduction time" or "thermal death rate" and defined as time (in minutes) at a particular temperature (°C) required to kill 90 percent of a microbial population.

Canning : It is defined as preservation of foods in sealed containers and usually implies heat treatment as the principal factor in the prevention of spoilage.

HTST : High temperature short time.

13.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Constituents include carbohydrate, proteins, fats, vitamins, minerals, fibre, water, flavouring compounds
2. Your answer should include the following points:
   - Palatability
   - Storage life
   - Food borne diseases
3. Your answer should include the following points:
   - Blanching - Leaching, thermal oxidation, product damage
   - Pasteurization - Enzymes
   - Commercial - Heating food enzymes
   - Sterilization
4. Your answer should include the following points:
   - Different heat treatment terms are:

UHT, Pasteurization, sterilization, commercial sterilization.

5. Your answer should include the following points:

   - Temperature – time relationship
   - Environment (Nutrients, incubation temperature, state of growth and age, desiccation
   - Substrate composition (moisture, pH, other constituents)

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Blanching
   - Pasteurization
   - Commercial sterilization

2. Your answer should include the following points:

   - Degree of heat application / HTST
   - Time of heat treatment
   - Better nutrition, flavour
   - Minimum cooked taste if any

3. Your answer should include the following points:

   - Heating at higher temperature
   - Complete elimination of microorganisms
   - Destruction of pathogenic, spoilage causing organism

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Types of peeling
   - Heating medium – boiling water, steam, roasting, steam under pressure
   - Softening, cracking, loosening of skin

2. Your answer should include the following points:

   - Heat application – in clarification and preservation of juice
   - Destruction of yeasts and moulds but not killing the spore forming bacteria
   - Time and temperature

3. Your answer should include the following points:

   - Food classification based on pH and acidity

4. Your answer should include the following points:

   - Mixing of fruit and sugar
   - Preparation of pectin or water extract for jelly making
   - Cooking point
   - Temperature of fruit and sugar mixtures

13.12 SOME USEFUL BOOKS

1. Ammerman, G.R. (1957) The effect of equal lethal heat treatments at various times and temperatures upon selected food compounds. Ph.D. Thesis. Purdue Univ., W. L Lafayette, IN.

2. Arthey, D. and Ashurst, P.R. (2001) Fruit Processing. Nutrition, Products, and Quality Management. A.N. ASPEN Publication. Aspen Publishers, Inc. Gaithersburg, Maryland.

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4. Frazier, W.C. and Westhoff, D.C. (1986) Food Microbiology. Tata Mc Graw-Hill Publishing Company Limited, New Delhi.

5. Karmas, E. and Harris, R.S. (1989) Nutritional Evaluation of Food Processing. An AVI Book, Published by Van Nostrand Reinhold Company, New York.

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7. Shapton, D.A., Lovelock, D.W. and Laurita–Longo, R. (1971) The evaluation of sterilization and pasteurization processes from measurements in degrees Celsius (°C). J. Appl. Bacteriol. 34, 491-500.

UNIT 14 DRYING AND DEHYDRATION OF FRUITS AND VEGETABLES

Structure

14.0 OBJECTIVES

After reading this unit, you should be able to:

- know the importance of drying/ dehydration of fruits and vegetables;
- know the drying and rehydration ratio and factors affecting the drying rate of fruits and vegetables; and
- describe the theories and methods of drying and dehydration of fruits and vegetables.

14.1 INTRODUCTION

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms is affected adversely. The dried or concentrated fruits and vegetable products are called as high sugar high acid foods or high value low volume foods. These dried or concentrated products save energy, money and space in shipping, packaging storing and transportation. Dehydration or drying process usually involves heating, in which water is removed from solid or near solid substances. Both term drying and dehydration mean the removal of water. The term **drying** is generally used for drying of the produce under the influence of non-conventional energy sources like sun and wind. **Dehydration** on the other hand refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow. The sun drying is dependent upon the elements which are beyond the strict control. It is a slow process and thus, not suitable for many high quality products. Generally, it will not lower the moisture contents below about 15% which is too high for storage stability of numerous products. Removal of water from foods provides microbiological stability and assists in reducing transportation and storage costs. Fruit juice is concentrated by evaporating of water and most of the aromatic juice should be heated for short time as possible and cooled rapidly. This minimizes the effect on flavour, aroma, and sugar compounds.

14.2 THEORIES OF DRYING AND DEHYDRATION

There are two steps involved in drying & dehydration.

1. **Heat transfer theory**

   Transfer of heat therefore, consists of transferring some of this molecular or atomic motion from one region to another. There are three broad mechanisms by which such transfer can occur, conduction, convection, and radiation. In conduction, the energy is transmitted from particle to particle by a process of direct contact or random Collin with no bulk movement of material. Transfer of heat by convection involves bulk mixing of fluids of different temperatures. Radiation is the transfer of energy from a radiating source through space which may or may not be occupied by matter. It is by radiation that we receive all our energy from the sun.

2. **Mass transfer theories**

   The removal of moisture from a food product involves simultaneous heat and mass transfer. Heat transfer occurs within the product structure and is related to the temperature gradient between the product surface and the water surface at some location within the product. As sufficient thermal energy is added to the water to cause evaporation, the vapours are transported from the water surface within the product to the product surface. The gradient causing moisture – vapour diffusion is vapour pressure at the liquid water surface, as compared with the vapor presser of air at the product surface. The heat and the mass transfer within the product structure occurs at the molecular level, with heat transfer being limited by thermal conductivity of the product structure, while mass transfer is proportional to the molecular diffusion of water vapour in air. The rate of moisture diffusion can be estimated by the expression for molecular diffusion. The mass flux for moisture movement is a function of the vapour pressure gradient as well as the mass diffusion for water vapour in air, the distance for water vapour movement within the product structure and temperature. The transport of vapour from the product surface to the air and the transfer of heat from the air to the product surface is a function of the existing vapour pressure and temperature gradients, respectively, and the magnitude of the convective coefficient at the product surface.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by drying and dehydration?

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2. What are the main objectives of drying?

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3. What are the main mechanisms by which heat can transfer?

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4. What are the functions of vapour pressure and temperature gradient?

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5. How evaporation is occurred during drying.

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14.3 ADVANTAGES OF DEHYDRATED FRUITS AND VEGETABLES

Fruits and vegetables that are properly dehydrated, particularly to a low moisture level (below 5%) have the following advantages:

1. Dehydration hardly affects the main calorie – providing constituents of fruit. It leaves the mineral content virtually unchanged. Therefore, the process is helpful in preserving the nutritive content of the final product. Vitamin losses are no grater with dehydration than with other preservation methods.

2. Dried fruits and vegetables have an almost unchanged shelf-life under proper storage conditions and there is no grater degree of bacteria, enzymatic changes, and mould actions.

3. Transportation, handling and storage costs are substantially lowered, and need of costly refrigeration during transportation and storage is eliminated Due to their reduction in average weight of $1/7^{th}$ to $1/9^{th}$ of the raw material shipping and handling weight is therefore reduced by approximately 90%.

4. They provide consistent product, an important modern marketing requirement. Seasonal variation in product quality is either absent or at a minimum with low –moisture fruits and vegetables.

5. They provide opportunities for maximum convenience, flexibility, and economics in production because they can be sized, shaped, formed, etc, to fit almost any requirement. With low moisture disposal and pollution problems.

6. They utilize the most economical and disposable from of packaging. The two major considerations in packaging dried fruits and vegetables are the exclusion of moisture and oxygen. Metal cans, plastic bags, and laminated bags and boxes effectively limit the passage of moisture and oxygen.

7. They offer many distinctive conventional as snack products.

14.4 MERITS OF DEHYDRATION OVER SUN DRYING

Dehydration is rapidly increasing importance over the sun drying because of its following characteristics:

1. **Drying conditions**

   Dehydration implies control over climatic conditions within a chamber, or micro environment control. Sun drying is at the mercy of the elements. Dehydration can be carried out throughout the year, irrespective of the prevailing climatic conditions of that region and require less land for drying activities. Sun drying of fruits and vegetables however, can be carried out in limited regions and time during which there is plenty of sun shine and practically little or no rain during the drying season, and require more land for drying activities.

2. **Sanitary conditions**

   In dehydration plant the sanitary conditions are controlled, and dehydration of fruits & vegetables is done under very hygienic conditions whereas in open field's contamination from dust, insect, birds and rodents are major problems.

3. **Relative cost**

   Dehydration has usually somewhat more costly than sun drying but undoubtedly the superior cooking quality of the dehydrated products will cause them to command a sufficiently higher price. For the small orchardist the cost of sun-drying trays is usually less than that of dehydrator, but for the large operator the cost of the dehydrator in some cases be no more than that of sun drying trays.

4. **Colour**

   During sun-drying green or slightly immature cut fruits such as peaches, and apricots, acquires the colour of its fully mature fruits. In dehydration the fruit retains the colour possessed at the time of cutting. Fruit of green, colour retaining this colour after dehydration, therefore, it is essential that fruit used for dehydration be fully mature. If the cut fruit is exposed to the sun for a few hrs before dehydration, the green colour disappear.

5. **Cooking quality**

   Dehydrated fruits, when cooked, more nearly resemble the cooked fresh fruits in flavour and colour than do cooked sun dried fruits. Comparison should be made of the refreshed and cooked fruits rather than the dried fruits. In coking quality, dehydrated foods are usually superior to sun dried counterparts.

6. **Relative yields**

   Dehydration usually gives a somewhat higher yield of dried product (calculated to a common moisture content) than is obtained by sun drying, even under ideal sun drying conditions. This difference is due probably to loss of sugar in sun drying through respiration or fermentation. During cloudy or raining weather loss of sugar in sun drying through fermentation becomes excessive.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why dehydrated products are considered as low cost technology product.

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2. How dehydration is better than sun drying.

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3. How the dehydrated product provide good opportunity for modern market.

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14.5 FACTORS AFFECTING DRYING

Food dehydration involves two steps (i) to get heat into the product and (ii) to get moisture out of the product. The above two steps are not always favoured by same operating conditions. For example food may be pressed between two heated plates. This would give close contact and improve heat transfer into the food through top and bottom, but the close contact of the plates would interfere with the escape of free moisture. Thus it might be better to use one bottom hot plate to get heat in and a free surface on top of the food to let moisture out. The following factors discussed below are playing very important role in affecting the drying rate.

Temperature

The rate of heat transfer into the food which provides the driving force for moisture removal. is affected by the temperature difference between the heating medium and the food. Greater the difference, greater will be the heat transfer and moisture removal. When the heating medium is air, temperature plays a second important role also of carrying away the water driven from the food in the form of water vapour. But the moisture will create a saturated atmosphere at the food's surface which will slow down the rate of subsequent water removal.

Surface area

The heat and mass transfer is affected by surface area and higher surface area result into increased rate of drying. Therefore, the food to be dehydrated is sub divided into small pieces or thin layers which speeds drying for two reasons. First larger surface area provides more surface in contact with the heating medium and thus, more surface area from which moisture can escape. Second smaller particles or thinner layers reduce the distance through which heat must travel to the centre of the food and reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.

Air velocity

High velocity air, in addition to taking up moisture will sweep it away from the drying foods surface, preventing the moisture from making a saturated atmosphere which would slow down subsequent moisture removal.

Dryness of the air

When the food dried in air, then food will dried rapidly due to more absorption and more holding capacity of moisture by dry air than the moist air . Moist air is closer to saturation and so can absorb and hold less additional moisture,

The extent of dryness of the air also determines how a low moisture content food product can be dried to low moisture content. Dehydrated food is hygroscopic and each food has own its equilibrium relative humidity. Equilibrium relative humidity (ERH) is the humidity at a given temperature where the food will neither lose moisture to the atmosphere nor pick up moisture from the atmosphere.

14.6 PRE-TREATMENTS FOR DRYING OF FRUITS AND VEGETABLES

To obtain excellent quality of a dried product the raw produce needs to be harvested and handled properly. For better quality of dried products following pre-treatments required to be undergo.

Harvesting

To obtain high quality dried fruits and vegetables, the raw product must be harvested at optimum maturity and processed as carefully and rapidly as possible, for example pear is a fruit that is held after picking, because the best quality product is obtained when they are picked green and allowed to ripen in storage.

Washing

Fruits and vegetables are usually rinsed in cold water. To remove surface dust particle and pesticides spray residues, a residual chlorine content of 10-20 ppm of water is recommended to decrease the initial count of raw material to minimum.

Peeling and slicing

Root vegetables, apple and some times cling-stone peaches are peeled prior to drying. This is accomplished by various means: refractory, lye, hot brine peeles, high pressure steam for root crops, mechanical knife peelers for apples and dilute lye for cling-stone peaches. Prunes, grapes, berries and cherries are dried as whole, although latter may be pitted. Apricots, nectarines and peaches are halved and pitted, pears are halved and apples are peeled, cored and either sliced or sectioned.

Pricking

Many pre-treatments given to food before drying are aimed at making the structure more porous to facilitate mass transfer and speedup drying rate. Many pre-treatments are given before drying. Peas, carrots and aonla are pricked to increase the drying rate. Pricking can be done by a hand operated pricking machine. In preserve making the whole fruits, vegetables or their slices are uniformly pricked with stainless steel prickers or forks. Pricking is also useful while preserving fruits and vegetables by osmotic dehydration.

Soaking

The fruits and vegetables slices after pricking are soaked in plan water, lime water, brine or alum solution for few hrs to few days before blanching and cooking.

Curing

Curing is practiced in onion and garlic. It dehydrates raw material by sun drying or by hot air drying at a temperature of 30°C. In garlic it is carried out until the segments can be easily separated.

Alkaline dip

Alkaline dip is used primarily for fruits that are dried as whole especially prunes and grapes. Dipping facilitates drying by forming fine cracks in the skin. A sodium carbonate or lye solution (0.5% or less) is used at a temperature ranging from 93-100°C.

In Australia and some Mediterranean countries cold dip solution such as carbonate or lye with olive or commercial solution are used. The main active ingredients of commercial solution are oleate esters. These dips accelerates moisture loss by causing the wax plates on the grape skin to dissociate thus, facilitating water diffusion.

Acid dip

Before sulphuring use of an acid pre-dip provides better colour stability to a product. A dip of 1% ascorbic acid and 0.25% malic acid has been used to retard enzymatic browning in peaches. Steeping of mushrooms in 0.5% to 1.0% citric acid for 16 hrs results into better quality dried products in respect of colour, appearance, rehydration properties and keeping quality. .

Blanching

Blanching is a partial pre-cooking treatment in which vegetables/ fruits are usually heated in water or in live steam to inactivate the enzymes before processing.

Purpose of blanching

- Reduces drying time
- Removes inter- cellular air from the tissues
- Causes softening of texture
- Retards the development of objectionable odour and flavour during storage by enzyme inactivation
- Retain carotene and ascorbic acid during storage
- Removes pungency (onion)
- Impart desired translucent appearance to the product.

Sulphuring

The whole fruits, slices or pieces are exposed to the fumes of burning sulphur inside a closed chamber known as sulphur box for 30-60 minutes.

Purpose of sulphuring

- Prevent oxidation and darkening
- Act as preservative/ antimicrobial agents
- Check the growth of moulds
- Prevent cut fruits from fermentation
- Prevent the vitamin losses

Sulphiting

Sulphitation is a process in which the product is dipped in a SO_2 in water.

Purpose of sulphiting

- Maintains an attractive colour
- Prevents spoilage
- Preserves certain nutritive attributes until marketing
- Act as antioxidants and protect the carotene and ascorbic acid content of dried fruits.

Post drying treatments

The practices as post drying treatments which are followed after drying are described as follow:

Sweating

Sweating is a practice of storage of dried product in bins or boxes for equalization of moisture or re-addition of moisture to a desired level. It is used primarily with some dried fruits and some nuts (almonds and walnuts).

Packaging

Most product are packaged after drying for protection against moisture, contamination with micro-organisms, and infestation with insect , although some dried foods (e.g. fruits and nuts) may be held as long as a year before packaging.

In-package desiccant

In package desiccant means the packaging of the dried product with a material like calcium oxide or silica' gel that will continue to absorb the remaining moisture during storage. Silica gel @ 1 to 2% in powdered foods, prevent moisture picking after seal of the package and brought down the moisture from 3% to 1% n case of orange juice powder without a significant loss of vitamins at 21.1 to 67.8°C for 6 months and thereby, eliminating caking.

Pasteurization

It is usually limited to dry fruits to kills any pathogens that might be present as well as destroys spoilage organisms. The fruits usually pasteurized in the package and the treatment varying with the fruits is from 30-70 min at 100% relative humidity at 65.6 to 85°C.

FRUITS/VEGETABLES
(mature and free from insects and diseases)
↓
WASHING
↓
PEELING
↓
PREPARATION
(as given in table for individual fruit/ vegetables)
↓
BLANCHING
↓
SPREADING ON FALAT WOODEN TRAYS
↓
SULPHURING
(usually @ 1.8 to 3.6 kg/ ton of fruit)
↓
DRYING /DEHYDRATION
(with occasional turning)
↓
SWEATING
↓
PACKING
(air tight tin containers or polyethylene bags)
↓
STORAGE
(at ambient temperature in dry place)

Figure 14.1: Flow-sheet for drying/dehydration of fruits and vegetables

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the factors which affect the drying rate?

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2. Explain why it is necessary to use bottom as hot and free surface on top during drying.

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3. Describe the role of temperature in drying.

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4. How the surface area affect the drying rate.

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5. How product size affect the drying rate.

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6. What is the role of pricking in fruits and vegetables?

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7. Why hole fruits are generally treated with alkaline solution?

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8. What are the main purposes of blanching?

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14.7 DRYING RATE

The initial removal of moisture occurs as the product and the water within the product start evaporation due to slight increases in temperature and followed the initial stages of drying . A significant reduction in moisture content then will occur at a constant rate and at a constant product temperature. The constant-rate drying period occurs within the product at the wet bulb temperature of the air. While the most situations, the constant rate drying period will continue until the moisture content is reduced to the critical moisture content. At moisture content below the critical moisture content, the rate of moisture removal decreases and followed the falling rate drying period.

14.8 DRYING AND RECONSTITUTION RATIO

Drying ratio

Drying ratio is always vary with the type of variety, growing conditions, time of harvest, grade of raw material and loss in preparation. In this connection, dehydration ratio should not express on the basis of moisture percent in the material, but it should be expressed on a dry basis i.e. as the ratio of water content to dry matter. The weight of dry matter going into the dryer will be the same as that taken out. The amount of water changes, but the dry matter does not.

Knowing the water content of the fresh material entering the dryer and of the product leaving the dryer, the drying ratio, or its reciprocal drying yield, can be calculated as follows.

$$\text{Drying ratio} = \frac{\text{Weight entering dryer}}{\text{Weight leaving dryer}} = \frac{100 - \text{M1}}{100 - \text{M0}} = \frac{\text{TO} + 1}{\text{T1} + 1}$$

Where M0 = is the percent moisture of the material entering the dryer,
M1 = percent moisture of the product leaving the dryer
T0 = lb of water per lb of bone-dry material entering the dryer
T1 = lb of water per lb bone-dry material leaving the dryer.

For example, potatoes, prepared and ready for the dryer, have about 78 percent moisture, when properly dried they have about 7 percent moisture. Then

M0 = 78, M1 = 7, T0= 78/22 = 3.55, T1 = 7/93 =0.075

$$\text{Drying ratio} = \frac{100 - 7}{100 - 78} = \frac{3.55 + 1}{0.075 + 1} = 4.23 = 4.23 : 1$$

$$\text{Drying yield} = \frac{100 - 78}{100 - 7} = \frac{0.075 + 1}{3.55 + 1} = 0.236 \text{ or } 23.6 \text{ percent}$$

It should be noted that the over all ratio between weight of raw material entering the plant and weight of finished product leaving it must take into consideration losses incurred during preparation and final inspection.

