PROTECTED CULTIVATION AND POST HARVEST TECHNOLOGY

Lecture notes and lab manual





K P Sudheer

P K Suresh Kumar

Geethu Krishnan

Sheeja PS

Department of Agricultural Engineering
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur-680656

Kerala Agricultural University

Course No. ENGG 3103

Course Title: Protected Cultivation and Post Harvest Technology

Credits: 2 (1 + 1)

Prepared by,

Dr. K.P. Sudheer, Prof. & Head, Dept. Agrl. Engg.

Dr. P.K. Suresh Kumar, Prof. Dept. Agrl. Engg

Er. Geethu Krishnan, Assi. Prof. (contract), Dept. Agrl. Engg.

Er. Sheeja P.S, Assi. Prof. (contract), Dept. Agrl. Engg.

Department of Agricultural Engineering,
College of Horticulture,
Vellanikkara, Thrissur-680656

March 2018

Citation: Sudheer, K.P, Sureshkumar, P.K, Geethu Krishnan, Sheeja, P.S. 2018. *Lecture Notes and Lab Manual of Protected Cultivation and Post Harvest Technology*.

Name of Contributors
Dr. K. P. Sudheer
Dr. P. K. Suresh Kumar
Er. Geethu Krishnan
Er. Sheeja P. S
Dr. Sankalpa K. B
Er. Saranya S
Er. Claudia K. L
Er. Greeshma K

Dept. of Agricultural Engineering

College of Horticulture, Vellanikkara

Thrissur-680656

Supported through ICAR Development Grant

Part A-Theory Lectures

Part B- Practical's

Lecture No.1

Greenhouse technology: introduction, concept & principles – Types of greenhouses; classification of greenhouse

Greenhouse is the most practical method of achieving the objectives of protected agriculture, where the natural environment is modified by using sound engineering principles to achieve optimum plant growth and yields.

1.1 Greenhouse:

A greenhouse is a framed or an inflated structure covered with a transparent or translucent material in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations.

The growing of off - season cucumbers under transparent stone for Emperor Tiberius in the 1st century, is the earliest reported protected agriculture. The technology was rarely employed during the next 1500 years. In the 16th century, glass lanterns, bell jars and hot beds covered with glass were used to protect horticultural crops against cold. In the 17th century, low portable wooden frames covered with an oiled translucent paper were used to warm the plant environment.

In Japan, primitive methods using oil -paper and straw mats to protect crops from the severe natural environment were used as long ago the early 1960s. Greenhouses in France and England during the same century were heated by manure and covered with glass panes. The first greenhouse in the 1700s used glass on one side only as a sloping roof. Later in the century, glass was used on both sides. Glasshouses were used for fruit crops such as melons, grapes, peaches and strawberries, and rarely for vegetable production. Protected agriculture was fully established with the introduction of polyethylene after the World war II. The first use of polyethylene as a greenhouse cover was in 1948, when professor Emery Myers Emmert, at the University of Kentucky, used the less expensive material in place of more expensive glass.

The total area of glasshouses in the world (1987) was estimated to be 30,000 ha and most of these were found in North- Western Europe. In contrast to glasshouses, more than half of the world area of plastic greenhouses is in Asia, in which China has the largest area. According to 1999 estimates, an area of 6, 82,050 ha were under plastic greenhouses. In most of the countries, green houses are made of plastic and glass; the majority is plastic.

Glasshouses and rigid plastic houses are longer-life structures, and therefore are most located in cold regions where these structures can be used throughout the year. In Japan, year-round use of greenhouses is becoming predominant, but in moderate and warm climate regions, they are still provisional and are only used in winter. In India, the cultivation in the plastic greenhouses is of recent origin. As per 1994-95 estimates, approximately 100 ha of India are under greenhouse cultivation. Since 1960, the greenhouse has evolved into morethan a plant protector. It is now better understood as a system of controlled environment agriculture (CEA), with precise control of air and root temperature, water, humidity, plant nutrition, carbon dioxide and light. The greenhouses of today can be considered as plant or vegetable factories. Almost every aspect of the production system is automated, with the artificial environment and growing system under nearly total computer control.

1.2 Greenhouse Effect

In general, the percentage of carbon dioxide in the atmosphere is 0.035% (345 ppm). But, due to the emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere. This causes the entrapping of the reflected solar radiation from the earth surface. Due to this, the atmospheric temperature increases, causing global warming, melting of ice caps and rise in the ocean levels which result in the submergence of coastal lines. This phenomenon of increase in the ambient temperature, due to the formation of the blanket of carbon dioxide is known as greenhouse effect. The greenhouse covering material acts in a similar way, as it is transparent to shorter wave radiation and opaque to long wave radiation. During the daytime, the shorter wave radiation enters into the greenhouse and gets reflected from the ground surface. This reflected radiation becomes long wave radiation and is entrapped inside the greenhouse by the covering material. This causes the increase in the greenhouse temperature. It is desirable effect from point of view of crop growth in the cold regions.

1.3 Advantages of Greenhouses

The following are the different advantages of using the green house for growing crops under controlled environment:

- Throughout the year four to five crops can be grown in a greenhouse due to availability of required plant environmental conditions.
- The productivity of the crop is increased considerably.
- Superior quality produce can be obtained as they are grown under suitably controlled environment.
- Gadgets for efficient use of various inputs like water, fertilizers, seeds and plant protection chemicals can be well maintained in a green house.
- Effective control of pests and diseases is possible as the growing area is enclosed.
- Percentage of germination of seeds is high in greenhouses.
- Agricultural and horticultural crop production schedules can be planned to take advantage of the market needs.
- Different types of growing medium like peat mass, vermiculate, rice hulls and compost that are used in intensive agriculture can be effectively utilized in the greenhouse.
- Export quality produce of international standards can be produced in a green house.
- When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped heat.

- Greenhouses are suitable for automation of irrigation, application of other inputs and environmental controls by using computers and artificial intelligence techniques.
- Self-employment for educated youth.

1.5 Types of Greenhouse

Greenhouse structures of various types are used successfully for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be considered as the best. Different types of greenhouses are designed to meet the specific needs.

1.5.1 Greenhouse type based on shape

Greenhouses can be classified based on their shape or style. For the purpose of classification, the uniqueness of the cross section of the greenhouses can be considered as a factor. As the longitudinal section tend to be approximately the same for all types, the longitudinal section of the greenhouse cannot be used for classification. The cross sections depict the width and height of the structure and the length is perpendicular to the plane of cross section. Also, the cross section provides information on the overall shape of the structural members, such as truss or hoop, which will be repeated on every day. The commonly followed types of greenhouse based on shape are lean-to, even span, uneven span, ridge and furrow, saw tooth and quonset.

a) Lean-to type greenhouse

A lean-to design is used when a greenhouse is placed against the side of an existing building. It is built against a building, using the existing structure for one or more of its sides. It is usually attached to a house, but may be attached to other buildings. The roof of the building is extended with appropriate greenhouse covering material and the area is properly enclosed. It is typically facing south side. The lean-to type greenhouse is limited to single or double-row plant benches with a total width of 7 to 12 feet. It can be as long as the building it is attached to. It should face the best direction for adequate sun exposure.

The advantage of the lean-to type greenhouse is that, it usually is close to available electricity, water, and heat. It is a least expensive structure. This design makes the best use of sunlight and minimizes the requirement of roof supports. It has the following disadvantages: limited space, limited light, limited ventilation and temperature control. The height of the supporting wall limits the potential size of the design. Temperature control is more difficult because the wall that the greenhouse is built on, may collect the sun's heat while the translucent cover of the greenhouse may lose heat rapidly. It is a half greenhouse, split along the peak of the roof.

b) Even span type greenhouse

The even-span is the standard type and full-size structure, the two roof slopes are of equal pitch and width. This design is used for the greenhouse of small size, and it is constructed on level ground. It is attached to a house at one gable end. It can accommodate 2 or 3 rows of plant benches. The cost of an even-span greenhouse is more than the cost of a lean-to type, but it has greater flexibility in design and provides for more plants. Because of its size and greater amount of exposed glass area, the even-span will cost more to heat. The design has a better shape than a lean-to type for air circulation to maintain uniform temperatures during the winter heating season. A separate heating system is necessary unless the structure is very close to a heated building. It will house 2 side benches, 2 walks, and a wide center bench. Several single and multiple span types are available for use in various regions of India. For single span type the span in general, varies from 5 to 9 m, whereas the length is around 24 m. The height varies from 2.5 to 4.3 m.

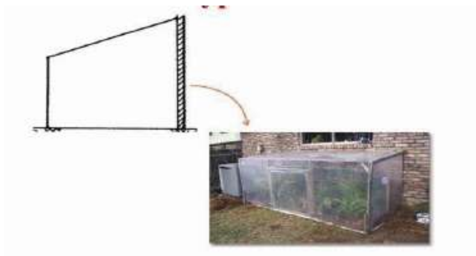


Fig. 1.1. Lean to type

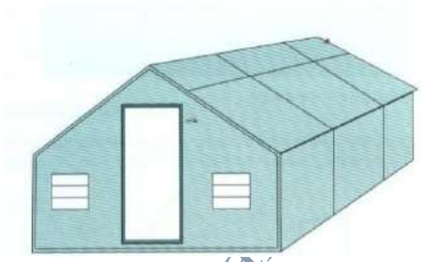


Fig1.2. Even span

c) Uneven span type greenhouse

This type of greenhouse is constructed on hilly terrain. The roofs are of unequal width; make the structure adaptable to the side slopes of hill. This type of greenhouses is seldom used nowadays as it is not adaptable for automation.

d) Ridge and furrow type greenhouse

Designs of this type use two or more A-frame greenhouses connected to one another along the length of the eave. The eave serves as furrow or gutter to carry rain and melted snow away. The side wall is eliminated between the greenhouses, which results in a structure with a single large interior, Consolidation of interior space reduces labour, lowers the cost of automation, improves personal management and reduces fuel consumption as there is less exposed wall area through which heat escapes. The snow loads must be taken into the frame specifications of these greenhouses since the snow cannot slide off the roofs as in case of individual free standing greenhouses, but melts away. In spite of snow loads, ridge and furrow greenhouses are effectively used in northern countries of Europe and in Canada and are well suited to the Indian conditions.

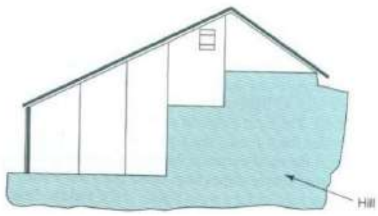


Fig.1.3. Uneven span

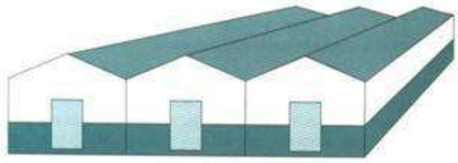


Fig.1.4. Ridge & furrow

e) Saw tooth type Greenhouse

These are also similar to ridge and furrow type greenhouses except that, there is provision for natural ventilation in this type. Specific natural ventilation flow path develops in a saw- tooth type greenhouse.

f) Quonset greenhouse

This is a greenhouse, where the pipe arches or trusses are supported by pipe purling running along the length of the greenhouse. In general, the covering material used for this type of greenhouses is polyethylene. Such greenhouses are typically less expensive than the gutter connected greenhouses and are useful when a small isolated cultural area is required. These houses are connected either in free, standing style or arranged in an interlocking ridge and furrow.In the interlocking type, truss members overlap sufficiently to allow a bed of plants to grow between the overlapping portions of adjacent houses. A single large cultural space thus exists for a set of houses in this type, an arrangement that is better adapted to the automation and movement of labour.

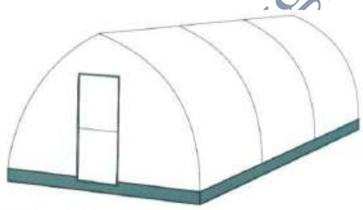


Fig.1.5. Quonset

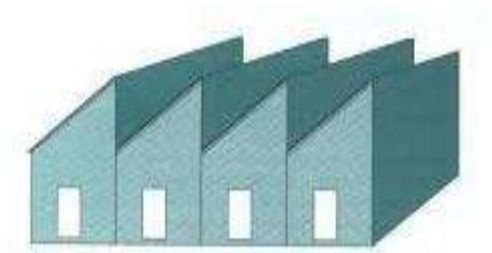


Fig.1.6. Saw tooth type

1.5. 2 Greenhouse type based on utility

Classification of greenhouses can be made depending on the functions or utilities. Of the different utilities, artificial cooling and heating of the greenhouse are more expensive and elaborate. Hence based on the artificial cooling and heating, greenhouses are classified as green houses for active heating and active cooling system.

a) Greenhouses for active heating

During the night time, air temperature inside greenhouse decreases. To avoid the cold bite to plants due to freezing, some amount of heat has to be supplied. The requirements for heating greenhouse depend on the rate at which the heat is lost to the outside environment. Various methods are adopted to reduce the heat losses, viz., using double layer polyethylene, thermo pane glasses (Two layers of factory sealed glass with dead air space) or to use heating systems, such as unit heaters, central heat, radiant heat and solar heating system.

b) Greenhouses for active cooling

During summer season, it is desirable to reduce the temperatures of greenhouse than the ambient temperatures, for effective crop growth. Hence suitable modifications are made in the green house so that large volumes of cooled air is drawn into greenhouse, This type of greenhouse either consists of evaporative cooling pad with fan or fog cooling. This greenhouse is designed in such a way that it permits a roof opening of 40% and in some cases nearly 100%.

1.5.3 Greenhouse type based on construction

The type of construction is predominantly influenced by the structural material, though the covering material also influences the type. Span of the house inurn dictates the selection of structural members and their construction. Higher the span, stronger should be the material and more structural members are used to make sturdy truss type frames. For smaller spans, simpler designs like hoops can be followed. Therefore based on construction, greenhouses can be broadly classified as wooden framed, pipe framed and truss framed structures.

a) Wooden framed structures

In general, for the greenhouses with span less than 6 m, only wooden framed structures are used. Side posts and columns are constructed of wood without the use of a truss. Pine wood is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for the construction.

b) Pipe framed structures

Pipes are used for construction of greenhouses, when the clear span is around 12m. In general, the side posts, columns, cross ties and purlins are constructed using pipes. In this type, the trusses are not used.

c) Truss framed structures

If the greenhouse span is greater than or equal to 15m, truss frames are used. Flat steel, tubular steel or angular iron is welded together to form a truss encompassing rafters, chords and struts. Struts are support members under compression and chords are support members under tension. Angle iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide truss frame houses of 21.3 m or more. Most of the glass houses are of truss frame type, as these frames are best suited for pre-fabrication.

1.5.4 Greenhouse type based on covering materials

Covering materials are the major and important component of the greenhouse structure. Covering materials have direct influence on the greenhouse effect inside the structure and they alter the air temperature inside the house. The types of frames and method of fixing also varies with the covering material. Based on the type of covering materials, the greenhouses are classified as glass, plastic film and rigid panel greenhouses.

a) Glass greenhouses

Only glass greenhouses with glass as the covering material existed prior to 1950. Glass as covering material has the advantage of greater interior light intensity. These greenhouses have higher air infiltration rate which leads to lower interior humidity and better disease prevention. Lean-to type, even span, ridge and furrow type of designs are used for construction of glass greenhouse.

b) Plastic film greenhouses

Flexible plastic films including polyethylene, polyester and polyvinyl chloride are used as covering material in this type of greenhouses. Plastics as covering material for greenhouses have become popular, as they are cheap and the cost of heating is less when compared to glass greenhouses. The main disadvantage with plastic films is its short life. For example, the best quality ultraviolet (UV) stabilized film can last for four years only. Quonset design as well as gutter-connected design is suitable for using this covering material.

c) Rigid panel greenhouses

Polyvinyl chloride rigid panels, fiber glass-reinforced plastic, acrylic and polycarbonate rigid panels are employed as the covering material in the quonset type frames or ridge and furrow type frame. This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse when compared to glass or plastic. High grade panels have long life even up to 20 years. The main disadvantage is that these panels tend to collect dust as well as to harbor algae, which results in darkening of the panels and subsequent reduction in the light transmission. There is significant danger of fire hazard.

1.5.5 Shading nets

There are a great number of types and varieties of plants that grow naturally in the most diverse climate conditions that have been transferred by modern agriculture from their natural habitats to controlled crop conditions. Therefore, conditions similar to the natural ones must be created for each type and variety of plant. Each type of cultivated plant must be given the specific type of shade required for the diverse phases of its development. The shading nets fulfill the task of giving appropriate micro-climate conditions to the plants. Shade nettings are designed to protect the crops and plants from UV radiation, but they also provide protection from climate conditions, such as temperature variation, intensive rain and winds. Better growth conditions can be achieved for the crop due to the controlled micro- climate conditions "created" in the covered area, with shade netting, which results in higher crop yields. All nettings are UV stabilized to fulfill expected lifetime at the area of exposure. They are characterized of high tear resistance, low weight for easy and quick installation with a 30-90% shade value range. A wide range of shading nets are available in the market which are defined on the basis of the percentage of shade they deliver to the plant growing under them.

Lecture No.2

Plant response to greenhouse environments - light, temperature, relative humidity, ventilation and carbon dioxide and environmental requirement of agriculture and horticulture crops inside green houses.

The productivity of a crop is influenced not only by its heredity but also by the microclimate around it. The components of crop microclimate are light, temperature, air compositions and the nature of the root medium. In open fields, only manipulation of nature of the root medium by tillage, irrigation and fertilizer application is possible. The closed boundaries in greenhouse permit control of any one or more of the components of the micro climate.

2.1 Light

The visible light of the solar radiation is a source of energy for plants. Light energy, carbon dioxide (Co_2) and water all enter in to the process of photosynthesis through which carbohydrates are formed. The production of carbohydrates from carbon dioxide and water in the presence of chlorophyll, using light energy is responsible for plant growth and reproduction. The rate of photosynthesis is governed by available fertilizer elements, water, carbon dioxide, light and temperature.

The photosynthesis reaction can be represented as follows

$$Co_2 + \text{water} + \text{light energy} \xrightarrow[\text{Plant nutrients}]{\text{Chlorophyll}} \text{carbohydrates} + \text{oxygen}$$

Considerable energy is required to reduce the carbon that is combined with oxygen in CO_2 gas to the state in which it exists in the carbohydrate. The light energy thus utilized is trapped in the carbohydrate. If the light intensity is diminished, photosynthesis slows down and hence the growth. If higher than optimal light intensities are provided, growth again slows down because of the injury to the chloroplasts.

The light intensity is measured by the international unit known as Lux. It is direct illumination on the surrounding surface that is one meter from a uniform point source of 1 international candle. Green house crops are subjected to light intensities varying from 129.6klux on clear summer days to 3.2 Klux on cloudy winter days. For most crops, neither condition is ideal. Many crops become light saturated, in other words, photosynthesis does not increase at light intensities higher than 32.2klux. Rose and carnation plants will grow well under summer light intensities. In general, for most other crops foliage is deeper green if the greenhouse is shaded to the extent of about 40% from mid spring (May) to mid fall (August and September). Thus, it is apparent that light intensity requirements of photosynthesis are vary considerably from crop to crop.

Light is classified according to its wave length in nanometers (nm). Not all light useful in photosynthesis process. UV light is available in the shorter wavelength range, i.eless than 400nm. Large of quantities of it is harmful to the plants. Glass screens are opaque to the most UV light and light below the range of 325 nm. Visible and white light has wavelength of 400 to 700nm.Far red light (700 to 750nm) affects plants, besides causing photosynthesis. Infrared of longer wavelengths are not involved in the plant process. It is primarily, the visible spectrum of light that is used in photosynthesis. In the blue and red bands, the photosynthesis activity is higher, when the blue light (shorter wavelength) alone is supplied to plants, the growth is retarded, and the plant becomes hard and dark in colour. When the plants are grown under red light (longer wavelength), growth is soft and internodes are long, resulting in tall plants. Visible light of all wavelengths is readily utilized in photosynthesis.

2.2 Temperature

Temperature is a measure of level of the heat present. All crops have temperature range in which they can grow well. Below this range, the plant life process stop due to ice formation within the tissue and cells are possibly punctured by ice crystals. At the upper extreme, enzymes become inactive, and again process essential for life cease. Enzymes are biological reaction catalyst and are heat sensitive. All biochemical reactions in the plant are controlled by the enzymes. The rate of reactions controlled by the enzyme often double or triple for each rise of temperature by 10^0C, until optimum temperature is reached. Further, increase in temperature begins to suppress the reaction and finally stop it.

As a general rule, green house crops are grown at a day temperature, which are 3 to 6^0C higher than the night temperature on cloudy days and 8^0C higher on clear days. The night temperature of greenhouse crops is generally in the range of 7 to 21^0C. Primula, mathiolaincana and calceolaria grow best at 7^0C, carnation and cineraria at 10^0C, rose at 16^0C, chrysanthemum and poinsettia at 17 to 18^0C and African violet at 21 to 22^0C.

2.3 Relative humidity

As the green house is a closed space, the relative humidity of the green house air will be more when compared to the ambient air, due to the moisture added by the evapo-transpiration process. Some of this moisture is taken away by the air leaving from the green house due to ventilation. Sensible heat inputs also lower the relative humidity of the air to some extent. In order to maintain the desirable relative humidity levels in the green houses, processes like humidification or dehumidification are carried out. For most crops, the acceptable range of relative humidity is between 50 to 80%. However for plant propagation work, relative humidity up to 90% may be desirable.

In summer, due to sensible heat addition in the daytime, and in winters for increasing the night time temperatures of the green house air, more sensible heat is added causing a reduction in the relative humidity of the air. For this purpose, evaporative cooling pads and fogging system of humidification are employed. When the relative humidity is on the higher side, ventilators, humidifiers and cooling coils are used for de- humidification.

2.4 Ventilation

A greenhouse is ventilated for either reducing the temperature of the green house air or for replenishing carbon dioxide supply or for moderating the relative humidity of the air. Air temperatures above 35^0C are generally not suited for the crops in green house. It is quite possible to bring the green house air temperature below this upper limit during spring and autumn seasons simply by providing adequate ventilation to the green house. The ventilation in a greenhouse can either be natural or forced. In case of small green houses (less than 6m wide) natural ventilation can be quite effective during spring and autumn seasons. However, fan ventilation is essential to have precise control over the air temperature, humidity and carbon dioxide levels.

2.5 Carbon dioxide

Carbon is an essential plant nutrient and is present in the plant in greater quantity than any other nutrient. About 40% of the dry matter of the plant is composed of carbon. Under normal conditions, carbon dioxide (CO_2) exits as a gas in the atmosphere slightly above 0.03% or 345ppm. During the day, when photosynthesis occurs under natural light, the plants in a greenhouse draw down the level of Co_2 to below 200ppm. Under these circumstances, infiltration or ventilation increases **carbon dioxide levels,** when the outside air is brought in, to maintain the ambient levels of CO_2. If the level of CO_2 is less than ambient levels, CO_2 may retard the plant growth. In cold climates, maintaining ambient levels of CO_2 by providing ventilation may be un- economical, due to the necessity of heating the incoming air in order to maintain proper growing temperatures. In such regions, enrichment of the green house with CO2 is followed. The exact CO_2level needed for a given crop will vary, since it must be correlated with other variables in greenhouse production such as light, temperature, nutrient levels, cultivar and degree of maturity. Most crops will respond favorably to Co_2 at 1000 to 1200 ppm.

Lecture No.3

Planning and design of greenhouses, Design criteria of greenhouse for heating and cooling purposes.

3.1 Planning & design of greenhouse

A greenhouse, is basically the purpose of providing and maintaining a growing environment that will result in optimum production at maximum yield. The agriculture in the controlled environment is possible in all the regions irrespective of climate and weather. It is an enclosing structure for growing plants, greenhouse must admit the visible light portion of solar radiation for the plant photosynthesis and, therefore, must be transparent. At the same time, to protect the plants, a greenhouse must be ventilated or cooled during the day because of the heat load from the radiation. The structure must also be heated or insulated during cold nights. A greenhouse acts as a barrier between the plant production areas and the external or the general environment.

3.1.1 Site selection and orientation

A greenhouse is designed to withstand local wind, snow and crop loads for a specific cropping activity. In this way, the structure becomes location and crop specific. The building site should be as level as possible to reduce the cost of grading, and the site should be well aerated and should receive good solar radiation. Provision of a drainage system is always possible. It is also advisable to select a site with a natural windbreak. In regions where snow is expected, trees should be 30.5 m away in order to keep drifts back from the greenhouses. To prevent shadows on the crop, trees located on the east, south, or west sides should be at a distance of 2.5 times their height.

3.2.2 Structural design

The most important function of the greenhouse structure and its covering is the protection of the crop against hostile weather conditions (low and high temperatures, snow, hail, rain and wind), diseases and pests. It is important to develop greenhouses with a maximum intensity of natural light inside. The structural parts that can cast shadows in the greenhouse should be minimized. The different structural designs of greenhouse based on the types of frames are available. A straight side wall and an arched roof is possibly the most common shape for a greenhouse, but the gable roof is also widely used**.** Both structures can be free standing or gutter connected with the arch roof greenhouse. The arch roof and hoop style greenhouses are most often constructed of galvanized iron pipe. If tall growing crops are to be grown in a greenhouse or when benches are used, it is best to use a straight side wall structure rather than a hoop style house this ensures the best operational use of the greenhouse. A hoop type greenhouse is suitable for low growing crops, such as lettuce, or for nursery stock which are housed throughout the winter in greenhouses located in extremely cold regions. A gothicarch frame structure can be designed to provide adequate side wall height without loss of strength to the structure. Loads in designing the greenhouse structures include the weight of the structure itself and, if supported by the structure, loads of the equipment for the heating and ventilation and water lines. Greenhouse structures should be designed to resist a 130 km/h wind velocity. The actual load depends on wind angle, greenhouse shape and size, and the presence or absence of openings and wind breaks.

The ultimate design of a greenhouse depends on the following aspects:

1. The overall structural design and the properties of the individual structural components.
2. The specific mechanical and physical properties which determine the structural behaviour of the covering materials.
3. The specific sensitivity of the crop to light and temperature to be grown in the greenhouse.
4. The specific requirements relevant to the physical properties of the covering material.
5. The agronomic requirements of the crop.

3.3.3 Covering materials

The following factors are to be considered while selecting the greenhouse covering material i.e., light, transmission, weight, resistant to impact, and durability to outdoor weathering and thermal stability over wide range of temperatures. Before selecting the covering material, two important points should be taken into consideration: the purpose for which greenhouse facility is intended and service life of material. In temperate regions where high temperatures are required, the covering material with high light transmission and far IR absorption must be selected. Also the loss of heat by conduction should be minimum.

Covering material Life span

Glass and acrylic sheet	20 years
Polycarbonate and fiberglass-reinforced polyester sheet	5-12 years
Polyethylene	2-6 months
Polyethylene stabilized for UV rays	2-3 years

The ideal greenhouse selective covering material should have the following properties:

1. It should transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.
2. It should absorb the small amount of UV in the radiation and convert a portion of it to fluoresce into visible light, useful for plants.
3. It should reflect or absorb IR radiation which are not useful to plants and which causes greenhouse interiors to overheat.
4. Should be of minimum cost.
5. Should have usable life of 10 to 20 years.

Precise control of various parameters of greenhouse environment is necessary to optimize energy inputs and thereby maximize the economic returns. Basically, the objective of environmental control is to maximize the plant growth. The control of greenhouse environment means the control of temperature, light, air composition and nature of the root medium. A green house is essentially meant to permit at least partial control of microclimate within it. Obviously green houses with partial environmental control are more common and economical. From the origin of greenhouse to the present there has been a steady evolution of controls. Five stages in this evolution include manual controls, thermostats, step-controllers, dedicated microprocessors and computers. This chain of evolution has brought about a reduction in control labour and an improvement in the conformity of greenhouse environments to their set points. The benefits achieved from green house environmental uniformity are better timing and good quality of crops, disease control and conservation of energy.

3.2 Active summer cooling systems

Active summer cooling is achieved by evaporative cooling process .The evaporative cooling systems developed are to reduce the problem of excess heat in green house. In this process cooling takes place when the heat required for moisture evaporation is derived from the surrounding environment causing a depression in its temperature. The two active summer cooling systems in use presently are fan-and pad and fog systems. In the evaporative cooling process the cooling is possible only up to the wet bulb temperature of the incoming air.

3.2.1 Fan-and Pad cooling system

The fan and pad evaporative cooling system has been available since 1954 and is still the most common summer cooling system in green houses. Along one wall of the green house, water is passed through a pad that is usually placed vertically in the wall. Traditionally, the pad was composed of excelsior (**wood shreds**), but today it is commonly made of a cross-fluted-cellulose materialsomewhat similar in appearance to corrugated card board. Exhaust fans are placed on the opposite wall. Warm outside air is drawn in through the pad. The supplied water in the pad, through the process of evaporation, absorbs heat from the air passing through the pad as well as from surroundings of the pad and frame, thus causing the cooling effect. Khus-khus grass mats can also be used as cooling pads.

3.2.2 Fog cooling system

The fog evaporative cooling system, introduced in green houses in 1980, operates on the same cooling principle as the fan and pad cooling system but uses quite different arrangement. A high pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 microns using suitable nozzles. These droplets are sufficiently small to stay suspended in air while they are evaporating. Fog is dispersed throughout the greenhouse, cooling the air everywhere. As this system does not wet the foliage, there is less scope for disease and pest attack. The plants stay dry throughout the process. This system is equally useful for seed germination and propagation since it eliminates the need for a mist system.

Both types of summer evaporative cooling system can reduce the greenhouse air temperature. The fan-and pad system can lower the temperature of incoming air by about 80% of the difference between the dry and wet bulb temperatures while the fog cooling system can lower the temperature by nearly 100% difference. This is, due to the fact that complete evaporation of the water is not taking place because of bigger droplet size in fad and pad, whereas in the fog cooling system, there will be complete evaporation because of the minute size of the water droplets. Thus lesser the dryness of the air, greater evaporative cooling is possible.

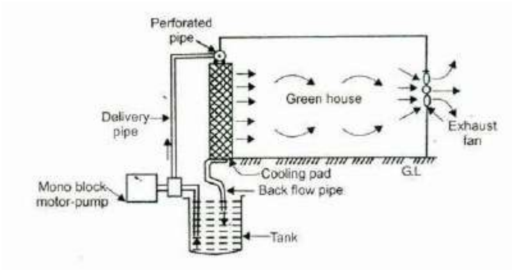


Fig.3.1. Fan &pad cooling system

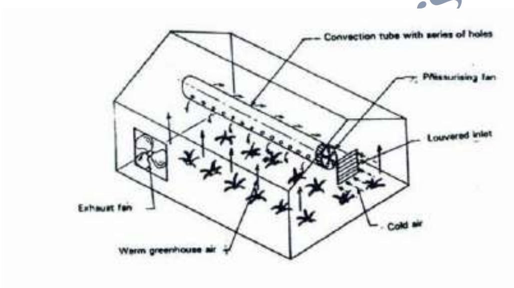


Fig.3.2.Convection type cooling system

3.3 Active winter cooling systems

Excess heat can be a problem during the winter. In the winter, the ambient temperature will be below the desired temperature inside the green house. Owing to the greenhouse effect the entrapment of solar heat can rise the temperature to an injurious level if the green house is not ventilated. The actual process in winter cooling is tempering the excessively cold ambient air before it reaches the plant zone. Otherwise, hot and cold spots in the green house will lead to uneven crop timing and quality. This mixing of low temperature ambient air with the warm inside air cools the green house in the winter. Two active winter cooling systems commonly employed are convection tube cooling and horizontal air flow (HAF) fan cooling systems.

3.3.1 Convection tube cooling

The general components of convection tube are the louvered air inlet, a polyethylene convection tube with air distribution holes, a pressurizing fan to direct air in to the tube under pressure, and an exhaust fan to create vacuum. When the air temperature inside the green house exceeds the set point, the exhaust fan starts functioning thus creating vacuum inside the green house. The louver of the inlet in the gable is then opened through which cold air enters due to the vacuum. The pressurizing fan at the end of the clear polyethylene convection tube, operates to pick up the cool air entering the louver. A proper gap is available for the air entry, as the end of the convection tube is separated from the louvered inlet by 0.3 to 0.6m and the other end of the tube is sealed. Round holes of 5 to 8 cm in diameter are provided in pairs at opposite sides of the tube spaced at 0.5 to 1m along the length of the tube.

Cold air under pressure in the convection tube shoots out of holes on either side of the tube in turbulent jets. In this system, the cold air mixes with the warm greenhouse air well above the plant height. The cool mixed air, being heavier gently flows down to the floor level, effects the complete cooling of the plant area. The pressurizing fan forcing the incoming cold air in to the convection tube must be capable of moving at least the same volume of air as that of the exhaust fan, thereby avoiding the development of cold spots in the house. When cooling is not required, the inlet louver closes and the pressurizing fan continues to circulate the air within the greenhouse. The process minimizes the temperature gradient at difference levels. The circulation of air using convection tube consumes more power than a circulation system.

3.3.2 Horizontal air flow cooling

HAF cooling system uses small horizontal fans for moving the air mass and is considered to be an alternative to convection tube for the air distribution. In this method the green house may be visualized as a large box containing air and the fans located strategically moves the air in a circular pattern. This system should move air at 0.6 to 0.9 $m^3/min/m^2$ of the green house floor area. Fractional horse power of fans is 31 to 62 W (1/30 to 1/15hp) with a blade diameter of 41cm are sufficient for operation. The fans should be arranged in such a way that air flows are directed along the length of the greenhouse and parallel to the ground. The fans are placed at 0.6 to 0.9m above plant height and at intervals of 15m.They are arranged such that the air flow is directed by one row of the fans along the length of the greenhouse down one side to the opposite end and then back along the other side by another row of fans. Greenhouses of larger widths may require more number of rows of fans along its length.

Temperatures at plant height are more uniform with HAF system than with convection tube system. The HAF system makes use of the same exhaust fans, inlet louvers and controls as the convection tube system. The only difference is the use of HAF fans in the place of convection tubes for the air distribution. Cold air entering through the louvers located at the higher level in the gables of the green house is drawn by the air circulation created by the network of HAF fans and to complete the cycle, proper quantity of air is let out through the exhaust fans. The combined action of louvered inlet, HAF fans and the exhaust fans distribute the cold air throughout the greenhouse.

Similarly to the convection tubes, the HAF fans can be used to distribute heat in the green house When neither cooling nor heating is required, the HAF fans or convection tube can be used to bring warm air down from the upper level of the gable and to provide uniform temperature in the plant zone.

3.4 Greenhouse ventilation

Ventilation is the process of allowing the fresh air to enter in to the enclosed area by driving out the air with undesirable properties. In the greenhouse context, ventilation is essential for reducing temperature, replenishing CO_2 and controlling relative humidity. Ventilation requirements for green houses vary greatly, depending on the crop grown and the season of production. The ventilation system can be either a passive system (natural Ventilation) or an active system (forced ventilation) using fans. Usually green houses that are used seasonally employ natural ventilation only. The plant response to specific environment factor is related to the physiological processes and hence the latter affects the yield and quality. Hence, controlling of environment is of great importance to realize the complete benefit of CEA. Manual maintenance of uniform environmental condition inside the green house is very difficult and cumbersome. A poor maintenance results in less crop production, low quality and low income. For effective control of automatic control systems like microprocessor and computer are used presently to maintain the environment.

3.4.1 Natural ventilation

In the tropics, the sides of greenhouse structures are often left open for natural ventilation. Tropical greenhouse is primarily a rain shelter, a cover of polyethylene over the crop to prevent rainfall from entering the growing area. This mitigates the problem of foliage diseases. Ventilators were located on both roof slopes adjacent to the ridge and also on both side walls of the greenhouse. The ventilators on the roof as well as those on the side wall accounts, each about 10% of the total roof area. During winter cooling phase, the south roof ventilator was opened in stages to meet cooling needs.

When greater cooling was required, the north ventilator was opened in addition to the south ventilator. In summer cooling phase, the south ventilator was opened first, followed by the north ventilator. As the incoming air moved across the greenhouse, it was warmed by sunlight and by mixing with the warmer greenhouse air. With the increase in temperature, the incoming air becomes lighter and rises up and flows out through the roof ventilators. This sets up a chimney effect which in turn draws in more air from the side ventilators creating a continuous cycle. This system did not adequately cool the greenhouse. On hot days, the interior walls and floor were frequently injected with water to help cooling.

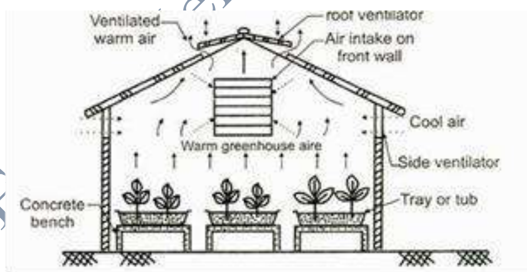


Fig.3.3.Natural ventilation

3.4.1.1 Roll up side passive ventilation in poly houses

In roll up method of ventilation, allowing the air to flow across the plants. The amount of ventilation on one side, or both sides, may be easily adjusted in response to temperature, prevailing wind and rain. During the periods of excessive heat, it may be necessary to roll the sides up almost to the top. Passive ventilation can also be accomplished by manually raising or parting the polyethylene sheet. The open vent areas must be covered with screens to prevent virus diseases. The holes must be large enough to permit free flow of air. Screens with small holes blocks air movement and cause a buildup of dust. Rollup side passive ventilation on plastic greenhouses is only effective on free standing greenhouses and not on gutter connected greenhouses.

3.4.2 Forced Ventilation

In forced or active ventilation, mechanical devices such as fans are used to expel the air. This type of ventilation can achieve uniform cooling. These include summer fan-and-pad and fog cooling systems and the winter convection tube and horizontal airflow systems. For mechanical ventilation, low pressure, medium volume propeller blade fans, both directly connected and belt driven are used for greenhouse ventilation. They are placed at the end of the greenhouse opposite to the air intake, which is normally covered by gravity or motorized louvers. The fans vents, or louvers, should be motorized, with their action controlled by fan operation. Motorized louvers prevent the wind from opening the louvers, especially when heat is being supplied to the green house. Wall vents should be placed continuously across the end of the greenhouse to avoid hot areas in the crop zone.

Evaporative cooling in combination with the fans is called as fan-and-pad cooling system. The fans and pads are usually arranged on opposite walls of the greenhouse. The common types of cooling pads are made of excelsior (wood fiber), aluminum fiber, glass fiber, plastic fiber and cross-fluted cellulose material. Evaporative cooling systems are especially efficient in low humidity environments. There is growing interest in building greenhouses combining both passive (natural) and active (forced) systems of ventilation. Passive ventilation is utilized as the first stage of cooling, and the fan-pad evaporative cooling takes over when the passive system is not providing the needed cooling. At this stage, the vents for natural ventilation are closed. When both options for cooling are designed in greenhouse construction, initial costs of installation will be more. But the operational costs are minimized in the long run, since natural ventilation will, most often meet the needed ventilation requirements.

Fogging systems is an alternative to evaporative pad cooling. They depend on absolutely clean water, Free of any soluble salts, in order to prevent plugging of the mist nozzles. Such cooling systems are not as common as evaporative cooling pads, but when they become more cost competitive, they will be adopted widely. Fogging systems are the second stage of cooling when passive systems are inadequate.

