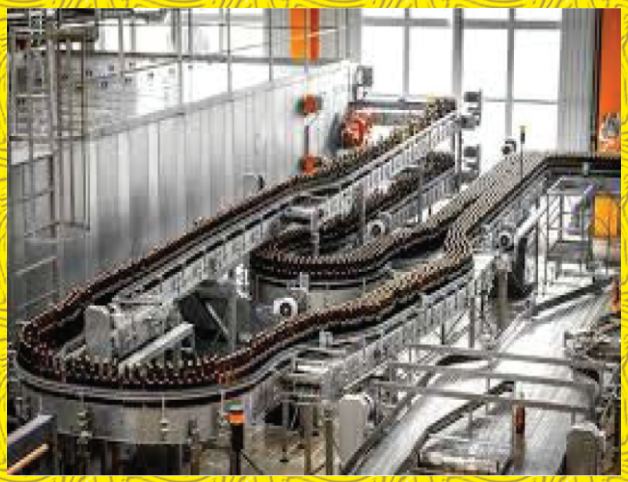
LECTURE NOTES
ON
POST-HARVEST ENGINEERING OF HORTICULTURAL CROPS

Dr Minati Mohapatra
Dr Sanjaya K. Dash









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PREFACE

This Lecture Notes on Post-Harvest Processing of Horticultural Crops gives an insight into the general Introduction about food processing in Indian context, Importance of processing of fruits and vegetables, spices and condiments, food supply chain, post-harvest unit operations, preservation techniques, different value-added finished products and the equipment used in the field of horticultural crops processing. This book is useful for both undergraduate and post graduate students as well as the researchers in the field of post-harvest processing of fruits and vegetables. The course coverage in this book can be found suitable for reference purposes also.

The author conveys gratitude to the Dean, College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar for giving the opportunities for writing this course manual helpful for undergraduate and post graduate students of Agricultural Engineering, Food Engineering and Food Technology discipline. The financial support provided by IDP-NAHEP, OUAT for printing this book is deeply acknowledged. The authors also acknowledge all the direct and indirect help rendered by the persons while preparing this manual.

Minati Mohapatra

Lecture wise Course Outline

Course: Post Harvest Engineering of Horticultural crops, Course No- PFE322 (1+1)

Lecture No.	Chapter	Details
1	**General Introduction**	General introduction: Food supply chain, Importance of processing of fruits and vegetables, spices, condiments; Flowcharts for preparation of different finished products.
2	**Properties of horticultural crops**	Characteristics and properties of horticultural crops important for processing: Physical properties, Mechanical properties, Aerodynamic properties, Thermal properties, Electrical properties, Optical properties.
3	**Preservation Technology**	Preservation Technology: General methods of preservation of fruits and vegetables, Brief description and advantages and disadvantages of different physical/ chemical and other methods of preservation
4	**Sorting and grading**	Sorting and grading equipment's: sorting and grading on the basis of size, shape, colour, weight, specific gravity and other parameters
5	**Peeling**	Peeling: Different peeling methods and devices (manual peeling, mechanical peeling, chemical peeling, and thermal peeling)
6	**Slicing/size reduction**	Slicing of horticultural crops: Disintegration methods with little change of form such as husking, shelling, pitting, coring, snipping and destemming; Disintegration methods with considerable change of form such as cutting, shredding, crushing, chopping, juice extraction, etc;. Equipment for slicing, shredding, crushing, chopping, juice extraction, etc
7	**Blanching**	Blanching: Importance and objectives; blanching methods, Steam blanching including fluidised bed blanching, Hot water blanching; effects on food (nutrition, colour, pigment, texture);

8	**Chilling**	Chilling and freezing: Application of refrigeration for perishable food products, Thermophilic, mesophilic & Psychrophilic micro-organisms, Chilling requirements of different fruits and vegetables, Equipment for chilling
9	**Freezing**	Freezing of food, freezing time calculations, slow and fast freezing and Equipment for freezing (mechanical & cryogenic), Effect on food during chilling and freezing, refrigerated vehicle and cold chain system; evaporative cooled storage
10	**Drying**	Dryers for fruits and vegetables, Osmo-dehydration
11	**Handling and transportation**	Handling and transportation of fruits and vegetables, Different modes of transportation Different types of conveyors and elevators. Brief discussion on belt conveyor, roller conveyor, chain conveyor, screw conveyor and bucket elevator, Cranes & hoists, Trucks (refrigerated/ unrefrigerated), Pneumatic transportation, Water flumes
12	**Post-harvest management of spices**	Post-harvest management and equipment for spices such as ginger, turmeric and chilli
13	**Packaging**	Pack house technology, Minimal processing; Packaging of horticultural commodities, Packaging requirements (in terms of light transmittance, heat, moisture and gas proof, micro-organisms, mechanical strength),
14		Different types of packaging materials commonly used for raw and processed fruits and vegetables products, bulk and retail packages and packaging machines,
15		Controlled atmospheric storage, Modified atmospheric packaging
16	**Quality control**	Quality control in Fruit and vegetable processing industry. Importance, Present scenario, Requirement, HACCP system Overall discussion

CHAPTER 1

General Introduction:
Food supply chain, Importance of processing of fruits and vegetables, spices, condiments

Indian agriculture supports about 60 per cent of population for their livelihood and contributes 17% of GDP in India. Total vegetable production: in India is 162.18 million MT in 2019. Total post-harvest loss incurred annually is 5-30% of total production of fruits and vegetables. Engineering inputs are vital for modernization of agriculture, agro-processing and rural living. It is needed for development and optimal utilization of natural resources, appropriate mechanism of unit operations of agriculture for increasing production, productivity with reduced unit cost of production for greater profitability, economic competitiveness and sustainability. It helps the farmers to achieve timeliness and precisely apply input for better efficiency, achieving higher productivity with reduced application of inputs. Agricultural produce and by-products are perishable in nature and thus gets exploited on the market floor compelling distress sales, absence of matching post-harvest technology (PHT) and agro-processing infrastructure. Agricultural Engineering inputs are therefore needed to assure remunerative prices to the growers and share in the value addition through on-farm PHT and value addition to their produce and by-products.

Food Processing

Food processing includes many unit operations that are used to process the raw food materials into final forms which can be consumed by human beings or animals.

- Raw food materials are transformed into edible products.
- Add value to the finished products to develop new products

The operations involved in food processing are mainly classified into two groups:

1. Primary processing
2. Secondary processing

- Primary processing relates to conversion of raw agricultural produce into a commodity that is fit for human consumption. It involves steps such as cleaning, grading, sorting, packing etc.
- Secondary and tertiary processing usually deal with higher levels of processing where new or modified food products are manufactured.

Present status of Food Processing in India

The food processing sector in the country is mainly handled by the unorganized sectors. About, 42% of outcome comes from unorganized sector, 25% organized sector and the rest from small scale players. The small-scale food processing sector is a major source of employment, however, under increasing threat and competition from the large manufacturers. Good packaging lies at the very heart of presentation and thus consumer appeal. It is an area of vital importance for small and medium food manufacturers. Improvement in processing efficiency, increased yield of usable product, is a tangible means of reducing food loss and increasing food supply. Demand for increased convenience of food preparation has created a need for new food forms as well as new ingredients.