Reconstitution ratio

Rehydration means the quantity of water absorbed by dehydrated foods.

Calculation can be made to express the results in terms of rehydration ratio" "coefficient of rehydration" and "percent of water in the rehydrated material"

Examples of such calculations are as follows:

Rehydration ratio

Suppose the weight of the dehydrated sample used for the test is 10 g (W_D) and the drained weight of rehydrated sample is 60 g (W_R).

Then $= \frac{W_R}{W_D} = \frac{60}{10} = \frac{6}{1}$, the rehydration ratio is 6 to 1 = 6:1.

Coefficient of rehydration

The drained weight of the rehydrated sample is 60 g (W_R), the weight of the dehydrated sample is 10 g (W_D) and contain 5 per cent moisture (W_M), and the original material before dehydration contained 87 percent moisture (A). Then

$$\frac{W_R}{\frac{(W_D - W_m)100}{100 - A}} = \frac{60 \times (100 - 78)}{10 - (10 \times 0.05)} = \frac{780}{9.5} = 82\% \text{ or } 0.82$$

Percent of water in rehydrated material

Knowing the drained weight of the rehydrated sample, the percent of water in the rehydrated material can be calculated;

$$\frac{60 - 9.5}{60} \times 100 = \frac{5050}{60} = 84.1\%$$

Note: For better rehydration it is suggested that the following conditions be met.

1. Detrmine the time of soaking and boiling that is compatable with optimum quality of the product.
2. Start the test with at least enough water to submerge the pieces , but do not use so much water that excess amount are present at the end of the test.
3. Shake or stir if necessary to insure wetting of all pieces during the test.
4. Control the rate of heating so as to prevent rapid and variable losses of water while boiling.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the constant rate and falling rate period?

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2. Differentiate between drying and reconstitution ratio.

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3. What are the factors which affect the reconstitution ratio?

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14.9 ROLE OF WATER ACTIVITY AND ITS IMPORTANCE IN DRIED PRODUCTS

Water activity (a_w) is defined as the ratio of the vapour on the aqueous solution to that of pure water at the same temperature i.e.

a_w = Vapour pressure of solution at T°C

Vapours pressure of pure water at T°C.

Water activity is also equal to the equilibrium relative humidity (ERH);

$$a_w = \frac{\text{Equilibrium relative humidity}}{100}$$

The a_w has a major role to play on microbiological spoilage and chemical changes produced in the food. The principles of water and microorganisms relation includes:

i) water activity, rather than water content determines the lower limit of available water for microbial growth. Most bacteria do not grow below a_w 0.91 and most moulds cease to grow at water activity of 0.80. Some xerphylic fungi have been reported to grow at water activities of o .65, but the range of 0.70 – 75 is generally considered their lower limit.

ii) Environmental factors affect the level of water activity required for microbial growth. The less favourable the other environmental factors (nutritional adequacy, pH, oxygen pressure, temperature) the higher becomes the minimum a_w at which microorganisms can grow.

iii) Some adaptation to low water activities occurs, particularly when a_w is depressed by addition of water soluble substances (principle of IMF), rather than by water crystallization (frozen foods) or water removal (dehydrated foods).

iv) When water activity is depressed by solutes. The solutes themselves may have effects which complicate the effect of a_w per se. For instance, at a given a_W microbial growth is less effectively depressed by glycerol than by sodium chloride. More recent (IMF) have resulted in the following additional findings.

a) Water activity modifies sensitivity of microorganisms to heat, light and chemicals. In general organisms are most sensitive at high water activities (i.e. in dilute solution) and minimum sensitivity occur in an intermediate moisture. Minimum water activities for production of toxins are often higher than those for microbial growth. The phenomenon may represent an important safety factor in the distribution of dehydrated and intermediate moisture foods.

b) The effect of water on chemical reactions in foods are more complicated than are its effect on microbial growth. It plays one or more of the following roles; a) as a solvent for reactant and for products, b) as a reactant (e.g. in hydrolysis reactions) c) as a product of reactions and d) as a modifier of the catalystic or inhibiting activities of other substances (e.g. water in activities some metallic catalysts of lipid per oxidation).

14.10 COMMON TYPES OF DRIERS USED FOR DRYING OF FRUITS AND VEGETABLES

A) Solar driers

These are suitable for drying of onion flakes. The matrix type solar air heater consists of an iron scrap as an absorber. The upper surface of this matrix is painted dull black. Air is made to flow through the matrix in the upwards direction. Similarly in rock type solar air heater is connected with the cubic shaped dehydration chamber, through an air duct of appropriate dimension. Dehydration chamber has provision for holding trays and thermometer a glass door and a chimney. Solar driers are different types like tent type drier, walk-through drier, air flow inside indirect drier cabinet, indirect chimney driers etc.

B) Air convention driers

Air convection driers have some sort of insulated enclosure, a means of circulating air through the enclosure and a means of heating this air. They also have various means of product support and special devices for collecting dried product, some have air driers for lower drying air humidity. Movement of generally is controlled by fans, blower and baffles. The air may be heated by direct or indirect methods. In direct heating the air is in direct contact with a flame or combustion gases. In indirect heating the air is in contact with a hot surface such as pipes or fins heated by steam, flame or electrically.

1. Kiln driers

This is the one of the simplest kind of air convention drier. In this dryer a furnace or burner on the lower floor generated heat and warm air rises through a slotted floor to the upper storey. Food such as apple slices spread out on the slotted floor of drier and turned-over periodically. This type of drier generally will not reduce moisture to below 10%. A rotary kiln drier dries the product in a rotating drum using a burner to blow hot air into the drum along with the product. Because of higher temperatures of drying, this method has some limitations with respect of limited nutrient levels and off- colour of the finished product.

2. *Cabinet tray and pan dryers*

   Cabinet drier are suitable for small scale operations. Fresh air is drawn by the fan through the heater coils, filtered by screened to remove dust, and than blown across the materials on trays to an exhaust system. The air may pass across and between the trays or may be directed up through the perforated trays. Cabinet tray and pan driers are comparatively inexpensive and easy to set in forms of drying conditions. These may run up to 25 trays high and will operate with air temperature of about 93°C (200°F) dry bulb and air velocities of about 2.5-5 m/s across the trays. They are commonly used to dry fruit and vegetable pieces and depending upon the food and the desired final moisture, drying time may be of the order of 10-20 hrs.

3. *Tunnel and continuous belt driers*

   The main construction feature by which tunnel driers differ is the direction of air flow relative to tray movement. When the direction of air flow and that of tray movement is opposite, then it is counter-flow or counter current principle. Its significant is that the air ,when it is the hottest and dries, contacts the nearly dry product, whereas the initial drying of entering carts get cooler, most air that has cooled and picked up moisture going through the tunnel. Since the initial product temperature and moisture gradients will not be great, the product is less likely to undergo case hardening or other surface shrinkage leaving wet centres. Further, lower final moisture can be reached since the dried product encounters the driest air. In contrast, there are also co-current flow, tunnels with the incoming trays and dry-hot air travelling in the same direction. In this case, rapid initial drying and slow final drying cause case hardening, internal splits and porosity as centres finally dry, which sometimes is desirable in special properties.

   The common features of the dryer include uniform automatic feeding of product to the belt in a controlled thin layer, zone heat and air flow control in different sections, tumbling over the product onto a second strand of belt, automatic collection of dried product and of course continuous operation.

4. *Belt trough driers*

   A special kind of air convection belt driers is the belt trough drier in which the belt from a trough and belt is usually made up of metal mesh and heated air blown up through the mesh. The belt moves continuously keeping the food pieces in the trough in constant motion to continuously expose new surface. This speeds-up drying with air of about 135°C (272°F) vegetable pieces dried to 7 to 5% moisture range in about 1 hr. High operating temperatures result in high drying rates without causing appreciable heat damage to vegetable pieces because the constant agitation keeps individual piece from being exposed to the very hot dry air for more than a movement. Then, each piece is surrounded by air at much lower temperature for a longer time before again moving into the zone of intense drying,. Onion slices dried in this way tend to separate and become entangled. Fruit pieces that exude sugar on drying tend to stick together and clump with the rumbling motion.

5. *Air lift drier*

   Several types of pneumatic conveyer dryers go a step beyond tem being to exposure more surface area of food products. These dryers tem being to finish dry materials that have been partially dried by other methods, usually to about 25% moisture or at least sufficiently low. So that the material becomes granular rather than having a tendency to clump and mat. A product from drum drier having 25% moisture can be brought to about 6% moisture more efficiency in a heated air steam than on the drum. This is because it is more difficult to remove moisture in this falling rate of dehydration. The suspended particles when dry are separated from the air and collected in a cyclone type separator.

6. *Fluidized bed drier*

   Another type of pneumatic conveyor drier is the fluidized bed drier. In fluidized bed drying heated air is blown up through the food particles with just enough force to suspend the particles in a gentle boiling motion. Semi dry particles such as potato granules gradually migrate through the apparatus until they are discharged dry. Heated air is introduced through a plate that supports the bed of granules. The moist air is exhausted at the top. This process is continuous and the duration of time that the particles remain in the drier can be regulated by the depth of the bed. This type of drier can be used to dehydrate peas and other particles. Fluidized bed drying has numerous advantages such as a) high drying intensity, b) uniform and closely controllable temperature throughout, c) high thermal efficiencies, d) time duration of the material in the drier may be chosen arbitrarily, e) elapsed drying time is usually less than in other types of drier, f) equipment operation and maintenance are relatively simple, g) the process can be automated without difficulty, h) fluidized drier are compact and relatively small, i) several process may be combined in a fluidized bed drier.

7. *Spray drier*

   By far the most important kind of air convection drier is the spray drier which is used widely for dehydrating liquid food products. It is limited to foods that can be atomized (liquid and low viscosity passes or purees). Automization into minute droplets results in drying in a matter of seconds with common inlet air temperatures of about 204^{o}C. The liquid product to be dried is automized into a chamber, where it is put in contact with a stream of hot air and rapidly dried. The dry particles suspended in air stream, flow into separation equipment where they are removed from the air, collected and packaged or subjected to further treatment, such as instantizing. A wide range of products like banana, potatoes, proteins from various plants sources, soy isolates, citrus juices, tomato puree corn hydrolysates etc. have been successfully drying by this dryer.

8. *Bin dryer*

   Bin drier are used, particularly for pieces from of vegetable products to complete the drying operation. Usually it is a finishing step after truck apron or tunnel drying during which most of the moisture has been removed. Typically, a bin drier reduces the moisture content of a particularly dried products (10-15% moisture) cut vegetable to 3-6% or even lower in the case of onion slices and possibly cabbage shreds. Win dryer consists of a metal or wooden box equipped with an air inlet at the bottom and a wire mesh deck or false bottom with an air supply duct below it so arranged that warm dry air can be passed through the nearly dry product piled on the deck.

C) Roller drier

Roller drier consists of one or two hollow drums which are fitted so that a heating medium, usually steam but occasionally water or a special high temperature, heat transfer liquid can be directed through them. The drums are mounted to rotate about the symmetrical axis and are customarily driven with a variable speed mechanism, feeding device applies a thin, uniform, layer of the material to be dried on the hot drum surface. A knife or doctor blade is fitted to the drum at an appropriate location. The material is dried as the heated drum rotates towards the doctor blade which scrapes the thin layer of dry material from the drum surface.

1. *Drum drier*

   In drum drying liquid foods, purees, pastes, and mashes are applied in a thin layer onto the surface of a revolving heated drum. The drum generally is heated from within by steam. Driers may have a single drum or a pair of drums. The food may be applied between the nip where two drums comes together, and then the clearance between the drums determines the thickness of the applied food layer. Drum drying has some inherent limitations which restrict the kinds of foods to which it is applicable. To effect rapid drying drum surface temperature must be high generally above 121°C. This give product, a more cooked flavour and colour than when they are dried at a lower temperature. Another limitation is the difficulty of providing zoned temperature control needed to vary the drying temperature profile. With a modified atmospheric double drum drier and with appropriate separating conditions, fruit and vegetables flakes are produced with commercial success. The vapour which evolved during drying are exhausted through hoods over and under the drums. The product collection zones are maintained at about 10-20% RH. Drum drying process are used successfully in the production of powdered cranberries, tomato cocktail, pea and bean soups, apple, flakes, potato flour, tomato juice flakes, mashed flakes and sweet potato flakes.

2. *Foam-mat drier*

   Foam-mat driers are used primarily for liquids which are pre-foamed by whipping, adding a few level of an edible whipping agent-to liquids that do not whip readily. Foaming a liquid exposes enormous surface areas for quick moisture removal which also permits use of lower drying temperatures. Foam is deposited in a uniform layers of many foods can be dried to about 2-3% moisture in approximately 12 min.

D) Vacuum dryers

In vacuum drying the temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and the intensity of heat input. Heat transfer to the food takes place largely by conduction and radiation. Vacuum drying methods usually can be controlled with a higher degree of accuracy than the n method which depends upon air convection heating. All vacuum drying system have four especial elements: a vacuum chamber of heavy construction to with stand outside air pressure that may exceed internal pressure by as much as 9800 kg/m^2 a heat supply, a device for producing and maintaining the vacuum, and components to collect water vapour as it is evaporated from the food.

1. *Vacuum puff drier*

   Vacuum puff drier refers to the dehydration of liquid materials in vacuum by evaporating water under pressure in excess of 1 mm of Hg, so that the products puff during drying and form expanded honey combed structures. This process is distinguished from freeze drying in that latter is done under extremely low pressure, always well below 1 mm and sometimes as low as 5 µm, with the materials in a frozen state.

   In puff drying of juice, a porous structure is obtained by applying vacuum to a viscous juice concentrate when bubbles of water vapour and entrapped air formed expand throughout the material. Vacuum temperature and velocity of the concentrate are controlled so that the puffed material has about 20 times the volume of the liquid concentrate. In certain juice such as tomato, which have low soluble solids content and a high insoluble solids or pulp content, puffing is not satisfactory unless air or another gas is incorporated into the concentrate.

2. *Vacuum shelf puff driers*

   One of the simplest kinds of vacuum driers is the batch type vacuum shelf drier. If liquids such as concentrated fruit juices are dried above 5 mm Hg, the juice boils and splatters, but in the range of about 3 mm Hg and below, the concentrated juice puffs as it losses water vapour. The dehydrated juice then retains the puffed spongy structure. High vacuum dehydrator operates at fractions of a millimetre of mercury. At 2 inch or 50 mm of mercury pure water boils at 38°C. Since temperatures well below 38°C (101° F) can be used, in addition to quick solubility there is minimum flavour change or other kinds of the heat damage. It is also suitable for the dehydration of food piece.

3. *Continuous vacuum belt puff drier*

   The drier consists of a horizontal tank like chamber measuring about 17m length and 3.7 m in diameter. The chamber is connected to a vacuum producing moisture condensing system. Two revolving hollow drums are mounted within the chamber and a stainless steel belt is connected around the drums which move in a counter clockwise direction. The drums on right as heated with steam confined within it. The drum heat the belt passing over it by conduction. As the belt moves it is further heated by infrared radiant elements. The drum to the left is cooled with cold water circulated within it and cools the belt passing over it. The liquid food in the form of a concentrate is pumped into a feed pan under the lower belt strand. An applicator roller dipping into the feed continuously applies a thin coating of the food onto the lower surface of the moving belt. The food is dried in a vacuum equivalent to 2 mm Hg. When the food reaches the cooling drum it is dried to about 2% moisture. At the bottom of cooling drum is a doctor blade which scrapes the cooled, product, into collection vessel. It is used commercially to dehydrate high quality citrus juice crystals and other delicate liquid foods. Products dried with this equipment have a slightly puffed structure.

E) Freeze driers

Freeze dryers are used to produce dehydrated foods of exceptional quality. In freeze dryers the material such as fruit juice concentrate, is first frozen on trays in the lower chamber of a freeze driers and the frozen material dried in the upper chamber under high vacuum. The material dries directly by sublimation of ice with out passing through the intermediates liquid stage. The dried product by this method is highly hygrospic. It reconstitutes readily. Mango pulp, orange juice concentrate and guava pulp have been found to give freeze dried powders of excellent quality in regard to taste, flavour, reconstitution properties etc.

F) Slush driers

Slush driers are used to obtained the benefit over the freeze dryer and air or vacuum drying without the drawback of drying from a partially frozen state where in 20-70% of water present is frozen with remainder being liquid. The high dissolved solid contents of the liquid portion of the mixture aids volatiles relation and the need for maintaining the ultra low temperature requirement for freeze drying is avoided.

Check Your Progress Exercise 5 ✍

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define water activity (a_w).

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2. What are the common features of tunnel drier?

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3. What are the advantages with fluidized bed driers?

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4. How the mass and heat transfer is controlled in vacuum drier.

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14.11 IDEAL CONDITION FOR PACKAGING AND STORAGE OF DRIED PRODUCTS

Packaging is an integral part of processing. It provides a barrier between the food and the environment. It controls light transmission, transfer of heat, moisture and gas, and movement of microorganisms or insects. The shelf life of a dehydrated product is influenced to a large extent by the packaging. So package must confirm the following special criteria:

a) Protection of the dehydrated product against moisture, light, air, dust, micro flora, foreign odour rodent etc.

b) Strength and stability to maintain original container properties through storage, handling and marketing.

c) Size, shape, appearance to promote stability of the product.

d) Composition of the container must be approved for use in contact with foods.

e) Cost of the package should not be more than the cost of content packed inside of the package.

Dried fruits and vegetable should be quite dry and should be packed in moisture proof container such as tin container. If care is not taken to guard against entry of excessive moisture the contents inside the package become mouldy. Wooden boxes or cardboard containers are not generally moisture proof and insect proof unless special methods are adopted to line them. Proper packaging of dehydrated fruit and vegetable products prevents, deterioration and spoilage during storage under ordinary conditions, as well as under extra ordinary conditions. With the recent introduction of a variety of plastic packaging materials and film, a great deal of research work has been carried out in many parts of the world to develop suitable packaging. In the case of fruit juices powders, some spice products etc their packaging becomes highly critical and decisive. Packages based on cheap indigenous materials such as brown casing paper (60 gauge) aluminium foil (0.0mm) polyethene (150 gauge) pouches with a 2 ply corrugated liner wax ed carton, etc have been developed to ensure a minimum shelf life of one year under field conditions.

Dried and dehydrated foods should be stored in a dark, dry, cool, place, and lower the temperature of storage, longer the life of the product. Storage practices for dried fruits are variable, but a temperature of 40°F is commonly used with little attempt humidity control. The best storage for most dried fruits is 32°F and 55 percent relative humidity. Some fruits such as dried apples, apricots and peaches, do not seem to be harmed by 80 percent relative humidity at 32°F. Other particulars raisins and figs gain moisture, and sugar to a harmful extent at this humidity.

14.12 DRYING PROCESS FOR FRUITS AND VEGETABLES

The process used for drying of individual fruit and vegetable is described as follows:

Fruits

Grapes: Raisins prepared from grapes are the most important dried fruit product. Muscat and wine varieties are dipped in boiling solution of 0.5% caustic soda followed by rinsing and sulphuring for 1 hr and then, drying at 55-60°C in a dehydrator or sun drying. Ripe bunches of grapes are hung inside the dark rooms known as Kishmish khanas till berries acquire a greenish or light amber tint colour. Monucca or raisins is prepared from large seeded Haitha grapes which are lye dipped prior to sun drying. In California, the Sultana or Thompson seedless grapes are dried.

Banana: Washing, peeling, cutting, into halves lengthwise or crosswise (12 mm thickness), sulphuring for 30 min followed by drying at 55-60°C in a mechanical or solar drier.