3.4.3 Microprocessors

Dedicated microprocessors can be considered as simple computers. A typical microprocessor will have a keypad and a two or three line liquid crystal display of, sometimes, 80-character length for programming. They generally do not have a floppy disk drive. They have more output connections and can control up to 20 devices. With this number of devices, it is cheaper to use a microprocessor. They can receive signals of several types, such as, temperature, light intensity, rain and wind speed. They permit integration of the diverse range of devices, which is not possible with thermostats. The accuracy of the microprocessor for temperature control is quite good. Unlike a thermostat, which is limited to a bimetallic strip or metallic tube for temperature sensing and its mechanical displacement for activation, the microprocessor often uses a thermistor. The bimetallic strip sensor has less reproducibility and a greater range between the ON and OFF steps. Microprocessors can be made to operate various devices, for instance, a microprocessor can operate the ventilators based on the information from the sensor for the wind direction and speed. Similarly a rain sensor can also activate the ventilators to prevent the moisture sensitive crop from getting wet. A microprocessor can be set to activate the CO_2 generator when the light intensity exceeds a given set point, a minimum level for photosynthesis.

3.4.4 Computers

Now-a-days, computer control systems are common in greenhouse installation throughout Europe, Japan and the United States. Computer systems can provide fully integrated control of temperature, humidity, irrigation and fertilization, CO_2, light and shade levels for virtually any size growing facility. Precise control over a growing operation enables growers to realize saving of 15 to 50% in energy, water, chemical and pesticide applications. Computer controls normally help to achieve greater plant consistency, on-schedule production, higher overall plant quality and environmental purity.

A computer can control hundreds of devices within a greenhouse (vents, heaters, fans, hot water mixing valves, irrigation valves, curtains and lights) by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, CO_2 levels and even the time of the day or night. Computer systems receive signals from all sensors, evaluate all conditions and send appropriate commands every minute to each piece of equipment in the greenhouse range thus maintaining ideal conditions in each of the various independent greenhouse zones defined by the grower (Fig.9). Computers collect and record data provided by greenhouse production managers. Such a data acquisition system will enable the grower to gain a comprehensive knowledge of all factors affecting the quality and timeliness of the product. A computer produces graphs of past and current environmental conditions both inside and outside the greenhouse complex. Using a data printout option, growers can produce reports and summaries of environmental conditions such as temperature, humidity and the CO_2 status for the given day, or over a longer period of time for current or later use.

As more environmental factor in the greenhouse is controlled, there comes a stage when individual controls cannot be coordinated to prevent system overlap. An example is the greenhouse thermostat calling for heating while the exhaust fans are still running. With proper software program, which uses the environmental parameters as input from different sensors, can effectively coordinate all the equipment without overlap and precisely control all parameters affecting plant development as desired. Despite the attraction of the computer systems, it should be remembered that the success of any production system is totally dependent on the growersknowledge of the system and the crop management. Computers can only assist by adding precision to the overall greenhouse production practice, and they are only as effective as the software it runs and the effectively of the operator. The advantages and disadvantages of computerized control system are as follows:

Advantages

- The computer always knows what all systems are doing and, if programmed properly, can coordinate these systems without overlap to provide the optimum environment.
- The computer can record the environmental data, which can be displayed to show current conditions or stored and processed ones to provide a history of the cropping period, and if desired it may also be displayed in table or graph form.
- A high-speed computer with networking facility can control several remotely located greenhouses, by placing the computer in a central area and the results can be monitored frequently by the management.
- With proper programming and sensing systems, the computer can anticipate weather changes and make adjustments in heating and ventilation systems, thus saving the energy.
- The computer can be programmed to sound an alarm if conditions become unacceptable to and to detect sensor and equipment failure.

Disadvantages

- High initial cost investment.
- Requires qualified operators.
- High maintenance, care and precautions are required.
- Not economical for small scale and seasonal production.

Lecture No.4

Irrigation system used in greenhouses-rules of watering, hand watering, perimeter watering, overhead sprinklers, boom watering and drip irrigation.

A well-designed irrigation system will supply the precise amount of water needed each day throughout the year. The quantity of water needed would depend on the growing area, the crop, weather conditions, the time of year and whether the heating or ventilation system is operating. Water needs are also dependent on the type of soil or soil mix and the size and type of the container or bed. Watering in the green house most frequently accounts for loss in crop quality. Though the operation appears to be the simple, proper decision should be taken on how, when and what quantity to be given to the plants after continuous inspection and assessment .Since under watering (less frequent) and over watering (more frequent) will be injurious to the crops, the rules of watering should be strictly adhered to. Several irrigation water application systems, such as hand writing, perimeter watering, overhead sprinklers, boom watering and drip irrigation, over sprinklers, boom watering and drip irrigation which are currently in use.

4.1 Rules of Watering

The following are the important rules of application of irrigation.

Rule 1: Use a well drained substrate with good structure

If the root substrate is not well drained and aerated, proper watering cannot be achieved. Hence substrates with ample moisture retention along with good aeration are indispensable for proper growth of the plants. The desired combination of coarse texture and highly stable structure can be obtained from the formulated substrates and not from field soil alone.

Rule 2: **Water thoroughly each time**

Partial watering of the substrates should be avoided; the supplied water should flow from the bottom in case of containers, and the root zone is wetted thoroughly in case of beds. As a rule, 10 to 15% excess of water is supplied. In general, the water requirement for soil based substrates is at a rate of 20 l/m^2 of bench, 0.3 to 0.35 litres per 16.5 cm diameter pot.

Rule 3: Water just before initial moisture stress occurs

Since over watering reduces the aeration and root development, water should be applied just before the plant enters the early symptoms of water stress. The foliar symptoms, such as texture, colour and turbidity can be used to determine the moisture stress, but vary with crops. For crops that do not show any symptoms, colour, feel and weight of the substrates are used for assessment.

4.2 Hand watering

The most traditional method of irrigation is hand watering and in present days is uneconomical. Growers can afford hand watering only where a crop is still at a high density, such as in seed beds, or when they are watered at a few selected pots or areas that have dried sooner than others. In all cases, the labour saved will pay for the automatic system in less than one year. It soon will become apparent that this cost is too high. In addition to this deterrent to hand watering, there is great risk of applying too little water or of waiting too long between waterings. Hand watering requires considerable time and is very boring. It is usually performed by inexperienced employees, who may be tempted to speed up the job or put it off to another time. Automatic watering is rapid and easy and is performed by the grower itself. Where hand watering is practiced, a water breaker should be used on the end of the hose. Such a device breaks the force of the water, permitting a higher flow rate without washing the root substrate out of the bench or pot. It also lessens the risk of disrupting the structure of the substrate surface.

4.3 Perimeter watering

Perimeter watering system can be used for crop production in benches or beds. A typical system consists of a plastic pipe around the perimeter of a bench with nozzles that spray water over the substrate surface below the foliage.Either polythene or PVC pipe can be used. While PVC pipe has the advantage of being very stationery, polythene pipe tends to roll if it is not anchored firmly to the side of the bench. This causes nozzles to rise or fall from proper orientation to the substrate surface. Nozzles are made of nylon or a hard plastic and are available to put out a spray are of 180°, 90° or 45°. Regardless of the types of nozzles used, they are staggered across the benches so that each nozzle projects out between two other nozzles on the opposite side. Perimeter watering systems with 180° nozzles require one water valve for benches up to 30.5 m in length.

4.4 Overhead sprinklers

While the foliage on the majority of crops should be kept dry for disease control purposes, a few crops do tolerate wet foliage. These few crops can most easily and cheaply be irrigated from overhead. Bedding plants, azalea liners, and some green plants are crops commonly watered from overhead. A pipe is installed along the middle of a bed. Riser pipes are installed periodically to a height well above the final height of the crop (Fig.14). A total height of 0.6 m is sufficient for bedding plants flats and 1.8 m for fresh flowers. A nozzle is installed at the top of each riser. Nozzles vary from those that throw a 360° pattern continuously to types that rotate around a 360° circle. Trays are sometimes placed under pots to collect water that would otherwise fall on the ground between pots and wasted. Each tray is square and meets the adjacent tray. In this way nearly all water is intercepted. Each tray has a depression to accommodate the pot and is then angled upward from the pot toward the tray perimeter. The trays also have drain holes, which allow drainage of excess water and store certain quantity, which is subsequently absorbed by the substrate.

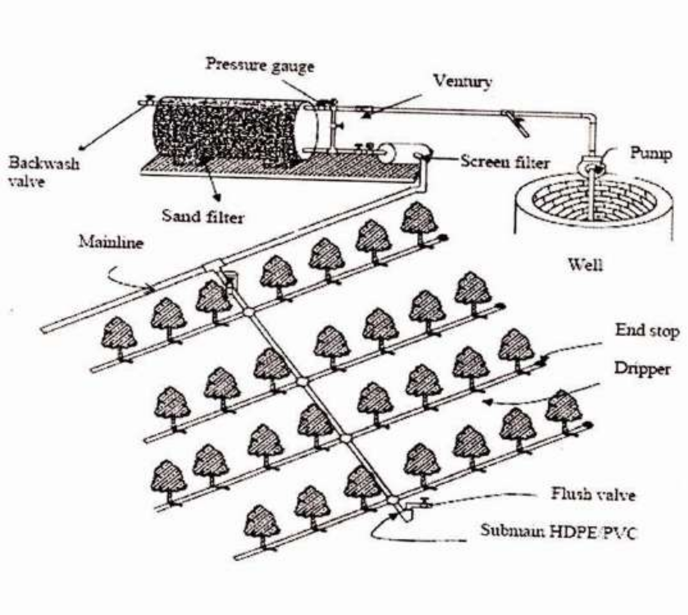
4.5 Boom watering

Boom watering can function either as open or a closed system, and is used often for the production of seedlings grown in plug trays. Plug trays are plastic trays that have width and length dimensions of approximately 30 × 61 cm, a depth of 13 to 38 mm, and contain about 100 to 800 cells. Each seedling is grown in its own individual cell. Precision of watering is extremely important during the 2 to 8 week production time of plug seedlings. A boom watering system generally consists of a water pipe boom that extends from one side of a greenhouse bay to the other. The pipe is fitted with nozzles that can spray either water or fertilizer solution down onto the crop. The boom is attached at its center point to a carriage that rides along rails, often suspended above the centre walk of the greenhouse bay. In this way, the boom can pass from one end of the bay to the other. The boom is propelled by an electric motor. The quantity of water delivered per unit area of plants is adjusted by the speed at which the boom travels.

4.6 Drip Irrigation

Drip irrigation, often referred to as trickle irrigation, consists of laying plastic tubes of small diameter on the surface or subsurface of the field or greenhouse beside or beneath the plants. Water is delivered to the plants at frequent intervals through small holes or emitters located along the tube. Drip irrigation systems are commonly used in combination with protected agriculture, as an integral and essential part of the comprehensive design. When using plastic mulches, row covers, or greenhouses, drip irrigation is the only means of applying uniform water and fertilizer to the plants. Drip irrigation provides maximum control over environment variability; it assures optimum production with minimal use of water, while conserving soil and fertilizer nutrients; and controls water, fertilizer, labour and machinery costs. Drip irrigation is the best means of water conservation. In general, the application efficiency is 90 to 95%, compared with sprinkler at 70% and furrow irrigation at 60 to 80%, depending on soil type, level of field and how water is applied to the furrows. Drip irrigation is not only recommended for protected agriculture but also for open field crop production, especially in arid and semi-arid regions of the world. One of the disadvantages of drip irrigation is the initial cost of equipment per acre, which may be higher than other systems of irrigation. However, these costs must be evaluated through comparison with the expense of land preparation and maintenance often required by surface irrigation. Basic equipment for irrigation consists of a pump, a main line, delivery pipes, manifold, and drip tape laterals or emitters as shown in figure.

The head, between the pump and the pipeline network, usually consists of control valves, couplings, filters, time clocks, fertilizer injectors, pressure regulators, flow meters, and gauges. Since the water passes through very small outlets in emitters, it is an absolute necessity that it should be screened, filtered, or both, before it is distributed in the pipe system. The initial field positioning and layout of a drip system is influenced by the topography of the land and the cost of various system configurations



4.7 Misters and Foggers

Fogging system is fairly effective and uniform method of greenhouse cooling that provides a reasonable increase in relative humidity inside greenhouse. Foggers are connected to lateral with micro-tube and it is hanging over iron wire in greenhouse (3 m above). Misters are attached to stakes in beds. Foggers and misters spray about 70 micron size of water in air and evaporated before falling onto the crop canopy. Foggers and misters are equipped with an anti-leak devices which does not allow flow of water droplets to fall down after the system is switched off. They have small discharge rate with small area coverage. The operating pressure of fogger and mister varies from 3 to 5 kg/cm^2.Generally the time of operation of foggers and misters are 30 to 60 sec, three or four times in an hour at specific time interval.

Lecture No.5

Design criteria and constructional details of greenhouses - construction of pipe framed greenhouses, material requirement, preparation of materials and procedure of erection.

The term greenhouse refers to a structure covered with a transparent material for the purpose of admitting natural light for plant growth. Two or more greenhouses in one location are referred to as a greenhouse range. A building associated with the greenhouses that is used for storage or for operations in support of growing of plants, is referred to as a service building or head house.

5.1 Design criteria of construction

For locating the greenhouse, a piece of land larger than the growersimmediate need should be acquired. The ultimate size of the greenhouse range should be estimated. Area should then be added to this estimated figure to accommodate service buildings, storage, access drives and a parking lot. The floor area of service buildings required for small firms is about 13% of the greenhouse floor area, and it decreases with the increase in size of the firm. On an average, service buildings occupy 10% of the growing area. The service building is centrally located in a nearly square design of the firm, which minimizes distance of movement of plants and materials. Doors between the service buildings and the greenhouse should be wide enough to facilitate full use of the corridor width. Doors at least 3.1 m wide and 2.7 m high are common. It is good to have the greenhouse gutter at least 3.7 m above the floor to accommodate automation and thermal blanket and still leave the room for future innovations.

5.2 Construction of glass greenhouses

Glass greenhouses have an advantage of greater interior light intensity over plastic panel and film plastic covered greenhouses. Glass greenhouses tend to have a higher air infiltration rate, which leads to lower interior humidity, which is advantageous for disease prevention. On the other hand, glass greenhouses have a higher initial cost than double-layer film plastic greenhouses. While comparing the price of a glass greenhouse to a film plastic greenhouse, one needs to take into account the initial purchase price of each as well as the cost of re-covering the film plastic greenhouse every three to four years.

Several types of glass greenhouses are designed to meet specific needs. A lean-to-type design is used when a greenhouse is placed against the side of an existing building. This design makes the best use of sunlight and minimizes the requirements for roof supports. It is found mostly in the retail industry. An even-span greenhouse is one in which the two roof slopes are of equal pitch and width. By comparison, a un-even-span greenhouse has roofs of unequal width, which makes the structure adaptable to the side of a hill. This style is seldom used today because such greenhouses are not adaptable to automation. Finally, a ridge-and- furrow design uses, two or more A- frame greenhouses connected to one another along the length of the eave. The sidewall is eliminated between greenhouses, which results in a structure with a single large interior. Basically, three frame types are used in glass greenhouses, which are wood frames (6.1 m in width), pipe frames (12.2 m in width) and truss frames (15.2 m in width). Latest glass greenhouses are primarily of the truss frame type. Truss frame greenhouses are best suited for prefabrication.

All-metal greenhouses proved cheaper to maintain since they required no painting. At present, virtually all glass greenhouse construction is of the metal type. The structural members of the glass greenhouse cast shadows that reduce plant growth during the dark months of the year. Aluminum sash bars are stronger than wooden ones; hence wider panels of glass can be used with aluminum bars. The reduction in materials and the reflectance of aluminum have given these metal greenhouses a great advantage over wooden greenhouses in terms of higher interior light intensity.

Glass greenhouse construction of today can be categorized as high profile or low profile. The low profile greenhouse is most popular in the Netherlands and is known as the Venlo greenhouse. The low profile greenhouses uses single panels of glass extend from eave to ridge. The low profile greenhouse slightly reduces exposed surface area, thereby reducing the heating cost, but more expensive to cool. The high profile greenhouses require more than single panel to cover the eave to ridge. A problem with this design is the unsealed junction between pieces of glass in the inner layer. Moisture and dust may enter between the layers and reduce light transmission.

5.3 Construction of pipe framed greenhouses

The choice of construction of pipe framed greenhouses often favours low initial investment and relatively long life. Galvanized mild steel pipe as a structural member in association with wide width UV- stabilized low density polyethylene (LDPE) film is a common option of greenhouse designers.

5.3.1 Material requirement

The following materials are required for a greenhouse having 4m x 20 m floor area:

- ✓ GI pipe class A (25 mm diameter, 85 cm long, 30 m total length)
- ✓ GI pipe class B (15 mm diameter, 6.0 m long, 21 No.s)
- ✓ GI sheet (20 gauge, size 90 24 cm, 4 sheets)
- ✓ MS flat (3 mm size, 4 m length)
- ✓ Lateral support to end frames (10 mm diameter rod, 10 m length)
- ✓ Cement concrete (1: 3: 6 mix, 1.0 m^3)
- ✓ UV- stabilized LDPE film (single layer 800 gauge, 5.4 m^2/kg, 154 m^2)
- ✓ Polygrip (channel 2000 3.5 4 cm, 2 No.s; Angle 2000 2 2 cm, 2 No.s; both made from the procured 20 gauge GI sheet, key 6 mm diameter, 56 mm length)
- ✓ Wooden end frames (5 5 cm wood, 0.15 m^3)
- ✓ Nuts and bolts 9 6 mm diameter, 35 mm long, 70 sets)
- ✓ Miscellaneous items like nails, hinges and latches as per requirement

5.3.2 Procedure of erection

1. A 4m by 20m rectangular area is marked on the site, preferably orienting the longer dimension in east-west direction. This rectangle will act as the floor plan of the greenhouse
2. Mark four points on the four corners of the rectangle.
3. Start from one corner point and move along the length of marked rectangle, marking a point every 1.25 m distance until reaching the other corner (16 bays; 17 points). The same procedure is repeated on the other side of the rectangle.
4. Dig 10 cm diameter holes upto 70 cm depth on all marked points with the help of bucket auger (or) a crowbar. This way a total of 34 holes on both the parallel sides of the greenhouse floor is obtained.
5. Polygrip sections formed according to the drawing into two 20m length.
6. Fix the prefabricated polygrip channels to the foundation pipes on 1.25 m spacing with the help of 6 mm diameter bolts.
7. Set these assemblies on temporary supports between the holes with the foundation pipes hanging vertically in the holes.
8. Pour cement concrete mix of 1: 3 : 6 around foundation pipes in such a way that the lower 15 cm to 20 cm ends are covered in concrete. The concrete is compacted around the foundation pipes with the help of the crowbar and is allowed to cure for 2-3 days.
9. After curing, fill the soil around the foundation pipes to the ground level and compact it well. (10) Position end frames on the two ends. Mark the position of legs and dug holes for fixing of legs. Now install both the end frames.
10. Put the ringside of lateral support members on adjacent foundation pipe to the corner, and other side is hooked to the end frame.
11. Put all the hoops in the foundation pipes in such away that straight portion of hoop is inserted into the foundation and rests on the bolt used for fixing of polygripchannel .
12. Take a 20 m long ridge line by spacing 15 mm diameter pipes together. Put the 20m long pipe at the ridge line of the hoops.
13. Use cross connectors on the ridge line pipe, in such a way that one half of it remains on the one side of the hoop and the other half on the other side.
14. Put two bolts of 6 mm diameter in the holes provided in the ends of cross-connector. Tie a few of them with the help of nuts.
15. Repeat the same procedure for joining all the hoops with ridge line pipe.
16. While forming cross-connectors, the distance between the cross-connectors or hoops should be maintained 1.25 m center to center. This poly grip mechanism will provide a firm grip of the ridge line pipe and hoops at right angles without allowing for slippage.

17. Spread polyethylene film over the structure from one end to the other end without wrinkles and keeping the edges together.
18. Place polyethylene film between the polygrip channel and right angle strip and secure them under pressure with the help of iron rods. The film is stretched gently and fixed on the other parallel side by polygrip. This way the polyethylene is secured on both the longer sides.
19. On the other two remaining ends, polyethylene is nailed to the end frames using wooden battens and nails.
20. The remaining portion of the end frames is covered with polyethylene film, which is secured with wooden battens and nails.
21. Mechanical ventilation, heating and cooling equipment is installed on the frames as per the crop requirement.

Lecture No.6

Greenhouse drying methods and applications, Solar dryer

6.1 Drying of agricultural produce inside greenhouse

In an efficiently managed greenhouse CEA, there will not be any time gap between crops. However, for some other management reasons, if crops are not grown in a particular period, the greenhouse can be utilized as a solar dryer. A small amount of 15 to 30% of the incoming solar radiation is reflected back from the surface of the greenhouse, with the remainder is transmitted into the interior. Most of this transmitted radiation is absorbed by plants, soil and other internal surfaces, the rest being reflected. The usage of greenhouse for the purpose of the drying is of recent origin. They were successful in advocating the year round utilization of the greenhouse facility and thus reducing the operation cost per unit output. In general, the produce is spread as thin layers in trays covering the greenhouse area. The trays can be fabricated with sheet metal and wire mesh. Trays should be arranged horizontally on existing growing benches or frames. For better operation, proper ventilation should be provided by either forced or natural ventilation, to remove the moisture liberating from the produce and to control the air temperature inside the greenhouse. The natural ventilation can be enhanced by using a black LDPE chimney connected to the greenhouse.

6.2 Greenhouse dryer:

The thought of a greenhouse dryer is to combine the function of the solar collector with a greenhouse system. The roof and wall of this solar dryer can be made of transparent materials such as glass, fibre glass, UV stabilized plastic or polycarbonate sheets. The transparent materials are fixed on a steel frame support or pillars with bolts and nuts and sealing to prevent humid air or rain water leaking into the chamber other than those introduced from the inlet opening. To increase solar radiation absorption, black surfaces should be provided within the structure. Inlet and exhaust fans are placed at proper position within the structure to guarantee even distribution of the drying air. If designed properly, greenhouse dryers can allow a greater degree of control over the drying process than the cabinet dryers and they will be more appropriate for large scale drying

Ekechukwu has developed a natural convection greenhouse dryer consisted of two parallel rows of drying platforms (along the long side) of galvanized iron wire mesh surface laid over wooden beams. A fixed inclined glass roof over the platform allowed solar radiation over the product. The dryer, aligned lengthwise in the north-south axis, had black coated internal walls for improved absorption of solar radiation. A ridge cap made of folded zinc sheet over the roof provides an air exit vent. Shutters at the outer sides of the platforms regulated the air inlet.

A simplified design of the typical greenhouse-type natural circulation solar dryer consists of a transparent semi-cylindrical drying chamber with an attached cylindrical chimney, rising vertically out of one end, while the other end is equipped with a door for air inlet and access to the drying chamber. The chimney (designed to allow for a varying height) has a maximum possible height of 3.0 m above the chamber and a diameter of 1.64 m. The drying chamber was a modified and augmented version of a commercially-available poly tunnel type greenhouse.

The dryer operates by the action of solar-energy striking directly on the product within the dryer. The product and a vertically-hung, black absorbing curtain within the chimney absorb the solar radiation and are heated which, in turn, heats surrounding air. As this heated air rises and flows up the chimney to the outside of the dryer, fresh replenishing air is drawn in from the other end of the dryer. Apart from the obvious advantages of passive solar-energy dryers over the active types (for applications in rural farm locations in developing countries), the advantages of the natural circulation solar-energy ventilated greenhouse dryer over other passive solar-energy dryer designs include its low cost and its simplicity in both on-the-site construction and operation. Its major drawback is its susceptibility to damage under high wind speeds

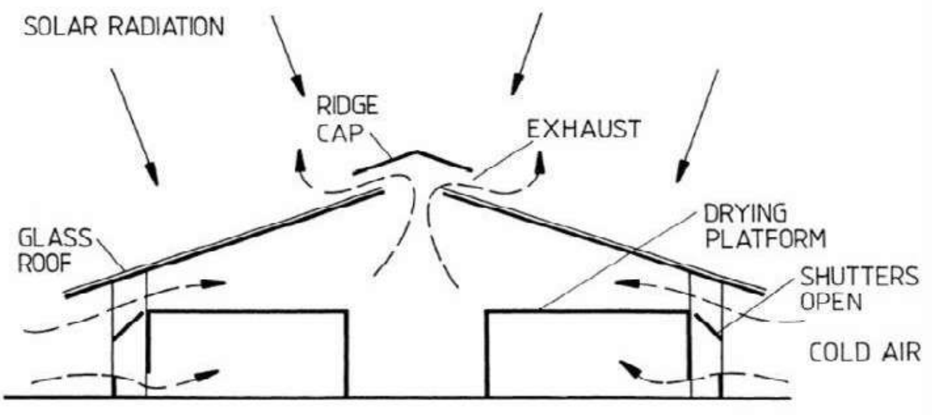


Fig.8.1. Greenhouse dryer

6.3 Types of solar dryers

1. Tent dryer: Tent solar dryers are cheap and simple to build and consist of a frame of wood poles covered with plastic sheet. Black plastic should be used on the wall facing away from the sun. The product to be dried is placed on a support above the ground. It takes same amount of time for drying of products as in open air drying. The main purpose of the dryers is to provide protection from dust, dirt, rain, wind or predators and they are usually used for fruit, fish, coffee or other products for which wastage is otherwise high. Tent dryers can also be taken down and stored when not in use. They have the disadvantage of being easily damaged by strong winds.

2. Box dryer: The box-type solar dryer has been widely used for small scale food drying. It consists of a wooden box with an attached transparent lid. The inside surface is painted black and the product is supported on a mesh tray above the dryer floor. Air flows into the chamber through holes in the front and exits from vent holes at the top of the back wall.

3. Solar cabinet dryer: The cabinet is a large wooden or metal box and the product is located in trays or shelves inside a drying cabinet. If the chamber is transparent, the dryer is named as integral-type or direct solar dryer. If the chamber is opaque, the dryer is named as distributedtype or indirect solar dryer. Mixed-mode dryers combine the features of the integral (direct) type and the distributed (indirect) type solar dryers. The combined action of solar radiation incident directly on the product to be dried and hot air provides the necessary heat required for the drying process. In most cases, the air is warmed during its flow through a low pressure drop solar collector and passes through air ducts into the drying chamber and over drying trays containing the crops. The moist air is then discharged through air vents or a chimney at the top of the chamber. It should be insulated properly to minimise heat losses and made durable (within economically justifiable limits). Construction from metal sheets or water resistant cladding, e.g. paint or resin, is recommended.

Heated air flows through the stack of trays until the entire product is dry. As the hot air enters through the bottom tray, this tray will dry first. The last tray to dry is the one at the top of the chamber.

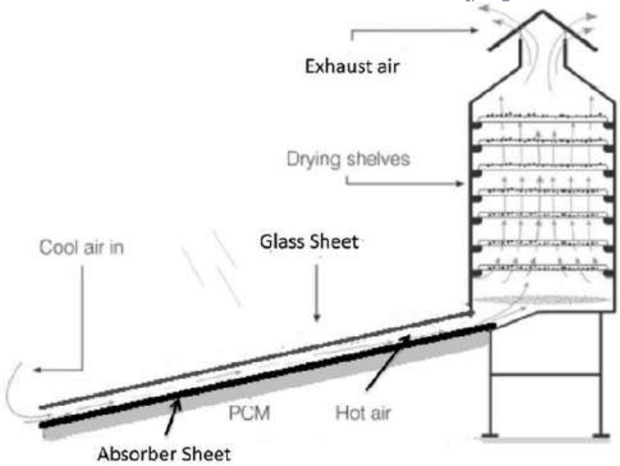


Fig.8.2. Solar cabinet dryer

Lecture No.7

Important engineering properties such as physical, thermal and aero & hydrodynamic properties of cereals, pulses and oilseeds

The knowledge of physical properties such as shape, size, volume, surface area, test weight, density, porosity, angle of repose, etc., of different grains is necessary for the design of different equipment for handling, processing and storage of grains.

7.1 Physical Properties

7.1.1 Shape and size

Shape of the grain is connected with the geometrical form of the grain. Size of the grain refers to the characteristics of an object which in term determine how much space it occupies and, within limits, can be described in terms of length, width, and thickness. The Shape and size together with other characteristics of the grains is important in the design of the seed grader. These factors determine the free flowing or bridging tendencies of the seed mass, and therefore, determine the suitable handling and feeding equipment. Sphericity and equivalent diameters are also used to describe the shape and size, respectively for the grains.

The sphericity (φ) defined as the ratio of the surface area of sphere having the same volume as that of the grain to the surface area of the grain, can be calculated from the axial dimensions of the grain as follows:

$$\varphi = \frac{(lbt)^{1/3}}{l}$$

The sphericity (φ) of the fruits can be calculated using the following formula.

$$\phi = \frac{abc^{\,1/3}}{a}$$

where, (a) = major diameter ; (b) = intermediate diameter; (c) = minor diameter
The geometrical mean diameter (GMD) can be calculated as follows:

$$GMD = (abc)^{1/3}$$

7.1.2 The bulk density

The bulk density (ρ_b) considered as the ratio of the weight of the grain in kg to its total volume in m3. The bulk density of grains is measured using 1 liter measuring cylinder and electronic balance. The bulk density of the food grains changes with the change in the moisture content. Hence, the moisture content of the food grains at which the bulk density was measured also to be reported. The bulk density can be calculated using the following formula

$$\rho_b = \frac{W_s}{V_s}$$

where, ρ_b= bulk density, kg/m^3,

Ws = weight of sample, kg and

Vs = volume of the sample i.e., 1000 cc or 10^{-3}

7.1.3 True density

The true density (ρ_t) defined as the ratio of mass of the sample (W) to its true volume. The true density (ρ_t) is determined using a Multivolume Pycnometer (Helium gas displacement method). Multivolume Pycnometer‘s Helium displacement method provides a rapid means for precisely determining the true volume of pores, porous materials, and irregularly shaped food grains. The true density of the grains is found to be decreased with an increase in moisture content as the increase in true volume of the grains is higher compared to the increase in moisture content of the grains. Since, the true density varies with the moisture content of the food grains, the moisture content of the food grains also to be reported. True density can be calculated using following formula.

True density $\rho_b = \dfrac{\textit{Total massof the grain, kg}}{V_{sample}}$

7.1.4 Porosity

Properties such as bulk density, true density and porosity of grains are useful in design of various separating, handling, storing and drying systems. Resistance of bulk grain to airflow is a function of the porosity and the kernel size. The porosity (ε) defined as the percentage of void space in the bulk grain which is not occupied by the grain can be calculated from the following relationship:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

where, ε = porosity

ρ_b= bulk density, kg/m^3

ρt = true density, kg/m^3

7.1.5 Angle of Repose

The flowing capacities of different grains are different. It is characterized by the angle of natural slope. The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the grain mass to a horizontal plane.

7.1.6 Coefficient of friction

The frictional properties of granular materials are important in designing of storage bins, hoppers, chutes, pneumatic conveying system, screw threshers and conveyors, forage harvesters, etc,. The ratio between the force of friction (F), and the force normal to the surface of contact (N), is known as the coefficient of friction (μ).

Mathematically,

$$coefficent\ of\ \ friction\ ,\ \mu = \frac{F}{N}$$

where, F = Frictional force (Amount of total Weights added + Suspended Pan)

N = Normal Load (Weight of the material + Circular Ring)

7.2 Rheology

Rheology has been defined as "a science devoted to the study of deformation and flow." Therefore, when the action of forces result in deformation and flow in the material, the mechanical properties will be referred-to as rheological properties. Moreover, rheology considers the time effect during the loading of a body. Rheologically then, mechanical behavior of a material is expressed in terms of the three parameters of force, deformation and time. Examples of rheological propertiesare time-dependent stress and strain behavior, creep, stress relaxation, and viscosity.

7.2.1 Strain

The unit change, due to force, in the size or shape of a body referred to its original size or shape. Strain is a non-dimensional quantity, but it is frequently expressed centimeters per centimeter, m/m, mm/mm etc.

7.2.2 Stress

It is defined as the intensity of a point in a body of the internal forces or components of force that act on a given plane through the point. Stress is expressed in force per unit of area (Kg/mm^2)

7.2.3 Compressive strength

It is the maximum compressive stress which a material is capable of sustaining. Compressive strength is calculated from the maximum load during a compression test and the original cross sectional area of the specimen.

7.2.4 Elastic Limit

The greatest stress which a material is capable of sustaining without any permanent strain remaining upon complete release of the stress.

7.2.5 Modulus of elasticity

It is the ratio of stress to corresponding strain below the proportional limit.

7.2.6 Poisson's ratio

The absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

7.2.7 Tensile strength

The maximum tensile stress that a material is capable of sustaining

7.3 Thermal Properties

The raw foods are subjected to various types of thermal treatment namely heating, cooling, drying, freezing etc., for processing. The change of temperature depends on the thermal properties of the product. Therefore knowledge of thermal properties namely, specific heat, thermal conductivity, thermal diffusivity is essential for the design of different thermal equipments and for solving various problems on heat transfer operation.

7.3.1 Specific Heat:

Specific heat of a substance is defined as the amount of heat required to raise the temperature of unit mass through 1^{o}C. In mathematical form, specific heat Cp, is written as Cp = Q/m. dT where Q is the amount of heat, m is the mass of material, and dT is the change in temperature.

7.3.2 Thermal Conductivity:

The thermal conductivity is defined as the amount of heat flow through unit thickness of material over an unit area per unit time for unit temperature difference.

7.3.3 Thermal diffusivity:

Thermal diffusivity indicates how fast heat can penetrate through the material under transient condition of heat-transfer conditions. Physically it relates the ability to conduct heat with its ability to store heat. The thermal diffusivity can be calculated by dividing the thermal conductivity by the product of specific heat and mass density.

7.4 Aero and Hydrodynamic Characteristics

In handling and processing of agricultural products often air or water is used as a carrier for transport or for separating the desirable product from the unwanted materials. The pneumatic separation and conveying has been in use in agricultural machinery and food processing equipment for many years. Use of water however, as a carrier for more economical transport or less injury to such products as fruits and vegetables, is a relatively new idea in the agricultural industry. In either case, fluid flow occurs around the solids and the problem involves the action of the forces exerted by the fluid on these solids. As the principles of this subject, known as fluid mechanics, find increasingly wide applications in handling and processing of agricultural products, it becomes necessary to have a knowledge of those physical properties which affect the aero and hydrodynamic behaviour of agricultural products.

7.4.1 Drag coefficient

When fluid flow occurs about immersed objects, the action of the forces involved can be illustrated by diagram as shown in figure. The pressure on the upper side of the object is less than and that on the lower side is greater than the pressure P in the undisturbed fluid stream. This results in a decrease of pressure, - *P*, on the upper side, and an increase of pressure, +*P*. In addition to these forces normal to the surface of the object, there are shear stresses, , acting tangential to the surface in the direction of flow and resulting from frictional effects.

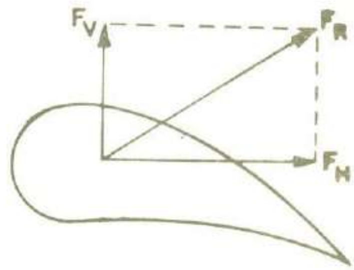


Fig.10.1. The Forces acting on a body immersed in a fluid current

The resultant force *F* may be resolved into components, *Fh*, the drag and *FL* the lift. In most agricultural engineering applications the moving object is usually free to assume its own random orientation. For this reason the net resistance force *Fr can* be given in terms of an overall drag coefficient C as follows

$$F_r = \frac{1}{2} c A_p \rho_f V^2$$

Where,

Fr = resistance drag force or weight of particle at terminal velocity, kg

C = overall drag coefficient (dimensionless)

Ap = projected areaof the particle normal to direction of motion, m^2

ρ_f = mass density of the fluid, $kg.s^2 / m^4$

V = relative velocity between main body of fluid and object, m/s

7.4.2 Terminal velocity

The terminal velocity of a particle may be defined as equal to the air velocity at which a particle remains in suspended state in a vertical pipe. In the condition of free fall, the particle attains a constant terminal velocity, *Vt*, the net gravitational accelerating force, *Fg*, equals the resisting upward drag force, Fr.

Lecture No.8

PHT equipment's design and operation

All machines should incorporate certain qualities:

1. It should perform the function for which it is designed.
2. Its work should be done cleanly, and the machine should be easily cleaned.
3. The machine should be as simply designed as possible and of such sturdy construction that few repairs are needed.
4. It should be economical in operation.

Food plant equipment design

1. All machine parts must be designed for quick dismantling and reassembling – some merely by removing and replacing a nut or wing screw by hand. It is also best to construct these parts of lightweight material so that they can be easily handled for cleaning.
2. All food contact surfaces should be inert, smooth, nonporous, and non-absorbing; they must withstand the application of chemical cleaners, sanitizers, and pesticides; they must be easily cleaned and readily accessible for inspection
3. Open seams in cooking kettles, mixers, blenders, storage vats, and filling machines must be eliminated.
4. Surfaces of equipment in contact with food must be smooth and continuous; rough spots and crevices must be avoided.
5. All junctions, particularly pipelines and ducts, must be curved or rounded. Cooking kettles, storage tanks, holding vats, and similar units must have long curves at the juncture of the bottom and sidewalls instead of sharp corners.
6. All machine parts in contact with food must be accessible for hand-brush cleaning and/or inspection.
7. Dead-end areas in all machines must be eliminated.
8. Metals like lead, antimony, and cadmium must not be used in fabricating equipment. Copper or copper-containing alloys are not recommended.
9. Stuffing boxes or glands in which food might accumulate and decompose should not be used.
10. Pipe fittings must have a sanitary thread and threaded parts must be accessible for cleaning.
11. Sanitary-type valves, such as plug type, should be used.
12. Runoff valves should be installed as close as possible to mixers, kettles, vats, and tanks.
13. Coupling nuts on piping and valves must have sufficient clearance and must be easily taken apart.
14. Food products should be protected from lubricants and condensates as moisture condensing on ceilings may pick up dirt and peeled paint, later to drop into open cooking kettles or holding vats.

15. Mixing blades should be welded to the drive shaft or both should be in one piece. Shaft and blades should be removable from the mixer at a point above the surface of the product.
16. Machine parts in contact with food should be constructed of noncorrosive metal.
17. Equipment like kettles, certain mixers, and holding vats and storage bins should have sectional covers, which are free from seams, hinges, crevices, and heads in which dirt might collect.
18. Drive shafts must be sealed so that lubricating grease does not work its way into the food.
19. Any horizontal parts of machines or supports should be at a minimum of 15 cm (6 in) above the floor. Tubular supports are preferred, but if squared tubing is placed horizontally, it should be rotated 45° to eliminate flat surfaces. Equipment occupying large floor areas should have a clearance of 46 cm (18 in) or more to facilitate cleaning.

Lecture No.9

Cleaning and grading, methods of grading, equipment for grading

All food raw materials are cleaned before processing. The purpose is obviously to remove contaminants, which range from innocuous to dangerous. It is important to note that removal of contaminants is essential for protection of process equipment as well as the final consumer. For example, it is essential to remove sand, stones or metallic particles from wheat prior to milling to avoid damaging the machinery.