Importance of Food Processing

All the raw food materials are processed to improve their palatability; nutritional value and shelf-life. Foods are processed for five major reasons:

1) Preservation for later consumption or sale to fetch better price
2) Removal of inedible portions
3) Destruction or removal of harmful substances
4) Conversion to forms desired by the consumer and

5) Subdivision into food ingredients.

Generally, the first - preservation for later consumption or sale – is the primary reason for food processing.

Scope of Food Processing in India

In India, there is an opportunity for large investments in food and food processing technologies, skills and equipment, especially in areas of Canning, Dairy, Packaging, Frozen Food/Refrigeration and Thermo-Processing. Fruits & Vegetables Processing, Fisheries, Milk & Milk Products, Meat & Poultry, Packaged/Convenience Foods, Alcoholic Beverages & Soft Drinks and Grain processing are important sub-sectors of the food processing industry. The consumer product groups like confectionery, chocolates and cocoa products, soya-based products, mineral water, high protein foods, soft beverages, alcoholic and non-alcoholic fruit beverages, etc. along with the health food and health food supplements is another rapidly rising segment of this industry which is gaining vast popularity.

Key constraints for Food Processing

Though there are many promising dynamics which support good growth of this industry, there are still some significant constraints which, if not addressed properly, can impede the growth prospects of the Food Processing Industry in India. capital intensive: It creates a strong entry barrier and allows lesser number of players to enter the market. Lesser players mean lesser competition and lesser competition means reduced efforts to improve the quality standards. poor quality standards and control for processing and packaging the processed foods. For example, vegetables may not be washed properly and processed into either 'ready to eat food' or packaged as 'cut and ready to cook' vegetables. Continuity of utilities i.e quality power, good quality of water for processing, Instruments for rapid and reliable analysis, versatile instruments/equipments for multi commodity, cultivars are not suitable for specific processing, etc. are other limitations for food processing industry.

Post-harvest losses

Post harvest loss is defined as any change in the quality or quantity of the product after harvest that decreases its value.The losses may range from slight defects to total loss of the produce.

Causes of post-harvest losses

External factors

Mechanical injuries

Parasitic diseases

- ✓ Internal factors

Physiological deterioration

Table 1 Post harvest losses estimated for major produces

Cereals	**:**	**2.8- 4.7%**
Pulses	**:**	**3.4- 5.0%**
Oilseeds	**:**	**2.2-9.1%**
Fruits	**:**	**4.2-13.9 %**
Vegetables	**:**	**4.6 – 37.0%**
Spices	**:**	**7.31 – 7.75 %**
Meat	**:**	**2.23 %**
Poultry	**:**	**3.65 %**
Egg	**:**	**6.55%**

(*Source: Harvest and post-harvest losses of major food crops and livestock produce, CIPHET, Ludhiana, 2012)*

Food Supply Chain

The food supply chain involves farmers, seed producers, fertilizer factories, financial institutions, millers, government, warehouses, fair price shops, retail shops, railways, truck transport companies etc. The food supply chain consists of different stages and stakeholders starting from farmers, intermediate handler/traders, processing industry, suppliers, transport, retailer and consumer and waste managers. All these stakeholders in the supply chain needs to devise ways and means for full utilization of agricultural produce keeping the wastage (losses) to be minimum

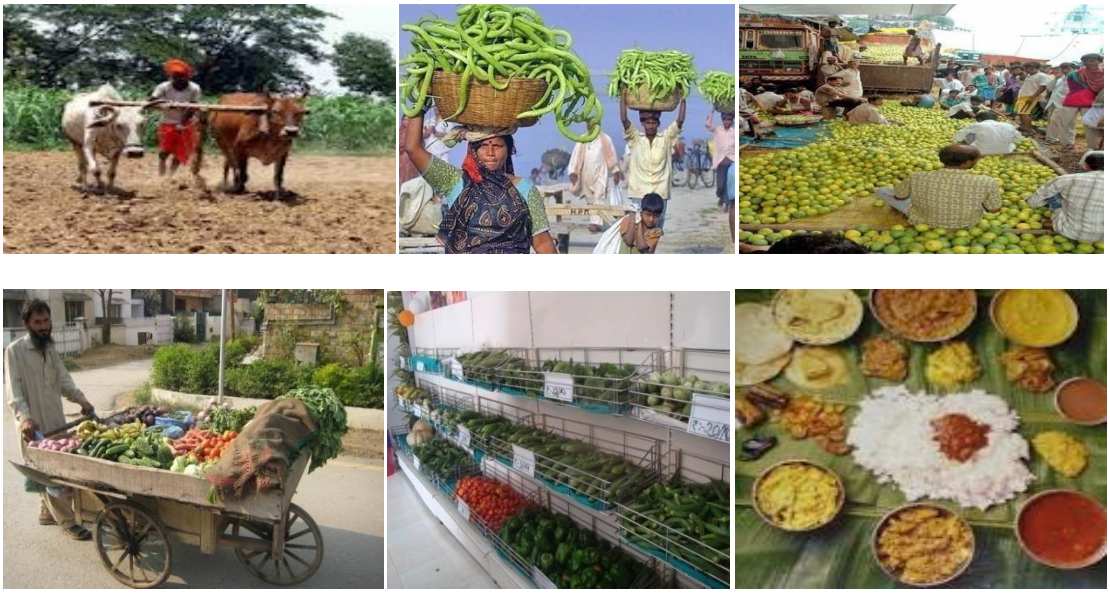


Fig.1 Different steps and stakeholders of Food supply chain

Food supply chain management of vegetables

Unit Operations

Food supply chain management of horticultural crops involves a series of unit operations as follows:

- Harvesting
- Handling
- Dumping
- Sorting
- Pre-cooling
- Cleaning/ drying
- Grading
- Packaging
- Transportation
- Marketing

Harvesting and handling

- Quality cannot be improved after harvest, but can only be maintained
- It is to be harvested at the proper stage of maturity, size and peak quality.

- Immature or over-mature produce may not last long in storage and affect the consumers appreciation.
- Utmost care must be taken for fewer bruises and other injuries so that less disease will occur at later stage (poor appearance and more water loss)

Washing/Pre-cooling

- Hydro cooling/ Air cooling and other cooling agents
- Washing not appropriate to potatoes to be stored, sweet potatoes, onion, garlics etc.

High respiration rate: Green onion, bean, Broccoli, mushroom, peas, sweet corn

Low respiration rate: Garlic, onion, potato, sweet potato

- ❖ Wash before cooling- tomato, cucumber, leafy greens
- ❖ Wash after storage: Potato, carrot, Sweet potato
- ❖ Don't wash: Green beans, cabbage, okra, peas, melons, raddish, cauliflower

Grading

Produce may be graded by

- Single dimension
- Two dimensions
- Three dimensions
- By weight

Grading by size

i. Parallel rods/riddle
ii. Stacked layout
iii. Oscillating riddle/bar screen/mesh
iv. Diverging roller
v. Diverging belt
vi. Expanding roller/variable aperture
vii. Length grader

The following important points to be taken into consideration while grading of fruits and vegetables:

- Use water dump to minimize impact
- Produce should be one line layer on grading surface
- Roll the produce to expose all sides for inspection
- Place experienced grader at the last
- Graders to use cotton gloves
- Minimize drop height
- Pad all surfaces

Packaging and storage

- Packaging prevents physical damage and is easy to handle.
- Refrigerated storage reduce respiration rate, retards ageing, metabolic changes.
- Temperature in cold storage to be constant.
- Exposure to alternate cold and hot temp. result in moisture accumulation on surface
- Air circulation in cold storage
- Chilling injury (cucumber, okra, pumpkin, sweet potato, Tomato)
- Prevention of moisture loss (High RH requirement, Water sprinkling)
- Sanitation to prevent disease and foodborne illness (Sodium hypochloride, Calcium hypochloride)
- Ethylene promotes ripening (Producers: apple, banana, papaya, tomato)



Fig. 2 Transportation of vegetables in Refrigerated Van



Fig. 3 Evaporative cooling chamber for storage of vegetables and Refrigerated storage in unit pack

Process Flow charts

A process flowchart is a graphical representation of a process through a flowchart. It's used as a means of getting a top-down understanding of how a process works, what steps it consists of, what events change outcomes etc.