Prunes: Washing, cleaning, pitting perforation and drying.

Apricot: Washing, cutting, into halves, destoning, sulphuring for 30 min. followed by drying at 50-60°C in a mechanical or solar drier.

Mango: Washing, peeling , cutting into 12 mm thick slices, sulphuring for 2 hrs followed by drying at 45-50°C in a mechanical or solar drier. Ripe mangoes are taken and juicy squeezed by hand and dried as Aam pappad.

Date: Washing, dipping in boiling solution of 0.5% caustic soda followed by rinsing and drying in a dehydrator at 45-50°C.

Fig: Washing, sulphuring for 1 hr followed by drying at 55 to 60°C in a mechanical or solar drier.

Aonla: Washing, grating followed by addition of salt @ 40 g/kg to the grated material and then, drying in mechanical or solar drier.

Apple: Washing, peeling, coring, trimming and slicing into 5 mm thickness, followed by sulphuring for 30 min or immersion in 1-2 % KMS solution for 30 min. This follows the drying at 60-65°C in a mechanical or solar drier.

Papaya: Washing, peeling, removal of seeds, cutting into 6 mm thick slices, sulphuring for 2 hrs followed by drying at 60-65°C in a mechanical or solar drier.

Pear: Washing, peeling, cutting into halves, holding in 1-2% salt solution, sulphuring for 30 min. or immersion for 20 min in 1-2%KMS solution followed by drying at 60-65°C in a mechanical or solar drier.

Peach: Washing, stone, peaches like july Elberta cultivars is used for drying. The drying process includes washing, removal of pits, cutting into halves, sulphuring for 30 min followed by drying at 60-65°C in a mechanical or solar drier.

Other Fruits: Pomegranate seeds are dried into Anardana, cherries and berries are also dried.

Varieties of the common fruits suitable for drying

Apples	Baldwin, Bellflower, Delicious, Gravenstein, Hoover, Jonathan, king, Yellow Newtown, Permain, Rhode Island greening, Rome Beauty, Wagener, Winesap
Apricot	Blenheim, Royal, Tilton
Figs	Adriatic, Black Mission, Calimyrna, Kadota
Nectarins	Hardwick, Newboy, Quetta, Stanwick
Peaches	California midsummer varieties and Phillips cling
Peaches (freestone)	Elberta, Lovell, Muir
Pears	Bartlett
Prunes	French, Imperial, Sugar, Robe de Sergeant
Raisins 9Golden bleached) dehydrated	Thompson Seedless
Currants (Zante)	Black Corinth

Vegetables

Onion and *garlic* make excellent dehydrated product: onion is dried in the form of flakes and powder whereas; garlic is dried as cubes and powder. Their use in the dry form has great scope particularly for export point of view.

Beans: Washing, peeling and cutting into 10 mm thick slices, steam blanching for 10 min. followed by drying at 60-65°C in mechanical or solar drier.

Beet: Washing, peeling and cutting into 10 mm thick slices, steam blanching for 10 min. and drying at 60-65°C in mechanical or solar drier.

Bitter gourd: Washing, removal of both ends cutting into 10 mm thick slices, blanching for 7-8 min. and drying at 65-75°C in mechanical or solar drier.

Brinjal: Washing, cutting lengthwise into 10 mm thick slices, blanching for 4-5 min and then, immersion for 1 hr in 1% KMS solution followed by drying at 50-52°C in mechanical or solar drier.

Cabbage: Washing, removal of outer leaves and cutting into fine shreds, blanching for 5-6 min, immersion for 10 min in 0.5% KMS solution and draining by drying at 55-60°C in mechanical or solar drier.

Cauliflower: Washing, removal of stalks, covering leavers and steams, breaking of curd suitable size pieces, blanching for 4-5 min. immersion for 1 hr in 1% KMS solution and draining followed by drying at 55-60°C in mechanical or solar drier.

Carrot: Washing, scrapping, stalks and tips, cutting into 10 mm thick slices blanching for 2-4 min. in boiling solution of 2% salt followed by drying at 60-65°C in mechanical or solar drier.

Chilies (red): Mature dark red pods are tied to a string and hanged in sun or dried at 50-55°C in a dehydrator.

Green peas: Washing removal of shell, blanching grains in boiling water or steam for 3-4 min. immersed in 0.5% KMS solution and draining followed by drying at 60-65°C in mechanical and solar drier.

Palak, methi and other leafy green vegetables: Sorting, washing, trimming-off rough stems and stalks and shred making followed by blanching for 2 min in boiling water or steam and then drying at 60-65°C in mechanical or solar drier.

Potato: washing, peeling, and cutting into 10 mm thick slices, blanching in boiling water or steam for 3-4 min. and immersion in 0.5% KMS solution followed by drying at 60-65°C in mechanical or solar drier.

Tomato: washing, blanching for 30-60°C, peeling and slicing into 1 cm thick slices followed by drying at 60-65°C in mechanical or solar drier.

Turnip: Washing, removal of stalk, peel, cutting into 5 mm thick slices, blanching for 2-4 min. in boiling water then immersion for 1-2 hr in 1%KMS solution, followed by drying at 50-55°C in mechanical or solar drier.

Mushroom slices: mushrooms are one of the most important vegetable prepared by dehydration. Steps include trimming, blanching with SO_2 @ 500-1000 ppm for 5-10 min. slicing followed by drying in mechanical or solar drier.

Ginger: trimming, washing, cutting or slicing and drying in mechanical or solar drier.

Drying schedule for fruits

Fruits	Preparation	Pretreatments (in boiling lye solution 0.2% NaOH)	Time of sulphuring (min)
Apple	Peel, core and cut in 5 mm thick slices	-	15-30
Apricot	Wash halves destine	-	20-25
Peach	Halves peel, destine	-	20-25
Grape	Wash	2-5 sec.	10-15
Banana	Wash peel, cut into thick slices	-	2 hrs
Mango	-do-	-	2 hrs
Papaya	Wash peel, cut into 5 mm thick slices	-	2 hrs
Pine apple	-do-	-	2 hrs

Drying schedule for vegetables

Vegetables	Preparation	Blanching in boiling water	Sulphitation in 0.5% KMS
Potato	Peel cut into 3mm thick slices	3-4 min	30 min
Carrot	-do-	4-5 min	30 min
Okra	Remove both ends and cut into 6mm thick slices	5-6 min	30 min
Cabbage	Remove outer leaves and cut into 4-8 mm thick shreds	5-6 min	30 min
Cauliflower	Remove stalks leaves and stem cut into 10 mm thick slices	5-6 min	30 min
Peas	Shelled peas	3-4 min in boiling water containing 0.5% KMS,0.1% Sodium bicarbonate and 0.1% magnesium oxide	30 min
Spinach	Short, wash thoroughly in water and cut into 10 mm portion	-do-	Nil

Fenugreek	Short, remove stalks and stem and wash leaves thoroughly	Blanch above for 2-3 min	Nil
Onion	Remove tops and tails, peel and cut into 4-8 mm thick shreds	Nil	Nil
Garlic	Peel and cloves cut into 6 mm thick shreds	Nil	Nil
Bitter Guard	Remove both end and cut into 6mm thick slices	Blanch in boiling water	30 min
Pumpkin	Peel remove seeds, and cut soft portions into 6mm thick slices	2 min	30 min

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the functions of packaging?

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2. What is the optimum storage temperature and relative humidity for dried products?

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14.13 LET US SUM UP

Dehydration or drying is an important and oldest preservation method in food processing. Water removal from food is primarily done to lower the water activity (a_w) so that microbial growth is inhibited. It also saves energy, moisture and space in shipping, packaging, storage and transportation of dried fruit and vegetable products. These are known as high value low volume food or high acid high sugar foods. Prolong heat processing of fruits and vegetables affect their delicious flavour, nutritional quality and acceptability. In recent years, the achievements in the drying / dehydration of fruits and vegetables have led to the development of more improved methods and techniques of drying including water removal at low or ambient temperature. These techniques include osmotic dehydration, foam-mat drying (especially micro flake process), modified drum drying, explosion puffing, slush drying, vacuum drying, freeze drying etc. Various treatment have been developed for treating fruits and vegetables to increase the rate of drying or decrease the drying time to reduce the production of brown pigment. So by using these techniques, the overall quality of the dried products including sensory and nutritional value, has been improved.

14.14 KEY WORDS

Water activity : Water activity (a_w) is the ratio of vapour pressure of food (P) and pure water (p_o) and expressed by aw = p/p_o.

Dehydration : Removal of moisture under control conditions of temperature, air flow and humidity.

Drying : Drying of the product under the sun.

Conduction : Transfer of heat with contact particle to particle.

Blanching : Partial pre-treatment in which vegetables are heated in water or live steam to inactivate enzyme before processing.

Sulphuring : Exposing the of fruits to the fumes of burning sulphure inside a closed chamber.

In-package desiccant : Packaging of the dried products with a material like calcium oxide or slica gel.

Sorption isotherms : water sorption isotherms is a graphical presentation of data which shows the water relationship of food.

Concentration : Removal of water from foods mostly by heat application and concentration of soluble solids or solutes.

Preservation	:	Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutrients and free from and microbial infection.
ERH	:	Equilibrium Relative Humidity.
Osmotic dehydration	:	Removal of water through a membrane from higher concentration to lower concentration.
Unit operation	:	It is a step in the complete process or a physical change in form or place, for example, peeling, cutting, grading, etc.
Drying ratio	:	Drying ratio is the reciprocal of fresh material to dried material.
Spoilage	:	The food which has been damaged or injured which make the food undesirable for human use.
Rehydration ratio	:	Reconstitution ratio is the quantity of water absorbed by dehydrated foods.
Reverse osmosis	:	Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

14.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Drying of commodity in the sun with non conventional sources of energy like sun and wind.
   - Drying the commodity under controlled conditions like temperature, relative humidity and air flow.

2. Your answer should include the following points:

   - To reduce the weight and bulk
   - To reduce the water activity

3. Your answer should include the following points:

   - Transfer of heat through conduction
   - Transfer of heat through convection
   - Transfer of heat through radiation

4. Your answer should include the following points:

   - Transfer of vapour from product surface to the air
   - Transfer of heat from air to the product surface

5. Your answer should include the following points:

   - By addition of thermal energy to the product
   - By transfer the heat to the product and water surface

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Transport cost less
   - Storage cost less
   - Shipping cost less

2. Your answer should include the following points:

   - Bette quality of finished product
   - Carry out through out the year
   - High yield of the product

3. Your answer should include the following points:

   - They can fit into any size
   - They can fit into any shape
   - They can fit into any forms
   - Low disposal and pollution

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Temperature and RH
   - Product size and surface area
   - Air velocity and dryness of the air

2. Your answer should include the following points:

   - To get heat in
   - To let out mass out

3. Your answer should include the following points:

   - Provides the driving force for moisture removal
   - Carry away the water driven in the form of water vapour

4. Your answer should include the following points:

   - Provide more surface in contact with heating medium
   - Provide moisture surface for moisture removal

5. Your answer should include the following points:
   - To reduces the travelling distance through which moisture is travel from the centre of the product.
   - To reduces the travel distance through which heat transfer from the surface to the centre.
6. Your answer should include the following points:
   - To facilitate mass transfer
   - To speedup drying rate
7. Your answer should include the following points:
   - To form fine cracks in the skin
   - To facilitate drying
8. Your answer should include the following points:
   - To inactivate enzyme
   - To reduce the drying time

Check Your Progress Exercise 4

1. Your answer should include the following points:
   - T constant rate the moisture same as critical moisture
   - At falling rate the moisture is below the critical moisture
2. Your answer should include the following points:
   - Drying means as drying the produce under the influence of conventional energy source like sun and wind, below a certain level of moisture, at which enzymes activity is nil.
   - Reconstitution ratio is expressed on a dry basis i.e. ratio of water content to dry mater.
3. Your answer should include the following points:
   - Optimum ratio of dried material and water/sugar solution
   - Time and temperature of the water/sugar solution
   - Shaking if necessary

Check Your Progress Exercise 5

1. Your answer should include the following points:
   - Water activity (a_w) is defined as the vapour on the aqueous solution to that of pure water at the same temperature.
2. Your answer should include the following points:
   - Uniform automatic feeding
   - Zone heat collection of dried product
   - Continuous operation
3. Your answer should include the following points:
   - High drying intensity
   - Uniform and closely controllable temperature
   - Operation and maintenance simple

4. Your answer should include the following points:
   - Regulating degree of vacuum intensity
   - Regulating heat input intensity

Check Your Progress Exercise 6

1. Your answer should include the following points:
   - Provide a barrier between food and environment
   - Control light transmission
   - Control transfer of heat and gas
   - Control the movement of microorganisms and insect.
2. Your answer should include the following points:
   - The optimum temperature 32°C
   - The optimum RH 55%.

14.16 SOME USEFUL BOOKS

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UNIT 15 FREEZING

Structure

15.0 OBJECTIVES

After reading this unit, you should be able to:

- basic principle of freezing preservation;
- importance of freezing;
- methods of freezing, packaging and storage; and
- maintaining quality in frozen foods.

15.1 INTRODUCTION

In the present chapter we will study about a technology that uses low temperature to preserve food products. You might have noticed that in majority of the preservation methods heat is often used to kill or inactivate microorganisms to extend the shelf life of foods. Subjecting the food materials to low temperature is yet another alternate method to preserve foods. Raw plant material is normally considered to unclean. This is because any raw plant or animal food may be assumed to contain a variety of bacteria, yeasts and moulds. These microorganisms constitute the surface microflora and they need optimum conditions to bring about undesirable changes in the food. Each microorganism present has an optimal, or best, temperature for growth and minimal temperature below, which it cannot multiply. As the temperature drops below this optimal temperature towards the minimal, the rate of growth of the organisms decreases and is slowest at the minimal temperature. The enzymatic reactions in foods also take place at optimum temperatures. If you lower the temperature the enzymatic reactions are also lowered and foods can be prevented from spoilage. This is the basic principle behind freezing preservation of foods.

Do you know what are basic principles of food preservation. I am sure you must have gone through them in other chapters. Let me refresh your memory. Basically there are three methods of preservation. Their main aim is to control the activities of microorganisms. In short you can also refer to them as 3K's. They are 1) Keep them away 2) Kill them 3) Keep them away from growing

The first K refers to use of asepsis methods to keep the microorganism away. The second K refers to killing pathogenic microorganisms to prevent spoilage. Finally the third K employs methods that create conditions which prevent or retard the growth of nonpathogenic type of microorganisms. The Freezing technology is based on the third principle of preservation. Low temperature retards the biochemical reactions occurring in foods and prevents biochemical reactions in food. Microorganisms also get inactivated at low temperature.

15.2 THE FREEZING POINT OF FOODS

Living cells contain much water, often two-thirds of more of their weight. In this medium there are organic and inorganic substances, including salts and sugars and acids in aqueous solutions, and more complex organic molecules, such as proteins which are colloidal suspension. Thus more the salt, sugar, minerals and proteins in a solution. The lower its freezing point (depression of freezing point) and the longer it will take to freeze when put in freezing chamber. If water and fruit juice for example are placed in a freezer, the water will freeze first. Further unless the temperature is considerably below freezing point of pure water, the juice will never freeze completely but rather will become icy and slushy. That is why most of the foods freeze at temperatures between 0-3°C. The temperature of the food undergoing freezing remains relatively constant until the food is mostly frozen, after which time the temperature approaches that of freezing medium. The freezing process is thus a process of lowering of the product temperature from its original value to the storage temperature. From each point, the heat must be removed by conduction to the surface of food. The surface heat is then removed to the refrigeration medium. The freezing time depends upon number of factors such as dimensions, shape of product, thermal properties, temperature of refrigerant medium.

Frozen foods have an excellent safety records and freezing has never been reported to be cause of food poisoning. The great advantage is that microorganisms do not grow in foods when the temperature is –10°C or colder. Foods preserved by means of other preservation methods (chilling, drying, canning) have been more or less directly involved in food safety problems because these foods are stored at temperatures that allow microbial growth.

Freezing has long been established as an excellent method of preserving high quality in food products. Generally freezing preserves taste, texture and nutritional value of foods better than any other preservation method. When done, properly it is the most satisfactory method of preserving many fruits and vegetables. More over the original flavour, colour, texture, and nutritive value is usually retained during freezing in comparison to other methods of freezing. Freezing, however does not, add anything to the original qualities of fresh fruits and vegetables. Therefore, for the highest quality frozen foods, they must be of highest quality in their fresh state, and well-tested ways of preparing them for freezing must be carefully followed. Frozen foods are considered as healthy. Recently, U.S. Food and Drug Administration's (FDA) petition on March 25, 1998 approved an American frozen food industry petition to allow frozen produce to be labelled as "healthy," The nutrient profiles of selected raw fruits and vegetables and frozen, of the same fruits and vegetables revealed relatively equivalent nutrient profiles. In fact, some data showed that the nutrient content level for certain nutrients was higher in the frozen version of the food than in the raw version of the food. In fact most fruits and vegetables during transportation or during retail storage undergo severe depletion of nutrients and essential vitamins. These losses can be prevented if they are frozen soon after they are harvested.

Before actually we see freezing let us understand the meaning of some terms which are often used while describing aspects of low temperature storage and are often are loosely defined. The common terms are Cool Storage, Refrigeration and Freezing. Let us see what is the difference between each other.

Difference between cool storage, refrigeration and freezing

	Cool storage	**Refrigeration**	**Freezing**	**Freezer storage**
Temperature	16 to –2°C	4.5-7°C	-2°C to lower	–18°C
Microorganism	Spoilage microorganisms can grow rapidly at temp. >10°C. Some grow below 0°C if water is unfrozen.	Pathogenic microorganisms grow slowly. Psychotrophic microorganisms grew.	No significant growth of spoilage or pathogenic microorganism. However, multiplication of microorganisms can take place if food is thawed.	

Frozen foods offer various advantages and disadvantages. Let us now see what are they.

15.3 ADVANTAGES OF FROZEN FRUITS AND VEGETABLES

1. The fresh vegetables and fruits closely resemble their frozen counterparts in freshness, since the metabolic activities are arrested to such an extent that all the enzymes are inactivated and microorganisms are under control.

2. The taste, flavour and colour of fruits and vegetables are preserved to a maximum.
3. They have high nutritive value since the retention of nutrients is maximum.
4. Since frozen vegetables have already been subjected to a heat treatment they require less time for cooking thus saves considerable time in kitchen and also saves fuel.
5. Greater convenience in handling and preparation.
6. Freezing is a suitable choice for preserving fruit juices containing anthocyanin and carotenoid pigments since the retention of pigments is maximum.
7. They offer more hygienic food
8. Cent percent edible portion of food of food in each package
9. Since the degradative effect of heat treatment is bypassed in this, the method of freezing can retain the pigment of such fruit juices and concentrates in its best form
10. Freezing can also serve as an intermittent technology for preserving commodities in bulk and supplying in a different form when demand arises eg peas can be frozen in bulk quantities and during demand defrosted put in a brine solution packed in flexible pouches and circulated in market whenever required.
11. Value for money especially off-season
12. No pollution problem in consuming areas
13. The waste collected during freezing can be utilized for production of value added products.

Limitations

1. Some water soluble nutrients may be lost during freezing as the process involves blanching in boiling water.
2. Users of quick frozen foods need to invest on freezers to maintain the quality of the product till used. This adds to the cost of the product.
3. Proper freezing transport facilities have to be developed for each product.
4. Quick freezing can be handled at the industrial level because it involves specialized freezing equipment, technological know-how, strict quality control which would not be feasible on a small scale.
5. Sales markets have to be established in all markets with refrigerated display cabinets.