The main contaminants are:

- unwanted parts of the plant, such as leaves, twigs, husks;
- soil, sand, stones and metallic particles from the growing area;
- insects and their eggs;
- animal excreta, hairs etc.;
- pesticides and fertilizers;
- mineral oil;
- microorganisms and their toxins.

- Cleaning is essentially separation in which some difference in physical properties of the contaminants and the food units is exploited.
- There are a number of cleaning methods available, classified into dry and wet methods, but a combination would usually be employed for any specific material.
- Selection of the appropriate cleaning regime depends on the material being cleaned, the level and type of contamination and the degree of decontamination required. In practice a balance must be struck between cleaning cost and product quality, and an _acceptable standard‘ should be specified for the particular end use. Avoidance of product damage is an important contributing factor, especially for delicate materials such as soft fruit.

9.1 Dry Cleaning Methods

The main dry cleaning methods are based on screens, aspiration or magnetic separations. Dry methods are generally less expensive than wet methods and the effluent is cheaper to dispose of, but they tend to be less effective in terms of cleaning efficiency. A major problem is recontamination of the material wit dust. Precautions may be necessary to avoid the risk of dust explosions and fires.

Screens are essentially size separators based on perforated beds or wire mesh. Larger contaminants are removed from smaller food items. Eg: straw from cereal grains, or pods and twigs from peas. This is termed as scalping. The main geometries are rotary drums and flatbed designs.

Abrasion, either by impact during the operation of the machinery, or aided by abrasive discs or brushes, can improve the efficiency of dry screens. Screening gives incomplete separations and is usually a preliminary cleaning stage. Aspiration exploits the differences in aerodynamic properties of the food and the contaminants. It is widely used in the cleaning of cereals, but is also incorporate into equipment for cleaning peas and beans.

9.1.1 Principle of aspiration cleaning

The principle is to feed the raw material into a carefully controlled upward air stream. Denser material will fall, while lighter material will be blown away depending on the terminal velocity. Terminal velocity in this case can be defined as the velocity of upward air stream in which a particle remains stationary; and this depends on the density and projected area of the particles (as described by Stokes' equation). By using different air velocities, it is possible to separate say wheat from lighter chaff or denser small stones. Very accurate separations are possible, but large amount s of energy are required to generate the air streams. Obviously the system is limited by the size of raw material units, but is particularly suitable for cleaning legumes and cereals.

Principle of aspiration cleaning

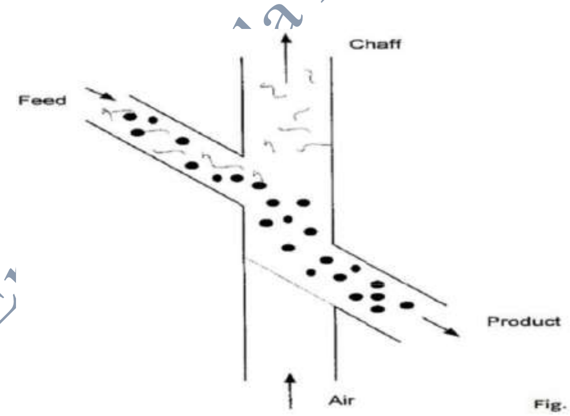


Figure9.3 Principle of aspiration cleaning

9.1.2 Magnetic cleaning

Magnetic cleaning is the removal offerrous metal using permanent or electromagnets. Metal particles, derived from the growing field or pic ked up during transport or preliminary operations, constitute a hazard both to the consumer and to processing machinery, for example cereal mills. The geometry of magnetic cleaning systems can be quite variable: particulate foods may be passed over magnetized drums or magnetized conveyor belts, or powerful magnets may be located above conveyors. Electromagnets are easy to clean by turning off the power. Metal detectors are frequently employed prior sensitive processing equipment as well as to protect consumers at the end of processing lines.

9.1.3 Electrostatic cleaning

Electrostatic cleaning can be used in a limited number of cases where the surface charge on raw materials differs from contaminating particles. The principle can be used to distinguish grains from other seeds of similar geometry but different surface charge; and it has also been described for cleaning tea The feed is conveyed on a charged belt and charged particles are attracted to an oppositely charged electrode according to their surface charge

9.2 Wet Cleaning Methods

- Wet methods are necessary if large quantities of soil are to be removed; and they are essential if detergents are used. However, they are expensive, as large quantities of high purity water are required and the same quantity of dirty effluent is produced.
- Treatment and reuse of water can reduce costs. Employing the countercurrent principle can reduce water requirements and effluent volumes if accurately controlled.
- Sanitizing chemicals such as chlorine, citric acid and ozone are commonly used in wash waters, especially in association with peeling and size reduction, where reducing enzymatic browning may also be an aim. Levels of 100–200 mg l–1 chlorine or citric acid may be used, although their effectiveness for decontamination has been questioned and they are not permitted in some countries

Soaking is a preliminary stage in cleaning heavily contaminated materials, such as root crops, permitting softening of the soil and partial removal of stones and other contaminants. Metallic or concrete tanks or drums are employed; and these may be fitted with devices for agitating the water, including stirrers, paddles or mechanisms for rotating the entire drum. For delicate produce such as strawberries or asparagus, or products which trap dirt internally, e.g. celery, sparging air through the system may be helpful. The use of warm water or including detergents improves cleaning efficiency, especially where mineral oil is a possible contaminant, but adds to the expense and may damage the texture.

9.2.1 Spray washing

Spray washing is very widely used for many types of food raw material. Efficiency depends on the volume and temperature of the water and time of exposure. As a general rule, small volumes of high pressure water give the most efficient dirt removal, but this is limited by product damage, especially to more delicate produce. With larger food pieces, it may be necessary to rotate the unit so that the whole surface is presented to the spray it may be necessary to rotate the unit so that the whole surface is presented to the spray.The two most common designs are drum washers andbelt washers. Abrasion maycontribute to the cleaning effect, but again must e limited in delicate units. Other designs include flexible rubber discs which gently brush the surface clean.

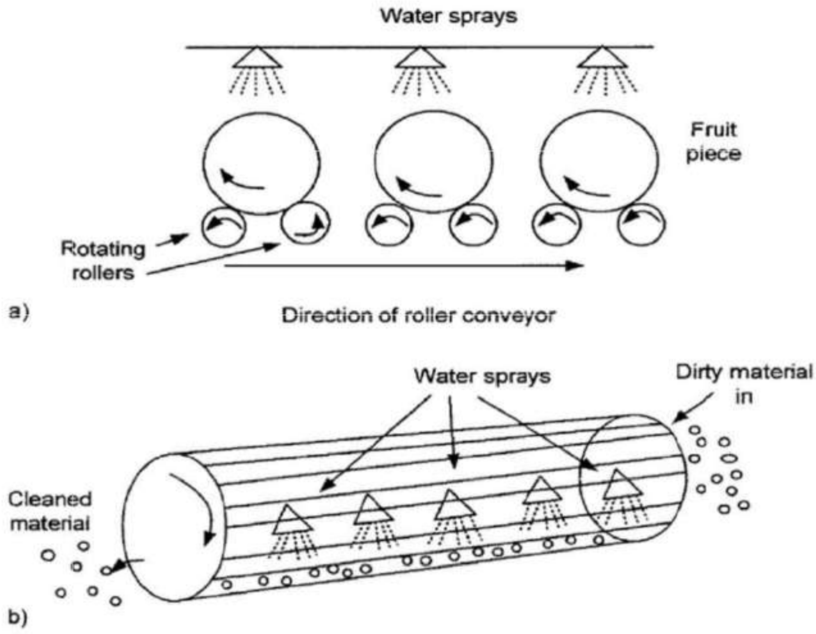


Fig.9.2 Water spray cleaning:(a) spray belt washer (b) drum washer

9.2.2 Flotation washing

Flotation washing employs buoyancy differences between food units and contaminants. For instance sound fruit generally flats, while contaminating soil, stones or rotten fruits sunk in water. Hence fluming fruit in water over a series of weirs gives very effective cleaning of fruit, peas and beans. A disadvantage is high water use, thus recirculation of water should be incorporated. Froth flotation is carried out to separate peas from contaminating weed seed and exploits surfactant effects. The peas are dipped in an oil/detergent emulsion and air is blown through the bed. This forms a foam which washes away the contaminating material and the cleaned peas can be spray washed.

9.3 Sorting

Sorting is the separation of foods into categories on the basis of a measurable physical property. Like cleaning, sorting should be employed as early as possible to ensure a uniform product for subsequent processing. The four main physical properties used to sort foods are size, shape, weight and colour

9.3.1 Shape and size sorting

The particle size distribution of a material is expressed as either the mass fraction of material that is retained on each sieve or the cumulative percentage of material retained.

The shape of some foods is important in determining their suitability for processing or their retail value. For example, for economical peeling, potatoes should have a uniform oval or round shape without protuberances. Shape sorting is accomplished either manually or mechanically. Size sorting (termed sieving or screening) is the separation of solids into two or more fractions on the basis of differences in size. It is particularly important when the food is to be heated or cooled as the rate of heat transfer is in part determined by the size of the individual pieces and variation in size would cause over-processing or under-processing. Additionally, foods which have a uniform size are said to be preferred by consumers. Screens with either fixed or variable apertures are used for size sorting. The screen may be stationary or, more commonly, rotating or vibrating.

Fixed aperture screens

Two common types of fixed aperture screen are the flat bed screen (or sieve) and the drum screen (rotary screen or reel). The multideck flat bed screen (Figure 5.3) has a number of inclined or horizontal mesh screens, which have aperture sizes from 20 µm to 125 mm, stacked inside a vibrating frame. Food particles that are smaller than the screen apertures pass through under gravity until they reach a screen with an aperture size that retains them. The smallest particles that are separated commercially are of the order of 50 µm.

Where vibration alone is insufficient to separate particles adequately, a gyratory movement is used to spread the food over the entire sieve area, and a vertical jolting action breaks up agglomerates and dislodges particles that block sieve apertures

Many types of drum screen are used for sorting small-particulate foods (for example nuts, peas or beans) that have sufficient mechanical strength to withstand the tumbling action inside the screen. Drum screens are almost horizontal (5–10º inclination), perforated metal or mesh cylinders. They may be concentric (one inside another), parallel (foods leave one screen and enter the next) or series (a single drum constructed from sections with different sized apertures). All types have a higher capacity than flat bed screens and problems associated with blinding are less severe than with flat bed screens. The capacity of drum screens increases with their speed of rotation up to a critical point. Above this the food is held against the screen by centrifugal force and results in poor separation. Similarly there is an increase in capacity with the angle of the screen up to a critical angle. Above this the residence time is too short and products pass through without separation.

Variable-aperture screens

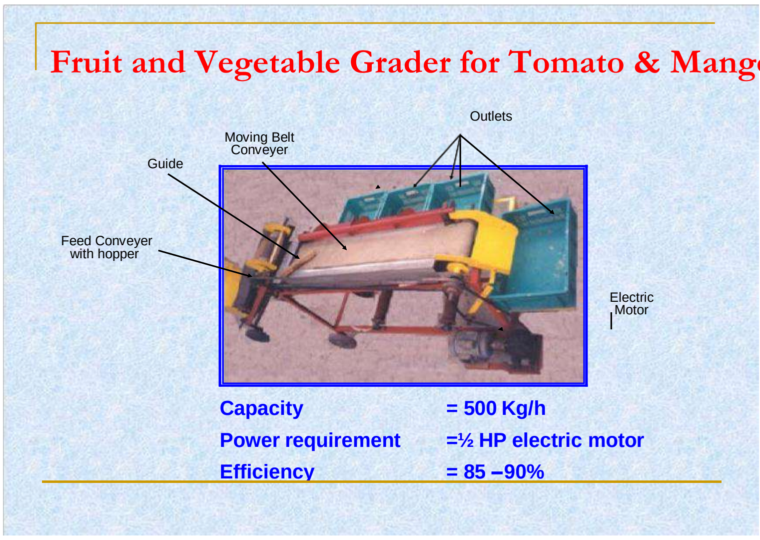
Variable-aperture screens have either a continuously diverging aperture or a stepwise increase in aperture. Both types handle foods more gently than drum screens and are therefore used to sort fruits and other foods that are easily damaged. Continuously variable screens employ pairs of diverging rollers, cables or felt-lined conveyor belts. These may be driven at different speeds to rotate the food and thus to align it, to present the smallest dimension to the aperture

Stepwise increases in aperture are produced by adjusting the gap between driven rollers and an inclined conveyor belt (Refer Figure on belt and roller sorter). The food rotates and the same dimension is therefore used as the basis for sorting (for example the diameter along the core of a fruit)

9.4 Grading

This term is often used interchangeably with sorting but strictly means _the assessment of overall quality of a food using a number of attributes‘. Sorting (that is separation on the basis of one characteristic) may therefore be used as part of a grading operation but not vice versa. Grading is carried out by operators who are trained to simultaneously assess a number of variables. For example, eggs are visually inspected over tungsten lights (termed _candling‘) to assess up to twenty factors and remove those that are for example, fertilized or malformed and those that contain blood spots or rot. Meats, for example, are examined by inspectors for disease, fat distribution, bone to flesh ratio and carcass size and shape. Other graded foods include cheese and tea, which are assessed for flavour, aroma, colour, etc. Apples are graded with the assistance of coloured cards that show the required characteristics of different grades in terms of colour distribution across the fruit, surface blemishes and size and shape of the fruit.

In some cases the grade of food is determined from the results of laboratory analyses (for example wheat flour is assessed for protein content, dough extensibility, colour, moisture content and presence of insects). In general, grading is more expensive than sorting owing to the higher costs of skilled operators. However, many attributes that cannot be examined automatically can be simultaneously assessed, and this produces a more uniform high-quality product.



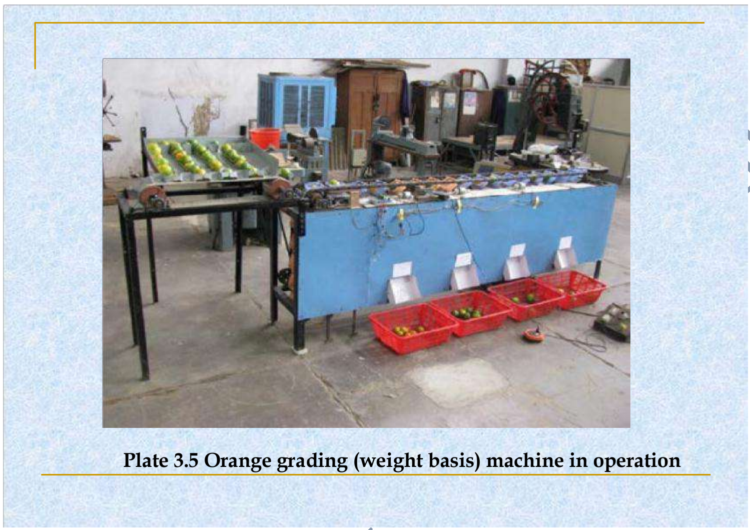
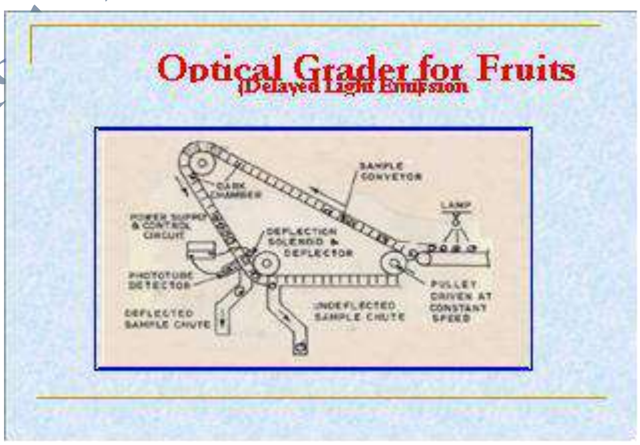


Plate 3.5 Orange grading (weight basis) machine in operation



Potato grader

Features

- Capacities range from 5 to 30 tonne/hr
- Washing
- Dry brushing lines
- Sizing
- Bagging lines

Onion grader

Features

- Capacities range from 8 tonne/hr to 30 tonne/hr
- Bulk receiver

Lecture No.10

Different cleaners and separators- length separator, cyclone separator, specific gravity separator, colour sorter, separators based on surface texture, working principles

To obtain quality seed, it is necessary to clean the seed obtained from the farm to get rid of inert materials, weed seeds, other crop seeds, other variety seeds, damaged and deteriorated seed. Different kinds of seeds can be separated when they differ in one or more physical characteristics. Physical characteristics normally used to separate seeds are size, shape, length, weight, colour, surface texture, affinity to liquids, electrical conductivity, etc. The problem lies in identifying the most important property and use the machine that separates seed using the identified property. Some of the identified properties and machines operating by following the properties are listed below:

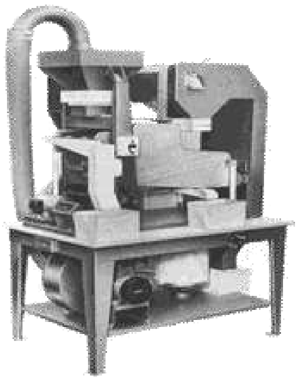
Name of the Separator	Property followed	Uses
Vibratory separator	Shape and surface texture	Removal of weed seeds
Spiral separator	Shape or the degree of its ability to roll	Separation of damaged/flat and wrinkled seeds from smooth seeds. Separation of mustard, rape, soybean and peas from wheat, flax, oats, etc., and round seeds from flat seeds.
Disk / Indented cylinder separator	Length	Dissimilar material like wheat, rye, mustard, barley from oats
Electrostatic separator	Electrical property	Johnson grass from sesame seed
Electronic colour sorters	Colour / brightness	Separation of off coloured seeds
Inclined draper	Shape and surface texture	Separation of smooth or round seeds from rough flat or elongated seeds
Magnetic separator	Surface texture and stickiness	Removal of contaminating weed seed from clovers, alfalfa seeds and iron metals
Roll mill	Shape and surface texture	Separation of smooth clover seed
Gravity separator or Destoner	Density or specific gravity	Removal of badly damaged, deteriorated, insect damaged crop seed and stones from good seeds.

Upgrading

Seed lots require further cleaning treatment to remove adulterants that are similar to pure seed in size and shape, to be separated by air screen cleaner. Removal of seeds larger or smaller than required size (sizing) and removal of cracked, damaged or otherwise defective seeds (grading) is accomplished in this final stage of processing.

10.1 Air-Screen cleaner cum grader

The air-screen machine is the basic cleaner in most seed processing plants. Almost all seed must be cleaned by air-screen cleaner before specific specifications can be attempted. Machine size varies from small, two-screen farm models to large industrial cleaners with 7-8 screens. Two-screen models are used on farms, in breeder and foundation seed programs and by experiment stations for processing small quantities of seed. In most machines separations are made on the basis of differences in only one physical characteristic. The air-screen machine, however, effects separations on the basis of differences in size and weight of seeds. This enables the air-screen machine to use three cleaning elements: aspirator, in which light material is removed from the seed mass; scalper in which good seed are dropped through screen openings; but larger material is carried over the screen into a separate spout; and grader, in which good crop seed ride over screen openings, while smaller particles drop through.



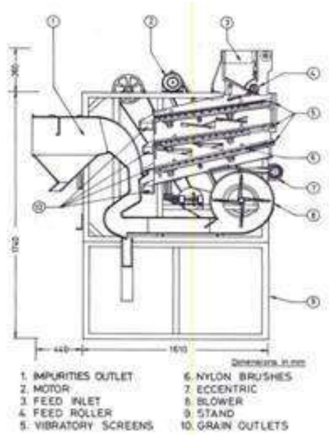


Fig.9.1. Air screen cleaner cum grader

10.2 Specific gravity separator

This method makes use of a combination of weight and surface characteristics of the seed to be separated. The principle of floatation is employed here. A mixture of seeds is fed onto the lower end of a sloping perforated table. Air is forced up through the porous deck surface and the bed of seeds by a fan, which stratifies the seeds in layers according to density with the lightest seeds and particles of inert matter at the top and the heaviest at the bottom. An oscillating movement of the table causes the seeds to move at different rates across the deck. The lightest seeds float down under gravity and are discharged at the lower end, while the heaviest ones are kicked up the slope by contact with the oscillating deck and are discharged at the upper end. This machine separates seeds of the same density but of different size and seeds of the same size but of different densities.

10.3 Spiral separator

Spiral separator, which classifies seed according to its shape and rolling ability, consists of sheet metal strips fitted around a central axis in the form of a spiral. The unit resembles an open screw conveyor standing in a vertical position. The seed is introduced at the top of the inner spiral. Round seeds roll faster down the incline than flat or irregularly shaped seeds, which tend to slide or tumble. The orbit of round seed increases with speed on its flight around the axis, until it rolls over the edge of the inner flight into the outer flight where it is collected separately. The slower moving seed does not build up enough speed to escape form the inner flight. Most spirals have multiple inner flights arranged one above the other to increase the capacity.

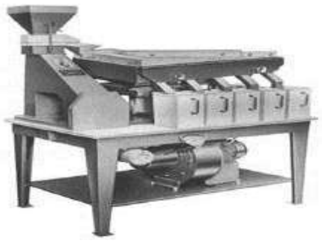


Fig.9.2. Specific gravity separator

Fig.9.3.Spiral separator

10.4Indented Cylinder Separator

Indent cylinders use centrifugal force and length differences to lift material from a seedmass, making a length-sizing separation. The indent-cylinder separator consists of a rotating, horizontal cylinder and a movable, horizontal separating trough. The inside surface of the cylinder has small, closely spaced, hemispherical indentations. In operation, the seed mass to be separated lies on the bottom of the cylinder. As the cylinder rotates on its axis, the short seeds in the mass are lifted from the mixture by the numerous indents. At some point before reaching the top of the rotation, the seeds drop from the indents and are received by an adjustable trough or vibrating tray.

10.5Magnetic Separator

The magnetic separator separates seed according to its surface texture or related seed characteristics. First, seed is treated with iron filings, which adhere to rough surface alone. The treated seed lot is passed over a revolving magnetic drum and separated from smooth, uncoated seed. It may help to add varied amounts of water while mixing seed and powder, depending on the seed type. At any rate, the effectiveness of magnetic separation depends on the components of the seed lot and on the powder and water used in the treating operation. The greater the difference between surface textures of the seed, more effective will be the separation.

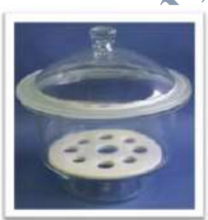


Fig.9.4. Indented cylinder separator

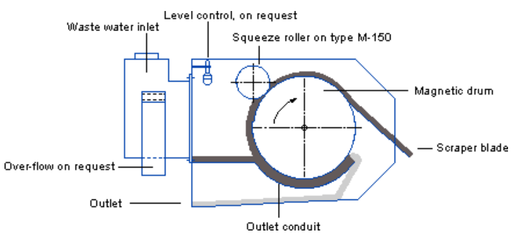


Fig.9.5.Magnetic separator

10.6 Colour Separator

The colour separator is used to separate dis-coloured seed, greatly of lower quality. Separation based on colour is necessary because the density and dimensions of dis-colouredseed are the same as those of sound seed, so other machines are not effective for separation. Electronic colour separation uses photocells to compare the seed colour with –background‖ which are selected to reflect the same light as the good seed. Seed that differs in colour is detected by the photo cells, which generate an electric impulse. The impulse activates an air jet to blow away the dis-coloured seed

Fig.9.6. Colour Separator

10.7 Inclined Draper

Like the spiral, the inclined draper also separates seeds on the basis of their ability to roll or slide. The rolling or sliding properties are governed by the shape and texture of the seeds, and by the frictional characteristics of the draper surface they are contacting. A seed mixture to be separated is metered from a hopper to the center of an inclined draper belt traveling in an uphill direction, as shown in Fig. Round or smooth seeds, like vetch, will roll and slide down the draper faster than the draper is traveling up the incline. In contrast, flat, rough, or elongated seeds, like oats, will be carried to the top of the incline, thereby making the separation. The seeds dropping off the draper at its lower endare gathered in one chute, and the seeds reaching the upper end are dropped into a second chute.

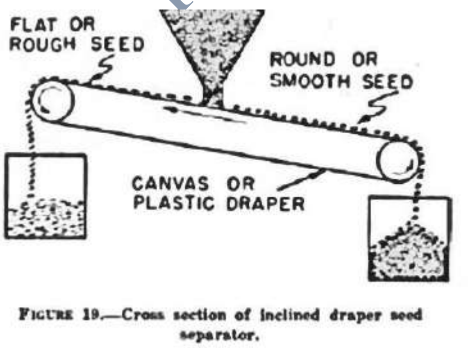


Fig. Inclined draper

10.8 Disc Separator

The disc separates materials on the basis of difference in length of various constituents. The separator has pockets or indentations on its surfaces. When the machine is operated, the smaller sized materials are caught in the pockets, while the larger ones are rejected. It is used especially for removing dissimilar materials like wheat, rye, mustard, barley from oats.

Lecture No. 11

Drying, Principles, Classification- conduction, convection and radiation driers, moisture contents, theory of grain drying

Generally the term drying refers to the removal of relatively small amount of moisture from a solid or nearly solid material by evaporation. Therefore, drying involves both heat and mass transfer operations simultaneously. Because of the basic differences in drying characteristics of grains in thin layer and deep bed, the whole grain drying process is divided into thin layer drying and deep bed drying.

11.1 Methods of Grain Drying

According to the mode of heat transfer, drying methods can be divided into: (a) conduction drying, (b) convection drying and (c) radiation drying. There are other methods of drying also, namely, dielectric drying, chemical or sorption drying vaccum drying, freeze drying etc.

Of them, convection drying is commonly used for drying of all types of grain and conduction drying can be employed for drying of parboiled grain.

11.1.1 Conduction drying

When the heat for drying is transferred to the wet solid mainly by conduction through a solid surface (usually metallic) the phenomenon is known as conduction or contact drying. In this method, conduction is the principal mode of heat transfer and the vaporized moisture is removed independently of the heating media. Conduction drying is characterized by:

a) Heat transfer to the wet solid takes place by conduction through a solid surface, usually metallic. The source of heat may be hot water, steam, flue gases, hot oil, etc.,

b) Surface temperatures may vary widely;
c) Contact dryers can be operated under low pressure and in inert atmosphere;
d) Dust and dusty materials can be removed very effectively; and
e) When agitation is done, more uniform dried product and increased drying rate are achieved by using conduction drying. Conduction drying can be carried out either continuously or batch wise. Cylinder dryers, drum dryers, steam tube rotary dryers are some of the continuous conduction dryers. Vacuum tray dryers, freeze dryers, agitated pan dryers are the examples of batch conduction dryers.

11.1.2 Convection drying

In convection drying, the drying agent (hot gases) in contact with the wet solid is used to supply heat and carry away the vaporized moisture and the heat is transferred to the wet solid mainly by convection. The characteristics of convection drying are:

a) Drying is dependent upon the heat transfer from the drying agent to the wet material, the former being the carrier of vaporized moisture;
b) Steam heated air, direct flue gases of agricultural waste, etc., can be used as drying agents;
c) Drying temperature varies widely;

d) At gas temperatures below the boiling point, the vapour content of the gas affects the drying rate and the final moisture content of the solid;

e) If the atmospheric humidity is high, natural air drying needs dehumidification; and

f) Fuel consumption per kg of moisture evaporated is always higher than that of conduction drying. Convection drying is most popular in grain drying. It can be carried out either continuously or batch-wise. Continuous tray dryers, continuous sheeting dryers, pneumatic conveying dryers, rotary dryers, tunnel dryers come under the continuous system, whereas tray and compartment dryers, batch through circulation dryers are the batch dryers.

11.1.3 Radiation drying

Radiation drying is based on the absorption of radiant energy of the sun and its transformation into heat energy by the grain. ‗Sun drying' is the example of radiation drying. Radiation drying can also be accomplished with the aid of special infra-red radiation generators, namely, infra-red lamps. Moisture movement and evaporation is caused by the difference in temperature and partial pressure of water vapour between grain and surrounding air. The effectiveness of sun drying depends upon temperature and relative humidity of the atmospheric air, speed of the wind, type and condition of the grain, etc.

11.2 Theory of Grain Drying

Generally the term drying refers to the removal of relatively small amount of moisture from a solid or nearly solid material by evaporation. Therefore, drying involves both heat and mass transfer operations simultaneously. In convective drying the heat required for evaporating moisture from the drying product is supplied by the external drying medium, usually air. Because of the basic differences in drying characteristics of grains in thin layer and deep bed, the whole grain drying process is divided into thin layer drying and deep bed drying.

11.2.1 Thin layer drying

Thin layer drying refers to the grain drying process in which all grains are fully exposed to the drying air under constant drying conditions, i.e, at constant air temperature, and humidity. Generally, up to 20cm thickness of grain bed (with a recommended air-grain ratio) is taken as thin layer. All commercial flow dryers are designed on thin layer drying principles.

11.2.2 Moisture content

Usually the moisture content of a substance is expressed in percentage by weight on wet basis. But the moisture content on dry basis is more simple to use in calculation as the quantity of moisture present at any time is directly proportional to the moisture content on dry basis. The moisture content, m, per cent, wet basis is:

$$m = \frac{w_m}{w_m + w_d} \times 100$$

Where, W_m= weight of moisture and W_d = weight of bone dry material,

The moisture content, M, dry basis, percent is:

$$m = \frac{w_m}{w_d} \times 100$$

11.2.3 Moisture measurement

Moisture content can be determined by direct and indirect methods. Direct method includes air-oven drying method (130+ 2^{0}C) and distillation method. Direct methods are simple and accurate but time consuming whereas indirect methods are convenient and quick but less accurate.

Direct methods

The air-oven drying method can be accomplished in a single stage or double stage in accordance with the grain samples containing less than 13 per cent or more than 13 per cent moisture content.

Single stage method

Single stage method consists of the following steps:

a) Grind 2-3 gm sample

b) Keep the sample in the oven for about 1 hour at 130+ 2 ^{0}C.

c) Place the sample in a dessicator and then weigh. The samples should check within 0.1 %.

Double stage method

a) In this method keep 25-30 gm whole grain sample in the air oven at 130+ 2 ^{0}C for 14-16 hours so that its moisture content is reduced to about 13 per cent.

b) Then follow the same procedure as in single stage method.

Indirect methods

Indirect methods are based on the measurement of a property of the grain that depends upon moisture content. Two indirect methods are described as follows:

Electrical resistance method

Resistance type moisture meter measures the electrical resistance of a measured amount of grain sample at a given compaction (bulk density) and temperature. The electrical resistance varies with moisture, temperature and degree of compaction. The universal moisture meter (U.S.A), Tag-Happenstall moisture meter (U.S.A) and Kett moisture meter (Japan) are some of the resistance type moisture meters. They take only 30 seconds for the moisture measurement.

Dielectric method

The dielectric properties of grain depend on its moisture content. In this type of moisture meter, 200gm grain sample is placed between the condenser plates and the capacitance is measured. The measured capacitance varies with moisture, temperature and degree of compaction. The Motomco moisture meter (USA) and Burrows moisture recorder (USA) are some of the capacitance type moisture meters. They take about 1 minute for the measurement of moisture. These are also known as safe crop moisture testers as they do not damage the grain sample.

11.2.4 Equilibrium Moisture Content

When a solid is exposed to a continual supply of air at constant temperature and humidity, having a fixed partial pressure of the vapour, p, the solid will either lose moisture by evaporation or gain moisture from the air until the vapour pressure of the moisture of solid equals p. The solid and the gas are then in equilibrium, and the moisture content of the solid in equilibrium with the surrounding conditions is known as equilibrium moisture content E.M.C (Fig).

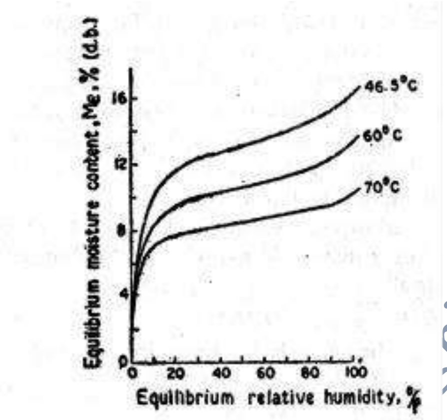


Fig.11.1.Equilibrium moisture content versus humidity graph

The E.M.C is useful to determine whether a product will gain or lose moisture under a given set of temperature and relative humidity conditions. Thus E.M.C is directly related to drying storage. Different materials have different equilibrium moisture contents. The E.M.C is dependent upon the temperature and relative humidity of the environment and on the variety and maturity of the grain. A plot of the equilibrium relative humidity and moisture content of a particular material at a particular temperature (usually 25^0C) is known as equilibrium moisture curve or isotherm. Grain isotherms are generally S-shaped and attributed to multi – molecular adsorption.

11.2.5 E.M.C Models:

A number of E.M.C equations namely BET equation (1938), Harkin and Jura equation (1944), Smith equation (1947), Henderson equation (1952), Chung and Fost equation (1967), have been developed for different ranges of relative humidity. A few purely empirical E.M.C equations namely Haynes equation (1961), Baker and Arkema equation (1974) etc., have also been proposed for different ranges of relative humidities for different cereal grains. Of them Henderson‘s equation is well known and discussed here: Using Gibb‘s adsorption equation, Henderson (1952) developed the following equation to express the equilibrium moisture curve mathematically:

$$1 - RH = \exp\left[-cTM_e^{\,n}\right]$$

Where RH = equilibrium relative humidity, decimal Me = E.M.C dry basis, per cent T = temperature, ^{o}K and c and n = product constants, varying with material

11.2.6Deep bed drying

In deep bed drying all the grains in the dryer are not fully exposed to the same condition of drying air. The condition of drying air at any point in the grain mass changes with time and at any times it also changes with depth of the grain bed. Over and above the rate of air flow per unit mass of grain is small compared to the thin layer drying of grain. All on farm static bed batch dryers are designed on deep bed drying principle. The condition of drying in deep bed is shown in fig.

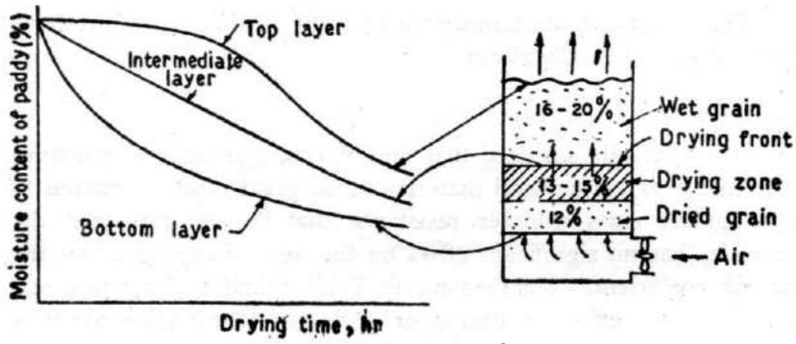


Fig.11.2.Deep bed drying

The drying of grain in a deep bin can be taken as the sum of several thin layers. The humidity and temperature of air entering and leaving each layer vary with time depending upon the stage of drying, moisture removed from the dry layer until the equilibrium moisture content is reached. Little moisture is removed; rather a small amount may be added to the wet zone until the drying zone reaches it. The volume of drying zone varies with the temperature and humidity of entering air, the moisture content of grain and velocity of air movement. Drying will cease as soon as the product comes in equilibrium with the air.

Lecture No. 12

Drying- constant and falling rate of drying, calculation on water evaporated from material, efficieny of drying

12.1Drying Curves

The plots of moisture content versus drying time or drying rate versus drying time or drying rate versus moisture content are known as drying curves.

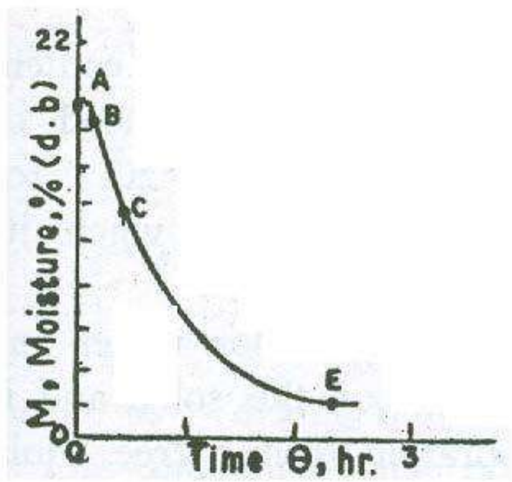


Fig.12.1 Moisture content versus drying time

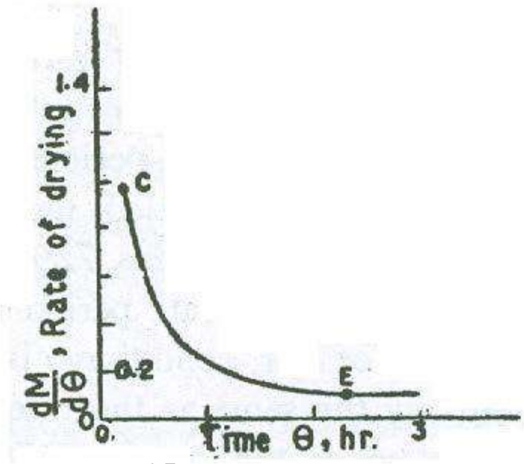


Fig. 12.2 Drying rate versus drying time

The figure clearly shows that there are two - major periods of drying, namely, the constant-rate period and the falling rate period.

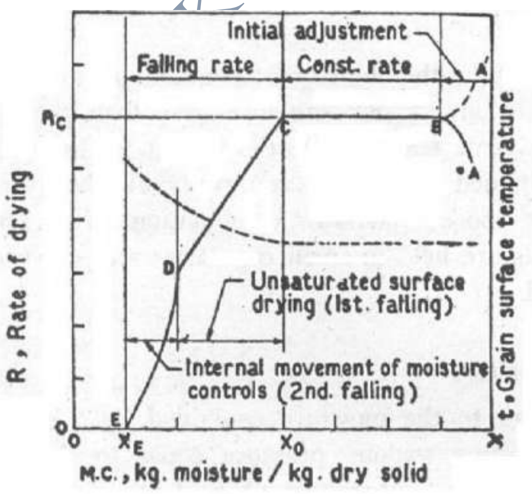


Fig. 12.3 Typical drying rate curve, constant drying condition.

12.1.1 Constant-rate period

Some crops including cereal grains at high moisture content are dried under constant-rate period at the initial period of drying. Falling –rate period follows subsequently. As for example, wheat is dried under constant-rate period when its moisture content exceeds 72%.
In the constant-rate period the rate of evaporation under any given set of air conditions is independent of the solid and is essentially the same as the rate of evaporation from a fee

liquid surface under the same condition. The rate of drying during this period is dependent upon: a) difference between the temperature of air and temperature of the wetted surface at constant air velocity and relative humidity, b) difference in humidity between air stream and wet surface at constant air velocity and temperature, and c) air velocity at constant air temperature and humidity.

12.2.2 Falling-rate period

Cereal grains are usually dried entirely under falling-rate period. The falling rate period enters after the constant drying rate period and corresponds to the drying cycle where all surface is no longer wetted and the wetted surface continually decreases, until at the end of this period the surface is dry. The cause of falling off in the rate of drying is due to the inability of the moisture to be conveyed from the center of the body to the surface at a rate comparable with the moisture evaporation from its surface to the surroundings. The falling- rate period is characterized by increasing temperatures both at the surface and within the solid. Furthermore, changes in air velocity have a much smaller effect than during the constant rate period. The falling rate period of drying is controlled largely by the product and is dependent upon the movement of moisture within the material from the center to the surface by liquid diffusion and the removal of moisture from the surface of the product. The falling rate period of drying often can be divided into two stages: a) unsaturated surface drying, and b) drying where the rate of water diffusion within the product is slow and is the controlling factor. Practically all cereal grains are dried under falling-rate period if their moisture contents are not very high.