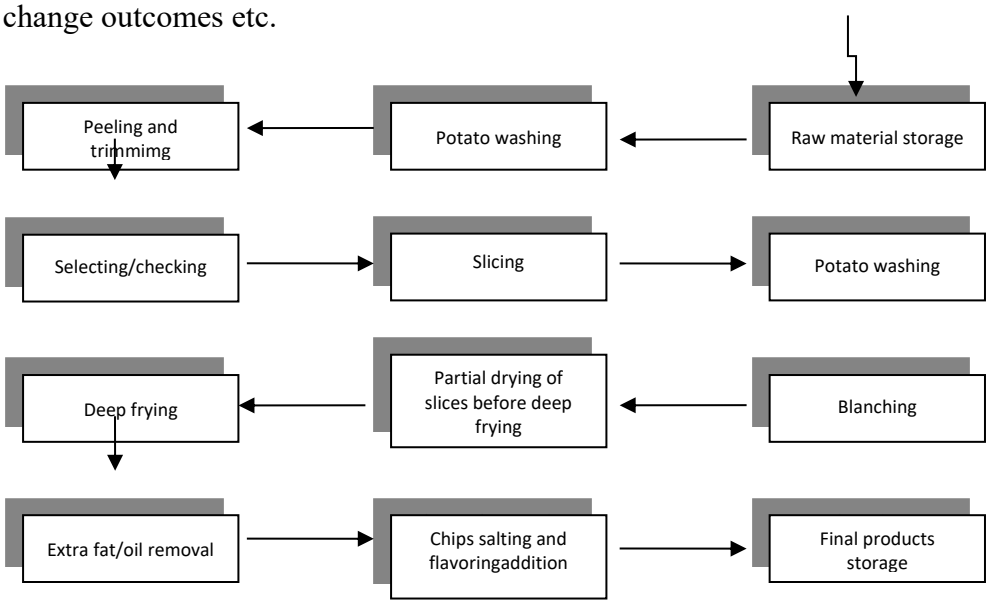


Fig.4 Process flow chart of preparation of potato chips

Process flow chart of fruit pulp RTS beverages

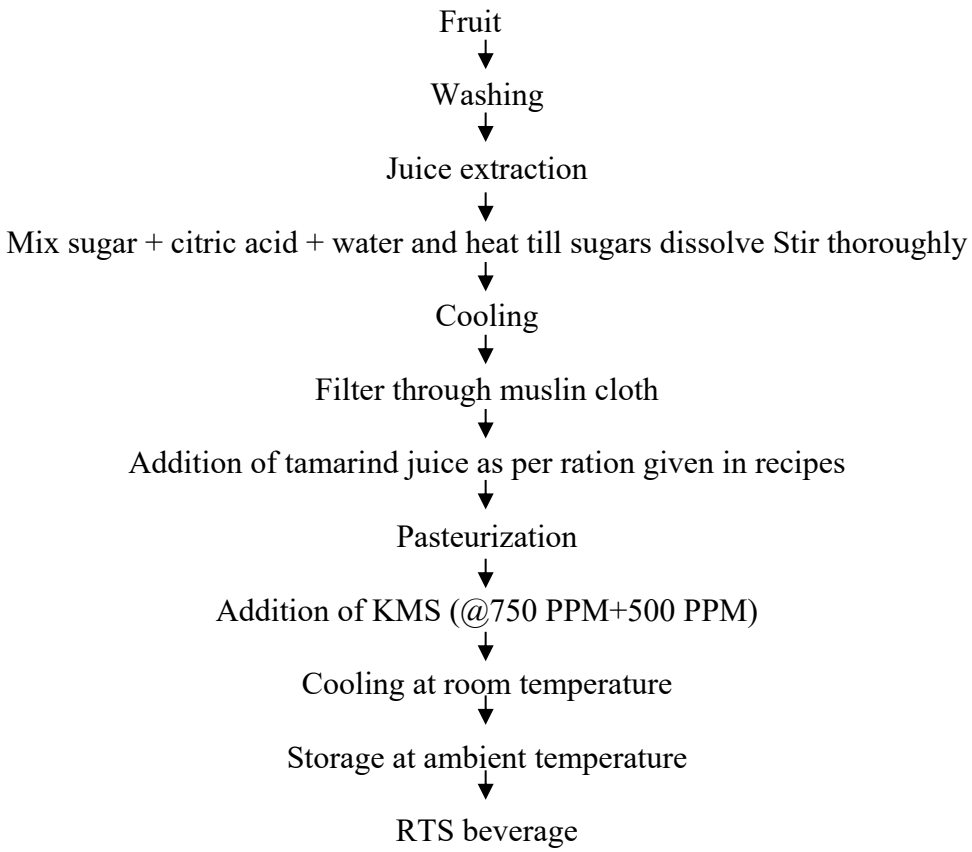


Fig. 5 Process flow chart of fruit juice RTS beverage

Process Flow in Packing House

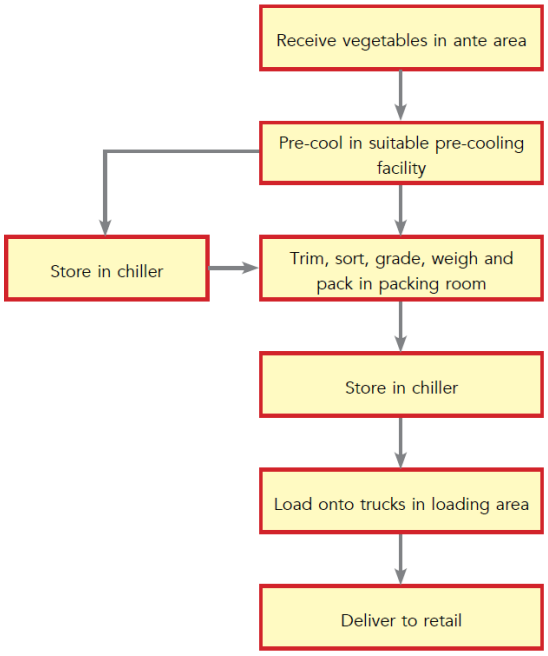


Fig. 6 Process flow in Packing House

CHAPTER 2

Properties of Horticultural Crops

Fruit and vegetables have many similarities with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. The important distinction between fruit and vegetables has come to be made on an usage basis.

- Generally eaten with the main course of a meal are considered to be vegetables.
- Those that are commonly eaten as dessert are considered fruits.