15.4 QUICK AND SLOW FREEZING

During freezing process the product temperature is lowered and most water is transferred into ice crystals. With decreasing temperature the liquid phase becomes more and more concentrated. As the volume of ice is about 10% larger than volume of water, internal pressure of food may rise to 10 bar or more. This pressure is sufficiently high to cause undesirable textural changes in foods but not as high as necessary to inactivate microorganisms. The size of ice crystal may vary with method of freezing i.e. quick freezing or slow freezing. Quick freezing is defined as the process where the temperature of the food passes through the zone of ice crystal formation in 10 minutes or less. The process removes quick removal of water and small ice crystals are formed in it. Whereas slow freezing involves slow removal of water and process may take 3-72 hours. This also involves ice crystal formation which have more damaging effect on the texture. The advantages of quick freezing over slow freezing are that 1) smaller ice crystal are formed hence there is less mechanical destruction of intact cells of the food; 2) there is shorter period of solidfication and therefore less time for diffusion of soluble materials and for separation of ice; 3) there is more prompt prevention of microbial growth; 4) there is more rapid slowing down of enzyme action. Quick frozen foods therefore are supposed to thaw to a condition more like that of the original food than slow-frozen foods.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Freezing is considered best method of preservation why?

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2. Frozen foods are healthy. Substantiate the statement.

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3. What is the difference between refrigerated storage and frozen storage?

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4. Which will freeze first at 0°C water or juice and why?

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5. What is slow and quick freezing?

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6. Point out main differences between quick and slow freezing.

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15.5 PRE-TREATMENTS PRIOR TO FREEZING

Fruit and vegetable pieces which need to be frozen must preserve their natural colour, flavour and texture and be free from antioxidants or other additives. This is especially required for high moisture product ingredients such as fruit salads or ice-creams. Apart from maintaining sensory properties they should also retain nutritive properties. Chemical and physical action of freezing are highly detrimental to fruit and vegetables, since their texture is mainly ensured by turgor pressure or turgescence (the ability to retain water inside the cells). Rupture of cell wall due to growth of ice crystals and/or enzymatic action during freezing causes loss of shape and prevents its return to the initial state. Loss of shape causes increased drip loss during thawing and a less defined texture. Water is an important molecule involved in deterioration reaction, during freezing and freezing storage. Water within food, migrates towards cold outer surface and then evaporates re-crystallizing as ice. Food surface becomes dry and colour fades. Water may also participate directly in deterioration reactions which involve changes in colour due to enzymatic or non-enzymatic reaction on pigments and production of off-flavour. To minimize such changes in food products, it is important to use certain pre-freeze treatments prior to freezing. These treatments reduce detrimental changes by inactivating the deterioration reactions and by reducing the water content in the material. Common pre-treatments used prior to freezing include washing, blanching, soaking and packaging. Let us now study these pre-treatments one by one.

15.5.1 Blanching

Blanching is a common heat pre-treatment commonly used for most vegetables that are to be frozen and ultimately cooked before use. The aim of blanching is to inactivate enzymes responsible for deterioration in food. Inactivation is achieved by denaturing the proteins that would otherwise take part in reactions leading to deterioration. However, there are also certain disadvantages of blanching:

1. Cellular tissues are affected by high temperature.

2. Loss of texture and an increased risk of microbial contamination due to removal of foods natural microbial flora.

This can however be overcome by using improved blanching treatments employing high temperature short time (HTST) exposure rather than low temperature long time (LTLT).

Lets us now see what are different blanching methods:

1. Immersion
2. Steaming

Immersion

Immersion blanching refers to blanching by directly immersing the food particles in boiling water. This treatment has number of advantages and disadvantages. Sometimes certain additives may be used in blanching water to complement blanching. For instances, addition of citric acid (0.5%) to immersion bath decreases pH. Addition of bisulfite (0.5%) prevents mushroom browning and yellowing of cauliflower. Blanching is quickly followed by a cooling stage. This is done by cooling the product under cool water to bring down its temperature. Rapid cooling avoids microbial growth on the exposed surfaces.

Steaming

Blanching by steaming has the advantage of minimizing the leaching out of soluble materials. However, at the same operating temperature, steam blanching takes 20-40% longer than immersion blanching because of poor thermal exchange.

15.5.2 Dehydro-Freezing

Sometimes depending upon the type of food, and its final use of product, some moisture is removed from the food. This is partial dehydration. Partial dehydration is generally achieved by air drying. The process is also called dehydro-freezing i.e. dehydration prior to freezing. It offers many advantages over conventional freezing:

1. Saves energy
2. Better quality and stability

For partial air drying, selection of food ingredient is very important. The food ingredient selected should be of high water activity (aw > 0.98), since water removal is limited to 50-60% of the original content. To avoid browning, blanching or other treatments such as dipping in antioxidant solution (ascorbic or citric acid, sulphur dioxide) can be used. The air dehydration step usually produces a weight loss up to 50%.

Apple, pear, peach and strawberry are commonly dried by air drying. Partial water removal from the food leads to the concentration of cytoplasmic components within the cells, and to the depression of the freezing point. However, there are certain disadvantages associated with such drying:

1. Free flow of the product is hindered due to particle agglomeration
2. Colour is affected.

For example, kiwi and strawberry fruits are susceptible to heat modifications. For such fruits, air drying must be replaced by osmotic dehydration, which is more effective even at room temperature and which operates away from oxygen.

15.5.3 Osmotic Dehydration

Conventional air-drying can be substituted by or combined with osmotic dehydration as a pre-freezer treatment. The process involves placing the solid food (whole or in pieces) into solutions of high sugar or salt concentration. Usually sucrose, corn starch syrup have been used as osmotic solutions. The principle behind osmotic dehydration is the same as that of osmosis. Placing the food pieces in high osmotic solution leads to ex-osmosis and concentration of the cytoplasmic content.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why are pre-freeze treatments required prior to freezing?

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2. What is blanching? Why it is necessary to blanch fruits and vegetables.

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3. What are advantages of osmotic dehydration over air-drying as pre-treatment prior to freezing?

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15.6 FREEZING TECHNOLOGY

After pre-treatments the material is subjected to the freezing step. Fruits and vegetables (F&V) can be frozen by various methods.

15.6.1 Air or Still Freezing

Air freezing is the oldest of the freezing methods. The equipment is the simplest. The food is simply placed in an insulated cold room at a temperature maintained in the range of –23°C to 30°C. This method is different from the air-blast freezing, which employs air velocities. Although there is some air movement by natural convection, in some cases gentle air movement is promoted by placing circulating fans in the room. This method is also referred as *still air freezing* or *sharp freezing*. It is similar to the freezing conditions that exist in home freezers except that temperatures are low i.e. –18 to –30°C.

15.6.2 Air-Blast Freezing

These freezers operate at temperatures of –30 to –45°C, with forced air velocities of 10-15 m/sec. Food is frozen as batch to tunnels through which carts or belts may be moved continuously. Particulate unpackaged foods, such as loose vegetables are fed onto the moving belt when speed is adjustable according to the required freezing time. In other designs, food moves on trays, in a vertical direction. Trays of particulate products such as peas or beans automatically move upward through a cold air blast.

Today, along with foods frozen as a single block in package, vegetables and other particulate items are frozen individually. This technology is called individually quick frozen or IQF. The freezing process allows the formation of small crystals of ice inside the cell of the product, in order to avoid cellular damage. Therefore when the product unfreezes, there is no spill out of the cellular fluids, warranting the nutritive value, texture and flavour of the product. The particulate items are frozen individually, so they can be poured from a bag for greater convenience. Since, there is some tendency for such particulates to stick together during freezing, product is mechanically dislodged from trays and passed through a beaker device to disaggregate to large clusters. Its major advantage is that you need not unfreeze all the product, only the required quantity be taken out and thawed. Did you know that Safal peas marketed by NDDB are IQF.

The air flow is normally counter-current air flow to bring the coldest air into contact with the already frozen product, and there is no tendency for product to rise in temperature and partially thaw through the freezing process. Normally, in concurrent system, coldest air enters the unfrozen products and tends to rise in temperature through the tunnel as product gives up heat and freezes. Whenever unwrapped food is placed in a cold zone, there is tendency for the food to lose moisture, after the food is frozen.

In freezer, this can have two consequences: 1) Frosting over of refrigerated coils or plates, necessitating frequent defrosting to maintain heat exchanger efficiency, and 2) Drying out of food at surface resulting in defect called **freeze burn**. The food shows brownish colouration at surface and nutrient losses are high. Rates of freeze burn is high in accelerated blast freezers where air is moving at high velocity. To minimize freeze burns, 2 techniques are employed:

1. Pre-chilling food with air of high RH at about –4°C. Because of high humidity, there is a minimum moisture loss. The food then moves into second colder zone when it is quickly frozen. This rapid finish-freezing provides minimum time for the already cold product to lose more moisture, which also decreases the defrosting requirement on freezer coils.
2. Second technique is to wet the unpackaged food pieces in pre-chilling zone so to freeze a thin ice glaze around each food piece.

15.6.3 Fluidized Bed Freezing

In various air-type freezers, cold air is blown up through a wire mesh belt that supports and conveys the product. This imparts a slight vibratory motion to food particles, which accelerates freezing rate. When the air velocity is increased to the point where it exceeds the velocity of free-fall of the particle, fluidization occurs; this is called *fluidized-bed freezing*. This motion not only subdivides the product and provides intimate contacts of each particle with cold air, but keeps clusters from freezing together.

15.6.4 Continuous Type Fluidized-Bed Freezer

Particulate foods are fed by a shaker onto a porous trough. The food is pre-chilled and high velocity refrigerated air fluidizes the product, freezes it and moves it in continuous flow for collection and packaging.

An interesting feature of this unit is continuous and automatic defrosting. Air is blown via fan through cooling coils and up through the porous food trough. Cold air tends to condense its moisture onto cooling coils. A spray of propylene glycol antifreeze is maintained over cooling coils to melt ice as it would be formed. In this way, cooling coils are maintained at maximum operating efficiency.

15.6.5 Indirect Contact Freezing

Indirect contact freezing is based on the principle of placing the food on plates, trays, belts or cold walls so that it is in indirect contact with the cold wall. The food, usually as flat packages, is placed between shelves and there is provision after loading for applying pressure to squeeze the shelves into more intimate contact with the top and bottom of the packages for faster freezing. All is enclosed within an insulated cabinet. The efficiency of freezing depends on the extent of contact between the plates and the food. For this reason, packages should be well filled or slightly over-filled to make good pressure contact with the plates.

15.6.6 Immersion Freezing

Immersing the food directly in a refrigerant other than cold air is called immersion-freezing. It has the following advantages:

1. There is intimate contact between the food or package and the refrigerant, therefore, resistance to heat transfer is minimized.
2. Although loose food pieces can be frozen individually by immersion freezing and air freezing, immersion freezing minimizes their contact with air during freezing, which can be desirable for foods sensitive to oxidation.

For direct immersion freezing, the refrigerant used must have the following properties:

1. It should be Non-toxic.
2. It should be Clean.
3. Free from frozen tastes, odour/bleaching agents.

There are two types of refrigerants for immersion freezing:

1. Low-freezing point liquids: They are chilled by indirect contact with another refrigerant e.g., solutions of sugars, sodium chloride and glycerol.
2. Cryogenic liquids such as compressed liquefied nitrogen, which owe their cooling effects to their own evaporation.

15.6.7 Immersion Chilling and Freezing (ICF) in a Concentrated Aqueous Solution

A third technique ICF is quite similar to osmotic dehydration, in that both involve direct contact between food pieces and a concentrated solution. However, ICF is carried at low temperature ranging from –20°C to 0°C, whereas in case of osmotic dehydration, the temperatures range from +30°C to 80°C. The characteristics of the dissolved solutes determine the extent in temperature to which the solution remains in the liquid state.

Advantages

1. Rapid heat transfer.
2. Individualized freezing.
3. Lower operating and investment costs.

Because of low operating temperatures, and the freezing process occurring inside the food during ICF, mass transfer rates are much lower than in osmotic dehydration ranging from 1 to 7% water loss and 0.5 to 1% solute gain.

However, in spite of its potentialities, ICF process has been developed little on an industrial scale, because of an inadequate control of mass transfer (water and solutes) between the product and the refrigerating solution. The freezing time depends upon (1) Dimension and shape of product, (2) thermal properties, (3) initial and final temperature, and (4) temperature of the refrigeration medium.

15.6.8 Immersion Freezing with Cryogenic Liquids

Cryogenic liquids are liquefied gases of extremely low boiling point such as liquid nitrogen and liquid carbon dioxide, with boiling point of –196°C and

–79°C respectively. Although liquid nitrogen is capable of freezing food down to –196°C, this is virtually never done, because it entails unnecessary cost and could even be damaging to some foods. The food is seldom frozen to a temperature below –45°C and quality results largely from the speed at which the temperature is reached. In most of the cases of fruits, vegetables, meat and fish items, it may take 1-3 minutes. Major advantages of liquid nitrogen freezing are as follows:

1. It undergoes slow boiling at –196°C, this provides great driving force for heat transfer.

2. Liquid nitrogen, like other immersion fluids, intimately contacts all portions of irregularly shaped foods, thus, minimizing resistance to heat transfer.

3. No primary refrigerant is required to cool this medium, since low temperature results from the evaporation of liquid nitrogen.

4. Liquid nitrogen is non-toxic and that to food constituents. Moreover, it can displace air from food and thus minimize oxidative changes during freezing and through packaged storage.

High quality frozen foods are produced because of high speed of liquid-nitrogen freezing. High cost of liquid nitrogen remains to be its major limitation. Liquid nitrogen is manufactured by comprising air and simultaneously removing the heat of compression. The cooled compressed air is then allowed to expand through specially designed valves. This expansion causes further chilling.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List some factors affecting the rate of freezing.

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2. List some important commercial freezing methods.

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3. What is cryogenic freezing? Why is the quality produced by cryogenic freezing the best?

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4. What is the difference between still air sharp freezing and air-blast freezing?

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5. What is IQF? What are its major advantages?

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6. What is freeze burn? Which food items are highly susceptible to freeze burn? How can you minimize this effect?

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15.7 PACKAGING AND STORAGE

A wide variety of materials have been used for packaging of frozen foods including plastics, metals and paperboards. Polyethylene (PE), low density Polyethylene(LDPE) and High density Polyethylene (HDPE) are commonly used for packaging of IQF foods i.e. fruits, vegetables and fish. Materials are easy to seal and can be easily printed. LDPE is also easily available and cheap. HDPE can tolerate temperature in excess to 100°C. Both HDPE and LDPE however provide relatively poor barrier protection from oxygen. Polyester tetraphthalate (PET) is another common material used. The trays of the material are suitable for reheating in conventional and microwave oven with stability at temperature in excess of 250°C. However the materials are expensive and can become brittle at freezer temperature. Polystrene (PS) is also general plastic material used for frozen food applications. Commercial storage of frozen storage of frozen products is usually done in deep freezers at –18 to –20°C.

15.8 QUALITY AND PHYSICAL CHANGES IN FROZEN FOODS

When the food is frozen it undergoes number of quality and physical changes. Lets us see what they are.

15.8.1 Concentration Effects

We have already seen that during freezing concentration of solutes take place. Damage due to concentration results in

1. Gritty, sandy texture of food due to precipitation of solutes out of solution.
2. Salting out at proteins effect due to solutes remaining in concentrated solution.
3. Drop in pH drop causing proteins to coagulate.
4. Gases in solution are also concentrated. This can cause super-saturation of gases and ultimately force them out of solution. Frozen beer or soda pop may have such a defect.

15.8.2 Ice Formation: Nucleation and Crystallization

The freezing process includes 2 main stages first is the formation of ice crystals which is termed as nucleation and subsequently crystallization or increase in crystal size. Nucleation is nothing but combining of molecules into an ordered particle of sufficient size to serve as a site for further crystal growth. It is important for freezing to initiate. When the temperature falls below 0°C, viscosity increases and nucleation stops. Now crystals start growing. Before we understand how ice-crystals are formed, it is important to understand the type of fluids in the cells. There are 2 types of fluids viz., Extra-cellular fluid (EF) and Intracellular fluid (IF). The concentration of salts and other soluble products is higher within the cells than outside. The cell membrane acts as osmotic barrier and maintains the difference in concentration. When the product is frozen, the first ice-crystals are formed outside the cells, since the freezing point is higher. The cells lose water by diffusion through the membrane and the water will crystallize to ice on the surface of the crystals already formed in the extra-cellular space. As the cells lose water, the remaining solution within the cell becomes more concentrated and their volumes shrink causing the cell wall to collapse. The large ice-crystals formed outside the cell wall occupy a larger volume than the corresponding amount of water and therefore, will execute a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid (Drip loss). If the freezing rate is high, ice-crystals are formed outside the cells. Only at a very high freezing rates, small crystals are formed uniformly throughout the tissue, both externally and internally with regard to the cells.

15.8.3 Freeze Cracking

Generally, light freezing rates lead to small ice crystals and to better quality food systems. However, some products may crack when submitted to high freezing rates as in cryogenic fluids. This is particularly seen in mango slices frozen by liquid nitrogen. Pre-cooling prevents freeze cracking.

15.8.4 Moisture Loss

Moisture loss, or ice crystals evaporating from the surface area of a product, produces freezer burn. We have already discussed what freezer burn is. This surface freeze-dried area is very likely to develop off flavours. Packaging in heavyweight, moisture-proof packaging material will prevent freezer burn.

15.8.5 Drip Loss

Formation of ice crystals causes a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid. This is called drip loss.

15.8.6 Rancid Flavour

Another group of chemical changes that can take place in frozen products is the development of rancid oxidative flavours through contact of the frozen product with air. This problem can be controlled by using a wrapping material which does not permit air to pass into the product. It is also advisable to remove as much air as possible from the freezer bag or container to reduce the amount of air in contact with the product.

The winning strategy of frozen good industry is to continually improve quality.

Here is a list of some tips to produce quality frozen products:

1. High quality raw material containing high level of vitamins (especially water-soluble ones, like vitamin C) and minerals to ensure that after pretreatments such as blanching the nutritional value remains high. Colour, flavour and texture are yet other factors affecting quality. Peas is an good example of the cultivar affect and harvesting period on the quality of frozen product. Consumers and the frozen industry prefer sweet and tender varieties with small seeds which are completely different from what is required by the canning industry and the fresh market.

   When peas are ripening, their sweetness is due to the sugars (about 6%) and to the low starch content (1%). Immediately after harvesting there is a rapid reaction conversion of sugar into starch which can exceed 4%. This reaction determines a gradual reduction of sweetness, an increase infirmness and sensation in mealiness.

2. Interval between harvesting and freezing Fruits and vegetables undergo fast changes in chemical composition, sensory attributes and nutritional value. The product should be processed as quickly as possible e.g., peas and spinach have intense metabolism (high respiration rate after processing) which means severe decrease in quality if the time between harvesting and processing is too long. By using quick refrigeration, these negative phenomena can be stopped.

15.9 STORAGE AND TRANSPORTATION OF FROZEN PRODUCE

To preserve quality and safety in frozen foods, strict temperature requirements are must during storage, handling, distribution, retail display and consumer storage. It is recommended that food temperatures are maintained at –18°C or colder, although exceptions for brief periods are allowed during transportation or local distribution when –15°C is permitted. Also, retail display cabinets should be at –18°C, to an extent consistent with good storage practice, but not warmer than–12°C. The transport and distribution sections of the chill chain are particularly important to control in order to ensure both safety and quality. It is important to check temperature of foods at each point within the chill chain from storage and transportation.