PROBLEMS ON MOISTURE CONTENT

Solved problems on moisture content

1) Two tones of paddy with 22% moisture content on wet basis are to be dried to 13% moisture content on dry basis. Calculate the weight of bone dry products andwaterevaporated.

2) Determine the quantity of parboiled paddy with 40 per cent moisture content on wet basis required to produce 1 tonne of product with 12 per cent moisture content on wet basis. Work out the problem on wet basis and check the answer using dry basis.

Lecture 13

Types of Dryers-mechanical dryers, batch, continuous, mixing and non mixing dryers-working principle

13.1 Recirculatory Batch Dryer (PHTC type)

This is a continuous flow non mixing type of grain dryer.The dryer consists of two concentric circular cylinders made of perforated (2mm dia) mild steel sheet of 20 gauge. The two cylinders are set 15 to 20cm apart. These two cylinders are supported on four channel sections. The whole frame can be supported by a suitable foundation or may be bolted to a frame made of channel section. A bucket elevator of suitable capacity is used to feed and recirculate the grain into the dryer. A centrifugal blower blows the hot air into the inner cylinder which acts as a plenum. The hot air from the plenum passes through the grain moving downward by gravity and comes out of the outer perforated cylinder. A torch burner is employed to supply the necessary heat with kerosene oil as fuel. The designs of PHTC dryer for ½, 1 and 2 tonnes holding capacity are available. The PHTC dryer of 2 tonnes holding capacity developed at PHTC, IIT, Kharagpur, India is shown in fig.

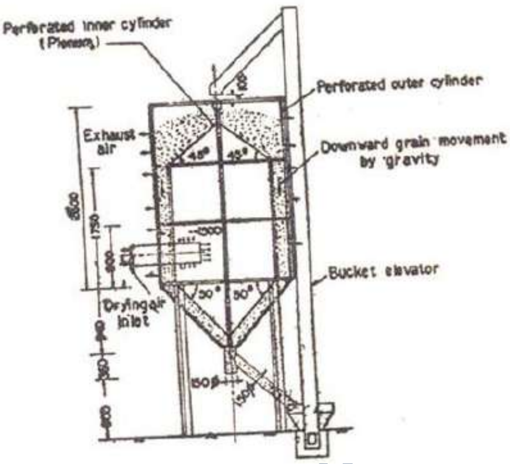


Fig. 13.1.Recirculatory batch dryer

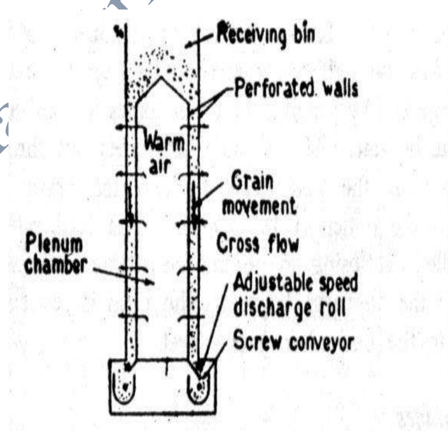


Fig.13.2. Continuous flow type non mixing type dryer

The grain is fed to the top of the inside cylinder. While descending through the annular space from the feed end to the discharge end by gravity, the grain comes in contact with a cross flow of hot air. The exhaust air comes out through the perforations of the outer cylinder and the grain is discharged through the outlet of the hopper. The feed rate of grain is controlled by closing or opening the gate provided with the outer pipe of the discharge hopper. The grain is recirculated till it is dried to the desired moisture level.

Advantages

1. Price is reasonable.
2. Simplest design amongst all flow type dryers
3. Easy to operate

4. It can be used on the farm and rice mill as well.
5. Operating cost is low with husk fired furnace.

Disadvantages
1. Drying is not so uniform as compared to mixing type.
2. Perforations of the cylinders may be clogged with the parboiled paddy after using it for a long time.

13.2Louisiana State University Dryer

This is a continuous flow-mixing type of grain dryer which is popular in India andtheU.S.A.It consists of 1) a rectangular drying chamber fitted with air ports and the holding bin, 2) an air blower with duct, 3) grain discharging mechanism with a hopper bottom, and 4) an air heating system.

1) **Rectangular bin**:
Usually the following top square sections of the bin are used for thedesign of LSU dryer.
i) 1.2m x 1.2m, ii) 1.5m x 1.5m,iii) 1.8m x 1.8m and iv) 2.1m x 2.1m the rectangular bin can be divided into two sections, namely top holding bin and bottom drying chamber.

2) **Air distribution system**: Layers of inverted V-shaped channels (called inverted Vports) are installed in the drying chamber. Heated air is introduced at many points through the descending grain bulk through these channels. One end of each air channel has an opening and the other end is sealed. Alternate layers are air inlet and air outlet channels. In the inlet layers, the channel openings face the air inlet plenum chamber but they are sealed at the opposite wall, where as in the outlet layers, the channel openings face the exhaust but are sealed other side. The inlet and outlet ports are arranged one below the other in an offset pattern. Thus air is forced through the descending grain while moving from the feed end to the discharge end. The inlet ports consists of a few full size ports and two half size ports at two sides. All these ports of same size are arranged in equal spacing between them. The number of ports containing a dryer varies widely depending on the size of the dryer. Each layer is offset so that the top of the inverted V ports helps in splitting the stream of grain and flowing the grains between these ports taking a zigzag path. In most models, the heated air is supplied by a blower.

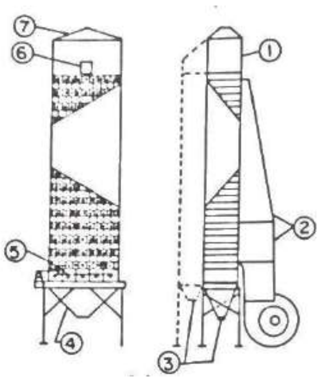
3) **Grain discharging mechanism**: Three or more ribbed rollers are provided at the bottom of the drying chamber which can be rotated at different low speeds for different discharge rates of grains. The grain is discharged through a hopper fixed at the bottom of the drying chamber. Causing some mixing of grain and air the discharge system at the base of the dryer also regulates the rate of fall of the grain.

4) **Air heating system**: The air is heated by burning gaseous fuels such as natural gas, butane gas, etc, or liquid fuels such as kerosene, furnace oil, fuel oil etc, or solid fuels like coal, husk, etc. Heat can be supplied directly by the use of gas burner or oil burner or husk fired furnace and indirectly by the use of heat exchangers. Indirect heating is always less efficient than direct firing system. However, oil fired burner or gas burners should be immediately replaced by husk fired furnace for economy of grain drying. The heated air is introduced at many points in the drier so as to be distributed uniformly through the inlet ports and the

descending grain bulk. It escapes through the outlet ports. This type of dryer is sometimes equipped with a special fan to blow ambient air from the bottom cooling section in which the dried or partially dried warm graincomes in contact with the ambient air. In general, the capacity of the dryer varies from 2 to 12tonnes of grain, but sometimes dryers of higher capacities are also installed. Accordingly power requirement varies widely. Recommended air flow rate is 60-70 m3/min/tonne of parboiled paddy and optimum air temperatures are 600C and 850C for raw and parboiled paddy respectively. A series of dryers can also be installed.

Advantages & Disadvantages

- Uniformly dried product can be obtained if the dryer is designed properly.
- The dryer can be used for different types of grains.
- High capital investment
- Cost of drying is very high if oil is used as fuel.



1. Garner
2. Duct
3. Dry material outlet
4. Hopper
5. Continuous flow
6. Door
7. Roof

Fig.13.2. LSU dryer

13.3 Tray Dryer

Schematic of a typical batch dryer is shown in fig. Tray dryers usually operate in batch mode, use racks to hold product and circulate air over the material. It consists of a rectangular chamber of sheet metal containing trucks that support racks. Each rack carries a number of trays that are loaded with the material to be dried. Hot air flows through the tunnel over the racks. Sometimes fans are used to on the tunnel wall to blow hot air across the trays. Even baffles are used to distribute the air uniformly over the stack of trays. Some moist air is continuously vented through exhaust duct; makeup fresh air enters through the inlet. The racks with the dried product are taken to a tray-dumping station

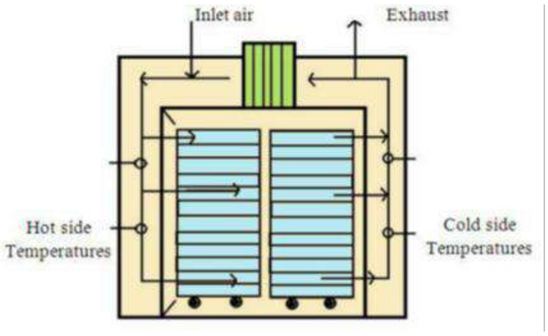


Fig.13.3. Tray dryer

These types of dryers are useful when the production rate is small. They are used to dry wide range of materials, but have high labor requirement for loading and unloading the materials, and are expensive to operate. They find most frequent application for drying valuable products. Drying operation in case of such dryers is slow and requires several hours to complete drying of one batch. With indirect heating often the dryers may be operated under vaccum. The trays may rest on hollow plates supplied with steam or hot water or may themselves contain spaces for a heating fluid. Vapour from the solid may be removed by an ejector or vacuum pump.

13.4 Drum Dryer

In drum dryers a liquid containing dissolved solids or slurry carrying suspended solids forms a thin layer on the outside surface of a large rotating drum. For a single drum unit thickness of the film can be controlled by an adjustable scraping blade. In case of a double drum unit thickness can be controlled by the gap between the drums. A gas, normally air may be blown over the surface for rapid removal of moisture. The rotation of the drum adjusted so that all of the liquid is fully vaporized and a dried deposit can be scrapped off with the help of flexible or adjustable knife. This type of dryer mainly handles the materials that are too thick for a spray dryer and too thin for a rotary dryer. The solid collects on an apron in front of the knife and rolls to a container or to a screw conveyor. The operation of the drum drier is continuous. The drum is rotated continuously by a gear driven by a pinion that receives its motion through a belt, a chain, or a reduction gear from. The speed of the drum may be regulated by a variable-speed drive to adopt the speed to any slight variation in the feed quality. The speed of the drum regulated depending upon the nature of materials (i.e wet or dry), if the product material is wet/dry quite a distance before the knife is reached, the speed should be decreased/increased. The design of the components is similar to that of drum filter. The knife may be held just against the surface. It may be brought closer by turning the adjusting wheels. The knife supports may be turned through part of a circle so that the angle of the blade of the knife relative to the drum surface may be selected for the greatest shearing effect. In recent years, double drum dryers have replaced single drum dryer in several applications due to their more efficient operation, wide range of products and high production rates.

12.5 Fluidized Bed Dryer

Fluidized bed dryer consist of a steel shell of cylindrical or rectangular cross section. A grid is provided in the column over which the wet material is rests. In this type of dryer, the drying gas is passed through the bed of solids at a velocity sufficient to keep the bed in a fluidized state. Mixing and heat transfer are very rapid in this type of dryers. The dryer can be operated in batch or continuous mode. Fluidized bed dryer are suitable for granular and crystalline materials. If fine particles are present, either from the feed or from particle breakage in the fluidized bed, there may be considerable solid carryover with the exit gas and bag filters are needed for fines recovery. The main advantage of this type of dryer are: rapid and uniform heat transfer, short drying time, good control of the drying conditions. In case of rectangular fluid-bed dryers separate fluidized compartments are provided through which the solids move in sequence from inlet to outlet. These are known as *plug flow dryers;* residence time is almost the same for all particles in the compartments. But the drying conditions can be changed from one compartment to another, and often the last compartment is fluidized with cold gas to cool the solid before discharge.

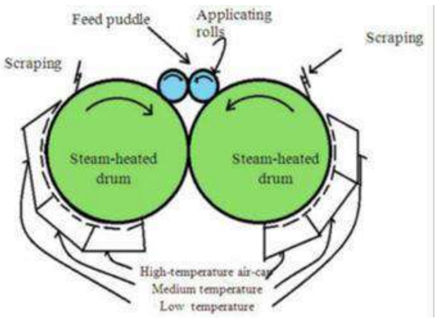


Fig. 13.4. Drum dryer

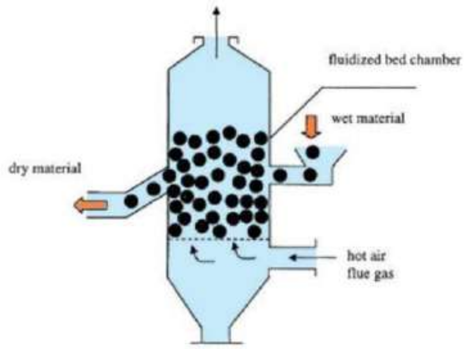


Fig. 13.5. Fluidized bed dryer

13.6 Spray Dryers

In a spray dryer, foods are transformed from slurry into a dry powder. A fine dispersion of pre-concentrated food is first _atomized‘ to form droplets (10-200 µm diameter) and sprayed into a current of heated air at 150-300°C in a large drying chamber The spray-drying operation is easily divided into three distinct processes; atomization, drying through the contact between the droplets and the heated air, and collection of the product by separating it from the drying air.

While liquid food droplets are moving with the heated air, the water evaporates and is carried away by the air. Much of the drying occurs during a constant-rate period and is limited by mass transfer at the droplet surface. After reaching the critical moisture content, the dry food particle structure influences the falling-rate drying period. During this portion of the process, moisture diffusion within the particle becomes the rate-limiting parameter.

After the dry food particles leave the drying chamber, the product is separated from air in a cyclone separator. The dried product is then placed in a sealed container at moisture contents that are usually below 5%. Product quality is considered excellent due to the protection of product solids by evaporative cooling in the spray dryer. The small particle size of dried solids promotes easy reconstitution when mixed with water.

13.7 Freeze Dryers

Freeze-drying is accomplished by reducing the product temperature so that most of the product moisture is in a solid state, and by decreasing the pressure around the product, sublimation of ice can be achieved. When product quality is an important factor for consumer acceptance, freeze-drying provides an alternative approach for moisture removal.

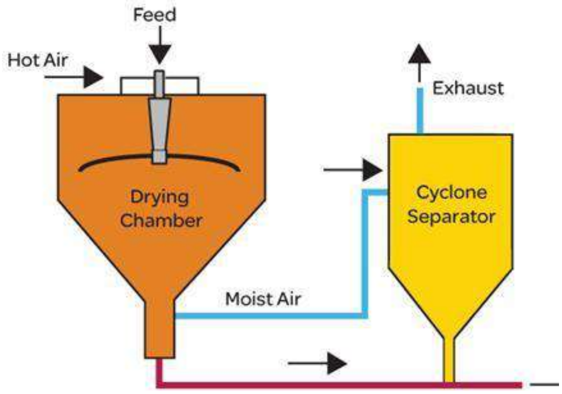


Fig.13.6. Spray dryer

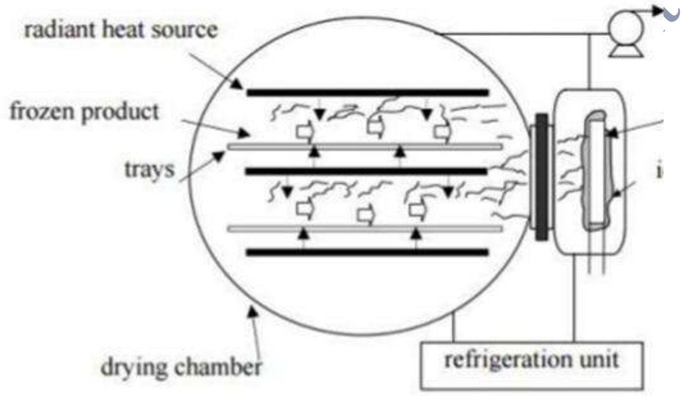


Fig. 13.7. Freeze dryer

Lecture 14

Material handling equipment; conveyer and elevators, their principle, working and selection

14.1 Material handling Equipment

Material handling includes a number of operations that can be executed either by hand (manual) or by mechanical means or devices to convey material and to reduce the human drudgery. The most common types of mechanical devices for grain handling are;

1. Belt conveyor
2. Bucket elevator
3. Screw conveyor
4. Chain Conveyor
5. Pneumatic conveyor

14.1.1 Selection of material Handling machines and Conveyors

The selection of proper conveying system is important for ease in operation and getting desired capacity for a particular product. Principles based on which the material handling equipment is selected:

- Based on the characteristics of the products being conveyed
- Working and climatic conditions.
- The capacity of conveying
- In a conveying system possibility of use of gravity.
- The capacity of handling / conveying equipment should match with the capacity of processing unit or units.
- Spillage of conveyed products should be avoided.
- Pollution of the environment due to noise or dust by the conveying system should also be avoided.

14.2 Belt conveyors

A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers. The belt may be flat for transporting bagged material or V-shaped. The belt conveyor consists of a belt, drive mechanism and end pulleys, idlers and loading and discharge devices.

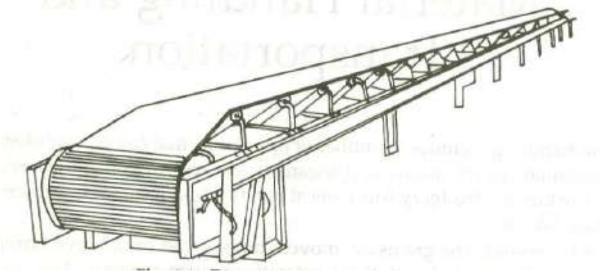


Fig.13.1. Diagram of belt conveyor

On the belt conveyor baggage/ product lie still on the surface of belt and there is no relative motion between the product and belt. This results in generally no damage to material. Belt can be run at higher speeds, so, large carrying capacities are possible. Horizontally the material can be transported to longer distance. The initial cost of belt conveyor is high for short distances, but for longer distances the initial cost of belt conveying system is low.

The first step in the design of a belt conveyor with a specified conveying capacity is to determine the speed and width of the belt. The belt speed should be selected to minimize product spillage or removal of fines due to velocity of the belt. For transportation of grains, the belt speed should not increase 3.5 m/s. Generally, for grain conveying, belt speed of 2.5 to 2.8 m/s is recommended. The selection of belt width will depend upon the capacity requirement, speed of operation, angle of inclination of belt conveyor, trough angle and depth.

14.3 Bucket Elevator

A bucket elevator consists of buckets attached to a chain or belt that revolves around two pulleys one at top and the other at bottom. The vertical lift of the elevator may range between few metres to more than 50 m. **Capacities of bucket elevators may vary from 2 to 1000 t/hr.** Bucket elevators are broadly classified into two general types, (1) spaced bucket elevators and (2) continuous bucket elevators.

The spaced bucket elevators are further classified as,

(1) centrifugal discharge elevators,

(2) positive-discharge elevators,

(3) marine leg elevators and

(4) high-speed elevators.

The continuous bucket elevators are classified as

(1) super capacity bucket elevators and

(2) internal-discharge bucket elevators.

The spaced bucket centrifugal discharge type is most commonly used for elevating the grains. The bucket elevator is a very efficient device for the vertical conveyance of bulk grains. Bucket elevators with belts are employed in food industries for vertical conveyance of grains, derivatives and flours. Bucket elevators are usually mounted at a fixed location, but they can also be mounted in a mobile frame. Bucket elevators have high capacities and it is a fairly cheap means of vertical conveyance.It requires limited horizontal space and the operation of conveying is enclosed in housing, thus it is dust free and fairly quite. The bucket elevator has limited wear problem since the product is enclosed in buckets. The buckets are enclosed in a single housing called leg, or two legs may be used. The return leg may be located at some distance from the elevator leg. The boot can be loaded from the front or back or both.

14.4 Screw Conveyor

The screw conveyor consists of a tubular or U-shaped trough in which a shaft with spiral screw revolves. The screw shaft is supported hanger bearings at ends. The rotation of screw pushes the grain along the trough. A typical screw conveyor is shown in the following Figure. The screw conveyor is used in grain handling facilities, animal feed industries and other installations for conveying of products generally for short distances. Screw conveyor requires relatively high power and is more susceptible to wear than other types of conveyors. The pitch of a standard screw which is the distance from the centre of one thread to the centre of the next thread is equal to its diameter. For example a 10 cm diameter screw has a pitch of 10 cm.

Fig.13.2. Screw conveyor

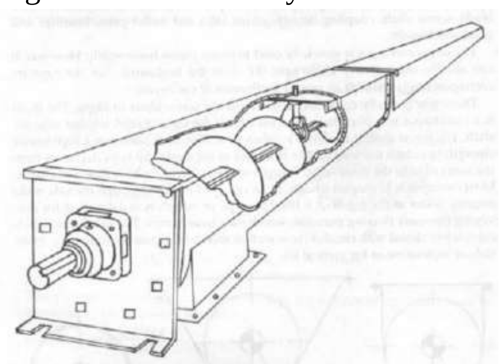
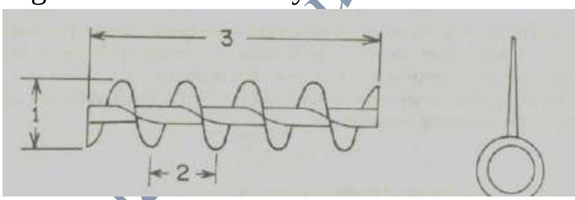


Fig.13.3. Screw conveyor details



As the screw conveyor's driving mechanism is simpler, and no tensioning device is required, the initial cost of the conveyor is lower than any other conveyor with the same length and capacity. The main parts of a screw conveyor are, screw blade, screw shaft, coupling, trough, cover, inlet and outlet gates, bearings and drive mechanism. The screw conveyor is generally used to move grains horizontally. However, it can also be used at any angle up to 90° from the horizontal, but the capacity correspondingly reduced as per the inclination of conveyance.

The screw basically consists of a shaft and the screw blade or flight. The flight is a continuous one piece helix shaped from a flat strip of steel welded onto the shaft. The screw shaft is usually a joint less tube with thick sides and a high tensile strength to reduce the weight. The thickness of the steel strip helix decreases from the inner edge to the outer edge. Troughs of screw conveyor have different shapes. Most common is U shaped trough. In an enlarged or flared trough the side walls become wider at the top (Figure). This type of trough is usually used for conveying non-easy flowing materials which may have lumps. The tubular trough is completely closed with circular cross-section and mostly used for conveying materials at inclination or for vertical lift.

14.5 Pneumatic Conveyor

The pneumatic conveyor moves granular materials in a closed duct by a high velocity air stream. Pneumatic conveying is a continuous and flexible transportation method. The material is carried in pipelines either by suction or blowing pressure of air stream. The granular materials because of high air pressure are conveyed in dispersed condition. For dispersion of bulk material, air velocities in the range of 15-30 m/s is necessary.

The pneumatic conveying system needs a source of air blowing or suction, means of feeding the product into the conveyor, ducts and a cyclone or receiving hopper for collection of product. There are three basic systems of pneumatic conveying. These are pressure or blowing system, suction or vacuum system, and combined push-pull or suck blow system. In blowing or positive pressure systems, the product is conveyed by using air pressures greater than the atmospheric pressure.

The selection of air mover is the most important aspect of the design of a pneumatic conveying system. In design, the two factors, (1) supply air pressure and (2) the volumetric flow rate of air should be considered. For separation of product particles from air, air-product separators are used. Cyclones are mostly used to collect the particles. Cyclone is a device which removes the bulk of the product particle from the conveying air stream by centrifugal force. In some cyclone, a fabric filter is attached to remove residual dust and fine product particles from the air stream.

Limitations of Pneumatic Conveying

1. Erosion of solid surfaces and equipment surfaces by solid particles with conveying air stream.
2. In case of bends or misaligned sections, the erosion problem becomes severe.
3. Chances of repeated impacts between the particles and the solid surfaces are high. Due to such impacts, product degradation results.

14.6 Chain Conveyor

A chain is a reliable machine component, which transmits power by means of tensile forces, and is used primarily for power transmission and conveyance systems. The function and uses of chain are similar to a belt. Chains are divided into five types based on material of composition or method of construction.

1. Cast iron chain
2. Cast steel chain
3. Forged chain
4. Steel chain
5. Plastic chain

Lecture 15

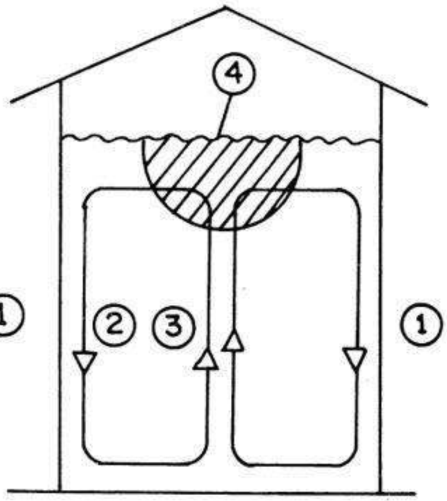
Effect of temperature, relative humidity and gas composition, traditional storages structures, Modified and Controlled atmosphere storage structures

15.1 Moisture and temperature changes in stored grains air movement inside the storage.

The migration of moisture in stored grain takes place due to change in temperature as per season i.e. winter and summer. One of the most important factors influencing storage life of the grain is moisture content. High moisture content and a warm climate promote mold growth, insect growth and increase rate of respiration of grains and due to this deterioration and losses of the stored grains takes place. Moisture migration takes place in stored bin even though the grains are stored at a desired moisture level i.e. safe for storage.

15.1.1 Air movement and migration of moisture inside storage bin in winter season

The grains after harvest in summer is stored in storage bin, grains become warm. When winter season comes, the atmospheric temperature is lowered down. The grain stored in summer is warmer than the atmospheric temperature. In this condition after passage of time the air at the surface of storage bin is cools because the outside temperature is lower than the temperature in the centre of bin due to the grains are warmer. The cool air at inside surface of bin moves down along the edge of the bin, across the bottom and then upward near the centre of the bin, where the air and grain are warm. The cool air moving through the centre of the bin picks up moisture from the grains and moves across the top of the sides. At this location the surface of the grain is cold and the moisture condenses on the grain at top surface and consequently the moisture content of grain at top surface is raised. Because of increased grain moisture, spoilage takes place at top of the bin.

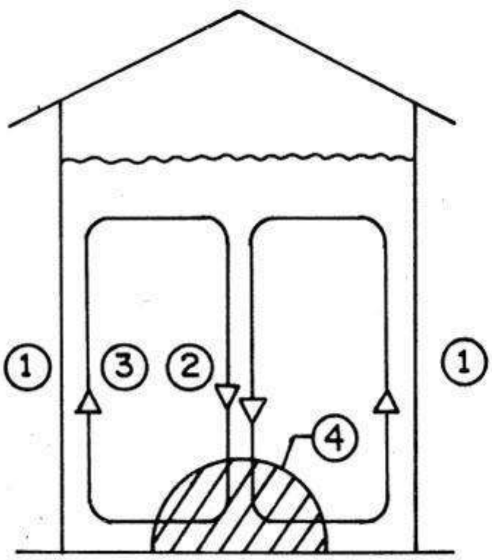


1.outer cool temperature
2.cool grain
3.warm grain
4.spot of moisture accumulation

Fig. 14.1. Spoilage of food grains due to temperature changes in winter season

15.1.2 Air movement and migration of moisture inside storage bin in summer season

Winter season over and summer season starts, the atmospheric temperature is higher. The grain stored in winter is cooler than the atmospheric temperature. Such grain is stored, after sometime the temperature of air in the grain along the surface rises. The atmospheric temperature in spring and later on rises. As a result air currents move top to bottom through the centre of the bin because at top of the bin the grain is warmer due to higher atmospheric temperature. The hot air at inside top surface of bin moves down at the centre to the bottom of bin and then upward near the surface edge of the bin, where the air and grain are warm. The hot air moving through the centre of the bin picks up moisture from the cool grains and moves across the bottom of the bin. The moist air condenses due to cool grain and moisture accumulation at bottom. Because of increased grain moisture, spoilage takes place at bottom of the bin.



1. outer warm temperature
2.cool grain
3.warm grain
4.spot of moisture accumulation

Fig.14.2.Spoilage of food grains due to temperature changes in summer season

15.2 Traditional storage structures- (Bulk type)

In this types of storage structures the grain is generally stored in bulk. This types of storage structures having generally capacities between 1 to 50 tonnes. The storage of grain is generally done in one of the following storage structures in the different rural and urban regions of India in bulk as well as in bag storage

15.2.1 Morai type storage structure

Morai type of structure is used for the storage of paddy, maize and sorghum (jowar) in the rural areas of eastern and southern regions of India. Its capacity varies from 3·5 to 18 tonnes. These structures are very similar to the shape of an inverted cone. They are placed on a raised platform supported on wooden or masonry pillars. The improved type of structure consists of a circular wooden plank floor supported on pillars by means of timber joints. The planks are joined together with lap joints. All around the wooden floor a 22 gauge corrugated metal cylinder of 90 cm height is nailed to it. The edge of the cylinder is flushed with the bottom end of the floor. Inside the cylinder, 7·5 cm diameter ropes made of paddy straw or similar material are placed, beginning from the floor level upto a height of 90 cm. Then bamboo splits are placed vertically along the inner surface without leaving any gap between them. The height of the bamboo splits is equal to the total height of the structure. Keeping the bamboo splits in position, the grain is poured in up to the height of the metal cylinder. By then the bamboo splits are held erect in position. Now the winding of the rope as well as the pouring in of grain are done simultaneously. This process continues tiIl the required height is attained. The top most ring of the rope is secured in position by tying to the lower four rings. To provide a smooth surface, about 1 cm thick layer of mud plaster is applied over the rope. A conical roof is placed on the top of the structure having an ample overhang all around

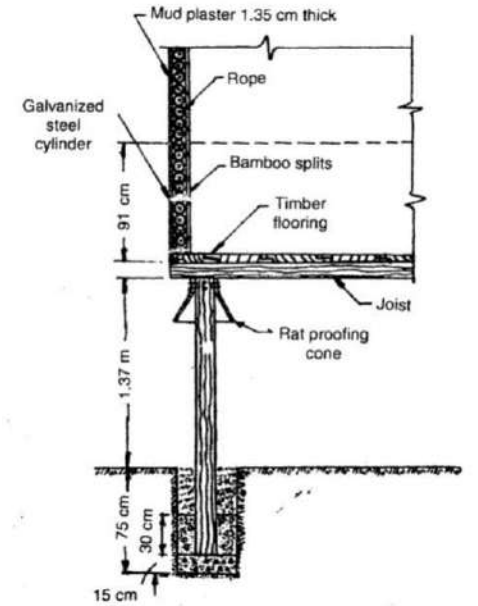


Fig. 15.3. Morai type storage structure

15.2.2 Bukhari type storage structure

Bukhari type storage structures are cylindrical in shape and are used for storage of sorghum, wheat, padd)" Bengalgram, maize etc. Bukhari structures generally have capacities between 3.5 to 18 tonnes, however, smaller capacity structures also exist. This may be made by mud alone or by mud and bamboo. The cylindrical storage structures are raised above the ground by wooden or masonry platform. The floor of the bin is made either by timber planks or by bamboo splits, plastered over with mud rilixed with dung and paddy straw. The walls of the structure are made of timber or bamboo frame work and bamboo matting. Over the walls, mud-straw plaster is applied on both sides. An overhanging cone type roof is provided on the cylindrical structure. The roof is generally made of bamboo framework and straw.

In improved bukhari type structure, the basic shape remains the same but the material and method of construction have been improved to make the structure more safe and durable. The circular floor of structure is either made of wooden planks joined by lap joints or by a double layer of bamboo splits closely set at right angles to each other. Over the floor, about 5 cm thick mud plastering is provided. The walls of structure are made of two sets of strong bamboo framework. The inter-space is filled with mud. The walls on both sides are plastered with mud. The roof is conical and made of bamboo frame-work and covered with paddy straw or similar other thatching material. The top of the conical roof is covered with 4 to 5 cm thick mud layer to provide additional protection from rains. The structure is raised on timber or masonry pillars to a height of about 1.5 m from ground level. Rat proofing cones are placed on all the four pillars to avoid rats entering the storage structure.

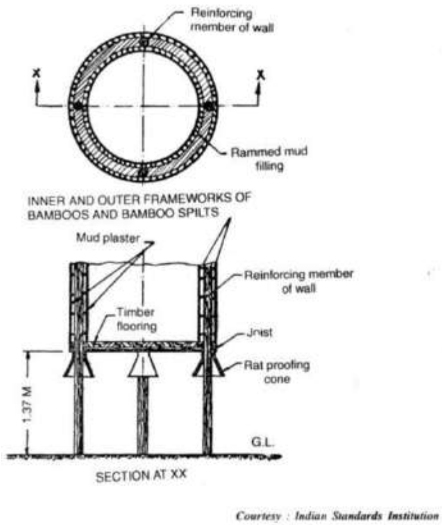
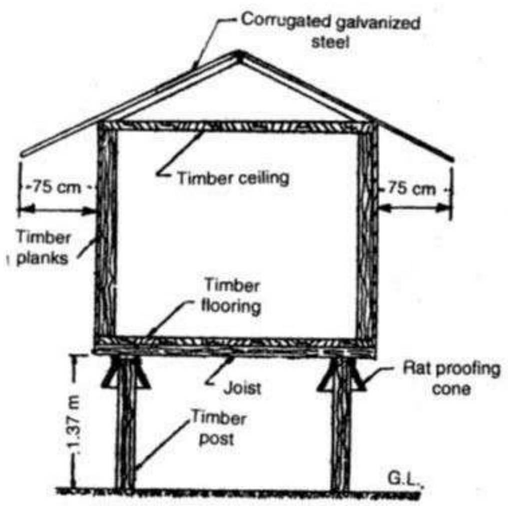


Fig.15.4.Bukhari type storage structure

15.2.3 Kothar type storage structure

These are used to store paddy, maize, sorghum, wheat etc. Their capacity varies between 9 to 35 tonnes. The storage structure is box like made of wood and raised on pillars. Both the floor and walls are made of wooden planks whereas the thatched or tiled roof is placed over it to protect the grains from the sun or rain. The improved Kothar structure is generally made of 5 cm thick wooden planks and beams. The walls and floor are made in such a way that no gap exists between the planks. The gabled roof on the top may be made of planks or corrugated metal sheets and should be sufficiently overhang on all sides. The storage structure is raised on timber post to a height of about 1.5 m above the ground. Rat proofing cones are provided on all posts to avoid entry of rats in the structure.



Courtesy : Indian Standards Institution

Fig. 14.5.Kothar type storage structure

15.2.4 Mud Kothi (Mud bin)

These storage structures are quite common in rural areas for storage of grains and other seeds. The capacity of such storage structures varies from 1 to 50 tonnes. These are made from mud mixed with dung and straw. These Kothies are generally rectangular in shape but cylindrical Kothi is also common in some region. There are many sizes and dimensions of Kothi made for storing grains.

15.2.5 Muda type of storage Structure

These are in use for storing grains in the rural areas of Bihar. The capacity of muda varies between 1 to 3 tonnes. It is being made of "Narai" ropes. The shape of muda is cylindrical and being made in various sizes.

15.2.6 Kanaj type of storage Structure

These storage structures are very common in the rural areas of Karnataka and Maharashtra for storage of grains. The capacity of Kanaj varies between 1 to 20 tonnes. It is being made by bamboo splits. The shape of storage structure is cylindrical. The walls of storage structure are sealed with mud plaster on both sides. The roof of the structure is conical and thatched. The roof overhangs on all sides.

15.2.7 Bag Storage Structure

These structures are generally used for the storage of 25 to 500 tonnes of grain. The length of the structure is about twice the width or greater than that. A typical floor plan of such a structure large enough to store about 6000 bags (500 tonnes) of grain. Bags of different capacities (35, 50, 75 and 100 kg) with or without inside plastic lining are used. The standard size of a 100 kg bag is 100 cm x 60 cm x 30 cm i.e. length of bag is 100 cm, width of bag is 60 cm and height of filled bag is 30 cm. This bag can store 93 Kg of Wheat and 75 Kg of Paddy.

Bag storage	**Bulk storage**
Flexibility of storage	Inflexible storage
Partly mechanical	mechanical
slow handling	Rapid handling
Considerable spillage	Little spillage
Low capital cost	High capital cost
High operating cost	Low operating cost
High rodent loss potential	Low rodent loss potential
Reinfestation occurs	Little protection against reinfestation

15.3 Types of improved storage structures

In improved type of storage structures, there are some improvements made in traditional storage structures. These types of storage structures have a higher storage capacity for long term storage of food grains than traditional storage structures. Improved types of storage structures have capacities generally in the range of 1.5 to 150 tons. The storage of grain is generally done in one of the following storage structures in the different rural and urban regions of India.

15.3.1 Pusa bin

Pusa bin is just like other traditional storage structure and is made of mud. To make this storage structure moisture proof, a plastic film is used on inner side of the bin. A platform of mud bricks is made, first. On this platform, a sheet of 700 gauge plastic is spread in such a way that it overlaps the platform on all sides by atleast 6 cm. On the plastic sheet, a layer of 7 cm thick kachcha bricks is then laid. Walls are made of kachcha bricks and these are sealed with mud plaster. Now the walls are raised to proper height and a wooden frame is placed on it. The upper roof of the structure is made of burnt bricks. For unloading of grains, an inclined wooden or steel pipe is fixed in such a way that grains may come out of structure by gravity. The mouth of pipe is closed by a cover. The inside of all the four walls and roof are covered with a plastic sheet. On the top, an open space of about 50 cm x 50 cm is left for loading of grains. Leaving this open space, the roof is sealed by mud. After the bin is filled with grains, the top open space is well covered by a plastic sheet so that air may not enter the bin.

15.3.2 Brick and cement bin

These storage structures are very strong and therefore, the effect of season on them is negligible. The bin is made on a platform raised at 60 cm above the ground. A ladder is provided on one side of the bin for loading of the grains. A hole of about 60 cm diameter is provided on the roof for the purpose of loading the material i.e. grains. The walls of bin are about 23 cm thick with cement plastered on both the sides. Roof is made of R.C.C. The base of bin is made inclined and an outlet is provided for unloading of grains. The capacity of such bin is usually between 1.5 to 60 tonnes. For cleaning of bin and complete unloading, a provision of iron rings steps is provided inside the bin for person can enter and exit the bin.

15.3.3 Bunker Storage

Bunker storage structure is used for long term storage of a larger volume of grains. The structure is successful as a means of storing grains safely, securely and economically. By controlling insects and the moisture, the losses in stored grains can be reduced upto 0.5%. In this type of storage structure, the grain is stored on a plastic sheet which is spread over ground and top covered with plastic sheet as is shown in fig. 36.2. A drain is also provided for drainage of rain water.