Table 2 Classification of Vegetables

Category	**Examples**
Earth vegetables roots	sweet potatoes, carrots
modified stems/tubers	potatoes
modified buds bulbs	onions, garlic
Herbage vegetables	
leaves	cabbage, spinach, lettuce
petioles (leaf stalk)	celery, rhubarb
flower buds	cauliflower, artichokes
sprouts, shoots (young stems)	asparagus, bamboo shoots
legumes	peas, green beans
cereals	sweet corn
vine fruits	squash, cucumber
berry fruits	tomato, egg plant
tree fruits	avocado, breadfruit

Classification of Fruits

The edible portion of most fruit is the fleshy part of the pericarp or vessel surrounding the seeds. Fruit in general is acidic and sugary. They commonly are grouped into several major divisions, depending principally upon botanical structure, chemical composition and climatic requirements.

Berries : small and quite fragile.
Grapes : fragile and grow in clusters.
Melons : large and have a tough outer rind.
Drupes (stone fruit): contain single pits and include such items as apricots, cherries, peaches and plums.
Pomes: contain many pits, apples, quince and pears.
Citrus: fruit like oranges, grapefruit and lemons are high in citric acid. Tropical and subtropical fruits include bananas, dates, figs, pineapples, mangoes.

Engineering properties of Foods

Any attribute affecting the processing or handling of a biological material can be defined as an engineering property. They are divided into the following categories:

- Physical properties
- Chemical properties
- Mechanical properties
- Rheological properties
- Frictional properties
- Thermal properties
- Aerodynamic and hydrodynamic properties
- Electromagnetic properties

Various food processing methods can potentially alter those properties and can cause desirable or sometimes not so desirable changes in nutrient. This chapter deals with the application of various engineering properties like physical, frictional, aerodynamic, thermal, optical, dielectric, electrical, acoustic, rheological and textural properties in the harvesting, post harvest handling, processing, storage and how it affects consumer's perception of food quality and safety.

Knowledge of engineering properties of foods/ biological materials is necessary for:

1. Defining or quantifying a depreciation of the biological/ food material.
2. Providing basic data for food processing and unit operations
3. Predicting behaviour of new food material

1. **Physical Properties**

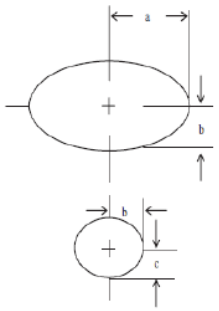
Size, shape, volume, surface area, weight, density, bulk and true density, porosity etc. are the physical parameters of foods useful for designing many separating, sorting, handling, storage or drying systems.

Size

It is very easy to specify size for regular particles, but for irregular particles the therm size must be arbitarily specified.Size can be determined using the projected area method.Three characteristics dimensions are defined as:

1. Major diameter, which is the longest dimension of the maximum projected area.
2. Intermediate diameter, which is the minimum diameter of the maximum projected area or the maximum diameter of the minimum projected area and
3. Minimum diameter, which is the shortest dimension of the minimum projected area.

Generally, length, width and thickness terms are commonly used which corresponds to the major, intermediate and minor diameters respectively. For example, In a Triaxial ellipsoid shape, all three perpendicular sections are ellipse, then D max, Dinter, Dmin are:



$D_{max} = 2a$

$D_{inter} = 2b$

$D_{min} = 2c$

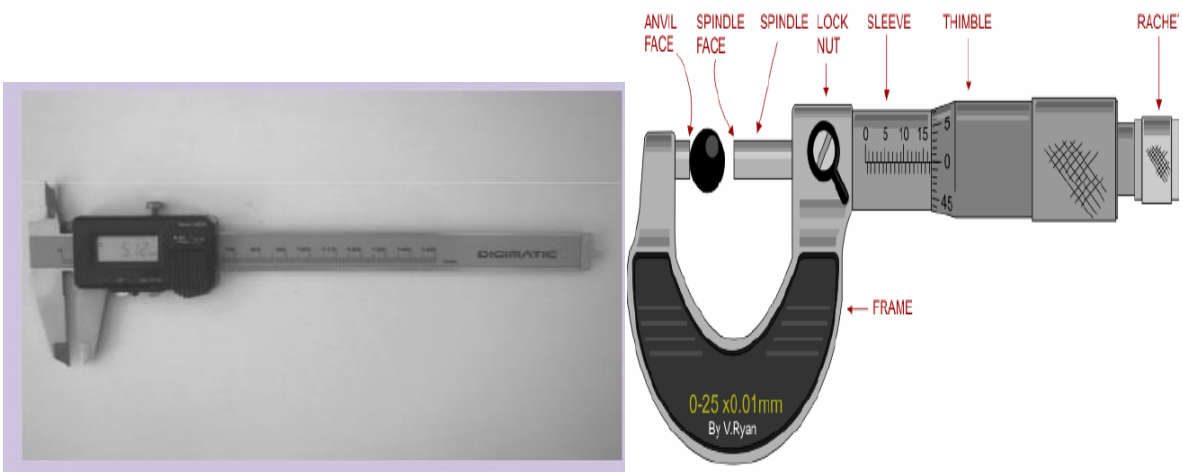
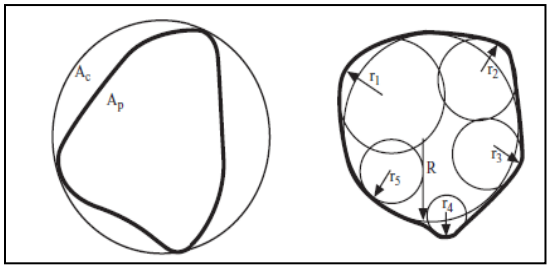


Fig.7 Slide caliper and Screw gauge

Measuring Instruments for measuring differenr dimensions of the foods are vernier calliper or screw gauge.

Shape

To characterize food's shape: roundness and sphericity



- Roundness is a measure of the sharpness of the corners of a solid

$$\text{Roundness} = \frac{A_p}{A_c}$$

Where,

A_p = largest projected area of object in natural rest position(m^2)

A_c = Area of the smallest circumscribing circle as defined in Fig. 1.4a (m^2)

OR

$$\text{Roundness} = \frac{\sum_{i=1}^{N} r}{NR}$$

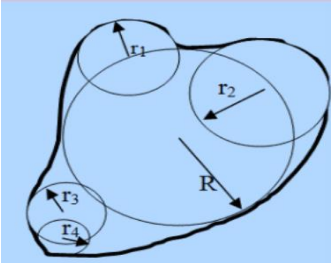
Where, r = radious of curvature

R= radious of the maximum inscribed circle (m)

N=total number of corners summed in numerator

- The shape of a food material is usually expressed in terms of its sphericity and aspect ratio.