15.10 FUTURE TRENDS IN FROZEN FOODS

Demand for frozen foods will grow

Growth of corporate cultures, dual incomes, western life styles and need for convenience are likely to lead to growth of this sector. Changing life styles are increasing both the consumption of convenient food products and eating out habits. In the food service sector and fast food chains, reliance on frozen food is greater because they offer the ability to control supply with variable demands. The frozen food consumption is bound to increase in India too. Consumers today view adoption of western life styles as index of progress. In near future, we should not therefore be surprised to see increased consumption of western style convenience foods as the amount of time available to women has been substantially decreasing. Certainly, we are already seeing the major food multi-functional giants, such as MAC Donalds', Pizza Hut, Dominos investing in these future markets.

Frozen foods will be more nutritious

The frozen food industry is in best position to deliver healthy products to the consumers. Careful selection of ingredients, superior genotypes, good formulation and processing and a well controlled frozen food chain have the ability to deliver products much closer to their original nutritional content than can possibly be achieved through the chilled chain wherever rapid deterioration is inevitable.

Anti-freeze proteins

An area of research that has caused great excitement in the scientific community and increasingly in the frozen food industry is the field of antifreeze proteins (AFP). These proteins were first discovered in Antarctic and Arctic fish species. The freezing point of sea water is –2°C. The freezing point of fish serum is –1°C. These proteins allow fish to survive below their melting point without freezing. AFP's have been extracted and identified in grasses such as polar fish, winter rye, in carrots and in a number of insects. These proteins can affect freezing by lowering freezing temperature and retarding recrystallization. Claims for AFP have been made from many food plant materials including carrots and brussel sprouts. Such discoveries have begun to show a possible future for AFP in food industry. We can see the potential of transforming plants (transgenic which can express AFP and therefore expected to have a greater resistance to re-crystallization damage during distribution with the resultant effect of increased textural quality and retention of nutrients on thawing.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are anti-freeze proteins?

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2. What type of packaging material is most suitable for freezing vegetables?

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15.11 LET US SUM UP

Among processing methods freezing is the best method as it results in quality product with high retention of nutrients. Quality of frozen foods can be constantly improved and maintained by selecting the right kind of fruit or vegetable, its right cultivar, pre-freezing treatment and technology. Storage at low temperature is important to maintain quality.

15.12 KEY WORDS

Freezing point	:	Temperature at which the liquid congeals into the solid state at a given pressure and temperature.
Refrigerated storage	:	Refers to storage temperatures above freezing point of water i.e. about 16 to –2°C.
Quick freezing	:	Quick freezing is defined as the process where the temperature of the food passes through the zone of ice crystal formation in 10 minutes or less. The process removes quick removal of water and small ice crystals are formed in the process.
Slow freezing	:	Slow freezing involves slow removal of water and process may take 3-72 hours.
Fluidized bed freezing	:	A method of freezing used for particulate items such as peas, diced carrots, corn and berries. The freezer employs a bed with a perforated bottom through which refrigerated air is blown vertically upwards.
Blanching	:	Blanching is a common heat pre-treatment commonly used before processing most vegetables. The main aim is to inactivate enzymes responsible for deterioration in food.
Sublimation	:	The change of state from ice to water vapour or water vapour to ice. Unpackaged frozen material changes to gaseous form e.g. dry ice(frozen carbon dioxide)when exposed to extreme cold air.
Dehydro freezing	:	Is pre-treatment given prior to freezing, involving partial removal of water
Individual quick freezing	:	Is the latest advanced technology for freezing particulate vegetable items. The product is frozen individually and helps in
Freeze burn	:	It refers to a defect which develops during frozen storage. Moisture loss due to sublimation from surface leads to discolouration in form of patches of light coloured tissues. This can be controlled by humidification or lowering of storage temperature or better packaging.
Antifreeze	:	Chemical substances that added to a liquid to lower its freezing point. These chemicals prevent freezing and are commonly used in coolants for aeroplanes and automobiles.

15.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   Freezing is considered best method of preservation because,

   - It preserves colour, taste, texture and nutritional value of foods better than any other preservation method.
   - Frozen foods have an excellent safety record and freezing has never been reported to be cause of food poisoning.

2. Your answer should include the following points:

   Have nutrient profiles higher or equal to raw food, e.g., freshly harvested fruit and vegetables may loose considerable amount of nutrients during transportation and retail outlet, but freshly harvested frozen foods retain most of nutrients

3. Your answer should include the following points:

   Refrigerated storage refers to storage temperature above freezing. Generally the temperature is maintained at 16 to -2°C. Commercial and household refrigerators operate at 4.5 to 7°C. Frozen storage however refers to storage temperature below –18°C.

4. Your answer should include the following points:

   At 0°C, water will freeze first than fruit juice because water is a pure fluid, whereas, juice has many dissolved organic or inorganic substances including salts, sugar and acids in the aqueous solution. Apart from this there are also proteins and colloidal suspensions. They cause a depression of freezing point, thus, to freeze juice, lower than 0°C temperature is employed.

5. Your answer should include the following points:

   Quick freezing: It is defined as the process where the food passes through the zone of maximum ice crystal formation in 10 minutes or less, whereas, in slow freezing the process may take 3-72 hrs depending upon the commodity.

6. Your answer should include the following points:

   Main differences between quick and slow freezing are:

Quick freezing	**Slow freezing**
The process involves quick removal of water, may take 10 min.	The process involves slow removal of water, may take 3-72 hrs.
Small ice-crystals are formed which maintain the textural integrity of cell.	Large ice-crystals are formed which seriously affect the cell texture.
Prompt prevention of microbial growth.	Slow prevention of microbial growth.
After thawing the food resembles like that of original food.	After thawing the food is soft and mushy.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   Pre-freeze treatments prior to freezing is mainly given to reduce the water content of cells which thereby

   - Prevents rupture of cells and maintains cell texture
   - Avoids increased drip loss
   - Also avoids changes in colour of food due to enzymatic and non-enzymatic reactions.

2. Your answer should include the following points

   Blanching: It is a common heat pre-treatment used prior to processing (drying, freezing and dehydration). It is necessary to blanch fruits and vegetables prior to freezing in order to inactivate enzymes responsible for deterioration in quality of frozen foods.

3. Your answer should include the following points:

   Advantages of osmotic dehydration over air drying:

   1. Retains better colour.
   2. Prevents particle agglomeration.
   3. Prevents oxidation.
   4. Effective at room temperature.

   Highly suited for fruits such as kiwi and strawberry which are susceptible to heat modification.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   Some factors affecting rate of freezing are:

   - Shape of the product.
   - Kind of the product.
   - Thermal properties of the product.
   - Temperature of the refrigerant medium.

2. Your answer should include the following points:

   Some important commercial freezing methods are:

   1. Air or still freezing.
   2. Air blast freezing.
   3. Fluidized bed freezing.
   4. Continuous type fluidized bed freezer.
   5. Immersion freezing.
   6. Immersion freezing with cryogenic liquid IQF (individual quick freezing is being used for freezing peas.

3. Your answer should include the following points:

   Cryogenic freezing is a freezing process involving liquid nitrogen (−196°C) as the refrigerant medium, is termed as cryogenic freezing. The quality of the food frozen by liquid nitrogen is best because:

   1. Food is quick frozen and takes 1-3 minutes.
   2. It is non-toxic to food constituents and can displace air from food, thus, minimizing oxidative changes during freezing.

4. Your answer should include the following points:

   Difference between still air freezing and air blast freezing:

Still air freezing	**Air blast freezing**
Temperature is maintained at −23 to −30°C.	Temperature is maintained at −30 to −45°C.
Air movement by natural convection.	Air movement with forced air velocity of 10-15 sec.

5. Your answer should include the following points:

   IQF is individual quick freezing. It is the latest technology for freezing particulate food items.

   Advantages:

   1. The particulate items are frozen individually.
   2. Small ice-crystals are formed. Thus, when the product unfreezes, there is no spill out.
   3. High nutritive retention and sensory quality.
   4. Allow greater convenience because only required quantity can be separated from the large cluster and thawed.

6. Your answer should include the following points:

   Drying and discolouration of the food at surface is termed as freeze burn. The food shows brownish discoloration at surface and nutrient losses subsequent to thawing. Frozen fish is most susceptible to freeze burn. The defect can be minimized by

   1. Pre-chilling the food with air of high RH at about −4°C.
   2. Wet the unpackaged food pieces in pre-chilling zone so as to freeze a thin ice glaze around each piece.

Check Your Progress Exercise 4

1. Your answer should include the following points:

   Antifreeze proteins are proteins that when added to a liquid to lower its freezing point. These proteins have been identified and isolated from many cold-tolerant insects and plants. These proteins are of great importance in improving the quality of frozen products.

2. Your answer should include the following points:

   A wide variety of materials have been used for packaging of frozen foods including plastics, metals and paperboards. Polyethylene (PE), low density Polyethylene (LDPE) and High density Polyethylene (HDPE) are commonly used for packaging of frozen foods.

15.14 SOME USEFUL BOOKS

1. Kennedy, Christopher J. (2000) Managing Frozen Foods. Woodhead Publishers in Food Science and Technology, CRC Press.
2. Potter, Norman N. (2000) Food Science. CBS Publishers.
3. Pulle, Mervyn (2003) Food processing insights into Food manufacturing. Food Technology series Part 4, KBS Publishers.
4. Smith, J. Scott (2004) Food Processing Principles and Applications, Blackwell Publishers.

UNIT 16 CHEMICAL ADDITIVES

Structure

16.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the meaning of a food additive;
- understand the role of additives in food preservation;
- discuss the different permitted preservatives in food industry and their concentrations;
- discuss the various applications of food additives; and
- know the simple low cost, low energy intensive preservation technologies.

16.1 INTRODUCTION

Fruits and vegetables are a major source of important vitamins and minerals. Owing to its vast agro-climatic conditions, India produces almost all types of fruits and vegetables. Being highly perishable, fruits and vegetables have to be preserved and processed for later use. India processes 1.8 per cent of the total fruit and vegetable produce. Chemical preservation of perishable commodities by various food additives forms a major part of the preservation industry which is used in conjunction with other forms of preservation like canning, freezing, dehydration etc.

Food additives as chemical preservatives have been used for centuries to extend shelf life of the variety of food products. Smoke, alcohol, vinegar, oils and spices were used more than 10,000 years ago to preserve foods. They have been used since man first learned to preserve food products from one harvest season to the next to preserve and conserve the food and its nutritional value. The use of salt and smoke for preservation dates back to thousands of years. The Egyptians used colours and flavourings to enhance the appeal of certain foods, while the Romans used saltpeter, spices and colours for preservation and quality improvement. In the past 40 years, developments in food science and technology as well as changes in consumer demand have led to a substantial increase in the use of food additives. This has given consumers a variety of foodstuffs of high and uniform quality at reasonable prices. They play a vital role in today's bountiful and nutritious food supply.

Social changes in this century have caused a rapid evolution of the food supply throughout the world. While a shrinking percentage of the population is engaged in primary food production, we demand more variety than ever before in the food we eat. With a growing percentage of both two-wage and single-parent families, the demand for convenience foods has never been greater. Meeting consumer demands for variety taste and convenience with food products that are at the same time wholesome, safe and affordable, can be achieved using modern food processing technologies including a variety of food additives proven useful and safe through long use and rigorous testing.

16.2 DEFINITION OF CHEMICAL ADDITIVES (FOOD ADDITIVES)

Additive means any substance which is not a normal constituent of the food material and is purposeful addition which is aimed for technological, organoleptic and nutritional reasons. According to the WHO, a food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants. Food additives have also been defined by the National Academy of Sciences as those chemicals that may be incorporated in foodstuffs, either directly or indirectly during growing, storage or processing of foods.

The Prevention of Food Adulteration Act (PFA) specifies any substance as additive which is not normally consumed as a food itself but used as a typical ingredient of food whether or not it has nutritive value, the intentional addition of which to food for technological reasons including organoleptic purpose during manufacturing, processing, preparation, treatment, packaging, transport or holding of such food results or may be reasonably expected to result in it or its by-products. PFA rules therefore encompass all food and food products in the country and aim at ensuring the consumers get food and food products of satisfactory composition by laying down mandatory quality standards.

16.3 FUNCTIONS OF FOOD ADDITIVES

- To enhance the consumer acceptability.
- To help in maintaining or improving the nutritional quality.
- They should be non-toxic, non-allergic, safe and effective.
- To enhance stability or keeping quality by acting as antimicrobial agents with the resulting reduction in waste and prevention of chemical and biological deterioration.
- To make food more attractive and provide sufficient aids in the food products for improving texture, colour and flavour.

- To check spoilage by inactivating microorganisms and maintain safety of foods.
- To facilitate preparation.
- To improve palatability of the product.

16.4 PERMITTED FOOD ADDITIVES AS PRESERVATIVES

Preservatives are substances when added to food to retard, inhibit or arrest the activity of microorganisms such as fermentation, acidification and decomposition.

16.4.1 Classes of Preservatives

CLASS I

Common salt, sugar, dextrose, spices, vinegar or acetic acid, honey. They are mainly natural products which are used comparatively in higher concentrations than class II preservatives.

CLASS II

They are generally synthetic chemicals used in small quantities. Benzoic acid and its salts, sulphur dioxide and the salts of sulphurous acid, nitrites and nitrates, sorbic acid and its salts, propionic acid and its salts, lactic acid and its salts are used. Potassium metabisulphite is generally used in non-coloured products whereas in coloured products containing anthocyanin pigment, sodium benzoate is used.

16.4.2 Legitimate Uses in Food Processing

Food additives have a legitimate use in the food processing and distribution systems in promoting the utilization of available foods. The use of food additives may be technologically justified when it serves the following purposes:

1. The maintenance of the nutritional quality of a food.
2. The enhancement of keeping quality or stability with resulting reduction in food losses.
3. Making foods attractive to the consumer in a manner which does not lead to deception.
4. Providing essential aids in food processing.

Safety in using an additive is an all important consideration. While it is impossible to establish absolute proof of the non-toxicity of a specified use of an additive for all human beings under all conditions, critically designed animal tests of the physiological, pharmacological and biochemical behaviour of a proposed additive ca provide a reasonable basis for evaluating the safety of use of a food additive at a specified level of intake.

The Food and Drug Administration of the Department of Health, Education and Welfare administers the Federal Food, Drug and Cosmetic Act, in the United States. The federal Food, Drug and Cosmetic Act controls the addition of all additives to food. Chemicals may be incorporated legally in the fabrication of many foods, and many chemicals indeed serve to improve the quality of many foods.

16.5 TYPES OF FOOD ADDITIVES

Of the variety of ways food additive have been classified, most involve functional groupings. Chemical groupings are convenient since they place molecules of similar structure and physical-chemical properties in comparable categories. Toxicological and metabolic studies also may be correlated with chemical groupings. However, compounds of a single chemical family perform different functions in the food industry. Moreover, since chemical structure does impart physical-chemical characteristics, many function classes follow responsible chemical lines; i.e., the enzymes are major classes in either system. The consumer viewpoint is less restricted than is the legal, governmental or scientific; without knowing hows or whys, he wants an attractive product which provides assurance of health. A functional classification is given to place in perspective the specific types. The classification presented in detail below is comparable to, but provides an overall view less well than, this simplified system of user.

16.5.1 Intentional Food Additives

- Nutritive
- Freshness maintenance
- Sensory
- Processing aids

16.5.2 Incidental Food Additives

Many of the 2-3000 chemicals added to food occur in nature. They may be isolated from rich source material and used at will. Some, i.e., enzymes, will never be commercially available from synthetic sources. However, it is more efficient to make most of them in the laboratory. Thus, although some more efficient to make most of them in the laboratory. Thus although some are isolated in relatively pure form from natural sources, most are man made.

Table 16.1: Range of concentration of chemical preservatives permitted in various processed foods are given below:

Preservative	Concentration (ppm)	Food
Sulphur dioxide or salts of sulphurous acid	49-3000	Squashes, fruit pulp, crushes, jams, syrups, beer, pickles, beverages etc.
Propionic acid and its salts	5000	Bread
Benzoic acid and its salts	50-600	Syrups, squashes, jams, jellies, RTS beverages, pickles, chutneys
Sorbic acid	200-3000	Beverages, cakes and icings, cheese, cider, dried fruits, salad dressings, wine, margarine
Nisin	1000	Cheese
Nitrites	200	Cooked pickled meat
Nitrates	500	Cooked pickled meat

Table 16.2: Uses of various food additives

Additive	Use
Preservatives	• Sorbates are used as mould and yeast inhibitor in processed cheese and spreads, salad dressings, dried fruits, yogurt, fermented milks, soft drinks, soup concentrates, wine, cider and cakes. • Propionates are used as mould and rope inhibitors in bread, baked goods and dairy products. • Benzoates are used in beverages, fruit juice, pickles, jams, beer, dessert sauces, marinated fish, coffee essence. • Parabens are used in low acid foods ($pH > 5.0$) e.g. meat products, fruit juices, pickles, jams, beer, dessert sauces, marinated fish, coffee essence. • Sulfur dioxide and sulfite salts are used in dried fruits, soft drinks, purees, fruit juices, fermentation industry, dessicated coconut, tinned crabmeat, powdered garlic, frozen mushrooms, sausage meat.
Antioxidants	Wine, beer, cider, fruit juices, dried fruits, milk.
Colouring Agents	Confectionery, cake and drinks industries and in dairy sector.
Flavours	Soft drinks, sugar, confectionary, ice cream, soups and jams, biscuit and cake industry.
Texture modifiers	Margarine, salad cream, chocolate, processed milk, ice-cream, jelly and sauces.
Sweeteners	Confectionery, bakery products, soft drinks, jam, jellies, and ice-cream.
Antifoaming agents	Bakery products, meat products, confections, dairy products, beverages, jams and jellies.
Firming agents	Canned vegetables, canned apples, frozen apples and cheese.
Acidulants	Baked goods, beverages, confections and gelatin desserts, dairy products, fruit and vegetable processing and processed meats.
Nitrite	Various meats and cheeses.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How are food additives important in our lives? List a few of them.

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2. Differentiate between Class I and Class II preservatives.

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3. Define the food additives.

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16.6 NUTRITIONAL ADDITIVES

The term nutritional additives can be used to mean the addition of vitamins, minerals, amino acids, fatty acids, as well as other pure chemical compounds to food in order to improve or maintain the nutritional quality of foods. However, manufacturers soon discovered that along with an improvement in nutritional qualities, nutritional additives often provide functional qualities.

Nutritional additives can be used to restore nutrients to levels found in the food before storage, packaging, handling, and processing. An early example of this is the enrichment of grain products, corn meal, and rice. Another use of nutritional additives is to improve the nutritional status or corrected nutritional inferiority in a food that replaces a more traditional nutritional food, an example would be fortification of breakfast drink substitutes with folacin and vitamin C. With the advent of nutritional levelling and increased public interest in nutritional properties of food, the food industry rapidly recognized that the addition of nutritional additives can be a selling point.

Although it is often thought that the major reason to add nutritional additives to a food supply is to provide nutrients and improve dietary status, nutrients are also added for a variety of other purposes. For example, vitamin C and E may be used for antioxidant properties; beta carotene may be used to provide colour. In these cases consumers obtain both functional and nutrient advantage.

Like all additives, nutritional additives are commercially available in an array of forms such as powders, encapsulated in gelatin, emulsified in oil. The form used depends upon the type of application. Nutrition additives are often protected by protective additives such as antioxidants. Two critical factors in the selection of the form of the additive are stability of the vitamin preparation and its miscibility with the intended food matrix.

16.7 THE POTENTIAL USE OF PROBIOTICS

Almost a hundred years have passed since the introduction of theories on the prolongation of life by modulation of intestinal ecosystem. The scientific basis for use of probiotic organisms has only recently been firmly established and some sound clinical studies have been published. The physiological and nutritional properties of selected bacterial strains are well characterized, and it is possible to verify that some strains are “probiotic” with document effects of maintaining and promoting the health of the host when used as part of the daily diet.