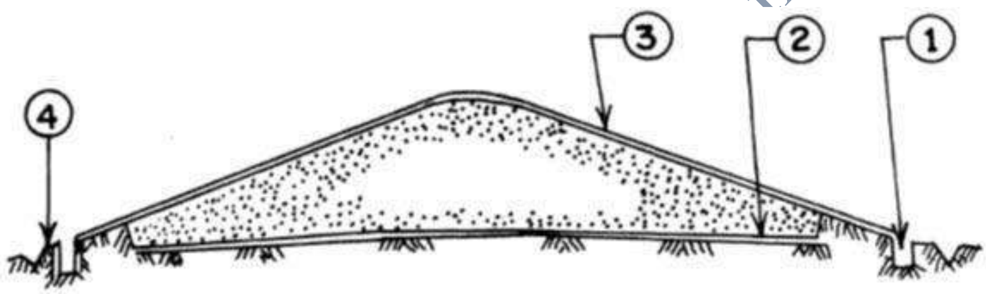


Fig.15.6. Schematic diagram of a bunker storage
1. trench for burying cover 2. plastic ground sheets 3.top cover 4.drain

15.3.4 'CAP' Storage structures

The 'CAP' is used for cover and plinth storage. The word plinth is means plinth from the bottom and cover means cover from the top. This type of open storage is considered as intermediate storage and serves the purpose of storage of food grains in bags for short period. This type of storage facility is cheaper as compared to conventional bag storage godowns. The cover is rectangular in shape having five sides and made from polyethylene film of 1000 gauge, leaving the bottom side open. The cover is used for protecting stack of bags. Normally the stack is built over a space of 9.11 x 6.1 m with a height of 18 bags which gives the storage capacity of around 150 tonnes. The cover having a dimension of 9.4 m x 6.4 m x 5.5 m normally weighs around 52 kg. Sometimes smaller covers are used for covering the stacks in covered varandah of conventional godowns. Such covers are called "Varandah covers". For storage of food grains under varandah covers, the stacks are built to a height up to 7 bags having an average capacity of 24 tonnes.

The following steps are normally followed in the construction of a 'CAP' storage

(i) Select a high elevated ground and make it level.
(ii) Wooden sleepers are spread with one or two layers of bamboo mat cover on the top as dunnage.
(iii) The Gutters are provided all around the area to drain off rain water easily.
(iv) The stacking is done to the height upto 18 bags on the dunnage and is covered with polyethylene.
(v) The stacks arc covered with polyethylene covers and tied with ropes to prevent from blowing off with high velocity wind.

15.4. Controlled And Modified Atmosphere Storage

Introduction

Controlled atmosphere (CA) and modified atmosphere (MA) storage are technologies for extending the shelf life of foods, especially fruits and vegetables; and for eliminating pests in stored grains and oilseeds. The most important application of CA and MA is for long-term storage of apples, but the shelf life of certain other fruits (pears, sweet cherries) and vegetables (cabbage) can also be extended by these methods. In addition, there is considerable evidence that MA can extend the shelf life of meat, fish, poultry, fresh pasta, sandwiches, eggs, and bakery products. Because grains and oilseeds are more stable than high moisture foods (e.g., fruits, vegetables, meats), CA and MA are used primarily for disinfestation rather than for increasing the shelf life

15.4.1 Controlled and Modified atmospheres for fruits and vegetables

The principle behind controlled and modified atmosphere technologies is to reduce the rate of respiration, reduce microbial growth, and retard enzymatic spoilage by changing the gaseous environment surrounding the food product. This is achieved by reducing the concentration of oxygen (O_2), which is required in respiration, or by adding an inhibitory gas such as carbon dioxide (CO_2) or carbon monoxide (CO). The balance between O_2 and CO_2 is critical, and an optimal ratio is required for each specific product. A major difference between CA and MA storage is in the degree of control of the gaseous composition of the storage atmosphere. The CA implies a higher degree of control than MA in maintaining specific levels of O_2, CO_2, and other gases. Also, in MA storage the composition of the atmosphere surrounding the product is generally created and maintained by the interaction of the commodity's respiration with the permeation of respiratory gases through the packaging material. Modified atmosphere conditions can also be established and adjusted by pulling a slight vacuum and replacing the package atmosphere with a desirable gas mixture, which can be further, adjusted through the use of O_2, CO_2, or ethene (C_2H_4) absorbers. In CA storage facilities, both temperature and gas composition of the storage atmosphere are regulated or controlled. The gas concentration ranges encountered in CA storages are 1 to 10% O_2, 0 to 30% CO_2, and the balance is nitrogen (N_2). Air consists of approximately 78% N_2, 21% O_2, 0.03% CO_2, and traces of several other gases that have no physiological significance.

Benefits and limitations of CA and MA storage

The benefits and concerns of CA and MA storage have recently been reviewed by several authors. The benefits can be divided into quality advantages and marketing and distribution advantages. The improvements in quality arise from the general reduction in the rates of metabolic processes, retardation of physiological aging, enzymatic spoilage, and reduction in microbial growth. In fresh fruits and vegetables stored under optimal CA or MA, practical quality advantages include:

1. Reduction in chlorophyll breakdown, with resulting higher color stability.
2. Reduction in enzymatic browning in cut produce, whenever low levels of O_2 are used.
3. Improvement in texture caused by the action of CO_2 on enzymes acting on cellular membranes.
4. Reduction in some physiological disorders induced by C_2H_4, such as scald of apples and pears and chilling injury of citrus fruits, avocado, chili pepper, and okra.
5. Reduction in microbial activity especially molds.

The marketing and distribution advantages of CA or MA technologies include:

1. Reduction in fresh food spoilage and quality loss through the distribution at the retail level.
2. Expanded radius of distribution systems and market area.
3. Improved branding options and product differentiation.
4. Potential for increased profitability in all fresh or chilled food operations.

In considering the above described benefits, a number of potential problems associated with CA or MA storage must be recognized. Above all is the potential health hazard associated with these technologies, especially modified atmosphere packaging or MAP. It has been pointed out that the same principles of atmosphere modification responsible for all the benefits of CA or MA are also the main cause of controversy surrounding the potential health hazards associated with these technologies. Modification of the atmosphere and, in particular, the reduction or elimination of O_2 from the package head space will in many cases disturb the equilibrium of the atmosphere in favor of anaerobic microorganisms. The aerobic bacteria that normally spoil the product, and in so doing warn consumers of any potential health hazard, may find themselves at an atmospheric disadvantage and their growth inhibited. In the absence of competing aerobic organisms, anaerobic non proteolytic toxin producers, such as Clostridium botulinum, are likely to have the right conditions for optimum growth, but their presence may not be obvious to the senses. The food may appear to be acceptable long after it has become microbiologically unsafe.

15.4.2 Controlled Atmosphere storage of Cereals and Oilseeds

In CA storage, an environment that is lethal to stored-grain pests is created by changing the proportions of CO_2, O_2, and N_2 in the atmosphere surrounding the bulk grain in storage structures. Controlled atmosphere storage is different from an airtight storage where gas ratios change naturally, although both are carried out in more or less gas-tight storage structures. In air-tight storage, the depletion of O_2 and the accumulation of CO_2 occur due to the metabolic processes of the insects, microflora, and the stored grain. Because the effectiveness of the air-tight storage is largely dependent upon the build-up of an infestation in the grain, it is not considered a satisfactory method. Controlled atmospheres are attained by introducing CO_2 or N_2 from external sources, possibly prior to the build-up of infestation, thereby preventing damage to the stored grain.

Advantages and limitations

The main advantage of CA to disinfest grain is its potential to replace pesticides used in the grain industry. The CA-treated grain does not have any chemical residues which can cause considerable health concerns. In addition to providing an effective control of pests, CA storage prevents mold growth, preserves grain quality, and maintains a high level of germination in the stored grain. However, as with any other method of pest control, CA storage has limitations. The major limitation appears to be the high initial cost of air-tight storage structures, and the cost of sealing existing structures to the desired air-tightness. There is also the cost of the generation and transportation of the gas. The interaction of CA gases with the storage structure can cause some practical problems. The introduction of CO_2 or N_2 into airtight structures has the potential to increase the internal pressure on bin walls, and steps need to be taken to permit pressure equilibration. The only chemical reaction observed with CA involves CO_2 in concrete silos. Carbon dioxide is bound by concrete through carbonation, which can result in reduced pressures developing in well-sealed new concrete bins. Also, carbonation of concrete can gradually extend to a depth where reinforcing steel is exposed and the steel may eventually corrode and weaken the storage structure.

Lesson 16

Storage of pulses, cereals, oilseeds, fruits and vegetables

16.1 Storage of Cereal Grains

Compared with fruits and vegetables, cereal grains are extremely amenable to storage for the reason that their moisture content at harvest is relatively low and their bio-composition is such that bio-deterioration is much slow. Harvesting is seasonal but the need for fresh cereal products is continuous. The least requirement for storage, therefore, is for the period between harvests. Under appropriate condition, this can easily be met and indeed storage for many years without serious loss of quality is possible. Even in biblical times long periods of storage were apparently achieved.

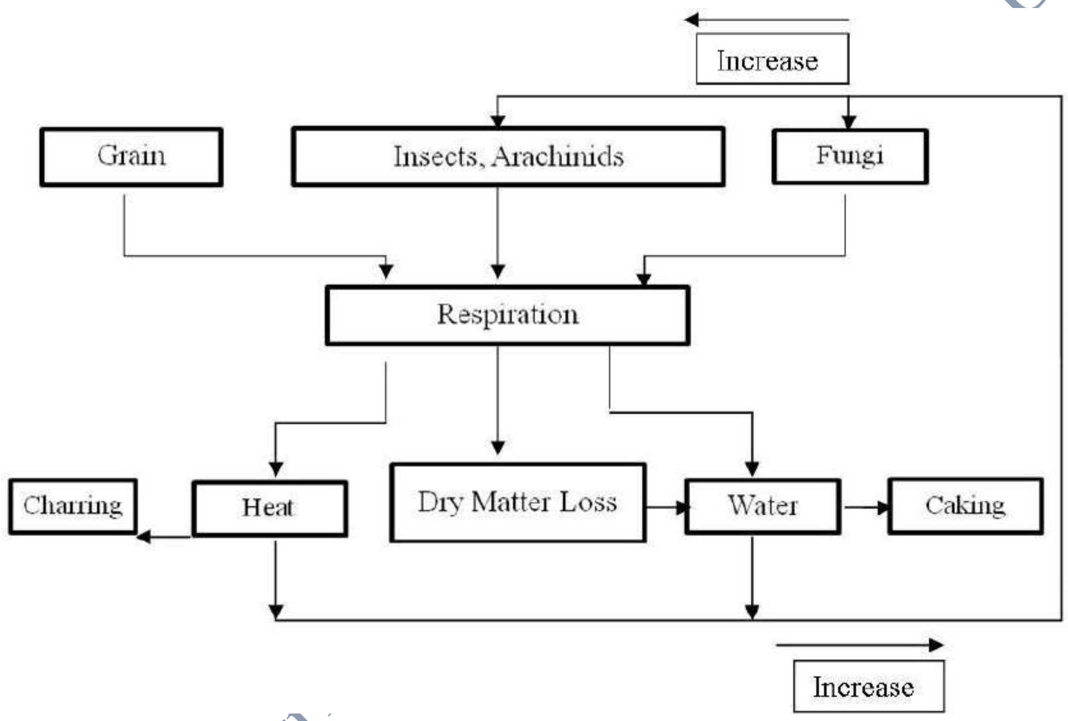


Fig. 15.1 Factors responsible for damage of grains during storage

In spite of the diversity of cereal grain types and the ambient conditions throughout the cereal producing and consuming world the hazards of storage are fundamentally similar although the relative difficulties involved in their avoidance vary with location. Successful storage method range from primitive to highly sophisticated. The hazards besetting cereal grain storage are excessive moisture content, excessive temperature, microbial infestation, insect and arachnid infestation, rodent predation, bird predation, biochemical deterioration, mechanical damage through handling

16.1.1 Moisture content and storage temperature

Moisture content is expressed as a percentage of the grains' wet weight. The safe moisture contents for storage varies according to the type of cereal but it is widely assumed that they are equivalent to the equilibrium moisture content of the respective grains at 75% RH and 25^{0}C and is shown below in table 15.1 for some of the cereals.

Table 15.1 Equilibrium moisture content of grains at 75% RH and 25^{0}C

Cereal types	**Moisture %**
Barley	14.3(25-28 ^{0}C)
Maize	14.3
Oats	13.4
Rice	14.0
Ryes	14.9(25-28 ^{0}C)
Sorghum	15.3
Durum Wheat	14.1
Red Wheat	14.7
White Wheat	15.0

In temperate regions the moisture contents at which grain is stored are closer to those described as wet rather than dry. The significance of moisture contents cannot be considered alone as the deleterious effects of excessive dampness are affected critically by ambient temperature and the composition of the surrounding atmosphere. The increase in relative humidity of the interseed atmosphere with temperature is slight. It amounts to about 0.6-0.7% moisture increase for each 10^{0}C drop in temperature.

Broken grains are almost always present to some extent as a result of damage during harvesting and transferring to sound clean samples. In broken grains endogenous enzymes and their substrates, kept separate in the whole grain can achieve contact and lead to necrotic deterioration. Endosperm and embryo are exposed to moisture, micro-organisms and animal pests whereas in the whole grain they are protected by fruit coat, seed coat, and possibly husks. Impurities can also reduce storage time in that weeds present in the crop ripen and dry at a different rate from the crop itself. Hence, still green plant material - with relatively high moisture content - can carry excessive moisture into store even when mixed with dry grain.

16.1.2 Changes during storage

Respiration

In a natural atmosphere gaseous exchange will occur in a stored cereal crop. This is due to respiration and it involves depletion in atmospheric oxygen and an increase in carbon dioxide with the liberation of water, and energy (as heat). Respiration rates measured normally include a major contribution from microorganisms that are invariably present at harvest; nevertheless even ripe dry grain, suitable for storing, contains living tissues in which respiration takes place, albeit at a very slow rate. The aleurone and embryo are the tissues involved and like other organism present, their rate of respiration increases with moisture content and temperature.Respiration is a means of releasing energy from stored nutrients (mainly carbohydrates) and a consequence of long storage is a loss of weight. Respiration can be reduced by artificially depicting the oxygen in the atmosphere.

Germination

Germination of grain is an essential and natural phase in the development of a new generation of plant. It involves the initiation of growth of the embryo into a plantlet, Roots develop from the redicle and leaves and stern develop from the plumule. Hydrolytic enzymes are released into the starchy endosperm, and these catalyze the breakdown of stored nutrients into soluble form available to the developing planet. Deterioration results from loss of weight due to enzyme activity and a loss of quality resulting from excessive enzyme activity in the products of processing.

Microbial infestation

Fungal spores and mycelia, bacteria and yeasts are present on the surfaces of all cereal crops. During storage they respire and given adequate moisture temperature and oxygen, they grow and reproduce, causing serious deterioration in grains. Field fungi thrive in a relative humidity (RH) of 90-100% while storage fungi require 70-90% RH.

As with other spoilage agents dependent upon minimum moisture content, fungi may be a problem even when the overall moisture in the store is below the safe level. This can result from air movements leading to moisture migration. Unless temperature gradients are extreme the exchanges occur in the vapour phase; nevertheless, variations in moisture content up to 10% within a store are possible.

Insects and Arachnids

Insects that infest stored grains belong to the beetle or moth orders; they include those capable of attacking whole grain (primary pest) and these that feed on grain already attacked by other pats (secondary). All arachnid pests belong the order Acarina (mites) and include primary and secondary pests. Most of the common insects and miles are cosmopolitan species found through out the world where grain is harvested and stored. Insects and mites can be easily distinguished as arachnids have eight legs and insects, in their most conspicuous form have six.

16.1.3 Design of Storage Facilities

The requirements of long term safe storage are protection against dampness caused by weather or other sources, micro-organisms, destructively high temperature, insects, rodents and birds Objectionable odours and contaminants and unauthorized disturbance. Clearly the simplest stores such as piles on the ground, unprotected, are suitable for short periods only. Other simple stores, system is suited to cob maize rather than threshed grains, as adequate space for air movement within the store is essential. Clearly the requirements of ventilation and exclusion of insects are not immediately compatible and hence careful design is essential.

Storage of maize as cobs practised now largely by small scale growers producing for the requirements of the local community. It was at one time adopted more widely even in highly commercial practice, much small gram cereals were stored unthrashed in ricks.

In the commercial context store are needed for three purposes:

1. Holding stocks on the farm prior to sale.
2. Centralization before distribution or processing during the year following harvest.
3. Storage of annual surpluses over a longer period.

Farm stores may consist of any available space that will keep out the elements. The facilities for protection against mould and pests are very variable. Stores range from small wooden enclosures in the barn to round steel bins holding 25-80 tonnes, to sues of larger capacities. Good on- farm storage facilities allow farmers to choose the time to sell, to receive the best prices. It is sometimes necessary to provide storage for grain beyond the normal capacity of an elevator facility or elsewhere. In such conditions a relatively inexpensive expedient is the flat store. This is little more than a cover for a pile of dry grain adopting its natural form as poured. Such a form is described by the angle of repose. In the case of wheat the angle is 27^0 to the horizontal, hence flat stores have roofs close to this angle, Very temporary stores may make use of inflatable covers.

Flat stores are easy to fill but, as they have flat floors, removal of stocks is more difficult, usually requiring the use of mechanic shovels. In contrast, silos usually have a floor formed like a conical hopper whose walls make an angle greater than 27^0 to the horizontal. Piles created by grains falling freely from a central spout are not uniform as whole grains tend to roll from the apex down the sloping surfaces. Small impurities and broken grains roll less readily and thus become trapped in the central core of the pile. Such a core is described as the spout line. As the interstices can grains rolls readily and thus become trapped in the central core of the pile. Such a core is described as the spout line. As the interstices can amount to 30% of the occupied space, fines in the spout line can reach that level. Because air circulation and hence heat loss is prevented, the spout line can be associated with early deterioration through overheating. The diameter of the spout line is proportional to the width of the bin. Also in contrast to tall tower-like stores, flat stores require little strength in the side walls. In a silo much of (he pressure of the column of grain is borne not by the floor but by theside walls. This is because each grain rests on several grains below it so that some of the weight is distributed laterally until it reaches the walls and, by friction, rests on them. In all stores some settling occurs and this varies according to the cereal type. Wheat is relatively dense and settling may be only 6% of volume but oats may pack as much as 28%. Settling is a continuous process arising in pan from the collapse of hulls, brush hairs embryo tips etc.

16.1.4 Control of Pests in storage

Deterioration in store is less likely if care is taken to ensure that the grain is in a suitable condition for storing, Criteria for the latter include suitably low moisture content, a low mould count and freedom from insects. Wheat containing live insects can be sterilized by passage through an entoleter, run at about 1450 rev/min. Hollow grains and insects may be broken up and can be removed by subsequent aspiration

The store itself should provide protection from weather (particularly wet) and intrusion by insects and rodents. High temperatures are undesirable and variation should be reduced to a minimum as this can lead to local accumulation of moisture. All spoilage agents depend upon respiration and hence a depletion of oxygen inhibits their as this can lead to local accumulation of moisture. All spoilage agents depend upon respiration and hence a depletion of oxygen inhibits their proliferation and activity. To achieve this it is necessary to provide a seal around the grain and a minimal headspace. In a sealed store oxygen depletion can be achieved by natural or artificial fans, Natural depiction results from respiration which in most organisms consumes oxygen and produces carbon dioxide. Artificial atmosphere control comes about by flushing of interstitial and head spaces with a gas other than oxygen. Usually nitrogen or CO_2 as these are relatively inexpensive. Complete removal of oxygen is not possible. Seated conditions are unusual and prevention of spoilage in many cases depends upon careful maintaining of the stored grains' condition, and prophylactics treatments with chemicals. Fortunately, nearly all threats to grain quality cause temperature rises and monitoring of temperature, through incorporation of thermocouples, can reveal a great deal about condition.

Forced ventilation can reduce temperatures but it may be necessary to remove the cause by use of chemical treatments. Such treatments are relevant primarily when the problem is caused by insects. Because of the possible persistence of pesticides on cereals, their use in stores is increasingly becoming regarded as a last resort. In most countries strict codes of practice apply to their uses.

Pesticides used to control insects, during storage of cereal grains, are of two types. Those that are designed as a respiratory poison and are hence applied as gas or volatile liquid, are described as fumigants. Those designed to kill by contact or ingestion arc described as insecticides. They may be applied in liquid or solid form.Of the gascous fumigants, methyl bromide and phosphine (PH) are the main examples. Examples of 'liquid' fumigant are mixture of 1,1 dichloroethane and tetrachloromethane although the most effective fumigant is methyl bromide, this gas does not penetrate bulk grain well and the use of a carrier gas such as tetrachloromethane is an alternative to the fan-assisted circulatory system required if methyl bromide is used alone. Few stores have the necessary fans.

The period of treatment required depends upon the susceptibility of the species of insects present to the fumigant. For example three day exposure to phosphine may eliminate the saw-toothed grain beetle but six days at low temperature may be needed to kill the grain weevil. A liquid-' fumigant penetrates bulks well. The proportions need to be adjusted to suit the depth of the grain stored. Fumigation requires the stores be sealed to prevent escape of the toxic fumes.

16.2 Storage Conditions For Various Fruits & Vegetables

Cold storage of fruits and vegetables was used extensively by our ancestors to keep food after the harvest season. In modern times, the year round availability of fresh produce in the supermarket has reduced the use of home storage. However, even today there are benefits of home storage, which make it a good alternative to buying produce from the store. Most importantly, farmers often have excess fruits and vegetables that cannot be consumed immediately but would store well. Stored fruits and vegetables harvested at peak maturity from the farm usually have better flavor and a higher nutritional value.

16.2.1 Temperature

All fruits and vegetables have a 'critical temperature' below which undesirable and irreversible reactions or 'chill damage' takes place. Carrots for example blacken and become soft, and the cell structure of potatoes is destroyed. The storage temperature always has to be above this critical temperature. One has to be careful that even though the thermostat is set at a temperature above the critical temperature, the thermostatic oscillation in temperature does not result in storage temperature falling below the critical temperature. Even 0.5°C below the critical temperature can result in chill damage.

Table 16.1. Storage conditions for various fruits and vegetables

	Temperature°C	Relative Humidity %	Maximum Storage time Reccomended (ASHARE handbook 1982)	Storage time in cold stores for vegetables in Tropical countries
Apple	0-4	90-95	2-6months	
Beetroot	0	95-99		
Cabbage	0	95-99	5-6m	2m
Carrots	0	98-99	5-9m	2m
Cauliflower	0	95	2-4w	1w
Cucumber	10-13	90-95		
Eggplant	8-10	90-95		
Lettuce	1	95-99		
Leeks	0	95	1-3m	1m
Oranges	0-4	85-90	3-4m	
Pears	0	90-95	2-5m	
Pumpkin	10-13	70-75		
Spinach	0	95	1-2w	1w
Tomatoes	13-21	85-90		

It can be seen from the table that there are basically three groups of fruit and vegetables: those stored at 0 - 4°C; those stored at 4 - 8°C; and those that require a storage temperature above 8°C. It is often more convenient to concentrate on one of these groups.

16.2.2 Relative humidity

For most produce, a high but not saturated, relative humidity is required, eg 85 - 95%. There is always some moisture loss during cold storage but excessive moisture loss is a problem. It is essential that the relative humidity is kept above 85%. This can be done by:

- allowing the produce to reach storage temperature and then covering in plastic
- sprinkling the produce with water, this should be done before storage since if the vegetables are sprinkled during storage condensation occurs at the refrigeration unit.

Once harvested, fruits and vegetables must be stored under proper conditions, the most important of which are temperature and humidity. Each fruit or vegetable has its own ideal set of conditions at which it will store most successfully for the maximum length of time. These conditions can be classified into four groups:

1. Vegetables which require cold & moist conditions
2. Vegetables which require cool & moist conditions
3. Vegetables which require cold & dry conditions
4. Vegetables which require warm & dry conditions

The tables on the following page list temperature and humidity requirements for most vegetables. In addition to proper temperature and humidity, all fruits and vegetables must be kept in a dark, aerated environment. While most vegetables like moist conditions, standing water must be avoided, as it will quickly lead to rot. Produce must not be allowed to freeze and should be protected from animal pests such as mice. It is important to remember that crops held in storage are still living plants, capable of respiration and affected by their environment. The goal of storage is to keep them in a dormant state. One other note, fruits and vegetables should always be stored separately. Fruits release ethylene, which speeds the ripening process of vegetables. Fruits are also very susceptible to picking up the taste of nearby vegetables

Table 16.2 Fruits & Vegetables that require cold, moist conditions

Vegetable	Temperature (°F)	Relative Humidity (%)	Length of Storage
Asparagus	32-36	95	2-3 weeks
Apples	32	90	2-6 months
Beets	32	95	3-5 months
Broccoli	32	95	10-14 days
Brussels Sprouts	32	95	3-5 weeks
Cabbage, Early	32	95	3-6 weeks

Cabbage, Late	32	95	3-4 months
Cabbage, Chinese	32	95	1-2 months
Carrots, mature	32	95	4-5 months
Carrots, immature	32	95	4-6 weeks
Cauliflower	32	95	2-4 weeks
Celeriac	32	95	3-4 months
Celery	32	95	2-3 months
Collards	32	95	10-14 days
Corn, sweet	32	95	4-8 days
Endive, Escarole	32	95	2-3 weeks
Grapes	32	90	4-6 weeks
Kale	32	95	10-14 days
Leeks, green	32	95	1-3 months
Lettuce	32	95	2-3 weeks
Parsley	32	95	1-2 months
Parsnips	32	95	2-6 months
Pears	32	95	2-7 months
Peas, green	32	95	1-3 weeks
Potatoes, early	50	90	1-3 weeks
Potatoes, late	39	90	4-9 months
Radishes, spring	32	95	3-4 weeks
Radishes, winter	32	95	2-4 months
Rhubarb	32	95	2-4 weeks
Rutabagas	32	95	2-4 months
Spinach	32	95	10-14 days

Table 16.3 Vegetables that require cool, moist conditions

Vegetable	Temperature (^oF)	Relative Humidity (%)	Length of Storage
Beans, snap	40-50	95	7-10 days
Cucumbers	45-50	95	10-14 days
Eggplant	45-50	90	1 week
Cantaloupe	40	90	15 days
Watermelon	40-50	80-85	2-3 weeks
Peppers, sweet	45-50	95	2-3 weeks
Potatoes, early	50	90	1-3 weeks
Potatoes, late	40	90	4-9 months
Tomatoes, green	50-70	90	1-3 weeks
Tomatoes, ripe	45-50	90	4-7 days

Table 16.4 Vegetables that require cool dry conditions.

Vegetable	Temperature (^oF)	Relative Humidity (%)	Length of Storage
Garlic	32	65-70	6-7 months
Onions	32	65-70	6-7 months

Table 16.5 Vegetables that require warm dry conditions.

Vegetable	Temperature (^oF)	Relative Humidity (%)	Length of Storage
Peppers, hot	50	60-65	6 months
Pumpkins	50-55	70-75	2-3 months
Squash, winter	50-55	50-60	2-6 months
Sweet Potato	55-60	80-85	4-6 months

16.2.3 Indoor Storage

There are many areas in dwellings that naturally provide, or can be adapted to provide, a variety of temperature and moisture conditions for storage. Assess specific situation; if possible, use a thermometer to monitor temperatures in various areas of your building during the fall and winter to find locations that are convenient and most readily adaptable for food storage.

Fig. 44.1 Indoor Storage

Any spot that is sufficiently and evenly cool (32-60 ^oF) can be adapted for some type of food storage. The relative humidity of these locations will also affect what can be stored there. Basements are generally the most logical place to adapt. Older homes are often less well-insulated, and have pantries, back halls, enclosed porches, sheds and bulkheads which are adaptable to storage.

16.2.4 Outdoor Storage

In areas with cold winters, vegetables requiring cool to cold, moist conditions can be stored in any of several types of outdoor storage areas. Earthen storages, from simple mounds to more elaborate root cellars, naturally provide cool, moist, dark and even conditions for a fairly long time. All outdoor storages have the disadvantage of sometimes being inaccessible, as well as being subject to damage by rodents and other vermin. To be successful, any outdoor storage must have thorough drainage.

16.2.5 Timing of Storage

Placing fruits and vegetables in storage, either in pits or in basement rooms, before cold weather starts in the fall is a frequent cause of early spoilage. One of the most difficult steps in successful storage is to keep the produce in prime condition from the time of optimum maturity until the night temperature is low enough to cool the storage area. The length of storage and retention of nutrients will be maximized if the produce can be stored under the proper conditions immediately after harvest.

16.2.6 Refrigerator Storage

One of the best ways to store small quantities of vegetables requiring cold or cool moist conditions is to use an old or extra refrigerator. The amount of current required to run a storage refrigerator is usually low because they are opened infrequently and can be located in an out of the way, cool location. For best storage, produce should be washed free of soil and placed into plastic bags with 2 to 4 ¼‖ holes for ventilation. The 5 or 10 pound bag size is usually most convenient for the average family. Vegetables in plastic bags do not wilt nearly so rapidly as those stored openly in the refrigerator.

16.2.7 Outdoor Sheds

Sheds, breezeways, enclosed porches, and garages can be used to store insulated containers. An insulated container stored in an unheated area should have 6-8‖ of insulation on the bottom, sides, and top, with 2-3‖ between layers of produce. Additional blankets or other coverings may be necessary depending on how cold the outside temperature reaches. Remember that produce must not be allowed to freeze.

16.2.8 Basement Storage Room

Modern basements with furnaces are generally at least 50-60 ^{0}F and dry. While this is appropriate for some types of food storage, in order to achieve the cool, moist conditions necessary for most fruit and vegetables it may be necessary to construct a separate room. This separate storage area should be located in the coldest part of the basement, away from the furnace. The north and the east sides of the house are preferred. Avoid heat ducts and hot water pipes that generate heat. The room should have an outside window for ventilation.

While the exterior walls do not need to be insulated, the inside partitions should have 3½‖ thick fiberglass insulation. Faced insulation should have the vapor barrier closest to the warm side of the storage. If unfaced insulation is used, a vapor barrier such as 6-mil thick polyethylene can be used. The ceiling also requires insulation and a vapor barrier. Temperature can be controlled in this storage room by opening and closing the outside window. Humidity can be kept high by pouring water on the floor or by keeping wet burlap sacks or some similar material in the room.

16.3 CA and MA storage conditions for various fruits and vegetables

Conditions for the optimal storage of fruits and vegetables are influenced by a variety of factors such as crop species, cultivar, growing conditions, maturity, quality, temperature, relative humidity, packaging, and duration of storage. Storage under CA and MA is influenced by the concentration of O_2, CO_2, ethylene, and other gases in the atmosphere immediate to product. Storage life quality and susceptibility to disease and physiological disorder can be modified considerably by production practices, weather, soil, and other factors. Delay in cooling after harvest of apples, for instance, can result in reduced storage life because of accelerated softening and ripening process, and increased probability of scald development, breakdown, and decay. Most apple cultivars benefit from storage at temperatures just above the freezing point of the fruit, a relative humidity in the range of 90 to 95%, O_2 concentration in the range of 1 to 2%, and CO_2 level in the range of 1 to 2%. For apples as well as for most other fruits, it is important that whenever O_2 concentration in the store space is low, CO_2 concentration must also be low enough. This is to prevent physiological alterations and to secure organoleptic characteristics of the fruits to a great deal.

Table 16.6 Controlled Atmosphere Storage Conditions for Selected Fruit Species

Cultivar	**Temperature**	**Relative Humidity (%)**	**O_2 (%)**	**CO_2 (%)**	**Approximate Storage Life (Months)**
Avocado	7–12	90	2–3	3–10	2 months
Cherry	0	95	3–10	10–12	30 days
Chestnut	0	90	3	10	3 months
Kiwifruit	0	98	2	4–5	7 months
Nectarine	–0.5–0	95	2	5	50 days
Peach	–0.5–0	95	2	4–5	40 days
Anjou	–0.5–0	90	1–2	0.5–2	6–7 months
Bartlet	–1.0–0	90	2–3	4–5	4–5 months
Plum	0	95	2	5	45 days

The severity of flavor loss depends on the atmospheric composition and duration of storage. The higher the CO_2 concentration, the lower is the O_2 concentration; and the longer the duration in CA storage, the greater is the flavor loss. Disorders in apples likely to occur during storage include bitter pit, scald, shrivelling, water core, chilling injury, core flush or core browning, decay, and breakdown. Of these disorders, scald, core- flush, breakdown, and decay can be controlled by handling and storage practices.

Delays in storage, high temperature, hot weather before and during harvest, immaturity, high fruit nitrogen, and extended storage periods all tend to increase scald. Controlled atmosphere and low O_2 storage reduce scald. Coreflush, or core browning, a common storage disorder of McIntosh apples is associated with low storage temperature and senescence. This disorder, which is accentuated by immaturity and excess fruit nitrogen level, generally appears in apples after 3 to 4 months of storage at –1 to 0°C and is intensified by a further 5 to 6 days at room temperature.

Apricots, peaches, cherries, raspberries, strawberries, and plums have a short storage life. In air at –1 to 0°C and 85 to 95% relative humidity, sweet cherries have a storage life of about 3 weeks, sour cherries only a few days. Mature soft fruit normally has a maximum 2-week storage life, whereas firm fruit can be stored for 2 to 4 weeks. Fresh strawberries can be held for a maximum of 10 days and rasp- berries can be held for a maximum of 5 to 7 days at 0°C and 85 to 95% relative humidity. Controlled atmosphere storage of soft and stone fruits can provide additional storage life. Controlled atmosphere storage of apricots using 3 to 5% CO_2 and 2 to 5% O_2 at –1 to 0°C can extend the storage life from 12 to 14 days to 18 to 20 days. Similarly, storage of sweet cherries in atmospheres containing 20% CO_2 and 21% O_2 at –1 to 0°C can extend storage life for 5 to 6 weeks. Recommendations for CA storage of pears, peach, nectarine, plum, avocado, cherry, chestnut, and kiwifruit are given in Table. Recommended storage temperature, gas concentration, and storage life expectancy of selected vegetables are given in Table. For vegetables, such as potatoes, carrots, garlic, and horseradish, which can be successfully stored in air, controlled atmosphere storage is not an economical option. For most other vegetables, the benefits of CA are generally low and consequently the level of application is slight.

The highest level of appreciation of CA in vegetables is with broccoli, cabbage, lettuce, asparagus, and Brussels sprouts. In broccoli, CA may extend the storage life by 1 to 2 weeks over that normally expected in cold storage. Optimum CA conditions (10% CO_2, 1% O_2 at 3 to 5°C) have been shown to retard chlorophyll loss, flower bud senescence, and toughening of broccoli. At O_2 levels below 0.5%, however, strong off-odor and off-flavor develop. Packaging of broccoli in polymeric films has been shown to extend shelf life and improve retention of color and nutrients, especially ascorbic acid.

Winter cabbage, held at 0°C and 90 to 95% relative humidity has a storage life of 3 to 7 months. In CA (5% CO_2; 2.5% O_2 at 0°C) cabbage can be stored for up to 10 months. This treatment is effective in preserving green color, maintaining succulence, and greatly retarding senescence. Cauliflower has a relatively short shelf life of only 4 weeks under optimal conditions of 0°C and 100% relative humidity. Storage life of this produce, however, can be extended with the use of CA. It is reported that under a CA of 3% O2 and 2.5 to 5% CO2 cauliflower was still commercially acceptable after 52 days of storage. Storage under higher CO2 levels, however, causes yellowing, softening, and microbial breakdown. Lettuce is also a short storage crop, and when its temperature is reduced rapidly to 0°C and held at this level while the humidity is kept very high, head lettuce can be stored for 2 to 3 weeks. Under CA of 2.5% CO2 and 2.5% O2 at 2°C head lettuce can be stored for up to 75 days. Studies of CA storage of minimally processed lettuce have shown that CA (3% O2, 10% CO2) can prolong the shelf life of shredded iceberg lettuce by limiting plant and microbial enzyme activity, without appreciably affecting microbial development.

Table 16.7 Controlled Atmosphere Storage Conditions for Selected Vegetables

Vegetable	Temperature	O_2 (%)	CO_2 (%)	Level of application
Artichokes	0	2–3	2–3	Slight
Asparagus	2	Air	10–14	High
Beans, green snap processing	7	2–3	4–7	Slight
Broccoli	0	1–2	5–10	High
Brussels sprouts	0	1–2	5–7	Slight
Cabbage	0	2–3	3–6	High
Cauliflower	0	2–3	3–4	Slight
Celeriac	0	2–4	2–3	Slight
Celery	0	2–4	3–5	Slight
Chinese cabbage	0	1–2	0	Slight
Cucumbers, fresh	12	1–4	0	Slight
Lettuce (crisphead)	0	1–3	0	Moderate
Cut salad	0	1–3	0	High
Lettuce (leaf)	0	1–3	0	Moderate
Cantaloupes	8	3–5	10–20	Slight
Mushrooms	0	Air	10–15	Moderate
Okra	10	Air	4–10	Slight
Onions	0	0–1	0	Slight
Onions (bunching)	0	2–3	0–5	Slight
Parsley	0	8–10	8–10	Slight
Pepper (bell)	12	2–5	0	Slight
Pepper (chili)	12	3–5	0–5	Slight
Radish (topped)	0	1–2	2–3	Slight
Spinach	0	7–10	5–10	Slight
Sweet corn	0	2–4	5–10	Slight
Tomatoes	12	3–5	2–3	Slight

Lecture 17

Food quality, measurements-destructive and non destructive methods- principles

17.1 Food Quality Measurement

Measurements very often are given as indices, which can be used as guides to desirable quality attributes such as taste, texture, storage life, and maturity. Any appropriate index that is found to be a suitable guide to a quality attribute can be used, and so the range of indices used is quite remarkable. In some cases visual observation is adequate; in others physical or chemical tests have been developed, often with limited scientific basis. These now serve as industry standards.

Measurement methods can be destructive or nondestructive. Destructive tests include tests that are themselves nondestructive but require samples to be cut from products. Tests can be further roughly grouped (according to the method used), into mechanical, visual (by human eye or by instrument), electrical, chemical, or biological. In some cases several methods may be combined to give an overall quality index.

17.2 Destructive methods

17.2.1 Mechanical Destructive Indices

1.Penetrometer

The most common device used to assess firmness is the penetrometer. This has a cylindrical probe, the end of which is pushed into the object to be measured. The force required to give a predetermined penetration is recorded. In most fruit a section of the skin is removed first to expose the flesh. The penetrometer then gives an index of the firmness of the product tissue.

2. Pea Tenderometer

This device is widely recognized as the standard measure for pea tenderness. A sample of peas is loaded into the testing chamber, and a set of blades cuts through the sample, using a rising pendulum weight to measure the force required

3. Texture Analyzers

Research laboratories commonly use universal testing machines to determine physical properties of crops. Very low loads are needed, and most machines in engineering laboratories are insufficiently sensitive. It is important to avoid external vibrations of and high stresses on the sample during mounting. For these reasons sensitive universal testing machines have been developed that are dedicated to the measurement of food texture. Modern systems use a computer for control and recording of data, and sophisticated loading cycles can be developed. Indenting heads include a penetrometer cylinder, a spherical indenter, and a flat plate to give compression tests between parallel plattens. One system measures the bursting strength of the skin of tomatoes and the whole-fruit compression resistance in the same test. Measurements can be taken on whole fruits and vegetables or cut samples.

Theoretical values can be obtained from stress–strain data, according to the loading geometry. Tensile tests also can be performed, especially for fibrous products. Shear tests and viscosity measurements also can be used. Common loading cycles include applying a fixed compression distance or a percentage of the fruit diameter. Alternatively the deformation after applying a fixed load for a given time can be determined.