- Sphericity or shape factor is the degree to which an object resembles a sphere. It is defined as the ratio of the volume of triaxial ellipsoid to the volume of sphere with D=D_{max} with a power of one third.



$$Sphericity = \left(\frac{Volume\ of\ solid\ sample}{Volume\ of\ circumscribed\ sphere}\right)^{1/3}$$

Assuming that the volume of the solid sample is equal to the volume of the triaxial ellipsoid with diameters equal to major, minor and intermediate diameter

$$\emptyset = \left(\frac{V_e}{V_c}\right)^{1/3}$$

Where,

$\emptyset$= sphericity,
Ve= volume of the triaxial ellipsoid with equivalent diameters (m^3),
V_c= volume of the circumscribed sphere (m^3)

Volume of the triaxial ellipsoid: Ve = 4/3 πabc

Then, sphericity is: $$\emptyset = \frac{(abc)^{1/3}}{a}$$

Particle size depends on particle shape, which is rarely spherical. Particle (grain, seed) maybe compact, plate-like or needle like

Table 3 Shape and description of various agro commodities

Shape	Description	Examples
Round	Approaching Spheroid	Cherry tomato, pea
Oblate	Flattended at the stem end and apex	Orange, pumpkin
Oblong	Vertical diameter greater than horizontal	Some apple varieties, capsicum, brinjal, rice, wheat
Conic	Tapered towered the apex	Ladies finger, carrot, reddish
Ovate	Egg shaped & broad at stem end	Brinjal, apple and guava
Oblique	Axis connecting stem and apex slated	Some apple varieties, tomato
Obovate	Inverted ovate-broad at apex	Mango, papaya
Elliptical	Approaching ellipsoid	Rice, wheat, pointed guard
Truncate	Having both hand squared or flattened	Capsicum
Unequal	One half larger than the other	Mango
Ribbed	In cross section, sides are more or less angular	Ladies finger
Regular	Horizontal section approaches a circle	Orange, apple, guava
Irregular	Horizontal section dearth materially from a circle	Mango, ladies finger, capsicum

Volume

- SI unit volume is m^3
- The most common definitions of volume:
- Solid volume/True volume (V_5)-volume of the solid material (including water) excluding any interior pores that are filled with air.
- Apparent volume (V_{app})-Volume of a substance including all pores within the material (internal pores).
- Bulk volume (V_{bulk})-is the volume of a material when packed or stacked in bulk.

Volume of solids can be determined experimentally by liquid, gas or solid displacement

Density

- *Density=Mass/Volume=m/V*
  SI unit:kg/m^3
- Density can be expressed in different forms.
  - Solid density (p_s)-mass per unit volume of the solid material and excludes any interior pores that are filled with air.

$$\rho_s = \frac{1}{\sum_{i=1}^{n} \frac{m_i}{\rho_i}}$$

Whereρ_i − densityofthe$i$ − thcomponent

m_i- mass fraction of the *i*-th component

- *Particle density (ρ_p)−mass of a paticle to its actual volume*.**Internal pores are included**.
- Bulk density (ρ_{bulk}) - the mass per total volume occupied by a large quantity of particles. Pores space among particles are included.

If the volume of the internal pores is negligible, there is
Solid density=Bulk density

- Density of solids and liquids changes in temperature and pressure.
- The density of food materials depends on temperature, and also depends on the major food components (pure water, carbohydrate, protein, fat, ash and ice);
  ρ_{water}= 997.18 + 3.1439 x $10^{-3}T$-3.7574x $10^{-3}T^2$
  ρ_{CHO}= 1599.1- 0.31046T
- Where; densities (ρ) are in kg/m^3 and temperature (T) are in ^oC and varies between -40 and 150^oC. (Ref; Based on Choi and Okos (1986)
- The density can be determined by using a pycnometer, etc.

Porosity

- It is the measure of void space between the materials.
- Porosity (ε) is the percentage of the total volume occupied by the air

Total volume=Volume occupied by particle/sample + Volume occupied by air

$$\text{Porosity (\%)} = \frac{\text{Total volume} - \text{particle volume}}{\text{Particle volume}} \text{x} 100\%$$

$$= \frac{\frac{\text{mass}}{\text{Bulk density}} - \frac{\text{mass}}{\text{Particle density}}}{\frac{\text{mass}}{\text{Bulk density}}} \text{x} 100\% = \left(1 - \frac{\text{Bulk density}}{\text{particle density}}\right) \text{x} 100\%$$

- Method to determine porosity:
  - Direct method-porosity is determined from the difference of bulk volume of a piece of porous material and its volume after destruction of all voids means of compression

Optical method-porosity is determined from microscopic view of a section of the porous medium.

Shrinkage

- Shrinkage is the reduction in volume or geometric dimensions during processing.
- Isotropic- the uniforms shrinkage of the materials under all geometric dimensions
- Anisotropic (non-uniform)-develops in different geometric dimensions
- How it occurs? Moisture loss, during freezing, drying, frying etc.

2. **Chemical Properties**

Focus on chemical composition and moisture content. Knowledge on the composition of biomaterials is useful for estimating bulk densities, thermal properties e.g. specific heat, thermal conductivity etc.

Chemical compositions of food and agricultural materials

- Knowledge on the approximate compositions of food and agricultural materials is useful for estimating densities and thermal properties.
- Similarity between food and agricultural materials; Contains 5 main component; Water, protein, carbohydrates, lipid and ash
- Difference in the composition of individual components
- Composition of food and agricultural materials not only influence nutritional value but also on moisture adsorption and electromagnetic properties.

Water

- Most of food and agricultural materials contain significant amounts of water.
- The amount of water is important because it can affects market value and length of time they can be successfully stored.
- Moisture content also affects mechanical properties, density, frictional properties and electromagnetic properties.

Moisture content

- Moisture content expresses the amount of water present in a moist sample.
- 2 way to express moisture content;
  - Moisture content wet basis (MC_{wb})
  - Moisture content dry basis (MC_{db})
- Moisture content wet basis is the amount of water per unit mass of moist (or wet) sample.
- MCwb=mass of water *I* mass of moist sample(mass of water + mass of dry solids)
- Moisture content dry basis is the amount of water per unit mass of dry solids(bone dry)present in the sample

MC_{db} = mass of water / mass of dry solids

Carbohydrates

- Starch,sugarandgums are the major carbohydrates in our food systems.
- Sources of carbohydrates -these includesuch as wheat, maize, rice, potatoes, sugar, bread etc.

The function of carbohydrates such as starch and sugar are providing the energy to our body.

Mechanical properties

Focus on strength properties and testing such as compressive strength, hardness, cutting strength etc.

Rheological Properties

Focus on food texture and rheological characterization. Knowledge of rhelogical properties are important in the design of flow processes in quality control for predicting storage and understanding and designing texture of food.

Frictional Properties

Coefficient of friction, angle of repose, angle of internal friction are few frictional properties which are helpful for designing equipment for storage, handling or flowing device. Angle of repose and coefficient of friction are important for designing of equipment for solid flow and storage structures. Angle of internal friction between seed and wall is useful for prediction of seed pressure on wall. Similarly, angle of internal friction between seed to seed is useful for the knowing the internal seed pressure and designing of storage structures or hopper designetc. Coefficient of friction is also important in designing storage bins, hopper design, chutes, screw conveyor, forage harvester, thresher etc.

Thermal properties

Thremal properties are required in almost all processing operations e.g. specific heat, thermal conductivity and thermal diffusivity etc. knowledge of these properties are useful for designing thermal load calculation for thermal processes e.g. pasteurization, sterilization, blanching, canning etc. These are also useful in cooling load calculations of foods in designing of refrigeration, cold storage or chilling systems.

Aerodynamic and hydrodynamic properties

Areodynamic and hydrodynamic properties include terminal velocity, drag coefficient etc. these are important in designing of aero/hydro conveying systems or separation equipments.

Air is generally used as a carrier agent for transport or separating desirable products, therefore, terminal velocity and drag coefficients are essential to know the air conveying and pneumatic separation of materials.

Electromagnetic properties

Dielectric properties include dielectric constant, dielectric loss factor, penetration depth. Dielectric properties are important in determination of interaction between the food material being processed and the electromagnetic energy. It is useful for designing and controlling thermal processing and moisture content determination.