Few well-documented probiotic dairy strains are available at present. The most important are listed in Table 16.3. Specific effects of probiotics include, for example, modulation of diarrhea from various causes, relief of lactose intolerance, and constipation. More recent claims with some strains include enhancement of immune functions, vaccine adjuvant effects, reduction of serum cholesterol levels, and changes in colour cancer-related parameters. The immune enhancing effects have been reported in several studies for two strains, *Lactobacillus acidophilus* LCI and *Lactobacillus* GG, which appear to act as immunoadjuvants. Effects on cholesterol levels remain to be verified since so many confounding factors have contributing to varying extents in different population groups. At the moment, no firm proof on any of the probiotic strains of lactic acid bacteria is available, and more well defined clinical work is needed.

The future of research on probiotic bacteria will focus on selecting new, more specific strains for the well being of the host. Different regions of the gastrointestinal tract may be benefiting from different probiotic bacteria and maybe the time has come for disease specific strains. This is particularly true with conditions such as rotavirus diarrhoea and gastritis caused by *Helicobacter pylori.* However, the requirement for good clinical studies will become ever more important. Carefully controlled studies on selected strains could result in the development of probiotic bacteria targeted for specific diseases and their prevention. Mixtures of such organisms may be of general therapeutic value as additives in clinical foods.

Table 16.3: Current probiotic bacteria and their reported effects

Sl. No.	Strain	Reported effects in clinical studies
1.	Lactobacillus acidophilus La-5	Immune enhancer, adjuvant, protection against traveller's diarrhoea; balance intestinal microflora.
2.	Lactobacciullus acidophilus NCFB 1748	Lowering of fecal enzymes, decreasing fecal mutagenicity, prevention of radiotherapy-related diarrhoea.
3.	Streptococcus boulardii	Prevention of antibiotic-associated diarrhoea; treatment of Clostridium difficile diarrhoea.
4.	Lactobacillus johnsonii LA1	Adherence to intestinal cells; balances intestinal microflora; immune enhancement; adjuvant in H. pylori treatment
5.	Lactobacillus casei Shirota	Prevention of intestinal disturbances, balancing intestinal bacteria, lowering fecal enzyme activities, positive effects on superficial bladder cancer.
6.	Streptococcus thermophilus; Lactobacillus bulgaricus	No effect on rotavirus diarrhoea; no immune enhancing effect during rotavirus diarrhoea; no effect on fecal enzymes; strain-dependent improvement of lactose introlerance symptoms.
7.	Bifidobacterium lactis Bb-12	Treatment of viral including rotavirus diarrhoea; balancing intestinal microflora; alleviation of food allergy symptoms.
8.	Lactobacillus reuteri	Shortening of rotavirus diarrhoea; colonizing the intestinal tract.

16.8 BASIS FOR CONCERN

Concern is directed toward synthetic rather than naturally occurring additives. In-home interviews found concern about additives was related to a general fear of chemicals and diseases, specially cancer (Sloan et al, 1986). Consumers believe chemicals present hidden and unknown dangers, which people are powerless to predict (McNutt et al, 1986). Consumer association with chemicals may relate to environmental concerns such as acid rain and toxic waste dumps. Over half of consumers indicated they think there is a connection between chemical spills and their feelings about chemicals in food. Almost 20% of the consumers believe that chemicals are never good for people and over 80% believe that chemicals cause cancer.

Consumers indicated a lack of trust in regulators and regulatory procedures. Both men and women believed that expert opinion was influenced by who paid their salary. Concern was believed justified since some approved additives were later withdrawn later on.

Food allergies may also trigger about additives. In the early 1980s, 26% of U.S. consumers said that they feared an allergic reaction to artificial ingredients, and 22% avoided particular food fearing the food may contain an allergen and avoided such foods. Similarly in Australia, the main concern given for food additives was allergies.

Consumer response to additives may also berelated quality. Over 75% of consumers indicated that artificial flavours give food a poorer taste than natural flavours. Their descriptions of artificial flavouring range from "too salt" to "too sweet" and from "strong tasting" to "flat tasting". Almost 70% of consumers attributed better quality to natural flavours.

Consumers appear unaware of potential benefits from additives. More than 80% of Canadian consumers surveyed in 1978 thought that food colours were unnecessary. They believed that additives made food are less safe. Sloan and co-authors believe that consumers will accept a product if benefits outweigh disadvantages and possible risks are small.

16.9 STEEPING PRESERVATION

Fruits and vegetables can be preserved safely in a chemical solution that checks enzymatic, oxidative and microbial spoilage in the preserved material. The chemical solution makes use of various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, which are quite cheap and easily available in the market. Any container (glass, porcelain or glazed earthenware jars) can be used for storing the steeped material. Flow sheet of steeping preservation of fruits and vegetables is as shown below:

Select raw vegetables such as cauliflower, ginger,
lotus stem, carrot, radish and raw mango slices

↓

Prepare the raw material by peeling, cutting and washing

↓

Fill the prepared material in clean glass jars

↓

Prepare chemical solution in potable water using 3%salt, 8% glacial acetic acid
and 0.2% metabisulphite
Fill the chemical solution up to the brim in glass jars
containing fruits and vegetables

↓

Maintain the ratio of material to solution 1:1.5. Close the

↓

jars tightly and store them in a cool and dry place
Wash vegetables thoroughly before use for culinary purpose.
For pickle, *pakora* and chutney preparations, material
can be used straight away after taking out from the solution

Advantages of Steeped Preserved Products

The steeped preserved products have many advantages:

- The method of preservation is very simple and cheap.
- Compared to canning or bottling where heat sterilization is essential, the vegetable or fruit in this method does not suffer much loss of texture even if it is blanched.
- Sulphur dioxide present in potassium metabisulphite (if added in the solution) helps to retain vitamin C content of the preserved material.
- The method can be used on a commercial scale, at the production centres by using large sized wooden vats coated with wax or wax coated cement tanks, which can be properly sealed.
- This low cost technology can be used for bulk packing in glut season for retail-off season sale in the market.
- Preserved material can be stored for 6-8 months at an ambient temperature and beyond one year, at a low temperature.
- Steeping preservation is used either for preserving the material for packing various products or for curing them for lactic fermentation for the preparation of fermented processed products.

16.10 PRESERVATION OF PULP, JUICES, SAUCES, CHUTNEYS, PUREES AND PASTES

Preservation of Pulps and Juices

Fruit pulps and juices can be preserved by adding 1g KMS and 10g citric acid per kilogram or pulp/juice. There is no need to add citric acid in acidic fruits such as lemon. The citric acid and KMS should be dissolved separately in little amount of water and then added in fruit juices. In coloured fruit juice, i.e. coloured grapes, phalsa and plums etc., sodium benzoate is added instead KMS as the latter bleaches the colour of the product. Preserved pulps and juices can be stored for 6-8 months at room temperature and beyond one year at low temperature. In this method, pulps and juices to be sterlized by heat initially, cool it and then use there preservatives. Similarly, the container used for packing should be reasonably impermeable to air and water vapour.

Preservation of Sauces, Chutneys, Purees and Pastes

Preservatives added for the preparation of pulp, juices, sauces, chutneys, purees and pastes are important constituents of these products. Vinegar, salt and sugar are common preservatives used for preservation of these products. The chemical preservatives such as sodium benzoate and potassium metabisulphite used in commercial scale preparations ensure long term storage by retarding the growth of microorganisms without interfering with the other physico-chemical and sensory characteristics of the preparation. Following are the consideration for the selection of a chemical to be used as a preservative in various food preparation.

- Type of organism to be controlled
- Length and conditions of product storage
- Physical and chemical characteristics of the food

16.11 USE OF CHEMICALS DURING CURING OF PICKLES

Fermented foods have many advantages such as prolonged shelf life, extended seasonal life, less time for cooking and sometimes increased acceptability and digestibility. They also act as laxatives. Vegetables can be preserved by simple lactic acid fermentation which enhances the organoleptic and nutritional quality of the product.

Commercial preservation of many pickle relies upon conversion of carbohydrates to organic acids during bulk storage and/or the addition of sufficient amount of sugar, vinegar and other ingredients to the fully cured and packed products to preclude any microbial growth. Organic acids, oils, salt and spices have antimicrobial properties at suitable concentration. Pickles in brine as such or after fermentation however, need some amount of preservative or pasteurization to prevent the spoilage.

Spices such as garlic, cloves, chillies, mustard seeds, dill herbs etc., have antimicrobial effect. Antibacterial and antifungal properties of mustard seeds are due to allylthiocyanate, a volatile aromatic compound which inhibits the growth of *Saccharomyces cerevisiae.* Mustard seeds promote growth of lactic acid bacteria and inhibit scum yeasts which can break down lactic acid. Essential spice oils such as thyme, sage, lemon and dill inhibit the growth of different yeasts in fermentation of olives, thereby, prolong in the effectiveness of lactic acid fermentation. Chemical preservatives such as sorbic acid inhibit fungi, yeasts and bacteria without interfering with the development of lactic flora.

16.12 PRESERVATION OF WHOLE TOMATO CONCENTRATE

Tomato is considered a necessary adjunct of almost all vegetable curries throughout the country. It adds to their taste, lends colour and supplements the nutritional quality of the vegetable preparations. Tomato crush is a distinct type of product which contains the whole of tomato inclusive of skin and seeds and thus differs from tomato puree and paste.

The tomato crush is prepared by boiling the tomatoes, blending and continuing to boil till a thick consistency. Preservatives are added to it prolong its shelf life. For every kilogram of the thick paste, 5ml of glacial acetic acid is added followed by boiling for 8-10 minutes. Then to the hot one kilogram of tomato crush, 0.4g potassium metabisulphite and 0.2 g sodium benzoate are added after dissolving in a small quantity of water. This mixture of two preservatives retains better red colour (lycopene) in tomato crush.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What is meant by steeping preservation?

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2. What is fermentation and what are its advantages?

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16.13 LET US SUM UP

In this unit on chemical additives we have examined the role of food additives in the food industry. This has included the study of the classes of different food additives, their role and mode of action, nutritional additives, the permitted preservatives and their applications.

We have also studied the simple, low cost, low energy processing technologies which are needed to keep the processed and preserved products within the reach of a much wider section of the population. These methods of chemical preservation and fermentation are easy to follow, economical and cater to the indigenous need, save losses of fruits and vegetables as well as their valuable nutrients, utilize market surplus, promote horticulture and give boost to the preservation industry, benefit the consumers and provide better returns to growers.

The chemicals, which are intentionally added to our food, constitute a small but important part of the many chemicals which man is adding to his environment. These chemicals are needed to efficiently produce an abundance of high quality food. The global and the scientific view still include unintentional and generally recognized additives as safe materials. Unintentional additives may have been incorporated into the food during its production, processing, storage or marketing. Intentional food additives include chemicals, which are used for nutritional purposes, consumer acceptance, preservation of quality and processing. The changing food industry allows the homemaker of today to spend only 90 minutes per day in the kitchen compared with the 5 hours used by her mother. Her convenience foods, which save time, effort and sometimes money, contain many of the direct additives.

16.14 KEY WORDS

Food additive : A substance or a mixture of substances other than the basic food stuff, which is present in food as a result of any aspect of production, processing, storage and packaging and does not include chance contaminants.

GRAS : Additives which are Generally Recognised As Safe.

Preservative : Substances which when added to food retard, inhibit or arrest the activity of microorganisms such as fermentation, acidification and decomposition.

Steeping preservation : Preservation in a chemical solution that contains various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, and checks enzymatic, oxidative and microbial spoilage in the preserved material.

Whole tomato crush : Tomato product which contains the whole of tomato inclusive of skin and seeds.

16.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Food additives help to improve the quality of food we eat. They enhance the consumer acceptability, help to maintain the nutritional quality, stability of the food, check spoilage by inactivating microorganisms, facilitate preparation of food and improve palatability e.g.: Preservatives, antioxidants, colouring agents, texture modifiers, antifoaming agents, acidulants, flavours etc.

2. Class I preservatives are natural products e.g.: salt, sugar, dextrose, spices, vinegar, honey etc which can be used at a higher concentration to preserve foods. Class II preservatives are synthetic chemicals such as benzoic acid, sulfurous acid, propionic acid, nitrites, nitrates etc. which are used in small concentrations to preserve food.

3. Your answer should include the following points.
   - Additive means any substance which is not a normal constituent of the food material and is purposeful addition which is aimed for technological, organoleptic and nutritional reasons.
   - According to the WHO, a food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants.
   - Food additives have also been defined by the National Academy of Sciences as those chemicals that may be incorporated in foodstuffs, either directly or indirectly during growing, storage or processing of foods.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Steeping Preservation implies preservation in a chemical solution that contains various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, and checks enzymatic, oxidative and microbial spoilage in the preserved material. It helps to preserve foods for more than a year.

2. Fermentation implies decomposition of carbohydrates and carbohydrate like substances under aerobic and anaerobic conditions. It helps to break complex material to easily digestible form and make it easily digestible. Fermented food have prolonged shelf life, require less time for cooking and increased digestibility and acceptability.

16.16 SOME USEFUL BOOKS

1. Arya, S.S. (1987) Role of food additives in convenience foods. Indian Food Industry 6(1), 11-16.
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3. Branen, A.L., Davidson, P.M., Salminen, S. and Thorngate III, J.H. (eds.) (2002) Food Additives. Marcel Dekker.Inc. New York. pp 938.
4. CRC Handbook of Food Additives. 2nd Edition, Volume I, Ed. Thomas E. Furia, Director, Food Science Dymap;. Palo Alto, California, Published by CRC Press, Inc. 18901 Cranwood Parkway, Cleveland, Ohio 44128 (Call No. 614.3(02)/F984H, Acc. 144368.
5. Food Additives, Second Editor Revised and Expanded. Ed. by A. Larry Branen, P. Michael Davidson, Seppo Salminen, Hon H. Thorngate III. (664.8/F686E, 243510).
6. Frederick, J. Frances (2000) Wiley Encyclopaedia of Food Science and Technology, Vol.2. Wiley Inter Science Publication, New York.
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EXPERIMENT 1 ASSESSMENT OF POST HARVEST LOSSES AT DIFFERENT LEVELS (FROM FIELD TO CONSUMERS)

Structure

1.1 INTRODUCTION

Assessment of Post Harvest losses from field to consumers is extremely important from the point of post harvest management. Saving all these losses indirectly means increase in availability of the commodity and finally helping the society. Estimating losses at different levels such as farm, wholesale and retail can accomplish the loss assessment by adopting appropriate sampling procedure at each stage. You should understand that a modest improvement in reducing wastage per unit handled at each level when multiplied by millions of unit at each stage in post harvest system could significantly increase the availability of fruits and vegetable.

Objectives

After studying and performing this experiment, you should be able to:

- determine pre-harvest loss of fruits & vegetables at field level due to insect, pest and disease incidence as well as the harvesting damage; and
- determine post-harvest loss of fruits & vegetables due to poor marketing efficiency including faulty packaging, inefficient transport, and inadequate storage facility at traders level.

1.2 EXPERIMENT

1.2.1 Principle

Pre and post harvest care of fruits and vegetables in India is by and large very poor which lead to high losses. The poor marketing efficiency including faulty packaging, inefficient transport, and inadequate storage facility is indirectly reflected in high loss. It is important to know the magnitude of post harvest losses at different stages of marketing as well as at farm. More attention to be given where losses are more and immediate corrective measures should be taken to reduce such losses.

1.2.2 Requirements

- Physical Balance/weighing scale.
- Quality assessment instruments viz. Refractometer, Pressure tester etc.
- Questioner/check list (To obtain data on losses at different level, from farmer, traders etc during survey).

1.2.3 Procedure

- Collect the loss assessment data by interviewing the farmers and traders on fresh, affected/ decayed/damaged/diseased quantity produced and handled respectively.
- Best way would be to draw a sample from the harvested produce of each commodity at farm level and a sample for each commodity at traders level taken randomly to assess the losses.
- At each stage segregate the sample into fresh/marketable and affected/unmarketable produce.

1.2.4 Observations

The sample of the fruits and vegetable collected is initially sorted into fresh (marketable) and unmarketable (decayed, diseased, damaged etc). The unmarketable ones are partly sold or processed (deformed, over/under size but free from spoilage) and partly rejected (diseased or decayed). The percentage of fresh (marketable) and affected (unmarketable) parts of the sample of fruits and vegetables at each level can be worked out easily.

1.2.5 Calculations

$$\%\ \text{loss} = \frac{\text{Q2 affected/unmarketable produce}}{\text{Q total quantity of sample}} \times 100$$

$$\%\ \text{fresh} = \frac{\text{Q1 fresh/marketable produce}}{\text{Q total quantity of sample}} \times 100$$

Q = total quantity of sample (Q1+ Q2)

Q1= fresh/marketable

Q2= affected/unmarketable

1.2.6 Result

Loss assessment is expressed = Percent (w/w)

1.3 PRECAUTIONS

- Prepare questionnaire for the interview of farmers and traders well in advance.
- Questions to be asked in a friendly manner in order to extract the maximum facts.
- Samples to be drawn at farmers and traders level with utter care so that it gives representative sample.

EXPERIMENT 2 DEMONSTRATION OF VALUE-ADDITION — BY POST HARVEST HANDLING AND PACKAGING

Structure

2.1 INTRODUCTION

Horticultural produce, in general, and fruits and vegetables, in particular, if they are properly handled i.e. sorted, graded, waxed, pre-cooled and unit packed can produce value added products. Unfortunately, in our country most of the fruit and vegetables immediately after harvest are sent to the market as a result a huge quantity of unwanted materials are also sent but if they are timely eliminated before marketing and gainfully utilized can not only add indirect value to the product but also reduce garbage in the metro cities. Ideally fruits and vegetables after harvest should be sorted, graded, waxed, pre-cooled and unit packed at packing stations situated at appropriate points in every district. This process will reduce the transportation and handling cost of inedible parts and help the consumer by providing a convenience food that can fetch higher price.

Objectives

After studying and performing this experiment, you should be able to:

- determine the importance of sorting, grading, waxing, pre-cooling and packaging, and how it can directly add value to the harvested produce; and
- determine the amount of fresh/marketable materials from the harvested lot and how to add value to the cull fruits and vegetables by making processed product.

2.2 EXPERIMENT

2.2.1 Principle

Sorting removes unwanted materials that are obviously unsuitable for sale, such as fruits and vegetables with severe mechanical injury, decay and under or over size that are unsuitable for fresh marketing. While grading groups commodity based on size, shape, colour etc. and is necessary to get suitable returns with respect to the quality attributes of the commodity. Acceptability depends on the size, attractiveness and organoleptic quality of the particular commodity. Therefore sorted and graded produce will add value. Waxing is an extra discontinuous layer applied manually or mechanically for the purpose of replacement of natural wax. This reduces water loss, gives cosmetic appearance and provides better shelf life. Prompt pre cooling reduces water loss and physiological activity, limits the growth of decay organisms, maintain quality and increase the shelf life. Ideal packaging reduces undue damage during handling and transportation, while unit packaging provides convenience and thereby increases the value of the commodity.

2.2.2 Requirements

- Sorting and grading – plastic crates and stainless steel/aluminium top tables, stools and weighing scale.
- Waxing – wax emulsion, perforated trays and electric fans.
- Precooling – ice, bucket and thermometer probe type.
- Unit packaging – stretch / cling film, small pulp/plastic tray and small baskets.