4. Twist Tester

An alternative destructive tester has been developed in which the fruit is pushed onto a blade mounted on a spindle, so that the blade enters the fruit at a predetermined depth under the skin. The fruit is rotated, so that the blade turns at a fixed depth. A rising weight on the end of an arm is used to apply an increasing moment (torque) to the blade, to resist the rotation. Eventually failure of the tissue occurs, and the moment can be calculated from the angle of the arm. In some versions fruit is rotated by hand, but in other versions the fruit is rotated on a set of pins driven by a motor. Output is determined either by reading the maximum angle to which the pendulum weight is lifted or by recording the angle as a function of time electronically. It has been used successfully to measure the texture of apples, kiwifruit, mangoes, plums, and other fruits.

17.2.2 Visual Destructive Tests

1. Physiological Changes

Some indices require the visual assessment of cut sections of fruit and vegetables. Some fruits (e.g., bananas) change their cross-sectional shape noticeably as they approach maturity, and the cross-sectional area therefore can be used as an index. Other fruits split open as they mature, to give a simple criteria for maturity. Pip, seed, or stone development inside the fruit also is often a good indicator of maturity. In kiwifruit the number of seeds and the uniformity of their distribution around the center are indications of quality. These are affected by pollination at the start of the life of the fruit.

2. Color

Flesh color is an important determinant of quality and maturity in many crops including melons, mangoes, and squash. Chemical analysis does not enable color estimation: Vegetable and fruit yellowing is often a result of the disappearance of chlorophyls, which allows the yellow–orange xanthophylls and carotenes to become more visible. Blueberry color is determined by anthocyanins, which are red when extracted.

Color can be defined by three parameters. Humans see color differently from electronic equipment, and use different scales. People can distinguish the level of lightness or color intensity of an object, its hue (i.e., its color name such as *red, blue*, or *green*), and its chroma (degree of color purity, saturation, brightness, or greyness). Color meters give an absolute determination of color using a standard three-component specification, known as the Hunter Lab scale. This uses lightness (*L*), red–green character in the absence of yellow or blue (a), and yellow–blue character in the absence of red or green (b). Thus an increase in yellowness on the Lab scale will result in a greater value of C*b;* while for human perception a more yellow color will result as the hue angle approaches 90 degrees. Thus, using just *b* values to denote yellowness could cause confusion

3. Refractometer

Although really a measurement of chemical composition, the levels of soluble solids in fruit and vegetable juices can be determined by measuring the refractive index of the juices. Laboratory and field devices require a small sample of juice placed on a glass cover. The refraction of the light produces an indication on a scale that gives a measure of the soluble solids directly. This is a useful indicator of maturity at harvest time, especially in kiwifruit. Refractometers are low in cost but may require calibration. Measurements may be affected by temperature and delays in carrying out the test after exposing fresh juice.

17.2.3 Electrical Destructive Measurements

Attempts to measure fresh-fruit and vegetable electrical conductivity have been reported in laboratory studies, but these have not been used widely as a measure of quality. Capacitative and inductive measurements also can be made, using high-frequency electrical signals. Electrical measurements have been used to determine moisture content of crops being dried, such as coconut copra. Conductivity is measured by pressing two stainless steel or platinum probes into the product and applying a fixed or alternating voltage. A range of moisture meters is used for grain-moisture assessment,

17.3 Nondestructive Testing Methods and Their Advantages

Nondestructive methods offer significant advantages over destructive methods. Obviously there is a saving in the number of fruits or vegetables wasted, but there are other advantages: First, the same fruit can be retested several times throughout its lifetime, giving a reduction in variability as a result of random sampling of fruit in growth and storage trials (each fruit becomes its own control). This means that test procedures should become more reliable and rigorous, because measurements can be correlated better with fruit performance by tracking the development and storage behavior of individual fruit. This improves predictions of storage life. Other advantages are that samples taken from packed fruit do not need to be replaced. This has major advantages for quality-control inspection procedures: There is no mess or problem of disposal of sampled fruit—they can be repacked or returned to the packing line. On-line assessment of every fruit is a possibility. In scientific experiments, because the same fruit can be used again and again without interrupting its normal life cycle, the number of samples required can be reduced. Tests that could be conducted in situ in the orchard have additional advantages. It would be possible to test fruit during growth, without removal from the tree, and to evaluate the relationship between orchard management and postharvest properties in a rigorous fashion.

The following tests are in principle nondestructive, although in some cases a test may result in damage. For example, mechanical test pressures may exceed tissue failure strength in some samples, especially as the fruit softens. Care should be taken to ensure that the test is not producing any effect that would be harmful in the long term.

17.3.1 Mechanical NDT Tests

1. Mass and Bulk Density

Mass is one of the most obvious quality indices and is easy to measure. Density can be measured using Archimedes‘ principle. The fruit is weighed in air and then suspended in water. The apparent loss in mass is equal to the volume of the fruit multiplied by the density of water. Computer-linked scales can perform the simple calculations automatically and shorten measurement times to a few seconds. Flotation systems can sort fruit and vegetables whose specific gravity is close to 1.0 (e.g., mangoes). Addition of salt or sugar solutions to the water tank can alter the density and hence the cut-off point between floating and sinking fruits. Bubbling air through water reduces the effective density, and this also can be used for sorting.

2. Quasistatic Low-pressure Indenters

A large number of different techniques involve applying low-pressure compression to intact fruits and vegetables. Some are quasistatic, and in general these can be set up using a modern texture analyser. For example, Jeffery and Banks described a kiwifruit indenter in which a modified micrometer dial gauge applied a fixed weight to a specimen placed underneath. The weight caused the sample to deform, and from the shape of the deformation curve a softness index was established by appropriate curvefitting techniques. This procedure was relatively slow and required a computer logging system. A similar approach has been taken in a commercial meter for testing avocados. In this case the load was applied using a weight hung at the end of a pivoted beam, with a dial gauge at the other end. Similar see- saw–type loading devices have been used by several researchers. For leafy vegetables such as lettuce and cabbage it is possible to assess the harvest maturity by lightly pressing the vegetable by hand. French workers have used a texture analyzer for this purpose.

3. Dynamic Low-pressure Indenters

Others indenters involve impact devices using small accelerometers to measure impact parameters. In the Soft-sense system (Hortresearch, Hamilton, NZ), kiwifruit are dropped from a small height onto a force transducer. The Kiwifirm applies a small impact load to the sample without producing apparent damage

4. Nondestructive Use of Texture Analyzers

Some researchers have used modern texture analyzers capable of following complex loading patterns. Provided the equipment is sufficiently sensitive and is capable of measuring force and displacement continuously, a wide range of nondestructive measurements can be taken. Measurements made include compressibility, energy absorption during a loading cycle, and whole-fruit modulus of elasticity determined by compression between flat platters. This latter test is suited to cherries and other soft fruits .

5. Acoustic Methods

Clark and Mikelson described the acoustic-response method, for an estimate of the overall or global texture of fruits that are approximately spherical. The acoustic impulse response method makes use of the sound signal emitted by the fruit as it vibrates in response to a gentle short duration shock, produced by tapping with a small rod or pendulum. The signal is captured by a microphone, and the principle frequency of vibration is then calculated by means of a fast Fourier transform. The technique has been applied successfully to the determination of melon ripeness. In other products, problems of interpreting the data remain. In principle, the resonant frequency of an object depends directly on its geometry, its mass, and the modulus of elasticity of the material of which it is made. In the case of fruit, the modulus of elasticity reduces as the fruit matures (from 5 MPa for an unripe green apple to 0.5 MPa for an overripe fruit), and this reduction may indicate changes in the turgor pressure and physical properties of the plant tissue.

17.3.2 Visual Nondestructive Measurements

1. Size and Shape

As fruits grow their shapes and sizes change. Assessment of size is one of the simplest methods for assessing maturity prior to and at harvest for many vegetables. In some cases the size determines the product: Capsicums may be marketed as zucchini while small, and as marrows when large. Baby corns, sweet corn, and maize may be the same cultivar (*Zea mays saccharata*) harvested at different stages. Mango maturity can be assessed in some cultivars by examining the position and angle the shoulder makes with the stalk and its point of attachment to the fruit.

2. Color

Surface color is used widely for maturity and quality assessment and is probably the most common characteristic used in the selection and harvesting of many fruit. Generally assessments are still performed manually, particularly in the field, although inside packing sheds color sorters are now available commercially for many crops. Although manual measurement may be subject to operator fatigue, human error, and variability, automatic systems are still often considerably inferior, because humans provide more subjective assessments than machines. Color assessment often can be complex: For example, in apples that develop a partial red color, harvest maturity is based on the background color, which remains in the green-to-yellow range of colors, even though the red color appears to dominate. Human graders have been shown to fail to grade fruit correctly due to the influence of the blush color

Lighting levels are particularly important in grading operations. High levels of illumination are recommended for most grading using natural or artificial lighting. Lux levels should be high (in excess of 1000), but it is also important to avoid glare and strong reflections from background tables and rollers. Black backgrounds maximize the relative light levels on the fruit being inspected, but if the light is directly overhead, and the operator is looking at the fruit from the side, then the lower part of the fruit may be too dark. For this reason non-white neutral colors (grays) are probably the most useful inspection backgrounds.

In storage, visual appearance is often a good indicator of changes in product quality. Random sampling and inspection for rots, shrivel, and decay are used widely to monitor long-term product quality.

3. Near-infrared Reflectance and Other Electromagnetic Radiation

Researchers have studied the use electromagnetic radiation from ultraviolet to infrared. As well as measuring moisture content, near-infrared reflectance measurements have been correlated with quality factors such as sugar content, firmness, carbohydrates, and acidity in various fruits including apples and mangoes. Near-infrared reflectance also has been used to detect bruising in apples.Gamma- and x-rays also have been used to detect internal disorders in fruit and vegetables. Radiographic systems have detected water core in apples, hollow heart in potatoes, split pits in peaches, and the maturity of lettuce heads at harvest.

4. Delayed Light Emission and Transmittance

Some fruit will re-emit radiation for a short time after exposure to a bright light. The amount of delayed radiation is a measure of the chlorophyll present, and this is inversely dependent on the maturity. The method has been used with satsumas, tomatoes, and papaya. Other studies have used the transmittance and reflectance of light for papaya and citrus.The reradiated energy is affected by wavelength and intensity of the exciting radiation, sample thickness, area of excitation, and ambient temperature, and there is considerable variation among similar samples

17.3.3 Nondestructive Testing—Electrical and Nuclear Magnetic Resonance

Very little success has been achieved in using electrical properties of fruit and vegetables for nondestructive assessment of quality. However, there is some evidence that electrical conductivity is affected by mechanical or physiological damage. Nuclear magnetic resonance has shown some potential as a method for detecting internal defects in apples, peaches, pears, onions, prunes, and olives. It also can be used to determine sugar content in bananas, potatoes, grapes, and carrots, and oil content in avocados. Magnetic resonance imaging can provide a three-dimensional image and has been used to detect defects in apples and other fruits. Nuclear magnetic resonance and magnetic resonance imaging are expensive techniques.

17.3.4 Nondestructive Testing—Chemical

1. Respiration Rate

Some fruits and vegetables change their rate of respiration as they mature and ripen. These changes can be used to identify when fruit and vegetables are near the end of their storage life and should be sold.

2. Head Gases and Aroma

Ripeness of fruit can be indicated by changes in the production of ethylene, or other volatiles. Although these changes may be too small for humans to detect, fruit flies and other insects may be attracted by volatiles. Monitoring sensors therefore also could be used.

17.3.5 Nondestructive Testing—Biological

Harvest dates can be estimated from the elapsed time after flowering for some fruits and vegetables. In practice it is difficult to be precise. Degree-day calculations (cumulative product of time and temperature) are a guide to maturity for some greenhouse crops

Biosensors

Biosensors that mimic taste and smell offer useful potential for quality assessment.These include ion-selective glass electrodes. These have enzyme or antibody film coverings that affect the number of hydrogen ions sensed. Metal-oxide gas detectors can react to specific gases. These detectors are still in the experimental stage.

17.4 Problems with Nondestructive Test Methods

There are a number of problems that need to be overcome before the benefits of nondestructive testing can be exploited. Nondestructive methods are relatively new, and in most cases the results of the measurement have yet to be interpreted in terms that are relevant to the industry. These methods are generally indirect, in the sense that they measure properties that may be a consequence of quality, but correlations between these properties and practical terms are not known.

Industry and researchers are familiar with current assessment measures, and although they recognize the inadequacy of most of the tests, they are reluctant to adopt new measurements until they are proven to be of value and well related to more familiar measures. This implies that before a new system is implemented, there is a need for full-scale trials including taste-panel assessments, conducted over a number of seasons.

The problem is always to correlate the reading from the device with an appropriate quality parameter such as bruising resistance or texture determined by taste panels. In general the correlations for most devices have been quite poor. However, better results have been obtained when more than one parameter has been measured, and correlations determined using a statistical treatment (such as principle component analysis) or an expert system approach. Nondestructive testing methods therefore offer some exciting possibilities for improving quality assessment but may be slow to gain industrial acceptance. New methods, however, are being developed continually.

Lecture 18

HACCP,GMP,GAP and quality standards

18.1 HACCP

HACCP stands for Hazard Analysis and Critical Control Point. Hazard is a biological, chemical or physical agent that is reasonably likely to cause illness or injury in the absence of its control. Hazards can be harmful microorganisms or chemical and/or physical contaminants. To ensure safe food, HACCP system is designed to identify hazards, establish controls and monitor these controls. HACCP is a preventive system of hazard control rather than a reactive one. Food processors can use it to ensure safer food products for consumers.

The Pillsbury Co. pioneered the application of the HACCP concept to food production during its efforts to supply food for the U.S. space program in the early 1960s.. It is not a zero-risk system, but it is designed to minimize the risk of food-safety hazards. In an assessment of the effectiveness of food regulation in the United States, the National Academy of Sciences (NAS) recommended in 1985 that the HACCP approach be adopted by all regulatory agencies and that it must be mandatory for food processors. Since then globally this system has been adopted to ensure safety of foods.

HACCP is a preventive system for ensuring food safety, but it is not a stand-alone system. HACCP must be built upon current food-safety programs such as Good Manufacturing Practices (GMPs) and others to make it work.

18.1.1 HACCP Plan:

To perform a hazard analysis for the development of a HACCP plan, food processors must gain a working knowledge of potential hazards. The HACCP plan is designed to control all reasonably likely food-safety hazards. Such hazards are categorized into three classes: biological, chemical and physical.

Biological Hazards

These hazards can come from raw materials or from food-processing steps used to make the final product. Microorganisms live everywhere: air, dirt, fresh and salt water, skin, hair, animal fur and plants. Microorganisms are classified into various groups. A few groups important in foods include yeasts, molds, bacteria, viruses and protozoa. Although thousands of kinds of microorganisms exist, only a few pose hazards to humans. Without adequate food, water and temperature, microorganisms stop growing and multiplying. Some die and others stop functioning until they get the elements they need. Some preservation methods, such as drying or smoking, control of water or nutrients in food make these essential elements unavailable to microorganisms.

Chemical Hazards

Chemical contamination can happen at any stage in food production and processing. Chemicals can be helpful and are purposefully used with some foods, such as preservatives. The presence of a chemical may not always represent a hazard. The amount of the chemical may determine whether it is a hazard or not. Some may require exposure over prolonged periods to have a toxic effect. Regulatory limits are set for some of those contaminants.

Chemical hazards can be separated into three categories:

- Naturally occurring chemicals.
- Intentionally added chemicals.
- Unintentionally or incidentally added chemicals.

Physical Hazards

Physical hazards include any potentially harmful extraneous matter not normally found in food. When a consumer mistakenly eats the foreign material or object, it is likely to cause choking, injury or other adverse health effects. The source of the hazard is often easy to identify.

18.1.2 Guidelines for the Application of the HACCP System

Prior to application of HACCP to any sector of the food chain, that sector should be operating according to the Codex General Principles of Food Hygiene, the appropriate Codex Codes of Practice and appropriate food safety legislation like FSSAI. Management commitment is necessary for implementation of an effective HACCP system.

During hazard identification, evaluation and subsequent operations in designing and applying HACCP systems, consideration must be given to the impact of raw materials, ingredients, food manufacturing practices, role of manufacturing processes to control hazards, likely end-use of the product, categories of consumers of concern, and epidemiological evidence relative to food safety.

18.2.3 Application

The application of HACCP principles consists of the following tasks as the Logic Sequence for Application of HACCP

Principles

The HACCP system consists of the following seven principles:

Principle 1: Conduct a hazard analysis.

Principle 2: Determine the Critical Control Points (CCPs).

Principle 3: Establish critical limit(s).

Principle 4: Establish a system to monitor control of the CCP.

Principle 5: Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.

Principle 6: Establish procedures for verification to confirm that the HACCP system is working effectively.

Principle 7: Establish documentation concerning all procedures and records appropriate to these principles and their application

18.2 Good Manufacturing Practices (GMP)

18.2.1 Primary Production

The Food establishment shall exercise control contamination of food produce / materials from air, soil, water, feedstuffs, pests, fertilizers, pesticides, veterinary drugs during production, handling, storage and transport, as appropriate. Plant and animal health are controlled so that it does not pose a threat to human health through food consumption

18.2.2 Location and Surroundings

Food establishment shall be located away from environmentally polluted areas and industrial activities which produce disagreeable or obnoxious odour, fumes, excessive soot, dust, smoke, chemical or biological emissions and pollutants which pose a serious threat of contaminating food; areas subject to flooding; areas prone to infestations of pests; and areas where wastes, either solid or liquid, cannot be removed effectively.

18.2.3 Layout and Design of Food Establishment Premises

The layout of the food establishment shall ensure a forward food preparation/ manufacturing process flow such that cross-contamination from earlier steps in the process is avoided in the later steps.

i. Equipment

Equipment and containers that come in contact with food and used for food handling, storage, preparation, processing, packaging and serving shall be made of materials, which do not impart any toxicity to the food material.Containers used to hold cleaning chemicals and other dangerous substances shall be identified and where appropriate, be lockable to prevent accidental contamination of food.

ii. Facilities

Water supply

Only potable water which meets the requirements of specifications of drinking water, with appropriate facilities for its storage, distribution and temperature control, shall be used, if required as an ingredient and also for food handling, washing, processing and cooking. Water storage tanks shall be cleaned periodically and records of the same shall be maintained.

Ice and steam

Ice and steam used in direct contact with food shall be made from potable water and complying with requirements specified. Ice and steam shall be produced, handled and stored to protect them from any contamination.

Drainage and waste disposal

The disposal of sewage and effluents (solid, liquid and gas) shall be in conformity with requirements of Environment Pollution Control Board. Adequate drainage, waste disposal systems and facilities shall be provided. They shall be designed and constructed so that the risk of contaminating food or the potable water supply is eliminated. Waste storage shall be located in such place that it does not contaminate the food process, storage areas, the environment inside and outside the food establishment. Waste shall be kept in covered containers and shall not be allowed to accumulate in food handling, food storage, and other working areas.

Personnel facilities and toilets

Personnel facilities shall include adequate means of hygienically washing and drying hands, including wash basins and a supply of hot and /or cold water; separate lavatories of appropriate hygienic design for males and females; and adequate changing facilities for personnel. Such facilities shall be suitably located so that they do not open directly into food process areas. Rest and refreshments rooms shall be separate from food process and service areas. These areas shall not lead directly to food production, service and storage areas.

Air quality and ventilation

Ventilation systems, natural or mechanical, including air filters, wherever required, shall be designed and constructed so that air does not flow from contaminated areas to clean areas; minimize air-borne contamination of food; control odours; control ambient temperatures and humidity, where necessary, to ensure the safety and suitability of food.

Lighting

Adequate natural or artificial lighting shall be provided to enable the undertaking to operate in a hygienic manner. Lighting fixtures should, where appropriate, be protected to ensure that food is not contaminated by breakages.

18.2.4 Food Operations and Controls

Procurement of raw materials

No raw material or ingredient shall be accepted by an establishment if it is known to contain parasites, undesirable micro-organisms, pesticides, veterinary drugs or toxic, decomposed or extraneous substances, which would not be reduced to an acceptable level by normal sorting and/or processing.

Storage of raw materials and food

Food storage facilities shall be designed and constructed to enable food to be effectively protected from contamination during storage; permit adequate maintenance and cleaning; and avoid pest access and harbourage.

Food Processing, Packaging and Distribution, Temperature control

The Food establishment shall develop and maintain system to ensure that time and temperature is controlled effectively where it is critical to the safety and suitability of food. Such controls shall include time and temperature of receiving, processing, cooking, cooling, storage, packaging, distribution and food service up to the consumer, as applicable.

Precautions against contaminants and cross-contamination

Systems shall be in place to prevent contamination of food materials and foods by physical, chemical and microbiological contaminants. Microbiological and chemical analysis, suitable detection devices for foreign objects shall be used, where necessary. Access to food preparation / processing / manufacturing facility shall be controlled. Further, staff from raw processing areas shall not be allowed to go to forward process areas.

Food Packaging

Packaging materials shall provide adequate protection for processed food products to prevent contamination, damage and accommodate proper labelling. Packaging materials or gases where used shall be non-toxic and not pose a threat to the safety and suitability of food under the specified conditions of storage and use.

Food Distribution / Service

Processed, packaged / ready-to-eat food shall be adequately protected during transport and service. Temperatures and humidity necessary for sustaining food safety and quality shall be maintained during transport and service. The conveyances /containers shall be designed, constructed and maintained such that they can effectively maintain the requisite temperature, humidity, atmosphere and other conditions necessary to protect food.

18.2.5 Management and Supervision

The Food establishment shall ensure that managers and supervisors have appropriate qualifications, adequate knowledge and skills of food hygiene principles and practices to be able to ensure food safety and quality of its products, judge food hazards, take appropriate preventive and corrective action, and ensure that effective monitoring and supervision takes place.

18.2.6 Documentation and Records

Appropriate records of food processing / preparation, production / cooking, storage, distribution, service, food quality assurance, cleaning and sanitation, pest control and product recall shall be kept and retained for a period that exceeds one year or the shelf-life of the product, which ever is more.

18.2.7 Traceability and Food Products Recall

The Food Business shall ensure that effective traceability procedures are in place from raw material to finished product and to the consumer so as to deal with any food safety hazard and to enable the complete, rapid recall of any implicated lot of the food product from the market.

18.3 Good Agricultural Practices (GAP)

Good Agricultural Practices (GAP) are basic food safety principles associated with minimizing biological, chemical and physical hazards from field through distribution of fresh fruits and vegetables. These principles are covered under the following categories: site selection, adjacent land use, water, fertilizers (including manure and municipal bio-solids), pesticides, worker hygiene, field and facility sanitation, cooling and transportation. Hotlink Annex Good Agricultural Practices In the United States the guidelines are based on applicable state and federal laws as well as the Guide to Minimize Microbial Food Safety Hazards in Fruits and Vegetables published by the Food and Drug Administration. Other countries, such as Mexico have developed their own Food Safety Guide, sometimes based on the FDA's and in some cases even exceeding the FDA's requirements.

18.4 Quality standards

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is carried out through ISO technical committees.

Food safety is related to the presence of food-borne hazards in food at the point of consumption. As the food safety hazards can occur at any stage of the food chain, adequate control throughout the food chain is essential. Thus, food safety is ensured through the combined efforts of all the parties participating in the food chain.

The International Standard ISO 22000:2005 specifies the requirements for a food safety management system that combines the following generally recognized key elements to ensure food safety along the food chain, up to the point of final consumption:

The International Standard integrates the principles of the Hazard Analysis and Critical Control Point (HACCP) system and application steps developed by the Codex Alimentarius Commission. By means of auditable requirements, it combines the HACCP plan with prerequisite programmes (PRPs). Hazard analysis is the key to an effective food safety management system, since conducting a hazard analysis assists in organizing the knowledge required to establish an effective combination of control measures.Since ISO 22000 is a generic food safety management standard, it can be used by any organization directly or indirectly involved in the food chain. It applies to all organizations in the food chain. It doesn't matter how complex the organization is or what size it is, ISO 22000 can help ensure the safety of its food products.

The food chain consists of the entire sequence of stages and operations involved in the creation and consumption of food products. This includes every step from initial production to final consumption. More precisely, it includes the production, processing, distribution, storage, and handling of all food and food ingredients.The food chain also includes organizations that do not directly handle food. These include organizations that produce feed for animals. It also includes organizations that produce materials that will eventually come into contact with food or food ingredients.

18.4.1 Advantages of ISO 22000: 2005

ISO 22000 will help you to achieve the following objectives:

a) To establish a food safety management system (FSMS).

b) To ensure that products do not cause adverse health effects.

c) To demonstrate compliance with external safety requirements.

d) To evaluate customers' food safety requirements.

e) To provide safe products and enhance customer satisfaction.

f) To export food products and penetrate international markets.

g) To communicate safety issues throughout the food chain.

h) To ensure compliance with company‘s food safety policy

18.4.2 Key Elements of ISO 22000

Interactive communication: Communication is essential along the food chain to ensure all relevant food safety hazards are identified and adequately controlled at each step within the food supply chain. This implies for both upstream and down steam in organizations.

System Management: The most effective food safety systems are to be designed, operated within the framework of structured management system then and incorporated into the overall management activities of the organization.

Prerequisite Program: The prerequisite programmes are classified into 2 subcategories. The Infrastructure and Maintenance programs which cover permanent features in food safety. The Operational prerequisite programs are designed to reduce the risk of hazards in the product or processing environment.

HACCP Principles: The HACCP plan is used to manage the critical control points determined to eliminate, prevent or reduce specific food safety hazard from the product, as determined during hazard analysis.

18.4.3 ISO 22000 Food Safety Management System

FSMS is a set of interrelated to establish policy and objectives and to achieve those objectives used to direct and control an organization with regard to food safety.

An effective FSMS should be well-established, documented, implemented, maintained and continually improved / updated and has its products / services that actually meet its intended usage and are safe and is proactive and innovative, scientific, risk-avoiding and prevention-oriented

Model of the ISO 22000

The ISO 22000 model is a continuous improvement process-based FSMS with systematic approach to developing, planning, validating, establishing, implementing, monitoring, verifying and improving the FSMS.

18.4.4 ISO 22000 Certification

ISO 22000 is designed to be used for certification/registration purposes. In other words, once company has established a FSMS that meets ISO's requirements, it can apply for certification to a certification agency to audit the system. If certification agencyfind after audit that the implemented system meets the ISO 22000 requirements, it will issue an official certificate that states that company‘s FSMS meets the food safety requirements.

However, it is not mandatory to go for certification. A company can be in compliance without being formally certified by an accredited certification agency. It can self asses the system implemented and declare ISO 22000 compliant company. But company customers and business partners are not likely to accept that the company has an effective FSMS if it is not certified.

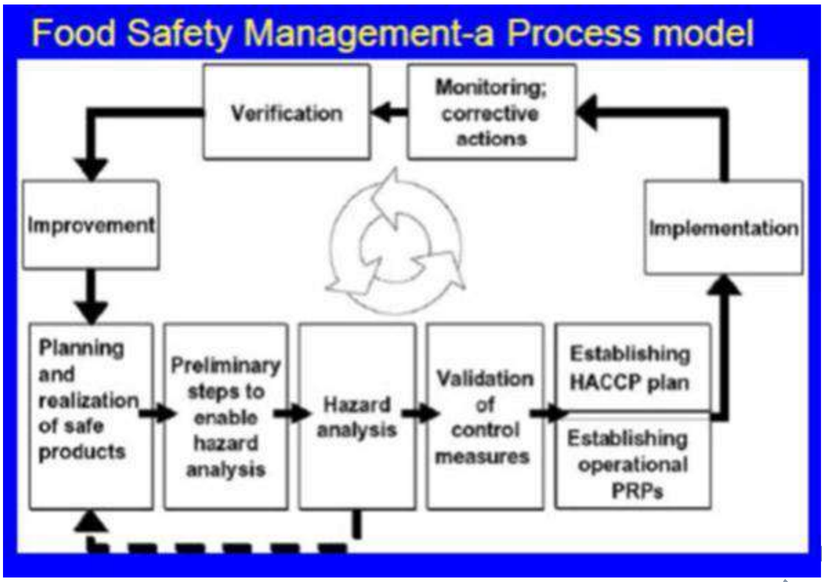


Fig.18.1.Food Safety Management-a Process model

Benefits of ISO 22000 for users

Organizations implementing the standard will benefit from:

- Organized and targeted communication among trade partners ;
- Optimization of resources (internally and along the food chain);
- Improved documentation;
- Better planning, less post process verification;
- More efficient and dynamic control of food safety hazards;
- All control measures subjected to hazard analysis;
- Systematic management of prerequisite programmes;
- Wide application because it is focused on end results;
- Valid basis for taking decisions;
- Increased due diligence;
- Control focused on what is necessary, and
- Saving resources by reducing overlapping system audits

PRACTICAL MANUAL

Ex. No. 1 **Date:**

STUDY OF DIFFERENT KINDS OF GREENHOUSES

Objective

To study different types of greenhouse based on shape construction and cladding material and collect information about the following.

Agro climatic conditions vary according to geographical locations. It is necessary to ensure the design of greenhouse meets the requirement of the peculiar agro climatic conditions. Therefore the type of greenhouse varies according to the climatic conditions of the area and utility of greenhouse. Greenhouses can be classified based on different parameters.

1. Classification based on shape

i. Lean to design
ii. Even span design
iii. Uneven span design
iv. Ridge and furrow
v. Quonset design
vi. Sawtooth design

1.1 Lean to design

Lean to design greenhouses are categorized as attached greenhouses and are placed against the side of existing wall preferably south wall of a building. This design maximizes the availability of sunlight with minimum constructional materials as the roof supports required are less. The roof of the building is extended with appropriate greenhouse covering material and the area is properly enclosed.

1.2 Even span

This design involves the two roof slopes of a greenhouse with equal pitch and width are attached to make a single roof. Construction of small greenhouses can follow this design. Several single and multiple span types are available for use in various regions of India. By using this deign the the rainwater can slide off the roofs automatically.

1.3 Uneven span design

This type of design can be adopted to construct greenhouse on hilly terrain. The two roof slopes of different width form the single roof of the greenhouse.

1.4 Ridge and furrow

Design of ridge and furrow type greenhouse involves connecting two or more A-frame along its length of the eave. The eave serves as the furrow or gutter to carry rain water away. The side walls at the joints are eliminated which provides large interior space inside the greenhouse.

1.5 Quonset design

This type of greenhouse is constructed by using pipe arches or trusses for support. The pipelines run along the length of greenhouse. The greenhouse is covered by polyethylene sheet. These houses are connected either in free standing style or arranged in an interlocking ridge and furrow.

1.6 Saw tooth design

Green houses with Saw tooth design have rooftops in the shape similar to teeth of a saw. It is similar to ridge and furrow type except there is provision for natural ventilation in this type greenhouse.

2. Classification based on cladding material

- **i.** Glass green houses
- **ii.** Plastic film greenhouses
- **iii.** Rigid panel greenhouses

2.1 Glass greenhouses

Only glass greenhouses with glass as covering material existed prior to 1950. Glass as covering material has the advantage of greater interior light intensity. These greenhouses have higher infiltration air rate, which leads to lower interior humidity and better disease prevention. Lean to type, even span, ridge and furrow type of designs are used for construction glass greenhouse.

2.2 Plastic film greenhouses

Flexible plastic films including polyethylene, polyester and polyvinyl chloride are used as covering material in this type of greenhouses. Plastics as covering material for greenhouse have become popular, as they are cheap and cost of heating is less when compared to glass greenhouses. The main disadvantage with plastic films is its short life as the covering material. For example, the best quality ultraviolet stabilized films can last for four years only. Quonset design as well as gutter connected design is suitable for using this covering material.

2.3 Rigid panel greenhouses

Polyvinyl chloride rigid panels, fiber glass-reinforced plastic, acrylic and polycarbonate rigid panels are employed as the covering material in this type of greenhouses. These panels can be used in the Quonset type frames or ridge and furrow type frames. This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse compared to glass or plastic. High grade panels have long life even up to 20 years. The main disadvantage is that these panels tend to collect dust as well as to harbor algae, which results in darkening of the panels and subsequent reduction in the light transmission. There is significant danger of fire hazard.

3.1 Classification based on construction

- i. Wooden framed structures
- ii. Pipe framed structures
- iii. Truss framed structures

3.1 Wooden framed structures

In general, for greenhouses with span less than 6 m, only wooden framed structures are used. Side posts and columns are constructed of wood without use of a truss. Pine wood is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for construction.

3.2 Pipe framed structures

When the clear span is around 12 m, pipes are use for the construction of greenhouse. In general, the side posts, columns, cross ties and purlins are constructed using pipes. Trusses are not used in this type of greenhouse also.

3.3 Truss framed structures

If the greenhouse span is greater than or equal to 15 m, truss frames are used. Flat steel, tubular steel or angle iron is welded together to form a truss encompassing rafters, chords and struts. Struts are support members under tension. Angle iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide truss frame houses of 21.3 m or more. Most of the glass houses are of truss frame type, as these frames are best suited for pre-fabrication.

Exercise:

a. Observe height of different greenhouses
b. Observe the span of single span and multispan greenhouses
c. Identify the shape of greenhouse suitable to Kerala conditions and discuss its properties
d. Observe the type of doors in greenhouse discuss the properties
e. Observe the insect proof net used for side ventilation

1. **Identify different greenhouses based on shape**

Sl. No.	Type of greenhouse	Category	Area	Ventilation	Drawing of Cross section

2. **Identify different greenhouses based on construction**

Sl. No	Type of greenhouse	Category	Constructional materials	Area	Ventilation

3. **Identify different cladding materials used for construction of greenhouse**

Sl. No	Cladding material	Type of greenhouse	Area	Ventilation

Ex. No. 2 **Date:**

AIR RATE EXCHANGE IN SUMMER-WINTER COOLING SYSTEM

Objective

To calculate air rate exchange in summer-winter cooling system

1. Rate of air removal in active summer cooling system

The rate of air removal is measured in cubic meters per minute. The rate of air removal from greenhouse depends up on the elevation of the area, light intensity available under greenhouse, temperature rise across greenhouse walls and pad to fan distance in greenhouse. The correction factors corresponding to these parameters should be applied while computing the air rate exchange.

The rate of air removal must increase as the elevation of the greenhouse site increases. The density of air decreases and becomes lighter with increase in elevation. The ability of air to remove solar heat from the greenhouse depends upon its weight and not its volume. Hence the values of elevation factor (F_{elev}) are directly proportional to the elevation. The values of elevation factors are used to correct the rate of air removal for a particular elevation are listed in table.

Elevation above sea level (m)	< 300	300	600	900	1200	1500	1800	2100	2400
F_{elev}	1.00	1.04	1-08	1-12	1.16	1.20	1.25	1.30	1.36

The rate of air removal is also depends upon the light intensity in the greenhouse. As the light intensity increases, a greater rate of air removal from the greenhouse is necessary. Hence, the values of light factor (F_{light}) vary directly with the intensity. The values of light factors used to adjust the rate of air removal are listed in table.

Light intensity (klux)	43.1	48.4	53.8	59.2	64.6	70.0	75.3	80.1	86.1
F_{light}	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60

Solar energy warms the air as it passes from pad to the exhaust fans. Usually a 4ºC rise in temperature is tolerated across the greenhouse. If it becomes important to have uniform temperature across the greenhouse, it will be necessary to raise the velocity of the air movement through the greenhouse. To maintain less temperature difference across the greenhouse more air is to be circulated. Hence the temperature factor (F_{temp}) increases as the difference in temperature across the pad to fan decreases. The temperature factors used for various possible temperature rises are given in table.

Temperature rise (°C)	5.6	5.0	4.4	3.9	3.3	2.8	2.2
F_{temp}	0.70	0.78	0.88	1.00	1.17	1.40	1.75

The pad and fan should be placed on opposite walls, either end walls or side walls of the greenhouse and the distance between them is important. A distance of 30 to 61 m is the best. The size of the exhaust fan should be selected to achieve proper temperature difference and good circulation. If the pad to fan distance is less, then there is less opportunity time for the flowing air to cool the surroundings; whereas with very large distance uniform cooling is not possible as fans may not pull enough air through the pads. To achieve a given degree of cooling, more amount of air is required when pad to fan distance is less and vice versa. So the velocity factors (F_{vel}) used to compensate for pad to fan distance are listed in table.

Pad to fan distance (m)	6.1	7.6	9.1	10.7	12.2	13.7	15.2	16.8	18.3
F_{vel}	2.24	2.00	1.69	1.58	1.58	1.48	1.41	1.35	1.29
Pad to fan distance (m)	19.8	21.3	22.9	25.9	25.9	27.4	29.0	> 30.5	
F_{vel}	1.24	1.20	1.16	1.08	1.05	1.05	1.02	1.00	

The rate of air removal required for a specific greenhouse can be calculated using these various factors discussed above. Firstly, the rate of air removal required for a greenhouse is determined under standard conditions (Q_{std}) using the following equation.

$$Q_{std}= LxWx2.5$$

Where L is the length and W is the width of greenhouse.

Now, the standard air removal is adjusted by multiplying it by the larger of the following two factors; F_{house} or F_{vel}. The value of F_{house} is calculated from the following equation.

$$F_{house}= F_{elev} x F_{light} x F_{temp}$$

Thus the final rate of air removal (Q_{adj}) by the exhaust fan must be:

$$Q_{adj}=Q_{std} x (F_{house} or F_{vel})$$

Numerical problems

1. Calculate the rate of air removal from a greenhouse of 15 m wide and 30 m long located at an elevation of 915 m. the greenhouse has a moderate coat of shading compound on it, providing the maximum light intensity of 53.8 klux. A 4°C in temperature can be tolerated from pad to fans.
2. A greenhouse of 24 m wide and 40 m long is located at an elevation of 1805 m. The temperature across pad and fan is 5.4°C and cladding material provides a maximum light intensity of 64 klux.

2. Rate of air removal in active winter cooling system

During winter, the outside temperature will be less than that is inside the greenhouse. Therefore simple missing of the outside ambient air by convection tubes does t the actual winter cooling. In active winter cooling systems, under standard conditions a volume of 0.61 cmm of air should be removed from the greenhouse for each square meter of floor area. The air volume obtained by multiplying the floor area by this would define the capacity of the exhaust fan. If a lower inside temperature is desired, cold air must be introduced into the greenhouse at a greater rate. Hence, in active winter cooling, the winter factor based on temperature difference (F_{winter}) between inside and outside air vary inversely with the required temperature difference. The compensating factors to be used in active winter cooling are given in table.

Temperature difference (ºC)	10.0	9.4	8.9	8.3	7.8	7.2	6.7	6.1	5.6	5.0
F_{temp}	0.83	0.88	0.94	1.00	1.07	1.15	1.25	1.37	1.50	1.67

The rate of air removal required for a specific greenhouse can be calculated using these various factors discussed above. Firstly, the rate of air removal required for a greenhouse is determined under standard conditions (Q_{std}) using the following equation.

$$Q_{std} = LxWx2.5$$

Thus the final rate of air removal (Q_{adj}) by the exhaust fan must be:

$$Q_{adj} = Q_{std} x \ (F_{house} or F_{vel})$$

Numerical problems

1. Calculate the rate of air removal from a greenhouse of 15 m wide and 30 m long located at an elevation of 915 m. the greenhouse has a moderate coat of shading compound on it, providing the maximum light intensity of 53.8 klux. A 4ºC in temperature can be tolerated from pad to fans.
2. A greenhouse of 24 m wide and 40 m long is located at an elevation of 1805 m. The temperature across pad and fan is 5.4ºC and cladding material provides a maximum light intensity of 64 klux.