CHAPTER 3

Preservation Technology

Food Preservation is the methods of treating foods to delay the deterioration of the food, changing raw products into more stable forms that can be stored for longer periods of time and allows any food to be available any time of the year in any area of the world.

Methods of preservation used to extend shelf life includes

- Removal of moisture
- Temperature control
- pH control
- Use of chemical preservatives
- Non-thermal Methods: Irradiation, HPP, Ultrasonic, PEF, Pulsed light etc.

Historical Methods of Food Preservation

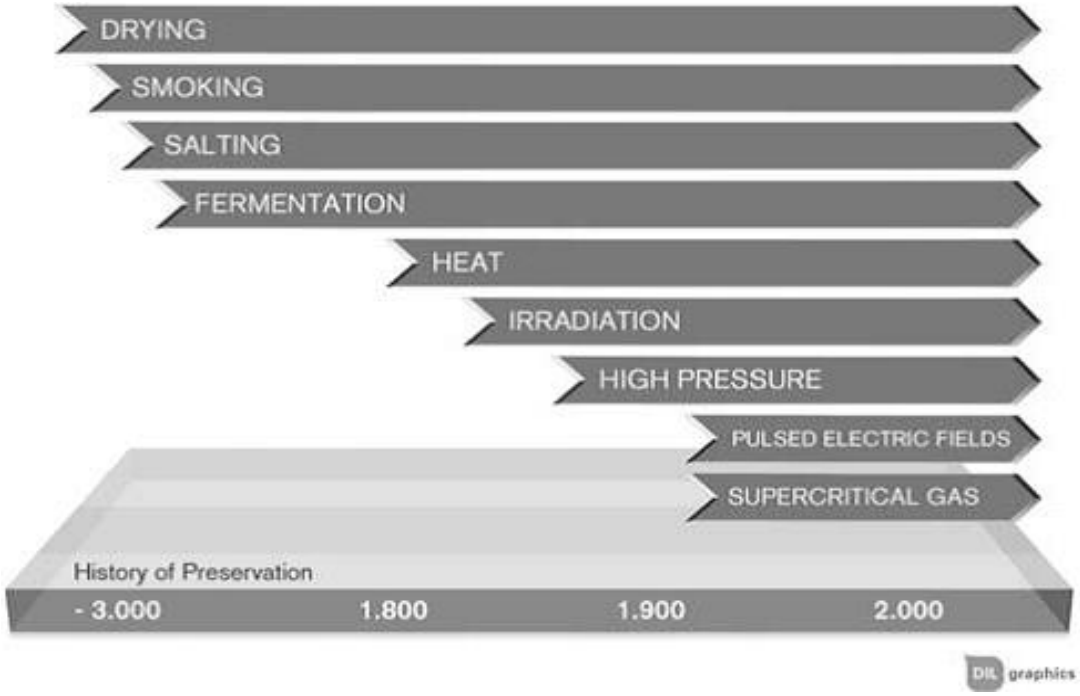


Fig. 8 History of food preservation in pictorial representation

Primitive and tedious methods

Drying: Used to preserve fruit, vegetables, meats, and fish. Mainly used in the south–warmer climate. However, it causes the loss of many natural vitamins and texture.
Salting: Used extensively for pork, beef, and fish. Costly due to high price of salt. Done mainly in cool weather followed by smoking.
Sugaring: Used to preserve fruits for the winter. Jams and jellies. Expensive because sugar is a costly commodity.

Pickling: Fermenting the food, used mainly to preserve vegetables. Use of mild salt and vinegar brine. It increases the salt content and reduces the vitamin content of the food. Oldest form of food preservation.
Cold storage: Used extensively in the northern U.S. Root cellars used to store vegetables at 30-40°F. Root cellars were replaced by ice boxes in the mid 1800's.

Food Preservation Shift

During the late 18th century, there was a great demand for better preservation methods for naval expeditions. Food preservation methods used were not effective enough for long term use; hence better methods were needed for safer food consumption.

Louis Pasteur believed that particles in the air cause contamination. He found out that heating foods quickly to 130°F after completion of fermentation processes would kill microbes, and unpleasant flavours. This process is now known as pasteurization, and is widely used in milk, wine and vinegar making.

Table 5 Preservation Methods

Physical	Chemical	Biological
Chilling and cooling Freezing Blanching Pasteurization Canning Drying/Dehydration Separation/Filtration Concentration Irradiation Modified/Controlled Atmospheric Packaging. HPP. PEF	Preservatives e.g Benzoates, Nitrites Sugar Salt Acids Spices Additives e.g. antioxidants	Fermentation: Alcoholic Acetic Lactic

Physical methods of preservation

Chilling and cooling

- Chilling may be referred to as the process that lowers the food temperature to a safe storage temperature between 0 to 5°C, whereas cooling is a more general term applied to the lowering of a food temperature.
- Chilled foods can potentially present a greater risk to public safety than frozen foods. Keeping products at a low temperature reduces the rate of microbiological and chemical deterioration of the food.
- In most processed chilled foods, it is the microbial growth that limits the shelf life; even the slow growth rates that occur under chilled conditions will eventually result in microbial levels that can affect the food or present a potential hazard. but pathogens, if present, may have the potential to grow and may show no noticeable signs of change in the food.

Freezing

- Freezing of food does not render it sterile, although it can reduce the levels of some susceptible microorganisms that is not significant in the context of the overall microbial quality of the food.
- freezing of the product takes place quickly, and the shelf-life is even longer.
- It is important to avoid repeated freezing and thawing as these damages the food resulting in a greater chance for microbial repair and growth.
- Rapid freezing in blast freezers is desirable to prevent the formation of large ice crystals that will tend to adversely affect the texture of the food by disrupting cell integrity in fruits and vegetables.
- Damage to tissue results from ice crystals, particularly in the case where slow freezing occurred, for example, in a domestic freezer. In commercial freezers, where temperatures of -40°C and below are maintained,

Heat Preservation

Microorganisms and enzymes are the major causes of undesirable changes in foodstuffs. They both are susceptible to heat, and appropriate heating regimes can reduce, inhibit or destroy their activity. The degree of heat treatment required to produce a product of acceptable stability will depend on:

- the nature of the food, its associated enzymes,
- the number and types of microorganisms,
- the conditions under which the processed food is stored and
- other preservation techniques used.

Blanching

- Blanching is a process designed to inactivate enzymes and is usually applied immediately prior to other thermal preservation processes either using high temperatures (e.g. thermal processing) or low temperatures (e.g. freezing).
- It reduces the microbial population on the surface of foods and also reduces the numbers of organisms of lower heat resistance, such as yeasts, molds and certain bacteria (e.g. Listeria, Salmonella, E. coli).
- Without a blanching step, the shelf life of frozen vegetables would be substantially reduced as a result of chemical breakdown during storage.

It is mainly used for fruits and vegetables by heating the food with steam or hot water and cooling in ice water or normal tap water.

Advantages of Blanching

- It helps clean the material and reduce the amount of micro-organisms present on the surface;
- It preserves the natural colour in the dried products;
- It shortens the soaking and/or cooking time during reconstitution.
- Destroys enzymes in the food.