2.2.3 Procedure

Sorting and grading

- Sorting and grading may be done manually or mechanically.
- In absence of a mechanical sorter and grader an experienced person can undertake both these operations efficiently.
- After collecting the sample of the fruits and vegetable, sort out the fresh/marketable and unmarketable/decayed/diseased/damaged ones.
- After sorting out fresh/marketable fruits and vegetable, grade them according to soundness, firmness, cleanliness, size, shape, weight, colour and maturity.
- But the most prevalent practice is size grading.

Waxing

- Wax the fruits by dipping them in wax emulsion for 30-60 seconds or give a spray of wax.
- Remove excess wax by allowing them dripping.
- Dry with the help of an electric fan.

Pre-cooling

- Collect the sorted and graded fruits and dip them in a bucket containing ice water.
- This is known as hydro cooling you follow this practice in fruits but not in all horticultural commodities.
- In the case waxed fruits one should follow air-cooling.

Packaging

- Ideally after sorting, grading and waxing the fruits and vegetables are packed in CFB (Corrugated fibre board boxes).
- Unit packaging of fruits and vegetables can be done conveniently with the help of stretch/cling film.
- This film has the property that under tension it stretches and when tension is released it comes back to its original forms.
- This property helps in unit packaging for retail sale.
- Take a few fruits on a tray or basket or individually and wrap them with stretch/cling film.
- The whole operation can be carried out without heat application.

The cull fruits and vegetables free from microbial infection should be processed into value added products.

2.2.4 Observations

After rejecting the unmarketable fruits and vegetables, from the harvested lot, one can easily find out the percentage of fruits and vegetables ideal for fresh market. Sorted, graded, waxed, and unit packed fruits and vegetables can fetch higher price because of better quality (appearance), reduction in transportation and handling cost and in addition it provides convenience to the consumer.

You can easily find out the effect of waxing and unit packaging by comparing the differences in terms of quality (appearance) and weight loss with that of un-waxed unpacked ones. Conducting sensory evaluation can assess the quality.

The pulp prepared and preserved from the cull fruits can be gainfully utilized for making various processed product as when required.

2.2.5 Calculations

$$\text{Idea for fresh market}\,\% = \frac{\text{Weight of Marketable fresh produce}}{\text{Total quantity of harvest lot}} \times 100$$

$$\text{Weight loss}\,(\%) = \frac{\text{Initial weight} - \text{weight at the end of storage}}{\text{Initial weight}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

2.2.6 Result

Weight loss and spoilage is expressed = Percent (w/w).

Freshness = Visual observations.

Sensory evaluation = overall score.

2.3 PRECAUTIONS

- Select only freshly harvested produce, which has not undergone any segregation or selection.
- If freshly harvested produce is not available collect representative sample from the bulk arrival in wholesale market.
- Packaging should only be done with the sorted and graded fruits and vegetables.
- Avoid rough handling of the material
- Sorted fruit and vegetables unfit for fresh marketing due to under size, oversize, deformed, physically damaged but free from microbial spoilage should be kept carefully for processing into a value added product.

EXPERIMENT 3 ON FARM STORAGE — PUSA ZERO ENERGY COOL CHAMBER

Structure

3.1 INTRODUCTION

In a tropical country like India, a tremendous amount of quality deterioration of horticultural produce takes place immediately after harvest due to lack of on-farm storage facilities. Refrigerated cool storage is considered to be the best method of storing fruits and vegetables. However, this method is not only highly energy intensive but also involves huge capital investment. The present trend world over is to develop a simple low cost cooling system for storage of fruits and vegetables. In order to overcome the problem of on farm storage, low cost environment friendly Pusa zero energy cool chambers have been developed. The greatest importance of this low cost cooling technology lies in the fact that it does not require any electricity or power to operate and all the materials required to make the cool chamber are available locally, easily and cheaply. Even an unskilled person can install it at any site, as it does not require any specialized skill. Most of the raw material used in cool chamber is also re-usable. The cool chamber can reduce the temperature by 10-18^{o}C of ambient temperature and maintain high relative humidity of above 90% throughout the year that can increase the shelf life and retain the quality of fresh horticultural produce.

Objectives

After studying and performing this experiment, you should be able to:

- construct the Pusa zero energy cool chamber even in remote area and learn how to maintain the temperature and humidity in side the chamber; and
- demonstrate the performance of Pusa zero energy cool chamber in increasing the shelf life of fresh fruits and vegetables.

3.2 EXPERIMENT

3.2.1 Principle

Based on the principles of direct evaporative cooling, the Pusa zero energy cool chamber works. Considerable cooling effect can be obtained by evaporation of water and faster the evaporation, greater is the cooling. Evaporative cooling occurs when air that is not already saturated with water vapour is blown across any wet surface. Theoretically the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature. The materials primarily used in constructing these chambers i.e. bricks and sand fortunately both has great capacity to absorb and/or retain water which evaporates slowly and steadily depending on the atmospheric temperature and humidity resulting in cooling.

3.2.2 Requirements

- Construction materials: bricks, sand, bamboo etc.
- Top cover: khas khas fixed in a bamboo-frame.
- Watering of the chambers: watering can or bucket and mug, water tank, drip system etc.
- Plastic crates for storage and plastic sheet for cover.
- Temperature and relative humidity: Maximum minimum and wet and dry bulb thermometer or digital thermo-hygrometer with extension cord.
- Hand sprayer (small) for spraying of insecticides/fungicides.

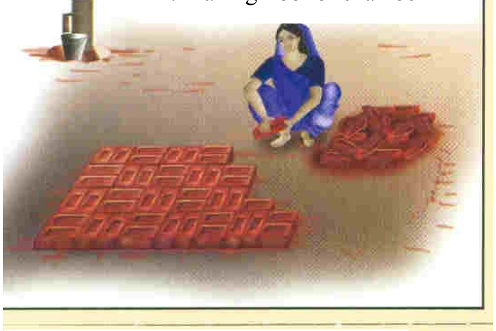
3.2.3 Procedure

For construction of Pusa zero energy cool chamber select an-upland having a nearby source of water supply.

- Make floor of the chamber with the help of bricks size 165 cm × 115 cm.
- Erect the double bricks wall on the above floor to a height of 67.5 cm leaving a cavity of 7.5 cm.
- Drench the chamber with water and soak the fine riverbed sand with water. Fill the cavity between the double brick wall with this wet sand.
- Make a frame of top cover with bamboo (165 cm × 115 cm) frame and 'sirki' straw or dry grass.
- Make a thatch/tin/asbestos shed over the chamber in order to protect it from direct sun or rain or snow.
- After construction following operation instructions are to be followed. Keep the sand, bricks and top cover of the chamber wet with water.
- In order to achieve desired temperature and relative humidity, water twice daily (morning and evening). Alternatively, fix a drip system for watering with plastic pipes and micro tubes connected to an overhead water source.
- Store the fruits and vegetables in this chamber by keeping in perforated plastic crates. Cover these crates with a thin polyethylene sheet.
- The cool chamber should be reinstalled once in 3 years with new bricks utilizing the old bricks for other purposes.

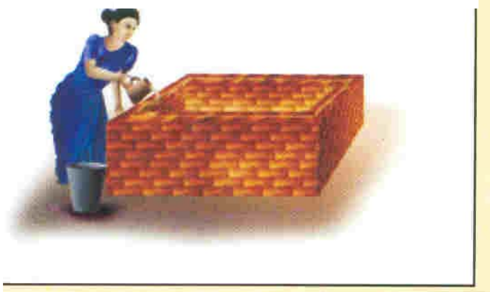
DIAGRAM FOR CONSTRUCTION OF PUSA ZECC

1. Making floor of chamber



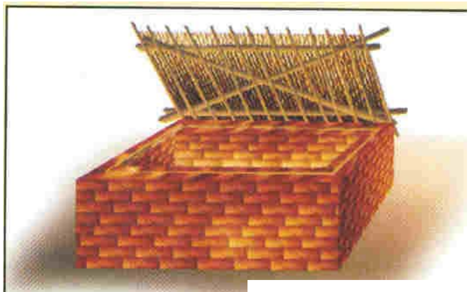
2. Erecting double wall with cavity

3. 3. Watering the chamber



4. Filling wet sand

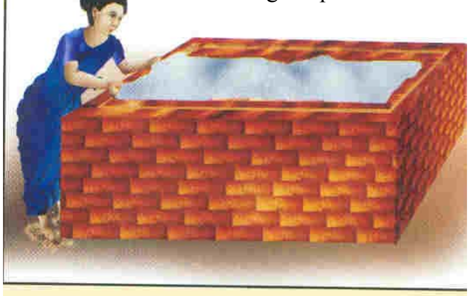
5. Making top cover



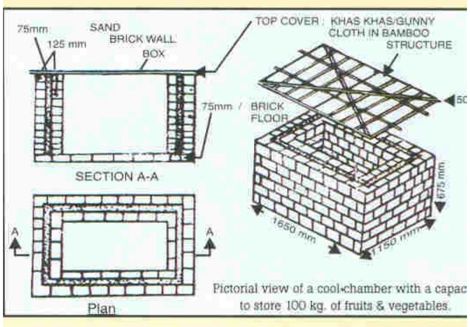
6. Cool chamber

7. Storing in plastic crates/baskets

8. Covering the plastic sheet



9. Cool Chamber under shed



3.2.4 Observations

Once the Pusa zero energy cool chambers is constructed, regular observations to be taken regarding the performance of cool chamber in terms of temperature and relative humidity as well as the shelf life increase of fruits and vegetables.

Temperature and Relative Humidity can be recorded with the help of Max. Min. Thermometer and Dry & Wet bulb Thermometer, otherwise it can be done with the help of digital thermo-hygrometer for display of temperature and relative humidity.

The shelf life increase of fruits and vegetables is recorded regularly by taking the weight, incidence of spoilage/diseases and assessing the quality (sensory evaluation).

3.2.5 Calculations

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{weight at the end of storage}}{\text{Initial weight}} \times 100$$

$$\text{Spoilage (\%)} = \frac{\text{Weight of spoilt material}}{\text{Initial weight}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavor/odour.

Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

3.2.6 Result

Weight loss expressed as Percent (w/w).

Spoilage expressed as Percent (w/w).

Freshness expressed as Visual observations.

Sensory evaluation expressed as overall score.

3.3 PRECAUTIONS

- The site should be selected where breezes blow and should be build in an elevated place to avoid water logging.
- Only clean, unbroken bricks with good porosity must be used sand should be clean and free from organic matters, clay etc.
- The bricks and sand should be kept saturated with water. The chamber should not be exposed to sun, rain or snow.
- Only plastic crates should be used for storage and avoid bamboo baskets, wooden/fibre board / boxes, gunny bags.
- Efforts should be made to prevent water drops coming in contact with stored material.
- The chamber should be kept clean and disinfect the chamber periodically with permitted insecticide/ fungicide/ chemical, to protect from fungus, insect / pests, reptiles, etc.

EXPERIMENT 4 SOLAR DRYING OF FRUITS AND VEGETABLES

Structure

4.1 INTRODUCTION

Preservation of food by drying is perhaps the oldest method. Large quantities of fruits and vegetables are dried in the sun in different parts of the world. Sun drying or solar drying of fruits and vegetables is practiced widely in tropical and sub-tropical regions where there is plenty of sunshine and practically little or no rain during the drying season. Only small capital investment is required with this simple procedure. Advantages of dehydrated fruits and vegetables are more viz. mineral content remain unchanged, hardly affects the main calories-providing constituents of food, long shelf life if packed and stored properly, transportation, handling and storage costs are substantially reduced and finally the consumer uses all that he buys thus no waste disposal and pollution problems. However, there are some disadvantages, since sun drying depends on uncontrolled factors, production of uniform and high quality product is not expected. Some over drying and contamination by dust, dirt, and insect infestation of the finished products is usually tolerated. It is a slow process, unsuitable for producing high quality products. If the ancient sun-drying technique is improved by creating ideal system of solar drying then quality of the dried product also be improved.

Objectives

After studying and performing this experiment, you should be able to:

- demonstrate the techniques of pre-drying treatments required for fruits and vegetables to produce a quality-dried product; and
- display the Improved Solar Drier / Black Polyethylene Cover drier by actually drying some fruit or vegetable following ideal conditions of packaging and storage of solar dried fruits and vegetables.

4.2 EXPERIMENT

4.2.1 Principle

The major purpose of drying or removal of water/moisture from fruits and vegetables is to protect them against deterioration. Microbes cannot grow and multiply in absence of sufficient water in the environment. Many of the enzymatic reactions are hydrolytic in nature and require water as one of the reactants. Chemical reactions in food materials are also slowed down in absence of an adequate water. Therefore, by removing water from the fruits and vegetables, it should be possible to preserve them by checking the spoilage causing agents. This principle forms the basis for preservation of fruits and vegetables by drying. Employing blanching, sulphuring or sulphitation can improve the quality of sun-dried fruit and vegetable products. The retention of green colour and β-carotene (provitamin A) can be improved by indirect solar drying. The quality of the dried fruits and vegetables can be retained successfully if they are ideally packed in moisture proof pack and stored in cool dry place.

4.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top
- Stainless steel peeling, coring and pitting knives
- Blanching tank/aluminum vessel
- Gas burner/heating arrangement
- Cooling tank
- Sulphitation/ SS tank or aluminum pan
- Sulfuring/Sulfur box
- Perforated aluminum trays
- Solar drier/facility for sun drying
- Black polyethylene sheet
- LDP/HDP pouches, Pouch sealing machine. Tin container with airtight closure.

4.2.3 Procedure

- Select fruits and vegetables very carefully for drying.
- Wash the fruits and vegetables thoroughly to remove any dirt and other extraneous matter.
- Prepare the fruits and vegetables by peeling and cutting into suitable sizes on the day of harvest itself.
- In the case of fruits, sulphuring is done as pretreatment to maintain their colour and also to avoid spoilage by microorganisms.
- Prepared fruits are then exposed to sulpher fumes by burning sulphur in a sulpher box.
- Blanching is used as pretreatment for vegetables, this is done by rapidly boiling the vegetables in water for known time to inactivate the enzymes and partially killing the microorganism.
- Immediately after blanching the vegetables are dipped in cold water to avoid over cooking.
- The blanched vegetables are sulphited by placing them in 0.5% solution of potassium metabisulphite for requisite time.

- The fruits and vegetables are then spread on perforated tray, dried in direct sun or in shade preferably in a well - ventilated room away from direct sunlight. Provision of a ceiling fan in the room will hasten the process of drying.
- Solar drying can be improved considerably by using black polyethylene structure.
- It should be made in such a way that it could hold trays containing fruits and vegetables for drying with the provision of entry of dry air from the bottom and exit of moist air from the top of the structure.
- The samples should be turned every 4-6 hours for uniform drying.
- Dried fruits and vegetables are highly susceptible to contamination and therefore, should be packed in polyethylene (plastic) bags/pouches as soon as they are cooled after drying is over.
- In order to prevent rodent attack, the plastic bags are placed in metal containers and closing the lid firmly.

4.2.4 Observations

During sun/ solar drying, it is necessary to observe that there is plenty of sunshine and practically little or no rain during the drying season. Weigh the trays at regular interval to determine the drying the rate. The vegetables should preferably be dried to a moisture level of about 5%, i.e. till the vegetables become crisp/brittle. In case of fruits higher moisture can be retained because of the presence of sugar. Observations are to be made on the aspect viz. drying rate, and ratio, final moisture content of the material and re-hydration ratio. Finally the quality has to be determined.

4.2.5 Calculations

The dehydration ratio can be worked out by taking the initial weight of the fruit or vegetable and final weight of the dried product.

$$\text{Dehydration ratio} = \frac{\text{Initial weight of the fruit or vegetables}}{\text{Final weight of the dried product}}$$

$$\text{Rehydration ratio} = \frac{\text{Weight of the dried fruit or vegetable}}{\text{Final weight of the soaked dried product after draining water}}$$

$$\text{Moisture (\%)} = \frac{\text{Initial weight} - \text{weight after drying}}{\text{Initial weight}} \times 100$$

Organoleptic quality / Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

4.2.6 Result

Yield of dried product and moisture is expressed as Percent (w/w).

Drying and rehydration as Ratio.

4.3 PRECAUTIONS

- For the purpose of drying select fruits and vegetables in prime condition of eating and cooking.
- Recommended pre-treatments and drying process should be strictly followed.
- Care must be taken to see that the dried products are packed at the right time and do not pick up moisture
- Rodent attack on the plastic pouches must be prevented.

EXPERIMENT 5 PRIMARY AND MINIMAL PROCESSING

Structure

5.1 INTRODUCTION

In India, perishable fresh fruit and vegetables are marketed immediately after harvesting without primary processing and adequate packaging. On the other hand, in the developed countries, most of the fruits and vegetables after harvesting are transported to packing stations for primary processing. They are then trimmed, sorted, graded, unit packed and marketed. In our country, because of the absence of primary processing, a lot of inedible material is transported to the market and finally to the homes of consumers where they end up in the garbage bin. Primary processing is therefore, necessary to streamline the marketing of fresh horticultural produce to urban markets. The solid wastes originating from horticultural crops in metro cities can create drainage problems and cause water logging, as well as invite stray animals near garbage dumps. These bio wastes also deteriorate very rapidly causing unhygienic conditions and increasing atmospheric pollution and provide a breeding ground for insects, pests and rodents. Minimally processed fruits and vegetables are cleaned, peeled, cut, sliced, packaged and/or lightly processed. These foods are in great demand because of their convenience. All fruits and vegetables need not be minimally processed. It is very often not convenient for the consumer with a small family to purchase commodities like pineapple, jackfruit, watermelon, pumpkin, ashgourd, yam, etc. Therefore if it is suitably sliced, peeled and packed consumer will be more inclined to buy it. In metro cities minimally processed vegetables like primary processing can solve one of the greatest problems of garbage disposal.

All fruits and vegetables need not be minimally processed. It is very often not convenient for the consumer with a small family to purchase commodities like pineapple, jackfruit, watermelon, pumpkin, ashgourd, yam, etc. If the vegetables are available in ready to cook form a large number of workingwomen in metro cities will be greatly benefited.

Objectives

After studying and performing this experiment, you should be able to:

- demonstrate the techniques of primary processing of fruits and vegetables and show how the solid wastes originating from fruits and vegetables can

be utilized in the farmers field thereby reducing cost of transport and the city garbage; and
- explain with practical demonstration of techniques of minimally processed fruits and vegetables and highlight its advantages.

5.2 EXPERIMENT

5.2.1 Principle

There is little difference in principle between primary and minimal processing. Primary processing is applicable in some fruits and vegetables, which carries lots of inedible/unmarketable part from the field to the market. Therefore, the main principle of primary processing is to eliminate the inedible parts without inflicting any damage to the main edible part. While minimally processed fruits and vegetables are cleaned, peeled, cut, sliced, packaged and/or lightly processed. One should keep in mind that while supplying minimally processed vegetable the maintenance of quality and hygiene must be of topmost priority.

5.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel peeling, coring and pitting knives.
- Stainless steel washing tanks, constant supply of potable water.
- Electric fan / blower / drying arrangement.
- Packaging in polyethylene pouches, small plastic crates, CFB boxes.
- Pouch sealing machine.
- Shrink wrap/cling films, small cardboard tray/bamboo basket/perforated plastic container.
- Refrigerated storage/ walking coolers.
- Stainless steel pretreatment tanks.
- Laboratory facilities.

5.2.3 Procedure

Both the primary processing and minimal processing can be explained properly by giving example of a particular fruit or vegetables.

Primary processing

Cauliflower

- Procure cauliflower immediately after harvest
- Remove the inedible outer leaves and stems by cutting them with sharp knife without inflicting any damage to the edible curd
- The curds can be either wrapped in plastic film or kept as such in plastic crates for shipment in the market.
- The leaf and stem portions eliminated can be used as cattle feed or any other value added products.