Ex. No. 3 **Date:**

ESTIMATION OF DRYING RATE OF AGRICULTURAL PRODUCTS INSIDE GREENHOUSE

Objective

To study about greenhouse dryer and drying inside greenhouse.

3.1Drying of agricultural produce inside greenhouse

In an efficiently managed greenhouse CEA, there will not be any time gap between crops. However, for some other management reasons, if crops are not grown in a particular period, the greenhouse can be utilized as a solar dryer. A small amount of 15 to 30% of the incoming solar radiation is reflected back from the surface of the greenhouse, with the remainder is transmitted into the interior. Most of this transmitted radiation is absorbed by plants, soil and other internal surfaces, the rest being reflected. The usage of greenhouse for the purpose of the drying is of recent origin. They were successful in advocating the year round utilization of the greenhouse facility and thus reducing the operation cost per unit output. In general, the produce is spread as thin layers in trays covering the greenhouse area. The trays can be fabricated with sheet metal and wire mesh. Trays should be arranged horizontally on existing growing benches or frames. For better operation, proper ventilation should be provided by either forced or natural ventilation, to remove the moisture liberating from the produce and to control the air temperature inside the greenhouse. The natural ventilation can be enhanced by using a black LDPE chimney connected to the greenhouse.

Greenhouse dryer:

The thought of a greenhouse dryer is to combine the function of the solar collector with a greenhouse system. The roof and wall of this solar dryer can be made of transparent materials such as glass, fibre glass, UV stabilized plastic or polycarbonate sheets. The transparent materials are fixed on a steel frame support or pillars with bolts and nuts and sealing to prevent humid air or rain water leaking into the chamber other than those introduced from the inlet opening. To increase solar radiation absorption, black surfaces should be provided within the structure. Inlet and exhaust fans are placed at proper position within the structure to guarantee even distribution of the drying air. If designed properly, greenhouse dryers can allow a greater degree of control over the drying process than the cabinet dryers and they will be more appropriate for large scale drying

Ekechukwu has developed a natural convection greenhouse dryer consisted of two parallel rows of drying platforms (along the long side) of galvanized iron wire mesh surface laid over wooden beams. A fixed inclined glass roof over the platform allowed solar radiation over the product. The dryer, aligned lengthwise in the north-south axis, had black coated internal walls for improved absorption of solar radiation. A ridge cap made of folded zinc sheet over the roof provides an air exit vent. Shutters at the outer sides of the platforms regulated the air inlet.

A simplified design of the typical greenhouse-type natural circulation solar dryer consists of a transparent semi-cylindrical drying chamber with an attached cylindrical chimney, rising vertically out of one end, while the other end is equipped with a door for air inlet and access to the drying chamber. The chimney (designed to allow for a varying height) has a maximum possible height of 3.0 m above the chamber and a diameter of 1.64 m. The drying chamber was a modified and augmented version of a commercially-available poly tunnel type greenhouse.

The dryer operates by the action of solar-energy striking directly on the product within the dryer. The product and a vertically-hung, black absorbing curtain within the chimney absorb the solar radiation and are heated which, in turn, heats surrounding air. As this heated air rises and flows up the chimney to the outside of the dryer, fresh replenishing air is drawn in from the other end of the dryer. Apart from the obvious advantages of passive solar-energy dryers over the active types (for applications in rural farm locations in developing countries), the advantages of the natural circulation solar-energy ventilated greenhouse dryer over other passive solar-energy dryer designs include its low cost and its simplicity in both on-the-site construction and operation. Its major drawback is its susceptibility to damage under high wind speeds

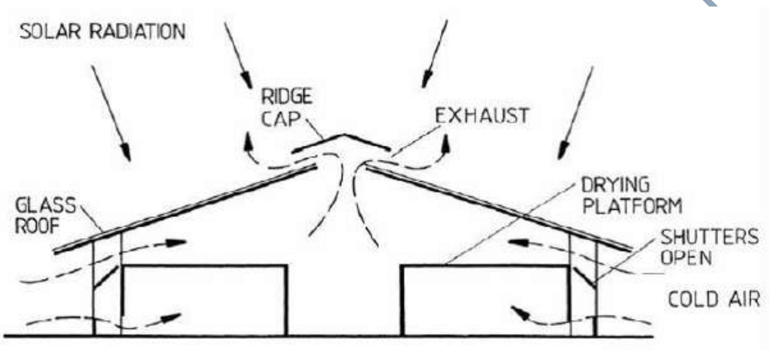


Fig.3.1 Greenhouse dryer

3.2 Types of solar dryers

3.2.1 Tent dryer:

Tent solar dryers are cheap and simple to build and consist of a frame of wood poles covered with plastic sheet. Black plastic should be used on the wall facing away from the sun. The product to be dried is placed on a support above the ground. It takes same amount of time for drying of products as in open air drying. The main purpose of the dryers is to provide protection from dust, dirt, rain, wind or predators and they are usually used for fruit, fish, coffee or other products for which wastage is otherwise high. Tent dryers can also be taken down and stored when not in use. They have the disadvantage of being easily damaged by strong winds.

3.2.2 Box dryer

The box-type solar dryer has been widely used for small scale food drying. It consists of a wooden box with an attached transparent lid. The inside surface is painted black and the product is supported on a mesh tray above the dryer floor. Air flows into the chamber through holes in the front and exits from vent holes at the top of the back wall

3.2.3 Solar cabinet dryer

The cabinet is a large wooden or metal box and the product is located in trays or shelves inside a drying cabinet. If the chamber is transparent, the dryer is named as integral-type or direct solar dryer. If the chamber is opaque, the dryer is named as distributed type or indirect solar dryer. Mixed-mode dryers combine the features of the integral (direct) type and the distributed (indirect) type solar dryers. The combined action of solar radiation incident directly on the product to be dried and hot air provides the necessary heat required for the drying process. In most cases, the air is warmed during its flow through a low pressure drop solar collector and passes through air ducts into the drying chamber and over drying trays containing the crops. The moist air is then discharged through air vents or a chimney at the top of the chamber. It should be insulated properly to minimize heat losses and made durable (within economically justifiable limits). Construction from metal sheets or water resistant cladding, e.g. paint or resin, is recommended. Heated air flows through the stack of trays until the entire product is dry. As the hot air enters through the bottom tray, this tray will dry first. The last tray to dry is the one at the top of the chamber.

Ex. No. 4 **Date:**

DESIGN OF GREENHOUSE

Objective

To study the design considerations and materials of construction for structural design of greenhouse

A basic important point for designing a greenhouse has been that the structure should be able to admit the maximum possible amount of sunlight during the winter season. Other major considerations involve shape of the roof, the material of roof etc. the design should be such that the angle of incidence of solar radiation is never greater than 40ºC. The structural design of greenhouse must provide safety from wind and other loads while permitting maximum light transmission to the crops. The framing members should be minimum size consistent with providing adequate strength to resist anticipated loads over the expected life of the structure. The various load should be considered to produce structurally sound and economical useful greenhouse.

4.1 Design load calculations

It is essential to consider all loads while erecting the greenhouse. The design of greenhouse structure is mainly governed by the dead load, live load, wind load and snow loads.

1. Dead loads are the weights of all materials (such as frame, covering material etc.) used in the construction of greenhouse.
2. Live loads are the weights superimposed by use (in greenhouse would include hanging baskets, vine ropes etc.). The minimum value of this is taken as 50 kg/sq.m in non-snow zones. In cooler areas the snow load may be added to this.
3. Wind loads are those caused by wind blowing any horizontal direction i.e. load due to wind velocity. The minimum value of this is taken as 100 kg/sq.m on vertically project area below 9.14metre height.
4. Snow loads are vertical loads applied to the horizontal projection of the building roof.

4.2 Site selection

- The soil should have a pH of of 5.5 to 6.5 and EC of 0.5 to 0.7 ms/cm
- Availability of continuous source of quality water (pH of 5.5 7.0 and EC should be less than 1 ms/cm)
- The site of construction should be elevated than the surrounding land.
- Transportation facility
- Land availability for future expansion

4.3 Orientation

Orientation of greenhouse depends up on light intensity, wind direction and wind velocity.

- Single span – East west orientation
- Multi span – north south orientation

- The opening of the top vent should be towards leeward side.
- Lengthwise slope – 0 to 2%
- Widthwise slope – 1.25% to 2.5 %
- Maximum width of greenhouse – 40 m

4.4 Materials

The selection of materials depends on its density, allowable stresses and economics. Initially wood and woo piped structures were common. Trusses, columns, beams or purlins made of these materials have different load bearing capabilities and in most instances, if maintained would remain sound. There are various materials available for fabricating the structure of greenhouse. The most commonly used are 1) wood 2) Steel 3) Aluminum

Wood

This is very common where the cost of wood is comparatively very low and is available in plenty. The construction of structure is also simple as local artisans are able to complete the jobs. It is easy to construct greenhouse with wood structure.

Steel

Today, in construction of greenhouse high tensile strength pipes and tubular steel pipes (galvanized) are widely used. There has been a considerable development in construction of greenhouse. Galvanized steel or zinc coated pipes are preferred to avoid corrosion. All parts of the structure are made with 2 mm thick galvanized pipe or galvanized iron.

Aluminum

It is light in weight, easy to handle and not adversely affected by most greenhouse conditions. Aluminum pipes, angles, channels and T sections are commercially available. These can be used for trusses, purlins and columns.

Specifications

- Polythene 1 kg = 5 sq.m
- IS code for pipe – IS 1239, IS 1165
- Steel requirement – 5.5 kg/sq.m
- Insect net proof
    - 50 mesh 130 GSM
    - 40 mesh 105-120 GSM
- GI pipe of B class

4.5 Cladding materials

Flexible greenhouse films are made from low density polyethylene (LDPE), linear low density polyethylene (LLDPE), ethylene-vinyl acetate copolymers (EVA) and similar polymers. UV stabilized 200 micron thick polyfilm should have 88 % light transmission and life expectancy of 3 years.

- Ultra violet – UV absorbers and stabilizers
- Anti fogging – avoids water drops
- Anti dust – avoids dust particles
- Anti petal blackening – UV block fill
- Anti algae – avoids algae in heavy rainfall area

- IR cool – heat reflective
- Colored shade nets – Special optical properties
- Shade net – Regulate light and temperature
- Insect net–Insect net it is used for cop protection in greenhouses as well as in net houses. 50 mesh and 40 mesh are commonly used. Insect nets having the capability to withstand even worst weather conditions thus can be used for numerous seasons.

Ex. No. 5 **Date:**

COST ESTIMATION OF GREENHOUSE

Objective

To study the preparation of cost estimate of greenhouse

Prepare the detailed estimate of material requirement for simple Pipe framed low cost green house(4x25m)

Sl.no.	Item of work / Detail of material	Requirement (Qty)	Rate / unit (Rs)	Total amount (Rs)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
	Total			

Ex. No. 6 **Date:**

STUDY OF IRRIGATION METHODS UNDER GREENHOUSES

Objective

To study various methods of irrigation used inside greenhouse

A well-designed irrigation system will supply the precise amount of water needed each day throughout the year. The quantity of water needed would depend on the growing area, the crop, weather conditions, the time of year and whether the heating or ventilation system is operating. Water needs are also dependent on the type of soil or soil mix and the size and type of the container or bed. Watering in the green house most frequently accounts for loss in crop quality. Though the operation appears to be the simple, proper decision should be taken on how, when and what quantity to be given to the plants after continuous inspection and assessment .Since under watering (less frequent) and over watering (more frequent) will be injurious to the crops, the rules of watering should be strictly adhered to. Several irrigation water application systems, such as hand writing, perimeter watering, overhead sprinklers, boom watering and drip irrigation, over sprinklers, boom watering and drip irrigation which are currently in use.

6.1 Hand watering

The most traditional method of irrigation is hand watering and in present days is uneconomical. Growers can afford hand watering only where a crop is still at a high density, such as in seed beds, or when they are watered at a few selected pots or areas that have dried sooner than others. In all cases, the labour saved will pay for the automatic system in less than one year. It soon will become apparent that this cost is too high. In addition to this deterrent to hand watering, there is great risk of applying too little water or of waiting too long between waterings. Hand watering requires considerable time and is very boring. It is usually performed by inexperienced employees, who may be tempted to speed up the job or put it off to another time. Automatic watering is rapid and easy and is performed by the grower itself. Where hand watering is practiced, a water breaker should be used on the end of the hose. Such a device breaks the force of the water, permitting a higher flow rate without washing the root substrate out of the bench or pot. It also lessens the risk of disrupting the structure of the substrate surface.

6.2 Perimeter watering

Perimeter watering system can be used for crop production in benches or beds. A typical system consists of a plastic pipe around the perimeter of a bench with nozzles that spray water over the substrate surface below the foliage.Either polythene or PVC pipe can be used. While PVC pipe has the advantage of being very stationery, polythene pipe tends to roll if it is not anchored firmly to the side of the bench. This causes nozzles to rise or fall from proper orientation to the substrate surface. Nozzles are made of nylon or a hard plastic and are available to put out a spray are of 180°, 90° or 45°. Regardless of the types of nozzles used, they are staggered across the benches so that each nozzle projects outbetween two other nozzles on the opposite side. Perimeter watering systems with 180° nozzles require one water valve for benches up to 30.5 m in length.

6.3 Overhead sprinklers

While the foliage on the majority of crops should be kept dry for disease control purposes, a few crops do tolerate wet foliage. These few crops can most easily and cheaply be irrigated from overhead. Bedding plants, azalea liners, and some green plants are crops commonly watered from overhead. A pipe is installed along the middle of a bed. Riser pipes are installed periodically to a height well above the final height of the crop (Fig.14). A total height of 0.6 m is sufficient for bedding plants flats and 1.8 m for fresh flowers. A nozzle is installed at the top of each riser. Nozzles vary from those that throw a 360° pattern continuously to types that rotate around a 360° circle. Trays are sometimes placed under pots to collect water that would otherwise fall on the ground between pots and wasted. Each tray is square and meets the adjacent tray. In this way nearly all water is intercepted. Each tray has a depression to accommodate the pot and is then angled upward from the pot toward the tray perimeter. The trays also have drain holes, which allow drainage of excess water and store certain quantity, which is subsequently absorbed by the substrate.

6.4 Boom watering

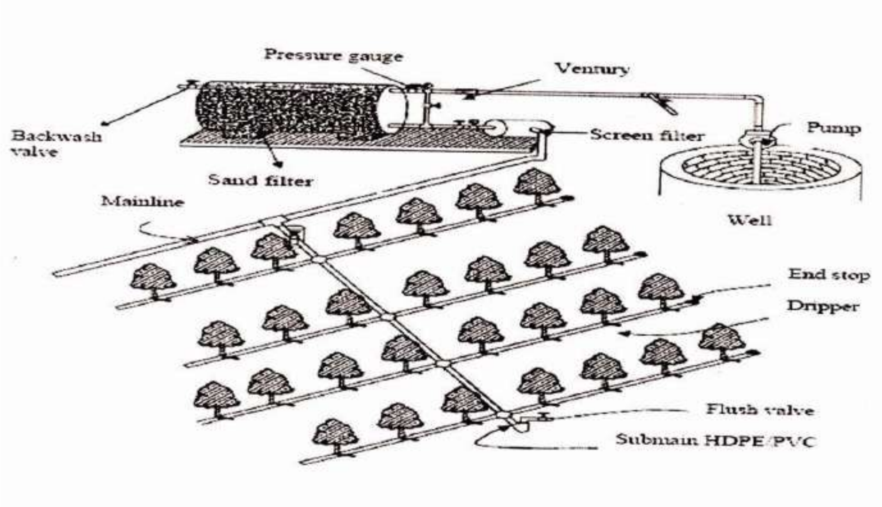
Boom watering can function either as open or a closed system, and is used often for the production of seedlings grown in plug trays. Plug trays are plastic trays that have width and length dimensions of approximately 30 × 61 cm,a depth of 13 to 38 mm, and contain about 100 to 800 cells. Each seedling grown in its own individual cell. Precision of watering is extremely important during the 2 to 8 week production time of plug seedlings.

A boom watering system generally consists of a water pipe boom that extends from one side of a greenhouse bay to the other. The pipe is fitted with nozzles that can spray either water or fertilizer solution down onto the crop. The boom is attached at its center point to a carriage that rides along rails, often suspended above the centre walk of the greenhouse bay. In this way, the boom can pass from one end of the bay to the other. The boom is propelled by an electric motor. The quantity of water delivered per unit area of plants is adjusted by the speed at which the boom travels.

6.5 Drip Irrigation

Drip irrigation, often referred to as trickle irrigation, consists of laying plastic tubes of small diameter on the surface or subsurface of the field or greenhouse beside or beneath the plants. Water is delivered to the plants at frequent intervals through small holes or emitters located along the tube. Drip irrigation systems are commonly used in combination with protected agriculture, as an integral and essential part of the comprehensive design. When using plastic mulches, row covers, or greenhouses, drip irrigation is the only means of applying uniform water and fertilizer to the plants. Drip irrigation provides maximum control over environment variability; it assures optimum production with minimal use of water, while conserving soil and fertilizer nutrients; and controls water, fertilizer, labour and machinery costs. Drip irrigation is the best means of water conservation. In general, the application efficiency is 90 to 95%, compared with sprinkler at 70% and furrow irrigation at 60 to 80%, depending on soil type, level of field and how water is applied to the furrows. Drip irrigation is not only recommended for protected agriculture but also for open field crop production, especially in arid and semi-arid regions of the world. One of the disadvantages of drip irrigation is the initial cost of equipment per acre, which may be higher than other systems of irrigation. However, these costs must be evaluated through comparison with the expense of land preparation and maintenance often required by surface irrigation. Basic equipment for irrigation consists of a pump, a main line, delivery pipes, manifold, and drip tape laterals or emitters as shown in figure.

The head, between the pump and the pipeline network, usually consists of control valves, couplings, filters, time clocks, fertilizer injectors, pressure regulators, flow meters, and gauges. Since the water passes through very small outlets in emitters, it is an absolute necessity that it should be screened, filtered, or both, before it is distributed in the pipe system. The initial field positioning and layout of a drip system is influenced by the topography of the land and the cost of various system configurations



6.6 Misters and Foggers

Misting and fogging system are fairly effective and uniform methods of greenhouse irrigation and cooling that provide a reasonable increase in relative humidity inside greenhouse. Foggers are connected to lateral with micro-tube and it is hanging over iron wire in greenhouse (3 m above). Misters are attached to stakes in beds. Foggers and misters produce about 70 micron of water in air and evaporated before falling onto the crop canopy. Foggers and misters are equipped with an anti-leak devices which does not allow flow of water droplets to fall down after the system is switched off. They have small discharge rate with small area coverage. The operating pressure of fogger and mister varies from 3 to 5 kg/cm^2.Generally the time of operation of foggers and misters are 30 to 60 sec, three or four times in an hour at specific time interval.

Ex. No. 7 **Date:**

STUDY OF VARIOUS GROWING MEDIA USED IN RAISING OF GREENHOUSE CROPS AND THEIR PREPARATION AND PASTEURAIZATION/STERILIZATION

Objective

To study various growing media used in raising of greenhouse crops and their preparation and pasteurization/sterilization

Soil mixes used for greenhouse production of potted plants and cut flowers are highly modified mixtures of soil, organic and inorganic materials. When top soil is included as a portion of the mixture, it is generally combined with other materials to improve the water holding capacity and aeration of the potting soil. Many greenhouses do not use topsoil as an additive to the soil mixes, but rather use a combination of these organic and inorganic components as an artificial soil mix. When managed properly as to watering and fertilization practices, these artificial mixes grow crops that are equal to those grown in top soil.

7.1 Media preparation for greenhouse production

Themedia used in greenhouse generally have physical and chemical properties which are distinct from field soils.

- A desirable medium should be a good balance between physical properties like water holding capacity and porosity.
- The medium should be well drained.
- Medium which is too compact creates problems of drainage and aeration which will lead to poor root growth and may harbour disease causing organisms.
- Highly porous medium will have low water and nutrient holding capacity, affects the plant growth and development.
- The media reaction (pH of 5.0 to 7.0 and the soluble salt (EC) level of 0.4 to 1.4 dS/m is optimum for most of the greenhouse crops).
- A low media pH (<5.0) leads to toxicity of micronutrients such as iron, zinc, manganese and copper and deficiency of major and secondary nutrients while a high pH (>7.5) causes deficiency of micronutrients including boron.
- A low pH of the growth media can be raised to a desired level by using amendments like lime (calcium carbonate) and dolomite (Ca-Mg carbonate) and basic, fertilizers like calcium nitrate, calcium cyanamide, sodium nitrate and potassium nitrate.
- A high pH of the media can be reduced by amendments like sulphur, gypsum and Epsom salts, acidic fertilizers like urea, ammonium sulphate, ammonium nitrate, mono ammonium phosphate and aqua ammonia and acids like phosphoric and sulphuric acids.
- It is essential to maintain a temperature of the plug mix between 70 to 75ºF. Irrigation through mist is a must in plug growing. Misting for 12 seconds every 12 minutes on cloudy days and 12 seconds every 6 minutes on sunny days is desirable.
- The pH of water and mix should be monitored regularly.

7.1.1 Gravel culture

Gravel culture is a general term which applies to the growing of plants without soil in an inert medium into which nutrient solutions are usually pumped automatically at regular intervals. Haydite (shale and clay fused at high temperatures), soft- or hard-coal cinders, limestone chips, calcareous gravel, silica gravel, crushed granite and other inert and slowly decomposing materials are included in the term “gravel”. The more important greenhouse flowering crops include roses, carnations, chrysanthemums, gardenias, snapdragons, lilies, asters, pansies, annual chrysanthemums, dahlias, bachelor buttons and others.

Desirable nutrient level in greenhouse growth media

S. No.	Category	Concentration (mg/l)			
		NO_3	N	P	K
1.	Transplants	75	125	10-15	250-300
2.	Young pot & foliage plants	50	90	6-10	150-200
3.	Plants in beds	125	225	10-15	200-300

7.1.2 Media ingredients and Mix

Commercially available materials like peat, sphagnum moss, vermiculite, perlite and locally available materials like sand, red soil, common manure/ compost and rice husk can be used in different proportions to grow greenhouse crops. These ingredients should be of high quality to prepare a good mix. They should be free from undesirable toxic elements like nickel, chromium, cadmium, lead etc.

7.2 Pasteurization of greenhouse plant growing media

Greenhouse growing medium may contain harmful disease causing organisms, nematodes, insects and weed seeds, so it should be decontaminated by heat treatment or by treating with volatile chemicals like methyl bromide, chloropicrin etc.

Agent	Method	Recommendation
Heat	Steam	30 min at 180° F
Methyl bromide	10 ml/cu. ft. of medium	Cover with gas proof cover for 24-48 hr. Aerate for 24-28 hr before use.
Chloropicrin	(Tear gas) 3-5 ml/cu. ft. of medium	Cover for 1-3 days with gas proof cover after sprinkling with water. Aerate for 14 days or until no odour is detected before using.
Basamid	8.0 g/cu.ft. of medium	Cover for 7 days with gas proof cover and aerate for atleast a week before use.
Formalin	20 ml/l of water (37%)	Apply 2 l/cu.ft. cover for 14 to 36 hr and aerate for at least 14 days.

Disinfection of the growing media can also be achieved by fungicides or bactericides

7.3 Fungicides and their effect on a few fungi

Chemical	Rate of application	Effect against
Captan	2 g/l of water	*Pythium, Fusarium, Rhizoctonia and Phytophthora. Some extent to root and stem rot, white mold,black rot, crown rot and damping off.*
Metalaxyl + Mancozeb (Ridomil MZ 72 WP)	1 g/l of water	*Pythium*, *Phytophthora*, *Fusarium* and other soil borne pathogens

7.4 Fumigation inside Greenhouse

Physical propagation facilities such as the propagation room, containers, flats, knives, working surface, benches etc. can be disinfected using one part of formalin in fifty parts of water or one part sodium hypochlorite in nine parts of water. An insecticide such as dichlorvos sprayed regularly will take care of the insects present if any. Care should be taken to disinfect the seed or the planting materials before they are moved into the greenhouse with a recommended seed treatment chemical for seeds and a fungicide –insecticide combination for cuttings and plugs respectively. Disinfectant solution such as trisodium phosphate or potassium permanganate placed at the entry of the greenhouse would help to get rid off the pathogens from the personnel entering the greenhouses.

Ex. No. 8 **Date:**

VISIT TO COMMERCIAL GREENHOUSES

Place of visit :

Type of greenhouse :

Covering material of greenhouse :

Construction material of greenhouse :

Irrigation technique used in greenhouse :

Types of crop grown :

Dimensions of greenhouse :

Description :

Ex. No. 9 **Date:**

DETERMINATION OF MOISTURE CONTENT USING MOISTURE METER AND COMPARING WITH OVEN METHOD

Objective

To determine moisture content of given sample using moisture meters and compare with oven method.

Materials Required

Sample,moisture meter, air oven, petri dishes, desiccators and weighing balance.

Theory

Moisture content of food grains and other agricultural products plays an important role in maintaining the desirable quality of the product and it is responsible for quick spoilage. Determination of moisture content is necessary because it tells us whether the product is suitable for safe storage or for any further processing. The amount of moisture in a product is given on the basis of the weight of water present in the product and is usually expressed in percent.

Universal moisture meter measures moisture content based on the electrical conductivity or resistance of the grain at a given compaction principle. The electrical resistance apart from compaction is also affected by grain temperature and impurities present in the sample. Such moisture meters are calibrated for grain / seed types, degree of compaction and temperature. Universal moisture meter gives fairly accurate readings of moisture content on wet basis. Air oven method is one of the direct methods of moisture content estimation. In this method air is heated passing through heaters and then hot air is passed through the layer of agricultural products in closed containers. Moisture present in the sample is removed by hot air through convection. The difference in weight of the sample is useful to determine the moisture content. It is expressed in either wet or dry basis.

Procedure

Moisture Meter Method

1. Switched on the moisture meter and calibrate with initial reference level.
2. Take out moisture sample cup from the moisture meter and fill the cup with sample.
3. Measure the weight of the sample using weighing balance.
4. Place the filled sample cup in moisture cup and close the cup with lid.
5. Note down the readings shown in the display of moisture meter. This gives the value of moisture content of sample.
6. Repeat the procedure for three times and note down the two equal values of moisture content.

Air Oven Method

1. Switched on the air oven and set the temperature to 100˚C and wait until oven reached to the required temperature.
2. Take 2 5 to 30 g of unground sample using weighing balance and take it in a Petri dish.
3. Take three sets of sample like above mentioned step for comparison.
4. Keep Petri dishes along with sample in air oven for 72-96 h.

5. Afterwards, the samples are taken out from oven and placed in a dessicator to cool down to room temperature.
6. Measure the weight of the sample using weighing balance. The drop in weight from the initial weight is useful to measure the moisture content of the sample.

Observations

Sl.No	Time (h)	Intial weight (W_1) (g)	Final weight (W_1) (g)	Moisture content (% w.b) $= \frac{W_1 - W_2}{W_1} * 100$

Formula

Conversion of moisture content from wet basis to dry basis

$$(d.b\,\%) = \frac{W.B\ (\text{In Decimals})}{1 - W.B\ (\text{In Decimals})} * 100$$

Result

Moisture content of the sample by moisture meter method = ____________(% w.b)

Moisture content of the sample by air oven method = ________________(% w.b)

Ex. No. 10 **Date:**

DETERMINATION OF MASS, VOLUME, DENSITY AND SURFACE

AREA Objective

To determine the Physical characteristics of fruit such as Mass,Volume, Density and Surface area.

Apparatus used

Balance, Platform scale, Fruits etc.

Procedure

The mass of the individual fruit was found using the weighing balance.

Volume and Density

A simple technique which applies to large objects such as fruits and vegetables is the platform scale. The fruit is first weighed on the scale in air and taken forced into the water by means of sinker rod. The second reading of the scale with fruit submerged minus the weight of the container and water which will be used in the following expression.

Volume (m^3) =weight of displaced water (gm)

weight density of water (g/cc)

knowing the weight in air and the volume, weight density of the fruit is then obtained by the ratio of weight to volume.

Surface Area

For measurement of surface area of fruits, the fruit was cut in narrow strips and the planitneter sum of the areas of the tracing of strips was taken as the surface area of the fruit.

Results

Physical properties such as mass, volume, density and surface area of fruit were determined.

Calculations

Wt. of container + water = w gm

Volume (cm^3) = Wt of displaced water (gm)

Wt density of water (gm /cc)

Wt of displaced water =(Wt of container + Wt of water + Fruit submerged) — (Wt of container +water)

Observations

Sl.No	Weight/Mass (gm)	Wt of displaced water (gm)	Volume of fruit (cm^2)	Density of fruit (g/cc)

Sample No.	Surface Area(cm^2)

Ex. No. 11 **Date:**

STUDY ON ENGINEERING PROPERTIES

Objective

Study on various engineering properties of food materials

11.1 Shape and size

Shape of the grain is connected with the geometrical form of the grain. Size of the grain refers to the characteristics of an object which in term determine how much space it occupies and, within limits, can be described in terms of length, width, and thickness. The Shape and size together with other characteristics of the grains is important in the design of the seed grader. These factors determine the free flowing or bridging tendencies of the seed mass, and therefore, determine the suitable handling and feeding equipment. Sphericity and equivalent diameters are also used to describe the shape and size, respectively for the grains.

The sphericity (φ) defined as the ratio of the surface area of sphere having the same volume as that of the grain to the surface area of the grain, can be calculated from the axial dimensions of the grain as follows:

$$\varphi = \frac{(lbt)^{1/3}}{l}$$

The sphericity (φ) of the fruits can be calculated using the following formula.

$$\phi = \frac{abc^{1/3}}{a}$$

Where,

(a) = major diameter

(b) = intermediate diameter

(c) = minor diameter

The geometrical mean diameter (GMD) can be calculated as follows:

$$GMD = (abc)^{1/3}$$

11.2 The bulk density

The bulk density (ρb) considered as the ratio of the weight of the grain in kg to its total volume in m3. The bulk density of grains is measured using 1 liter measuring cylinder and electronic balance. The bulk density of the food grains changes with the change in the moisture content. Hence, the moisture content of the food grains at which the bulk density was measured also to be reported. The bulk density can be calculated using the following formula

$$\rho_b = \frac{W_s}{V_s}$$

where, ρ_b= bulk density, kg/m^3,

Ws = weight of sample, kg and

Vs = volume of the sample i.e., 1000 cc or 10^{-3} m^3

11.3 True density

The true density (ρ_t) defined as the ratio of mass of the sample (W) to its true volume. The true density (ρ_t) is determined using a Multivolume Pycnometer (Helium gas displacement method). Multivolume Pycnometer's Helium displacement method provides a rapid means for precisely determining the true volume of pores, porous materials, and irregularly shaped food grains. The true density of the grains is found to be decreased with an increase in moisture content as the increase in true volume of the grains is higher compared to the increase in moisture content of the grains. Since, the true density varies with the moisture content of the food grains, the moisture content of the food grains also to be reported. True density can be calculated using following formula.

$$\text{True density } \rho_b = \frac{\textit{Total mass of the grain}, kg}{V_{sample}}$$

11.4 Porosity

Properties such as bulk density, true density and porosity of grains are useful in design of various separating, handling, storing and drying systems. Resistance of bulk grain to airflow is a function of the porosity and the kernel size. The porosity (ε) defined as the percentage of void space in the bulk grain which is not occupied by the grain can be calculated from the following relationship:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

where, ε = porosity

ρ_b= bulk density, kg/m^3

ρ_t = true density, kg/m^3

11.5 Angle of repose

Angle of repose is important in designing a structure for storage of food grains in bulk. When a granular material is allowed to flow freely from a point into a pile, the angle which the side of the pile makes with horizontal plane is called the angle of repose. The angle of repose is influenced by size, shape, moisture content and orientation of the particles. It has been found that the angle of repose increases with the increase in moisture content. The cohesive materials have larger angle of repose. Lower angle of repose represents easier flowability.

Angle of repose of the grain can be calculated experimentally using the following formulae:

$$\theta = \tan^{-1} \frac{2H_c}{D_c}$$

where, Hc = height of cone formed measured with depth gauge

Dc = diameter of the platform on which the cone formed

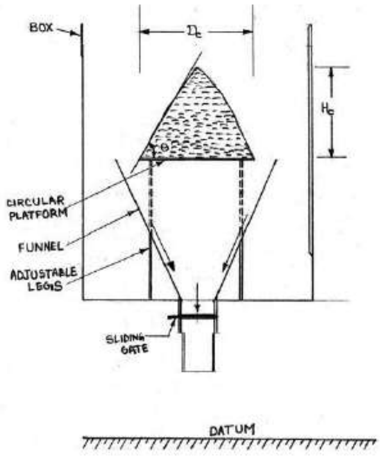


Fig.11.1 Line diagram of Experimental Set up for Angle of Repose

11.6 Coefficient of static friction

The frictional properties of granular materials are important in designing of storage bins, hoppers, chutes, pneumatic conveying system, screw threshers and conveyors, forage harvesters, etc,. The ratio between the force of friction (F), and the force normal to the surface of contact (N), is known as the coefficient of friction (μ).

Mathematically,

$$\textit{coefficent of friction}, \mu = \frac{F}{N}$$

where,

F = Frictional force (Amount of total Weights added + Suspended Pan)

N = Normal Load (Weight of the material + Circular Ring)

11.7 Coefficient of internal friction

The friction of the kernels or grains against each other is known as internal friction whereas the friction between the grain mass and the contact surface is known as static friction. The coefficient of the internal friction of the grains is required in predicting the lateral pressure on a retaining wall in silos or design of silos and hoppers for gravity flow. The method employed for the determination of the coefficient internal friction is by tri-axial compression test apparatus or Shear test apparatus.

The direct shear test apparatus consists of a shear cell, a controlled loading device and a recorder. The normal load is applied by weights acting vertically. The shearing action is provided by means of an electrical or mechanical drive with a load cell or dynamometer in line for force measurement. The shearing force acts in the plane of contact between the base and the ring. The shear cell assures a uniform stress distribution across the specimen sample and shear of solid in the plane between the ring and base.

Shear test apparatus is used to estimate the coefficient of internal friction of the grains.

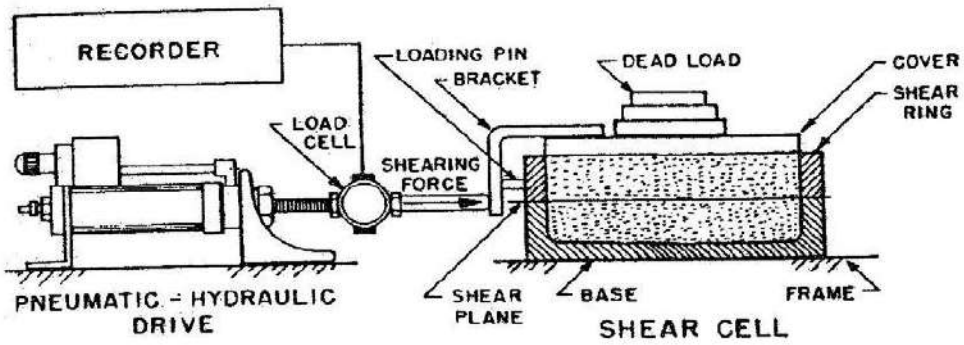


Fig. 11.2 Experimental set up for coefficients of internal friction

11.8 Colour

The optical properties such as light transmittance and reflectance properties of fruits or grains are important in electronic sorting and grading, maturity, and surface color determinations. The surface color of the fruits and food grains are measured using the Hunter Lab in terms of CIE _L‘, _a‘ and _b‘ values. Hunter scale, L measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The chromaticity dimensions (a and b) give understandable designations of color as follows, _a‘ measures redness when positive, gray when zero, and greenness when negative. _b‘ measures yellowness when positive, gray when zero, and blue when negative.

Ex. No. 12 **Date:**

STUDY ON CLEANERS AND GRADERS, THEIR COMPONENTS AND OPERATIONS

Objective

To study the parts and working principles of various Cleaners and Graders

To obtain quality seed, it is necessary to clean the seed obtained from the farm to get rid of inert materials, weed seeds, other crop seeds, other variety seeds, damaged and deteriorated seed. Different kinds of seeds can be separated when they differ in one or more physical characteristics. Physical characteristics normally used to separate seeds are size, shape, length, weight, colour, surface texture, affinity to liquids, electrical conductivity, etc. The problem lies in identifying the most important property and use the machine that separates seed using the identified property. Some of the identified properties and machines operating by following the properties are listed below:

12.1 Air Screen Cleaners

The screen used in combination with air blast performs satisfactory cleaning and separation operations for most of the granular materials. The air screen cleaner uses three cleaning systems; blowing or aspiration, scalping screens and grading lower screens. The air screen grain cleaner can be classified in two distinct types: (i) vibratory screen, (ii) rotary screen, based on the movement of screening surface

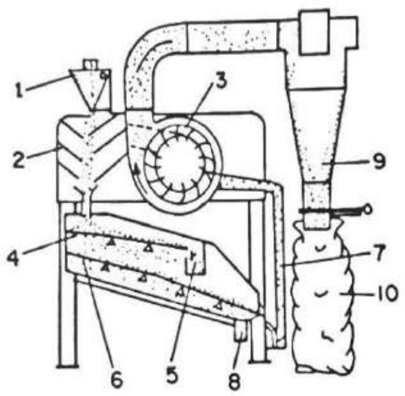


Fig.12.1 Vibratory air screen cleaner

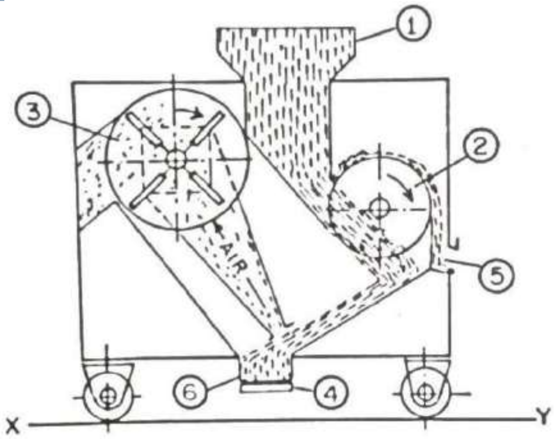


Fig. 12.2 Rotary screen cleaner

12.2 Disc Separator

The disc separates materials on the basis of difference in length of various constituents. The separator has pockets or indentations on its surfaces. When the machine is operated, the smaller sized materials are caught in the pockets, while the larger ones are rejected. It is used especially for removing dissimilar materials like wheat, rye, mustard, barley from oats.

12.3 Indented Cylinder Separator

Indent cylinders use centrifugal force and length differences to lift material from a seedmass, making a length-sizing separation. The indent-cylinder separator consists of a rotating,horizontal cylinder and a movable, horizontal separating trough. The inside surface of the cylinder has small, closely spaced, hemispherical indentations. In operation, the seed mass to be separated lies on the bottom of the cylinder. As the cylinder rotates on its axis, the short seeds in the mass are lifted from the mixture by the numerous indents. At some point before reaching the top of the rotation, the seeds drop from the indents and are received by an adjustable trough or vibrating tray.