Disadvantages of Blanching

- During hot water blanching, some soluble constituents are leached out: water-soluble flavours, vitamins (vitamin C) and sugars. With potatoes this may be an advantage as leaching out of sugars makes the potatoes less prone to turning brown.
- Blanching is a delicate processing step. Time, temperature and the other conditions must be carefully monitored.
- Sodium bicarbonate is added to the blanching water when okra, green peas and some other green vegetables are blanched. The chemical raises the pH of the blanching water and prevents the fresh green colour of chlorophyll being changed into unattractive brownish-green.
- If products are over-blanched (boiled for too long) they will stick together on the drying trays and they are likely to have a poor flavour.

Blanching requirements of some vegetables and fruits

- Green beans, carrots, okra, turnip and cabbage should always be blanched. The producer can choose whether or not potatoes need blanching.
- Blanching is not needed for onions, leeks, tomatoes and sweet peppers. Tomatoes are dipped into hot water for one minute when they need to be peeled but this is not blanching.
- As a rule fruit is not blanched.

Pasteurization

- This is a heating regime (generally below 105°C) that primarily aims to achieve commercial sterility by virtue of additional factors that contribute towards preserving the food.
- The actual degree of heat process required for an effective pasteurization will vary depending on the nature of the food and the types and numbers of microorganisms present.
- Milk is the most widely consumed pasteurized food, and the process was first introduced commercially in the UK during the 1930s, when a treatment of 63°C for 30 min was used. Milk pasteurization uses an equivalent process of 72°C for 15 s.
- Once the food product is exposed to temperatures of 60-70°C, microbial growth stops, and enzyme inactivation starts. As the temperature is increased (80-90°C), the vegetative forms of microorganisms are destroyed and the rate of enzyme inactivation increases.
- Heat processing of acid products, such as fruits and fruit juices, is usually done at higher temperatures (100°C), for short times (10-15 s).

Canning

Can retorting or processing is a term that is still widely used in the food industry to describe a wide range of thermal processes where the food is heated within the pack to achieve a commercially sterile packaged food. The heating takes place in retorts that are basically batch-type or continuous hot water and/or steam-heated pressure cookers.

Different types of canning are:

- Boiling water canning
- Pressure canning

Safe canning is determined by:

- Processing temperature
- Processing time
- Sealed lid
- Acid level
- Container & size
- Preparation method
- Consistency of food
- Altitude

The principle of food canning is that no microbial growth occurs in the food under normal storage conditions at ambient temperature until the package is opened. Once the package is opened, the effects of canning will be lost, the food will be regarded as perishable and its shelf life will depend on the nature of the food itself.
The most heat-resistant pathogen that might survive the canning process of low-acid foods is *C. botulinum*. This bacterium can form heat-resistant spores under adverse conditions that germinate in the absence of oxygen and produce a highly potent toxin, causing a lethal condition known as botulism which can cause death within seven days.

Table 6 Heat processing requirements-dependent on product acidity

Acidity class	pH value	Food item	Processing Temperature requirements
Low acid	6.0	Peas, carrots, beets, potatoes, asparagus, poultry, meat, sea foods, milk etc.	High temperature processing 116-121°C (240-250°F)
	5.0	Tomato soup	same as above
Medium acid	4.5	Tomatoes, pears, apricots, peaches	Boiling water processing 100°C (212°F)
Acid	3.7	Jams, sauces, fruits, Sauerkraut, apple,	Temperature of 93-100^{o} C, (200-212^{o} F)
High acid	3.0	Pickles	-

Source: Desrosier and Desrosier (1977)

Chemical and Biological Methods of Food Preservation

Salt and sugar have long been used as effective means of extending shelf life of various products as these solutes bind water, leaving less water available for the growth of microorganisms.

- Essentially the water activity (aw) of the product is reduced.

- Salt and sugar in concentrated solutions have high osmotic pressure. When these are sufficient to draw water from microbial cells or prevent normal diffusion of water into these cells, a preservative condition exists.
- usually, 70% sucrose in solution will stop growth of all micro-organisms in foods
- Salt becomes a preservative when its concentration is increased and levels of about 18% to 25% in solution will prevent all growth of micro-organisms in foods.

Acids

- Acids such as citric acid, acetic acid (vinegar) and ascorbic acid
- In these cases, the pH of the product is shifted to being low, that is, more acidic, where very few molds, yeast and bacteria are able to grow and multiply.
- Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent moulds
- It is also a product of the lactic-acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid.
- The main application of vinegar (acetic acid) includes products such as pickles, sauces and ketchup.

Other acidulants

- Malic and tartaric (tartric) acids is used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies, etc.
- Citric acid is the main acid found naturally in citrus fruits; it is widely used (in carbonated beverages) and as an acidifying agent of foods because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.
- Ascorbic acid or vitamin C, its isomer iso-ascorbic acid and their salts are highly soluble in water and safe to use in foods.

Lypophilic acid food preservatives

Benzoic acid

- Benzoic acid in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, pickles, preserves, fruit cocktails, etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.
- Sorbic acid
- Sorbic acid is generally considered non toxic and is metabolized; among other common food preservatives the WHO has set the highest acceptable daily intake (25 mg/kg body weight) for sorbic acid. Sorbic acid and its salts are practically tasteless and odourless in foods, when used at reasonable levels (< 0.3 %) and their antimicrobial activity is generally adequate.

Sorbates

- Sorbates are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, syrups, jellies, jams, preserves, high moisture dehydrated fruits, etc.
- Potassium sorbate

- Potassium sorbate, a white, fluffy powder, is very much soluble in water (over 50%) and when added to acid foods it is hydrolysed to the acid form. Sodium and calcium sorbates also have preservative activities but their application is limited compared to that for the potassium salt, which is employed because of its stability, general ease of preparation and water solubility.

Gaseous chemical food preservatives

Sulphur dioxide and sulphites

- Sulphur dioxide (SO_2) has been used as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml at 25°C).

The various sulphite salts contain 50-68% active sulphur dioxide. A pH dependent equilibrium is formed in water and the proportion of SO_2 ions increases with decreasing pH values. At pH values less than 4.0 the antimicrobial activity reaches its maximum. The antimicrobial action of sulphur dioxide against yeasts, molds and bacteria is selective, with some species being more resistant than others.

Carbon dioxide

- Carbon dioxide (CO_2) is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice it is sold as a liquid under pressure (58 kg per cm^3) or solidified as dry ice.
- Carbon dioxide is used as a solid (dry ice) as a means of low-temperature storage and transportation of food products. Besides, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic micro-organisms and prevents spoilage of the food (fruits and vegetables, etc.).

Chlorine

- The various forms of chlorine constitute the most widely used chemical sanitizer in the food industry. These chlorine forms include chlorine (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(ClO)_2$) and chlorine dioxide gas (ClO_2).

- These compounds are used as water adjuncts in processes such as product washing, transport, and cooling of heat-sterilised cans; in sanitising solutions for equipment surfaces, etc.

General rules for Chemical Preservatives

- Chemical food preservatives are added in very low quantities (up to 0.2%).
- It does not alter the organoleptic and physico-chemical properties of the foods at all or only very little.
- They are used to improve the colour and keeping qualities of the final product for some fruits and vegetables.
- Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more.
- "Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.

- The use of chemical preservatives MUST be strictly limited to recognized as being without harmful effects on human beings' health and are accepted by national and international standards and legislation.