Banana

- Harvest mature banana bunches carefully without causing any damage to banana fingers.
- Separate the banana hands from the bunch with help of a sharp knife.
- If facilities available wash the hands wax and dry them.
- Put the banana hands individually in plastic bag and place them in the crates for shipment.
- The banana stems left out can be used as value added product.

Minimal processing

- Select good quality fruits and vegetables for this purpose.
- Peel the fruits and vegetables and cut them into convenient pieces.
- Place them into appropriate containers or pouches for marketing.
- Some pre-treatments are recommended varies from commodity to commodity should be followed strictly.
- Transport and store the minimally processed under refrigerated condition.

5.2.4 Observations

It is advisable to maintain strict hygienic condition of the place and equipment. Strict vigil on the quality of primary and minimally processed fruits and vegetables are to be carried out. Yield of primary and minimally processed fruits and vegetable is to be recorded.

Shelf life or marketable life can be observed by determining the quality both in terms of microbial and organoleptic quality.

5.2.5 Calculations

The yield of the finished product and weight loss during storage should be determined.

$$\text{Primary processed produce}\ \% = \frac{\text{Weight of primary processed produce}}{\text{Weight of the original fresh produce}} \times 100$$

$$\text{Minimally processed produce}\ \% = \frac{\text{Weight of minimally processed produce}}{\text{Weight of the original fresh produce}} \times 100$$

$$\text{Waste}\ \% = \frac{\text{Weight of waste}}{\text{Weight of the original fresh produce}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

5.2.6 Result

Yield and wastage expressed as Percent (w/w).

Quality assessment is reported on Hedonic scale.

5.3 PRECAUTIONS

- Handle only freshly harvested horticultural produce for this purpose.
- Care must be taken to see that surface moisture from the finally prepared material before packaging should be removed.
- Once the primary/minimally processed fruits and vegetables are prepared and packed it should straight away go to refrigerated store.
- Keep rejects such as peel, seeds/stones or any other vegetable parts carefully for processing into a value added products and not thrown as garbage.

EXPERIMENT 6 EXTRACTION AND PRESERVATION OF PULPS AND JUICES

Structure

6.1 INTRODUCTION

The demand of fresh juices and pulp are increasing very rapidly. They are rich in essential minerals, vitamins and other nutritive factors. Freshly extracted fruit juices and pulp are the most palatable. It is desirable that juices and pulp should retain quality characters satisfactorily to the maximum extent while extraction. One should keep in mind that extraction of fruit juices and pulp are of utmost importance. There is no guidelines or specification that particular equipment is dedicated to extraction of juice or pulp of a particular fruit. It entirely depends on the equipment that gives the best juice or pulp of high quality. Generally, crushing and pressing extract juice from fresh fruits. In one case it is done continuously in one operation where as in the other the fruits are either crushed or cut into small pieces/halves and subsequently juice is pressed out. There are various types of equipment used in extraction of fruit juices and pulp.

Freshly extracted juices and pulps are highly attractive in colour and excellent in flavor, but deteriorate very rapidly if they are not preserved immediately, various factors influence and/or accelerate the loss of quality both internally and externally. The internal factors viz. water content, chemical composition; enzyme system etc. and the external influences such as temperature, hygiene or presence of contaminants play a significant role in retaining the quality of juices and pulp. There are various ways for the preparation of fruit juices and pulps, but preservation of pulp and juices by chemical preservatives, heat processing and freezing are very popular.

Objectives

After studying and performing this experiment, you should be able to:

- learn different methods and equipment to be used for extraction of juices and pulp that depends upon the structure of fruit, location and character of the tissues in which the juice is located;
- learn how to avoid destruction of vitamin C and undesirable oxidative changes in colour and flavour that occur during extraction and subsequent processing;

- conduct experiment/practical on how pulp and juices can be preserved by heat processing; and
- demonstrate preservation of pulp and juices by chemical preservatives.

6.2 EXPERIMENT

6.2.1 Principle

The method of extraction of pulp and juices depends upon the structure of fruit, location and character of the tissues in which the juice is located. In fruits like aonla, apple, grapes etc the juice is located throughout the fruit and is readily recovered by crushing and pressing. While in case fruits like apricot, peaches, plum, mango, tomato etc. the raw or cooked fruits are passed through a pulper or similar machine. In case of citrus fruits the juice is embedded in a sac and it requires entirely different machine such as halving and burring machine halving and burring machine. One must remember that undue aeration must be avoided during the extraction of juices/pulp from fruits that have not been heated to destroy enzymes, since destruction of vitamin C and undesirable oxidative changes in colour and flavour takes place. It is necessary to remember that the metal equipment should not contain traces of iron and /or copper that deteriorate the quality.

Fruit juices and pulp are generally preserved by application of heat, addition of chemicals and by freezing. Both the microbial and enzymatic spoilage can be well checked by application of heat. Preservation of pulps and juices by application of heat is known as pasteurization, in this process the pulps and juices are heated below 100° C but above 88° C to kill spore-forming bacteria, mould and inactivate enzymes. Acid fruit juices and pulp require lower temperature and less time for pasteurization than the less acid ones. Chemical preservatives are substances capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of fruit juices and pulps. The permitted preservatives used in this country are sodium benzoate and potassium metabisulphite where the active agents are benzoic acid and sulphur dioxide respectively. Generally beverages like squashes, cordial etc. are preserved by chemicals as well as bulk preservation of pulps and juices.

6.2.2 Requirements

Requirements for extraction and preservation of pulps and juices are as follows:

Extraction

- Pulpers
- Screw type juice extractor
- Citrus juice extractor/ Rosing machine
- Citrus halving machines
- Fruit mill/fruit grater
- Basket press/hydraulic press/rack and cloth press,
- Crown corking/pp cap sealing machine
- Gas burner/heating arrangement
- Double seamer / crown corker

- Processing & cooling tank
- Stain less steel storage tanks
- Sterilization equipment
- Thermometer
- Aluminum pan
- Wooden laddle
- Mixing tank

Preservation

- Sodium benzoate
- Potassium metabisulfite (KMS)
- Citric acid
- Bottle filling machines
- Beer bottles, Jerry cans, Glass containers and closures

6.2.3 Procedure

Extraction

In general you can extract juices/pulp from fresh fruits and vegetables by crushing and pressing, but the method of extraction and equipment used varies. It would be more clear once it is explained with examples as follows:

Mango, tomato, papaya etc.

- These are all pulpy fruits therefore a pulper can extract the juice/pulp easily.
- Peel and cut the fruits in general before placing in the pulper.
- These are then crushed and pressed by the paddles against the cylindrical sieve.
- The juice/pulp flows out through the sieve into jacket and collect the juice/pulp by placing in a container below the pulper.
- The coarse residue, stone etc, passes out at the lower end of the sieve.

Citrus fruits

- Cut the citrus fruits in to two halves by revolving or stationery knife.
- Hold or press the cut half against the revolving burr or rose of extracting machine.
- Collect the reamed juice in a container placed below.

Apple, aonla, grape, pineapple, jamun, carrot etc.

- In order to extract the juice from the above-mentioned fruits and vegetables you have to grate or crush them in a grater or crusher.
- Then place the grated or crushed mass in a filter cloth tie it properly but loosely.

- Carefully put the filter cloth containing grated or crushed mass inside the basket.
- Put the load/wooden disc on the filter cloth containing grated or crushed mass and press the juice out by hand operated or hydraulic type press.

All the three types extraction methods are explained above however it is necessary to mention that the Screw type juice extractors can be used universally for extracting juices/pulp from all types of fruit pieces including citrus segments.

Preservation

The following two methods of preservation are to be conducted.

Heat processing

- Preservation of juices and pulps by heat processing are most popular and desirable method.
- Heat the juice or pulp to about 100o C for sufficient time to kill the microorganisms causing spoilage.
- Fill the almost boiling hot juice in preheated glass bottles without giving any head space and crown cork immediately.
- Keep the bottles in a horizontal position and cool them in air.
- Preserve the fruit and vegetable pulp by heat processing in open top can or in wide mouth bottles having closures, which can be sealed hermetically.

Chemical preservatives

- You know two permitted preservatives viz. i) sodium benzoate and ii) Potassium metabisulphite (KMS) used in preservation of fruit and vegetable juices and pulps.
- Benzoic acid is an effective agent but it is sparingly soluble in water however, its sodium salt is water-soluble therefore sodium benzoate is used.
- Addition of 0.06 to 0.1 percent sodium benzoate is sufficient in juice having a pH of 3.5 to 4.0.
- Potassium metabisulphite is soluble in water and used as a stable source of sulphur dioxide, which is an effective agent.
- Addition of 0.15–0.2 percent potassium metabisulphite is sufficient in juice/pulp having a pH of 3.5 to 4.0.
- Weigh exact amount of preservative and dissolve in small quantity of freshly boiled and cooled water before adding to heated and cooled pulp/juice.
- Fill in the container (glass jar, jerry can etc) and close it securely so that sulphur dioxide does not escape.

6.2.4 Observations

The main observations to be taken are selection of fruits, % of juice, % of pomace/rag, % of peels, % of stone, % of unknown loss, % of acidity and degree Brix or % of total soluble solids (TSS).

6.2.5 Calculations

$$\text{Juice (\%)} = \frac{\text{Weight of juice extracted}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Pomace/rag (\%)} = \frac{\text{Weight of residue after extraction}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Stone (\%)} = \frac{\text{Weight of stone removed}}{\text{Initial weight of the fruit}} \times 100$$

Calculation for acidity and degree Brix or total soluble solids (TSS), you should consult the practical manual viz BPVI-003 and BPVI-007.

6.2.6 Result

- Yield of juice is reported as Percentage
- Yield of pomace is reported as Percentage
- Yield of peel is reported as Percentage
- Yield of seed is reported as Percentage
- Acidity is reported as Percentage
- Total soluble solids (TSS) = % or ^{o}Brix

6.3 PRECAUTIONS

- Avoid overripe and microbiologically spoiled fruits for making juice and pulp.
- Wash the extractors and other equipment with hot water to reduce the chance of infection.
- Preserve the juice and pulp immediately after extraction in order to avoid quality deterioration and incidence soilage.
- Dry the pomace immediately in order to avoid spoilage and use it for the production of value added products.

EXPERIMENT 7 PREPARATION OF WHOLE TOMATO CONCENTRATE

Structure

7.1 INTRODUCTION

Tomato is one of the few nutritious vegetables, which has a great demand both in the fresh and processed form. During the season of abundance when there is a glut in the market and tomatoes are sold at through away prices and the growers do not get the remunerative price. It is an item of daily use and also an important ingredient in our culinary system. Unlike other ingredients such as onion, garlic, ginger etc. which are peeled/scaled before using, tomato is added whole without eliminating seeds or peel portion while cooking either in vegetarian or non-vegetarian food. Therefore, there is a great scope of preserving the whole tomato in the concentrated form along with its seeds and peel.

Objectives

After studying and performing this experiment, you should be able to:

- determine the importance of preserved tomatoes in the form of whole tomato concentrate to be used in off- season or when they are very costly in the market; and
- determine the importance of low cost processing of tomato in value addition and retention of quality attributes particularly the colour i.e. Lycopene known for its anti-oxidant property and as precursor of vitamin A.

7.2 EXPERIMENT

7.2.1 Principle

Whole tomato including peel and seeds are crushed, concentrated and preserved by combination of heat and chemical preservatives. This can be used for cooking purpose when prices are more for fresh tomato. It is a complete substitute for fresh tomatoes. By this way of low cost preservation, a huge quantity of post harvest loss of tomato can be prevented.

7.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel knives.
- Gas burner/heating arrangement.
- Aluminum pan / stainless steel pan.
- Wooden ladle.
- Wide mouth glass or plastic bottles with closures.
- Chemicals – Acetic acid, potassium meta bisulphate (KMS) and sodium benzoate.

7.2.3 Procedure

- Select fully ripe and red tomatoes, wash them and cut into pieces after removing the green portions.
- Boil them in a stainless steel or aluminium vessel while crushing constantly with the help of a wooden ladle to get a homogenous mass including seed and peel.
- The whole tomato pulp should be concentrated to approximately one third (3 kg of fresh tomato will yield 1Kg of tomato concentrate) of its original weight when it forms a thick paste.
- Towards the end, boil the tomato concentrate for a couple of minutes by adding 0.5% glacial acetic acid.
- Cool the tomato concentrate to room temperature and add a mixture of 200ppm each of sulpher dioxide and sodium benzoate i.e. 0.4 g KMS and 0.2 g sodium benzoate per kg of concentrate after dissolving them in a small quantity of water.
- The mixture of two preservatives help in retention of red colour apart from helping in preservation of pulp.
- Fill the whole tomato concentrate in a clean dry glass/bottle and close it properly.
- Store the bottles in cool dry place and use as and when required.

7.2.4 Observations

Careful observation to be made that the green portions are totally eliminated(trimmed) tomatoes otherwise it will hamper the colour of the end product.

To avoid charring the product should be constantly stirred. The weight of the final product should be I/3 rd of the original weight.

7.2.5 Calculations

$$\text{Trimming (\%)} = \frac{\text{Weight of trimming}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Tomato concentrate (\%)} = \frac{\text{Weight of concentrate}}{\text{Initial weight of tomato}} \times 100$$

7.2.6 Result

Waste (trimmings) = %

Tomato concentrate = %

7.3 PRECAUTIONS

- Select fully ripe red tomatoes for making tomato concentrate reject the infected ones.
- Avoid over-boiling after addition of acetic acid.
- Add chemical preservatives towards end when the material is cooled to room temperature.
- Pack immediately in glass bottles or plastic pouches after addition of preservatives.

EXPERIMENT 8 UTILIZATION OF WASTE GENERATED DURING FRESH HANDLING AND PROCESSING

Structure

8.1 INTRODUCTION

One of the reasons for the food processing industries based on horticultural produce not being economically viable in our country is non-utilization of the valuable waste accumulated during handling and processing. The huge quantity of fruit and vegetable waste generated in the packhouse and fruit processing units can also be gainfully utilized for making value added products, thereby reducing the price of processed products. By doing so the processed food products of daily use of the common man will be well within their budget and food processing will become a more popular industry. In addition by utilizing the waste at the right time the problem of disposal of solid waste from the food factory can be solved to a great extent.

Objectives

After studying and performing this experiment, you should be able to:

- determine the extent of waste generated in a packing station and processing factory using fruits and vegetables; and
- explain the technique of utilization of fruits and vegetable waste material into a value added product.

8.2 EXPERIMENT

8.2.1 Principle

The waste generated both in fruit and vegetable packhouse and processing units in terms of cull fruits, peel, stone, cores, pits, seeds, trimmings, stems, pods are highly perishable. All these waste materials should be processed immediately into durable products, utilizing various techniques of preservation such as heat application, dehydration, addition of chemicals etc. otherwise they will convert into garbage. Various types of by products can be produced from the waste including both as feed material for the animal and food for human. The most common by products are pectin, citric acid, oils, vinegar, and alcohol. A large number of other materials like colour, essential oil, and nutrients can also be produced apart from processed food items like juices, jams, pickle, candies etc.

8.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel peeling, coring and pitting knives.
- Blanching tank/aluminum vessel.
- Gas burner/heating arrangement.
- Solar drier/facility for sun drying.
- Pulpers.
- Fruit mill/fruit grater.
- Basket press/hydraulic press.
- Crown corking/pp cap sealing machine.
- Mixing tank, Beer bottles, Jerry cans for storage.

8.2.3 Procedure

As already mentioned waste generated both in fruit and vegetable pack house and processing units can be utilized for production of various types of value added products including human food and animal feed. It is not possible to describe the procedure of all these items. Therefore we have selected three items of waste, which can be gainfully utilized.

Fruit pulp from culled fruits – Fruits that are rejected both by the packing station and processing factories can be gainfully converted into pulp

- Collect the fruits (apple) and wash them thoroughly after rejecting the spoilt ones.
- Cut the apples into four to six pieces depending on the size. Remove the core portion containing seed.
- Separate the seeds and sundry them which can be sold to the nurseries
- The fruit pieces are then cooked/ boiled in requisite amount of water with constant stirring to soften them
- Pass the hot mass through a pulper or stainless sieve and collect the apple pulp.
- Adjust the acidity of the apple pulp to 0.5% with citric acid and preserve the apple pulp in a jerry can by addition of 2g of KMS (preservatives) per kg of pulp.
- The apple pulp can be used as such and you can be prepare various types of products viz. fruit slab, nectar/fruit drink, fruit toffee etc as and when required.

Cauliflower waste in packing station

Cauliflower produces about 60% leafy part and 40% edible curd. Utilize the leafy part as a value-added product both for human food and feed for cattle.

- Cauliflower produces about 60% leafy part and 40% edible curd. Utilize the leafy part as a value-added product both for human food and feed for cattle.
- Remove the thick midrib (stem) from the leafy portion and keep them separately.
- Cut both the leafy portion and the stem into small pieces and wash them thoroughly in running water.
- Blanch them separately in boiling water for 2 minutes before drying.
- Dry them separately preferably under polyethylene cover till they are crisp dry.
- Pack them in polyethylene bags and them securely in a tin container.
- Finally convert the dried leaves into cauliflower leaf powder, this is a rich source of β-carotene (pro-vitamin A) and is a potential source of fortification that could solve the acute problem of vitamin-A deficiency.
- Similarly stems cut into pieces blanched and dried could be used as animal feed in time of shortage or fodder crisis.

Candied citrus peel in a juice factory

- Collect the citrus peels after extraction of juice then remove the seeds and rags from inside the cup.
- Place the peel in 2.0 % common salt solution. Increase the strength of the solution by 2% every 24 hours until the strength reaches 8.0%. This takes about 4 days.
- On the fifth day wash the peels thoroughly and place them in freshly prepared 8.0% common salt solution. Containing about 0.2% potassium metabisuphite and 1.0 calcium chloride and store. Calcium chloride helps in keeping the peels firm.
- As and when required they are washed thoroughly in running cold potable water and then boil in order to soften them.
- After this put the peels in a vessel and cover them with cold syrup of 30° Brix and leave them for 48 hours.
- On the third day the brix will come down much below 30° it is then raised by 10 degrees, and the peels are boiled with syrup for about 5 minutes. The process is repeated until the brix is reaches 60 degrees.
- At this stage citric acid is added @ 1 g per Kg of peel. The strength of the syrup is raised to 75 degrees brix, 5 degree every day.
- The peels are then left in the syrup for 2-3 weeks. Finally they are dried on a stainless steel wire tray at room temperature till they are no longer sticky.

8.2.4 Observations

Note the amount of waste generated from a particular commodity during handling in the packing station and also while processing. Keep a record of the different types of waste and their quantity. You can add value to these waste by processing into some useful products, this will have an economic gain on the final product. This way the impact of value addition on the pricing of the original processed product can easily determined.

8.2.5 Calculations

Find out the percentage of total waste and also the percentage of different types of (leaf, stem, peel, seed/stone, core etc) waste generated from a particular commodity.

$$\text{Waste (\%)} = \frac{\text{Weight of the waste}}{\text{Weight of the commodity}} \times 100$$

Determination of economic gain, this can be done by actually calculating in terms of rupees as follows:

Price/value of the original processed product with out waste utilization = X

Price/value obtained from the waste material utilized by processing = Y

Price/value reduction of the original product X - Y = Z

Economic gain = X - Z

8.2.6 Result

Amount of waste is reported as %.

Economic gain is reported in rupees (or can also be expressed as %).

8.3 PRECAUTIONS

- Segregate the waste material like leafy portion, inedible/unmarketable parts in a packing station and seed, stone, peel and pomace in a processing industry.
- In order to avoid decomposition and stabilize the waste, dry the high moisture materials like pomace, peel etc for future use.
- Do not throw waste as it create environment pollution.