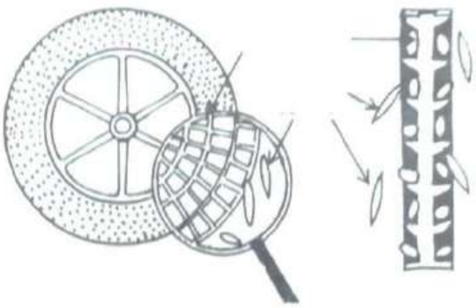


Fig.12.3 Disc Seperator

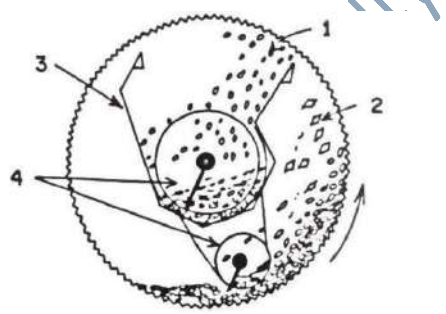


Fig.12.4 Indented cylinder separator

12.4 Magnetic Separator

The magnetic separator separates seed according to its surface texture or related seed characteristics. First, seed is treated with iron filings, which adhere to rough surface alone. The treated seed lot is passed over a revolving magnetic drum and separated from smooth, uncoated seed. It may help to add varied amounts of water while mixing seed and powder, depending on the seed type. At any rate, the effectiveness of magnetic separation depends on the components of the seed lot and on the powder and water used in the treating operation. The greater the difference between surface textures of the seed lot‘s components, more effective will be the separation.

12.5 Specific Gravity Separator

This method makes use of a combination of weight and surface characteristics of the seed to be separated. The principle of floatation is employed here. A mixture of seeds is fed onto the lower end of a sloping perforated table. Air is forced up through the porous deck surface and the bed of seeds by a fan, which stratifies the seeds in layers according to density with the lightest seeds and particles of inert matter at the top and the heaviest at the bottom. An oscillating movement of the table causes the seeds to move at different rates across the deck. The lightest seeds float down under gravity and are discharged at the lower end, while the heaviest ones are kicked up the slope by contact with the oscillating deck and are discharged at the upper end. This machine separates seeds of the same density but of different size and seeds of the same size but of different densities.

12.6 Spiral Separator

The separator, which classifies seed according to its shape and rolling ability, consists of sheet metal strips fitted around a central axis in the form of a spiral. The unit resembles an open screw conveyor standing in a vertical position. The seed is introduced at the top of the inner spiral. Round seeds roll faster down the incline than flat or irregularly shaped seeds, which tend to slide or tumble. The orbit of round seed increases with speed on its flight around the axis, until it rolls over the edge of the inner flight into the outer flight where it is collected separately. The slower moving seed does not build up enough speed to escape form the inner flight. Most spirals have multiple inner flights arranged one above the other to increase the capacity.

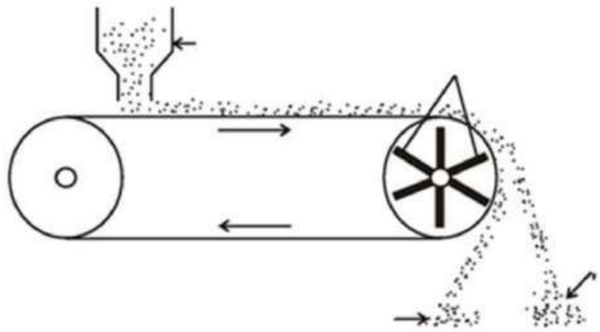


Fig.12.5. Magnetic Separator

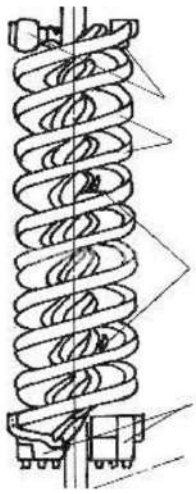


Fig.12.6. Spiral separator

12.7 Inclined Draper

Like the spiral, the inclined draper also separates seeds on the basis of their ability to roll or slide. The rolling or sliding properties are governed by the shape and texture of the seeds, and by the frictional characteristics of the draper surface they are contacting. A seed mixture to be separated is metered from a hopper to the center of an inclined draper belt traveling in an uphill direction, as shown in Fig. Round or smooth seeds, like vetch, will roll and slide down the draper faster than the draper is traveling up the incline. In contrast, flat, rough, or elongated seeds, like oats, will be carried to the top of the incline, thereby making the separation. The seeds dropping off the draper at its lower endare gathered in one chute, and the seeds reaching the upper end are dropped into a second chute.

12.8 Colour Separator

The colour separator is used to separate discoloured seed, greatly of lower quality. Separation based on colour is necessary because the density and dimensions of discoloured seed are the same as those of sound seed, so other machines are not effective for separation. Electronic colour separation uses photocells to compare the seed colour with ―background‖ which are selected to reflect the same light as the good seed. Seed that differs in colour is detected by the photo cells, which generate an electric impulse. The impulse activates an air jet to blow away the discoloured seed.

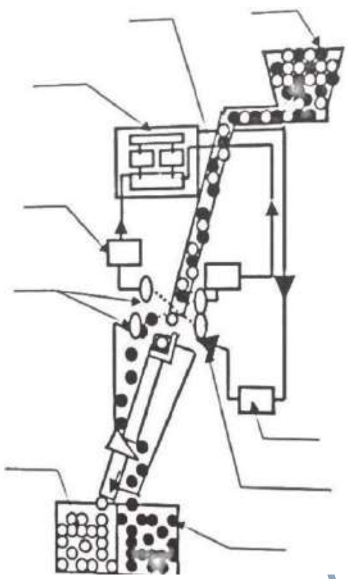


Fig.12.7. colour separator

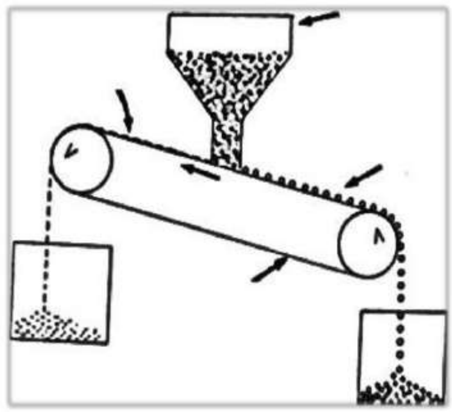


Fig.12.8. Inclined Draper

Ex. No. 13 **Date:**

STUDY ON DRYERS

Objective

To study the parts and working principles of various dryers

13.1 Tray Dryers

These types of dryers use trays or similar product holders to expose the product to heated air in an enclosed space. The trays holding the product inside a cabinet or similar enclosure (Fig.1) are exposed to heated air so that dehydration will proceed. Air movement over the product surface is at relatively high velocities to ensure that heat and mass transfer will proceed in an efficient manner. In most cases, tray dryers are operated as batch systems and have the disadvantage of non-uniform drying of a product at different locations within the system.

13.2 Tunnel Dryers

These may be regarded as developments of tray dryer, in which trays on trolleys move through a tunnel where heat is applied and vapours removed. The flow of heated air in the tunnel dryer may be concurrent or counter current.

13.3 Fluidized Bed Dryers

In a fluidized bed dryer, the food material is maintained suspended against gravity in an upward flowing air stream. Heat is transferred from the air to the food material, mostly by convection. It is mainly used for drying granular materials.

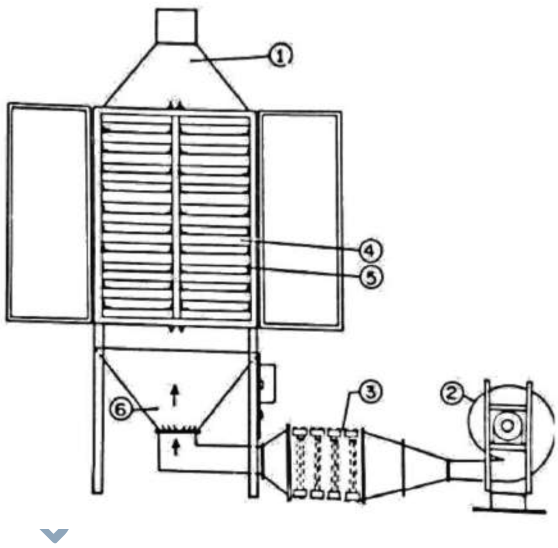


Fig.13.1. Schematic diagram of tray drier

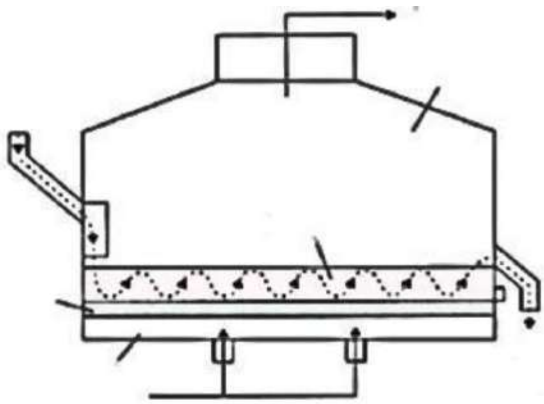


Fig.13.2. Fluidized bed drier

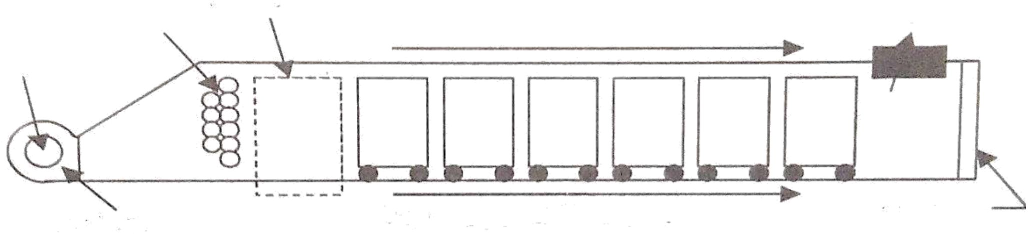


Fig. Schematic diagram of concurrent flow tunnel drier

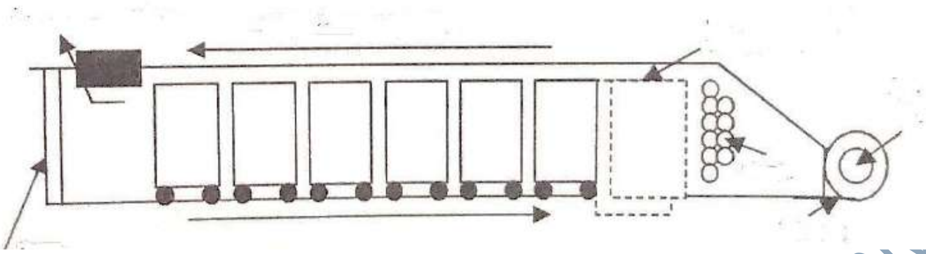


Fig.13.3.Schematic diagram of counter current flow tunnel drier

13.4 Roller or Drum dryers

In these driers, food is spread over the surface of a heated drum. The drums are heated internally by pressurized steam of 120 to170°C. Food remains on the drum surface for greater part of rotation, during which time drying takes place and is then scraped off by using doctor blades. Drum drying is regarded as conduction drying.

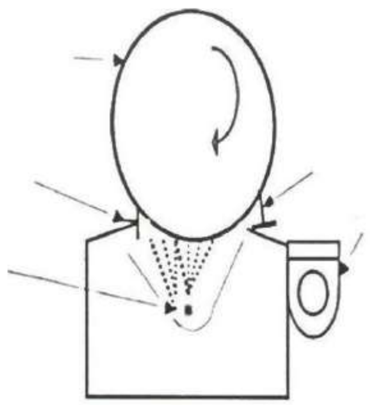


Fig. 13.4.Single drum drier

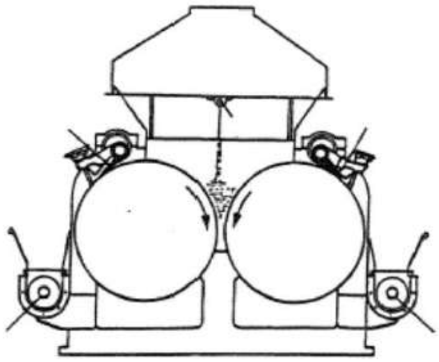


Fig. 13.5.Double drum drier

13.5 Spray Dryers

In a spray dryer, foods are transformed from slurry into a dry powder. A fine dispersion of pre-concentrated food is first _atomized‘ to form droplets (10-200 µm diameter) and sprayed into a current of heated air at 150-300°C in a large drying chamber The spray-drying operation is easily divided into three distinct processes; atomization, drying through the contact between the droplets and the heated air, and collection of the product by separating it from the drying air.

13.6 Freeze Dryers

Freeze-drying is accomplished by reducing the product temperature so that most of the product moisture is in a solid state, and by decreasing the pressure around the product, sublimation of ice can be achieved. When product quality is an important factor for consumer acceptance, freeze-drying provides an alternative approach for moisture removal.

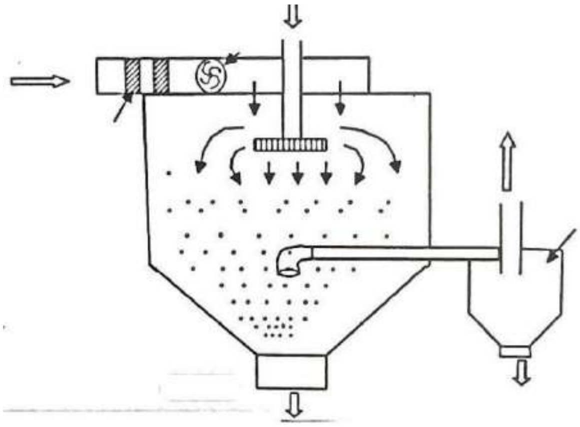


Fig.13.6 Spray drier

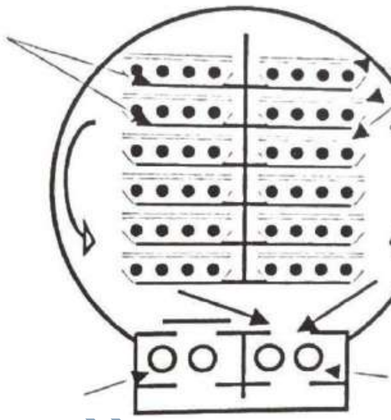


Fig.13.7 Freeze drier

13.7 Tunnel Dryers

These may be regarded as developments of the tray dryer, in which the trays on trolleys move through a tunnel where the heat is applied and the vapours removed. In most cases, air is used in tunnel drying and the material can move through the dryer either parallel or counter current to the air flow. Sometimes the dryers are compartmented, and cross-flow may also be used.

13.8 Pneumatic Dryers

In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particles in suspension. Heated air accomplishes the drying and often some form of classifying device is included in the equipment. In the classifier, the dried material is separated, the dry material passes out as product and the moist remainder is recirculated for further drying.

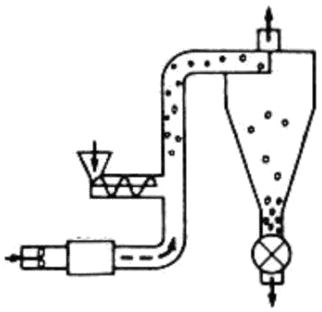


Fig.13.8. Pneumatic drier

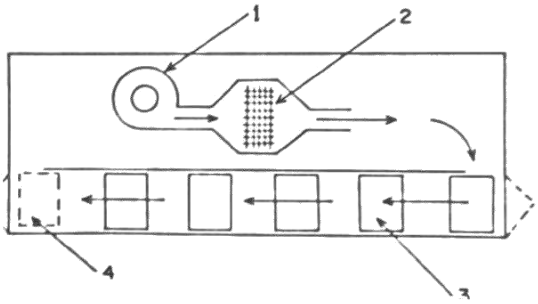


Fig.13.9.Tunnel drier

13.9 LSU dryer

LSU dryer is developed at Louisiana state university (LSU).It is acontinuous mixing type dryer and is developed specifically for rice to ensure gentle treatment, good mixing & good air to grain contact. The drier consists of rectangular chamber, holding bin, blower with duct, grain discharging mechanism and air heating system. Layers of inverted V shaped channels are installed in the drying chamber; heated air is introduced through these channels at many points. Alternate layers are air inlet & outlet channels; arranged one below the other in an offset pattern.Inlet port consists of few full size ports & two half size ports; all ports are of same size arranged in equal spacing. Ribbed rollers are provided at the bottom of drying chamber for the discharge of grain.

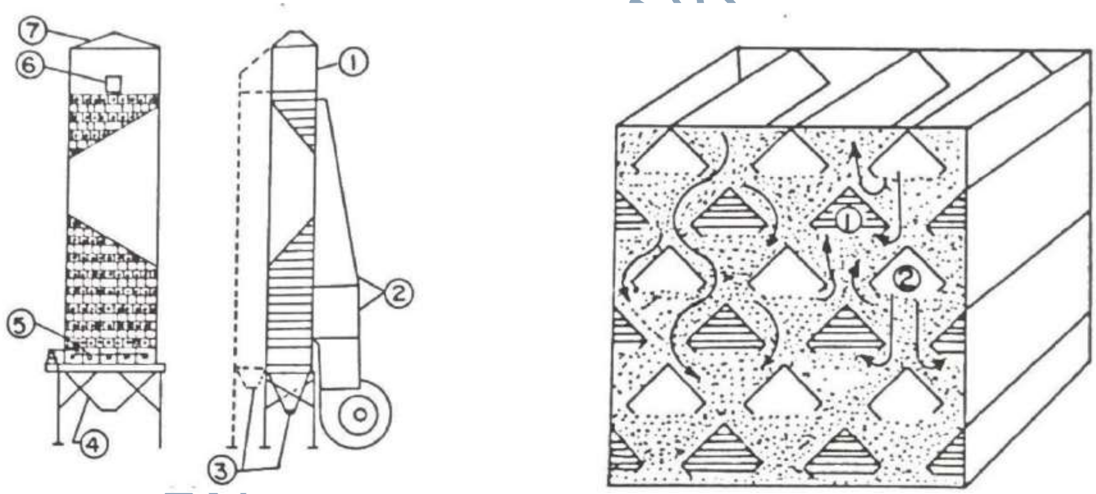


Fig.13.9. LSU drier

Ex. No. 14 **Date:**

DRYING RATE AND DRYING EFFICIENCY CALCULATIONS

1) In an experiment on drying of raw paddy at an air temperature of 55°C, the following data were obtained. Initial weight of the sample = 1000gm.
   Initial moisture content = 30.8% (d.b)

Sl.No	Drying time in min	Moisture removed in gm
1	0	0.0
2	10	22.9
3	20	38.2
4	40	57.4
5	60	68.8
6	80	78.0
7	100	84.0
8	140	101.0
9	180	112.5
10	220	121.0
11	260	128.4
12	300	131.8

Prepare the drying rate curve for the experiment.

Practical-15

Ex. No. 15 **Date:**

STUDY ON OTHER PHT EQUIPMENTS

Objective

To study the parts and working principles of rice mill, vegetable & fruit pulper& extruder

15.1 Rice Mill

Modern mills mean many things to many persons. When one speaks of a modern rice mill complex, one has in mind a fairly big industrial factory. It has a modern, efficient rice mill, a paddy receiving-cleaning-drying section, huge godowns or silos, parboiling-drying system, a huge husk furnace-cum – boiler, ash handling section, bran – handling-processing section, etc. A modern rice mill as such is a much simpler affair. It is basically a sheller mill, but the sheller is not an emery-disc sheller but a rubber-roll sheller. And it has all the other secondary systems needed for good rice milling. It should be understood that what is called modern mill today is nothing but a mill which incorporates a rubber-roll sheller along with the full combination of a paddy separator, efficient polisher, grader, etc. It should also be noted that disc sheller mills also usually incorporate all these combinations. In such case, these mills approach a so-called modern mill. The extra yield obtained by processing in modern mills is at least 2% in case of raw paddy and about ½ - 1% in case of parboiled paddy as compared to disc sheller-cum-cone polisher mills. Head rice yields in the modern mills average about 5% more than those in sheller mills and 10-15% more than in huller mills.

Modern Rice Milling Process:

A flow chart of important operations, followed in sequence, for milling of rice in a modern rice mill is shown. The operations are as follows:

Cleaning
⇩
Parboiling
⇩
Dehusking
⇩
Husk separation
⇩
Paddy separation
⇩
Polishing
⇩
Grading

15.1.1 Cleaning

Cleaning is the first step in modern rice milling. It not only enables the production of clean rice but also protects the other milling machinery and increases milling capacity. Impurities that are lighter than paddy are removed by an aspirator. This prevents spreading of dust inside the building and creates hygienic conditions. Metallic (iron) impurities are removed by the use of a magnet. Impurities larger or smaller in size but heavier than paddy are removed by sieves. Vibrating or rotating sieves or a combination of both are used. Impurities that have the same size as paddy but are heavier than paddy are removed by specific gravity separators, namely destoners. Intake paddy is often subjected to a preliminary partial cleaning (scalping) prior to storage and prior to the main cleaning in the mill.

Cleaner:

The paddy is fed into this machine through an opening in the top. The suction fan draws air through the film of grain and separates all dust and light impurities, which drop to the cone-shaped bottom of the aspiration housing for automatic discharge. The paddy falls to a vibrating sieve with large perforations which removes large impurities such as straws, big stones, etc. The paddy and remaining small impurities fall to the bottom vibrating sieve with small perforations which removes small impurities. The overflow from this sieve is again subjected to strong aspiration to remove the last traces of light impurities.

Destoner:

The destoner consists of a perforated deck mounted at angle and operated by a reciprocating motion. A large amount of air is blown from below through the sieve. When a mixture of paddy and stone is fed at the top of the sieve, the air coming through the sieve stratifies the materials according to their density (or heaviness). The heavier stones remain on the deck and are carried backward to the top end by the reciprocating motion of the deck and discharged. The lighter paddy remains floating and slides down and is discharged from the lower end. The separation can be controlled by adjusting the rate of feed, air flow and sieve tilt.

15.1.2 Parboiling

Parboiling is a hydrothermal treatment followed by drying before milling for the production of milled parboiled grain. In general, the three major steps in parboiling, i.e, soaking, steaming and drying, have a great influence on the final characteristics and quality of parboiled rice. Soaking of paddy is done at or below the gelatinisation temperature. The lower the temperature the slower is the process of soaking and vice versa.

Improved Parboiling Method of CFTRI, Mysore, India (Batch)

The system developed by CFTRI (Central Food Technological Research Institute) was primarily aimed at improving the yield and quality of rice with a lower capital investment. The soaking and steaming is done in the same mild steel cylindrical tank. Steam enters through the perforated pipe at the centre and there are more perforated pipes arranged radially at the bottom of the tank. The base of the tank is cone-shaped and is closed at the bottom by a water tight hatch. At the side of the hatch there is a valve for draining of the steeping water.

During parboiling the tank is filled with water heated by steam injection to 85^0C. The paddy is then poured inside the tank. The temperature of water drops to 70-75^0C. After two to three and a half hours steeping, the water is drained off. Pressurized steam is then passed through the perforated pipes until the husks just begin to crack open. After steaming the hot paddy is unloaded through the bottom hatch and then spread over the drying floor.

15.1.3 Dehusking (Shelling):

The object of dehusking is to remove the husk from the paddy with a minimum of damage to the bran layer and without breaking the brown rice grain.

Disc sheller:

It consists of two horizontal iron discs coated with emery. The top disc is fixed to the frame housing, and the bottom disc rotates. The rotating disc can be moved vertically up or down to adjust the clearance between the two discs. The clearance is thus adjusted to the size of the paddy grain.

Paddy is fed into the centre of the machine. As it reaches the rotating disc, it moves outward by centrifugal force. During its travel outward, whenever it is up-ended, it is caught between the top (stationary) and bottom (rotating) discs and is dehusked by shear. The clearance between the two discs is critical to avoid excessive breakage.

Rubber –roll sheller:

The rubber –roll sheller consists of two rubber rollers rotating in opposite directions at different speeds. Both rolls have the same diameter, but one roll moves about 25% faster than the other. The difference in peripheral speeds subjects the paddy grains falling between the rolls to a shearing action that strips off the husk. One roller is fixed in position and the other is adjustable laterally in order to increase or decrease the clearance between the two rolls. Rolls are cooled by blowing air on the roll surface. The shelling (i.edehusking) rate is generally maintained at about 85%.

For operation, at no time should there by a rubber to rubber contact. Otherwise, there would be excessive heat, excessive wear and tear of the rolls as well as discolouring of the grains. The durability or capacity of the rubber rolls varies with cleanliness of paddy, moisture content, pressure applied to the rolls, heating of rolls, the paddy variety (abrasiveness of the husk, short or long grain) as well as the quality of the rolls. A pair of good quality rolls has an average capacity of about 100 tonnes for raw paddy and 200 tonnes for parboiled paddy.

To obtain more operational life per pair of rubber rolls, they should be frequently interchanged to ensure uniform wear. It is best to interchange rolls every 2-3mm of wear. Uneven wear of roll changes the relative peripheral speed and reduces hulling capacity. Compared with the disc sheller, the rubber-roll sheller has the advantage of giving negligible breakage.

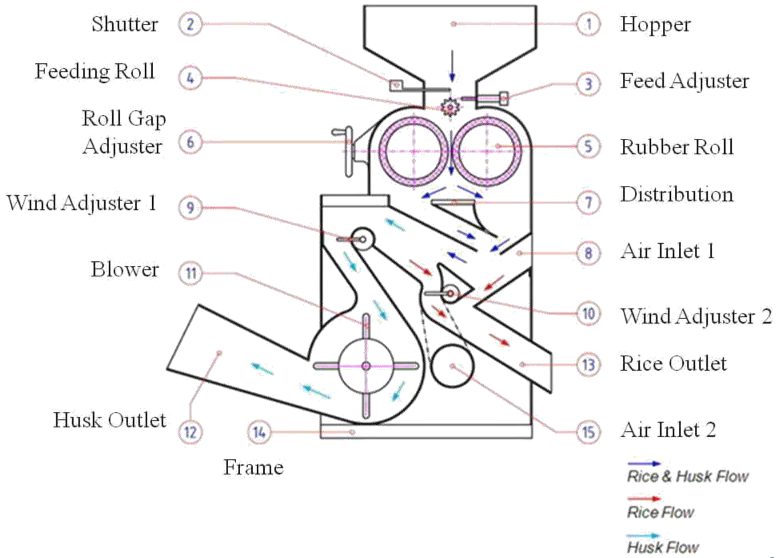


Fig. 15.1 Rubber roll sheller

Husk separation

A mixture of dehusked rice (brown rice), remaining unshelled that has been split off the paddy comes out of the sheller. This mixture is subjected to sieving-cum aspiration to separate brokens and husk. Sieving prior to aspiration helps in separating and recovering the small brokens formed during shelling, particularly from the discshellers which would be otherwise carried away along with the husk. Light weight paddy husk is separated from the heavier paddy and rice by aspiration.

Husk separator:

The mixture of paddy, brown rice, brokens and husk are fed at the top of a vibrating sieve. The brokens pass through the perforations of the sieve. As the mixture of husk, paddy and brown rice overflows from the sieve, air is blown or sucked through the mixture. Husk is carried away by the air. The paddy and brown rice are collected separately.

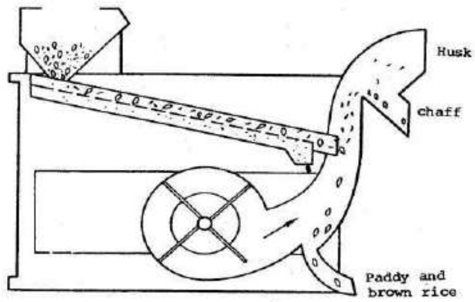


Fig. 15.2 Husk separator

Paddy separation

Shelling is never done to the level of 100% to avoid rice breakage. The grains also differ in size, so that the smaller grains remain unshelled. Therefore a paddy separator is used to separate the remaining unhusked paddy from husked brown rice. The separated paddy is returned to the dehusker for dehusking while the brown rice is carried forward to the polisher. The separation is accomplished in the separator by taking advantage of the difference in physical density (heaviness), size and surface smoothness (or roughness) of paddy and brown rice.

Compartment – type separator:

The oscillating table is divided into zigzag channels and is inclined from one side to the other along the zigzag channels. The surface of the table is of smooth steel. The table oscillates cross wise, i.e perpendicular to the direction of the channels. The mixture of paddy and brown rice is fed from the hopper to the center of the channels. The impact of the grains on the sides of each channel causes the unhusked paddy grains to move up the inclined slope toward high side of the table. The dehusked brown rice slides down the slope to the low side of the table. The slope and stroke of the table are adjusted to meet the needs of paddy of different size or condition and to ensure complete separation. Usually there are several decks one above the other.

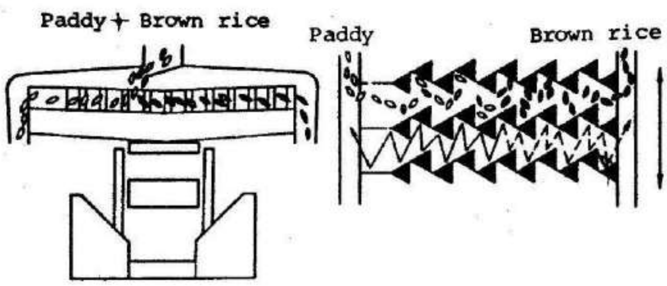


Fig. 15.3 compartment tray separator

Tray separator:

It consists of several indented trays (i.e trays having a large number of depressions) mounted one above the other, all attached to an oscillating frame. The tray section moves up and forward, making a slight jumping movement.

The mixture falls on each tray at the top corner from the inlet hopper. The smooth, smaller and heavier brown rice tends to go below and paddy to float up due to the motion of the tray. Further, the brown rice, being smaller, is caught in the indentations (depressions) and moves upward along with each jump of the tray. Thus it is carried to the upper side of the tray and discharged there. The free-flowing paddy slides downwards and is discharged there. Unseparated paddy and brown rice remaining at the middle portion are discharged in between and are returned to the hopper for recirculation. The table inclination is adjustable to meet different grain sizes and conditions.

Operation: For efficient paddy separation, feed rate, speed, stroke and table inclination should be carefully set. Improper setting would result in brown rice going with return paddy or return paddy going with brown rice, or both, affecting capacity of the plant and the yield and quality of milled rice.

15.1.4 Polishing

The brown rice is next polished to remove bran layers. Some amount of polishing is essential for easy cooking and storage, although excessive polishing reduces the nutritive value of rice. There are two types of polishers, one of emery and other of metal. The emery polishers (called whiteners) polish the grains by abrasion with emery while the metal polishers (called pearler) polish by friction between the rice grains. The emery polishers are again of two types – vertical (cone polisher) and horizontal.

Cone polisher:

It consists of a vertical truncated cone, covered with emery, which rotatesinside a wire screen. The clearance between the cone and screen can be adjusted by raising or lowering the cone. At regular intervals around the cone, the wire screen is divided into segments by vertical adjustable rubber brakes.

The brown rice enters at the top center and moves outward by centrifugal force to the edge of the cone. As the brown rice moves down between the cone and the screen around the cone, the abrasive action of the emery peels the bran off the grains. The bran goes out through the screen and is collected separately. The polished rice is discharged at the bottom.

Horizontal abrasive polisher:

The machine consists of an abrasive cylindrical emery stone attached to a steel shaft rotating in a cylindrical, perforated metallic screen mounted horizontally. Brown rice enters at one end, and moves round and round the abrasive roll to the opposite discharge end. The pressure on the grain is controlled by hanging different weights on the discharge gate. As the grain passes through the space between the roll and the perforated screen, the bran layers are peeled off from the grain. The bran passes out through the perforated screen and polished rice is discharged through the outlet. The abrasive roll is made of carborundum.

Horizontal friction polisher:

The machine consists of cylindrical steel roller rotating inside a hexagonal perforated screen. The cylinder has a long slit along its length and a hollow shaft for passing air. The clearance between the screen and cylinder is adjustable by opening or closing the screen. The pressure on the rice is further controlled by hanging weights on the discharge gate. A strong stream of air is blown by a centrifugal blower through the hollow shaft and long slit of the cylinder. The air helps in separating the bran and removing the heat generated by the friction between rice and rice.

Operation:

Stepwise polishing in several polishers gives minimum breakage during milling, thus increasing total and head rice recovery. Keeping the abrasive roller uniform and in balance reduces grain breakage. When parboiled rice is milled, the bran tends to stick to the screens. In this case, the quantity of aspirated air is increased to overcome choking of the screens. The bran coming out of the polisher should be checked often to make sure that it does not contain broken rice, not to speak of head rice, ie, to detect any damage to the polisher screen. Aspiration of air through the polisher prevents heating, thus reducing the breakage, and keeps dust out of the mill.

Pneumatic bran separator:

This equipment separates rice germs and brokens from bran and also conveys the bran pneumatically (i.e by air). It consists of a powerful centrifugal fan which aspirates the bran from the polisher and delivers it to a cyclone. A blower and an auxiliary cyclone aspirates the bran from the outlet of the main cyclone. Thus fine bran is separated from coarse materials (germs and brokens).

15.1.5 Grading

After polishing operation, the milled rice contains, in addition to _whole grains, broken grains of different sizes as well as some bran and dust. Separation of these materials, termed _grading‘, must now be done. Bran and dust particles are removed by aspiration. Brokens may be separated either by a _plansifter‘ or by a _Trieur‘.

Plansifter:

It is a single or double-decked sieve which is given a swinging motionproduced by an eccentric drive. It consists of two sheets of different perforations (first small and then large) to separate two grades of brokens from the polished rice. The grain moves across the swinging sieve in a continuous spiral path.

A plansifter, being of sieve type, cannot separate all broken grains from head rice. Big brokens remain along with head rice, while small brokens (less than half size) are removed. Sieves of the grader should be kept free from clogging for maximum removal of brokens.

gffgfhgf

Commercially available materials like peat, sphagnum moss, vermiculite, perlite and locally available materials like sand, red soil, common manure/ compost and rice husk can be used in different proportions to grow greenhouse crops. These ingredients should be of high quality to prepare a good mix. They should be free from undesirable toxic elements like nickel, chromium, cadmium, lead etc.

15.2 Extruder

Extruder is a device to shape by forcing material through a specially designed opening often after a previous heating of the material. An extruder is a thermodynamic unit. A typical extruder consists of a power supply to operate the main screw, a feeder to meter in the raw ingredients, and a barrel, which surrounds the screw. The screw conveys the raw material through towards a shaped hole, the die that shapes the product. Pre-ground and conditioned ingredients enter the screw where they are conveyed, mixed, and heated by a variety of processes. The product exits the extruder through a die where it usually puffs and changes texture from the release of steam and normal forces. Cereal processing using an extruder offers good opportunities for small-scale businesses in India because raw materials are readily available, extruders are reasonably affordable and if the products are chosen correctly, they have a good demand and can be profitable. The processing units have evolved from simple conveying devices to become very sophisticated in the last decade.

Principle of Extrusion Cooking

The raw materials are allowed into the extruder barrel and the screw(s) then convey the food along it. Further down the barrel, smaller flights restrict the volume and increase the resistance to movement of the food. As a result, it fills the barrel and the spaces between the screw flights and becomes compressed. As it moves further along the barrel, the screw kneads the material into a semi-solid, plasticized mass. If the food is heated above 100ºC the process is known as extrusion cooking (or hot extrusion). Here, frictional heat and any additional heating that is used cause the temperature to rise rapidly. High temperature of operation in presence of water promotes gelatinization of starch components and stretching of expandable components. The food is then passed to the section of the barrel having the smallest flights, where pressure and shearing is further increased. Finally, it is forced through one or more restricted openings (dies) at the discharge end of the barrel as the food emerges under pressure from the die, it expands to the final shape and cools rapidly as moisture is flashed off as steam.

The basic elements of proper extrusion cooking are the following:

1) Feeding of granular or milled material in the extruder should be continuous at desired feed rates.
2) The material should be pre-conditioned with steam at controlled temperature of 82^{O}C to 99^{O}C at atmospheric pressure.
3) The moisture should be uniformly applied to the product.
4) The equipment must transform the granular or processed floury material into a dough at 82^{O}C to 110^{O}C.
5) The temperature of the dough should be elevated to 115^{O}C to 200^{O}C during last 10 to 30 seconds in their extruder to cook and expand the product.
6) Formation of desired shape and size of the product by a nozzle or die at the end of the process. The extrudate is cut into desired lengths.
7) Drying and cooling of the extrudate.

Single-screw extruders

These contain a single rotating screw in a metal barrel, and come in varying patterns. The most commonly used single-screws have a constant pitch. Single-screws usually consist of three sections. 1) Feed 2) Transition or compression 3) Metering

Feed section

The portion of the screw which accepts the food materials at the feed port usually the feed section is characterized by deep flights so that the product can easily fall in to the flights. The function of the feed section is to assure sufficient material moved or conveyed down the screw and the screw is completely filled.

Compression section

The portion of the screw between the feed section and the metering section is called as compression section. The food ingredients are normally heated and worked into a continuous dough mass during passage through the transition section.

Metering section

It is the portion of the section nearest the discharge of the extruder which is normally characterized by having very shallow flights. The shallow flights increase the shear rate in the channel to the maximum level with in the screw.

The raw materials are fed in a granular form at the hopper located in the feed section. The rotating action of the screw conveys the material to the transition section. In the transition section, the screw channel becomes shallower and the material is compacted. A major portion of mechanical energy is dissipated in this section, which results in a rise in temperature of the material. Starch becomes gelatinized, and the material becomes more cohesive. It is transported further by the metering section and pushed through the die opening. The barrels of single-screw extruders usually have helical or axial grooves on the inner surfaces. This helps to convey and mix the material more effectively.

Single-screw extruders are usually characterized by their length to diameter (L/D) ratio and their compression ratio, which is the ratio of the maximum channel depth to the minimum channel depth. The most commonly used compression ratio is 3 to 1. The throughput (mass flow rate) capacity of a single-screw extruder is linked to screw speed, screw geometries, and material characteristics.

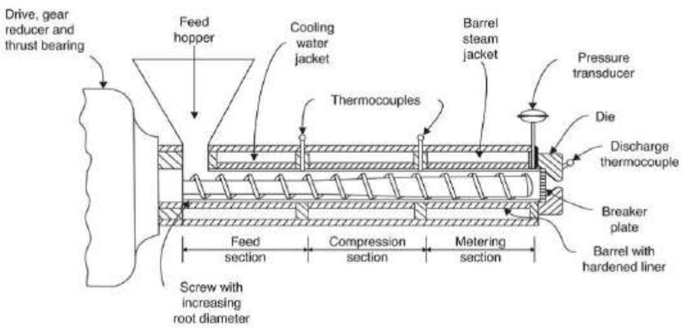


Fig 15.4. A typical single screw extruder

Ex. No. 16 **Date:**

VISIT TO COLD STORAGE STRUCTURE

Location :

Type of commodity stored :

Storage Conditions :

Insulation material used :

Refrigerant used :

Other details :

Ex. No. 17 **Date:**

VISIT TO GRAIN PROCESSING CENTRE

Location :

Type of grain stored :

Type of cleaning equipment used :

Type of dryer used :

Type of grading equipment used :

Type of packaging equipment used :

Other equipments used :