Preservation by Fermentation

- Food fermentation is usually carried out with the use of micro- organisms, producing alcoholic, acetic or lactic acid as end products as a result of their action on simple sugars present.
- These reactions take place in the absence of oxygen, that is anaerobic, and are responsible for the production of wine, vinegar, yoghurt and pickled vegetables among others.
- Having pure cultures of the desirable microorganism in the food products is critical for obtaining clean", characteristic flavours of end products.
- It is a process in which food spoils but results in the formation of an edible product. example: cheese. Fresh milk does not remain in edible condition for a very long period of time.
- Bread is another food product made by the process of fermentation. The addition of yeasts brings about the fermentation of sugars present in the mixture, resulting in edible much longer.

CHAPTER 4

Cleaning, Sorting and Grading of Fruits and Vegetables

The purpose of post-harvest processing of crops is:

- To prevent post harvest losses
- To add value to the commodity
- To maintain or improve the quality
- Better utilisation of the surplus production
- Availability in off season
- Entrepreneurship development

The primary processing operating of fruits and vegetables are:

- Cleaning
- Pre-Cooling
- Sorting and grading
- Packaging
- Storage
- Transportation

Cleaning

Cleaning is the unit operation in which contaminating materials are removed from the food to leave the surface of the food in a suitable condition for further processing.

- Contaminats: Metals, Minerals, Plant., Animals, Chemicals, Microbial cells, Microbial products.

Cleaning of foods are of two types:

1. Wet cleaning procedures: soaking, spraying, floatation washing or ultrasonic cleaning; Equipments: spray washer, brush washer, drum or rod washer, ultrasonic cleaner or floatation tank.
2. Dry cleaning procedures: separation by air, magnetism or physical methods Equipments: Air classifiers, magnetic separators, screen separators

Table 7 Difference in wet cleaning and dry cleaning of foods

Wet cleaning	Dry cleaning
More effective for removing dirt, soils of root crops or dust and pesticide residues from soft fruits and vegetables.	Useful for products that are smaller having greater mechanical strength and possess a lower moisture content e.g. grains and nuts.
It is dustless and causes less damage to foods.	After cleaning surfaces are dry which aid further processing.
Allows flexibility in operations with diff. combination of detergents and sterilants.	Generally involve smaller cheaper equipments.
Produce large volume of effluent , with high conc. of dissolved and suspended solids.	Produce a concentrated dry effluent which may be disposed of more cheaply.
There is a need for purchase of clean water and to pay for high effluent disposal.	Plant cleaning is simpler and microbial detoriation of food is reduced.
To reduce costs, recirculated, filterte and chlorinated water is used whenever possible.	However, additional capital investment may be necessary to prevent dust which causes health hazards.

Brenan et al., (1976)

Sorting

- Removal of under size, over or under ripe, misshapen and damaged ones
- To meet requirement of grade
- Improve attractiveness.
- Reduces quantity for subsequent handling
- Removal of damaged ones reduces loss during storage and handling

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

Effectiveness of sorting process:

$$\text{effectiveness} = \frac{P\bar{x}_p\, R(1-\bar{x}_r)}{F\bar{x}_f\, F(1-\bar{x}_f)}$$

where P (kg s^{-1}) = product flow rate, F (kg s^{-1}) = feed flow rate, R (kg s^{-1}) = rejected food flow rate, $\bar{x}_p$ = the mass fraction of desired material in the product, $\bar{x}_f$ = the mass fraction of desired material in the feed and $\bar{x}_r$ = the mass fraction of desired material in the rejected food.

Shape sorting:

- Manually
- Mechanically
  - Belt and Roller sorter
  - Disc sorter
  - Image processing

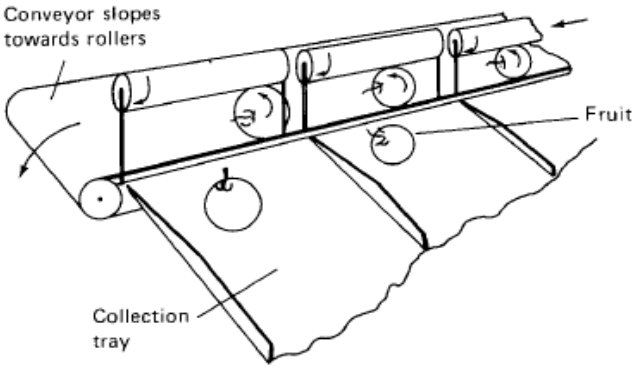


Fig. 9 Belt and roller sorter

Size Sorting

Size sorting (termed *sieving or screening)* is the separation of solids into two or more fractions on the basis of differences in size. 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.

Equipments:

- Screens with either fixed or variable apertures
- The screens may be stationary or most commonly rotating or vibrating.

Fixed apparatuses screens

- Flat bed screen
- Drum screen (rotary screen or reel)

Multitask Flat Bed screen / Flat bed screen

The multideck flat bedscreen 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.
The smallest particles that are separated commercially are of the order of 50 μm

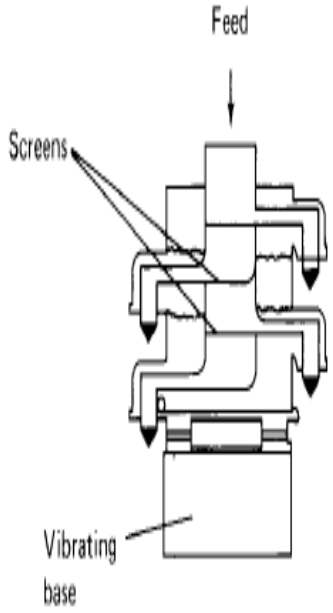


Fig. 10 Multideck Flat Bed screen

The capacity of a screen is the amount of food that passes through per square meter per second.
The rate of separation is controlled by:
• the shape and size distribution of the particles
• the nature of the sieve material
• the amplitude and frequency of shaking
• the effectiveness of methods used to prevent blocking

- widely used for sorting dry foods (flour, sugar and spices).

The main problems encountered are:
• Excessive moisture or high humidity causes agglomeration

- blinding, particularly if the particle size is close to that of the screen aperture

• high feed rates

Drum screen

- 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.
- Useful for small-particulate foods e.g. peas or beans that have sufficient mechanical strength to withstand the tumbling action.



Fig. 11 Parallel drum screen

- Drum screens are almost horizontal (5–10º inclination), perforated metal or mesh cylinders.
- Concentric
- Parallel
- Series

Image processing

- It is used to sort foods on the basis of length, diameter, number of surface defects and orientation of the food on a conveyor as well as colour .
- It has been used e.g. maize cobs, which pass beneath three video cameras, placed 120º apart above a conveyor belt.
- The images of the surface of the cob are recorded and stored in the memory of a microprocessor.
- The information is then analyzed and compared with pre-programmed specifications.

Colour sorter

These include monochrome (black and white), bichrome (4100 shades of red and green) trichromatic or full colour (262 000 shades of red, green and blue, with optional infrared).
Each is controlled by a programmable logic controller which has pre-set programs for different products that are easily changeable by operators using a video
display. Up to 10 tons of product per hour pass beneath the cameras on conveyors operating at 150–180 m per min.

- Light sensitive cells in the camera (termed ‘pixels’) produce a voltage that is proportional to the intensity of light received. An electronic circuit that receives a lower voltage than the pre-set value can thus detect darker objects or areas which reflect less light than normal.

- Useful for detecting diffectives on the surface of tomatoes, potatoes and other vegetables.

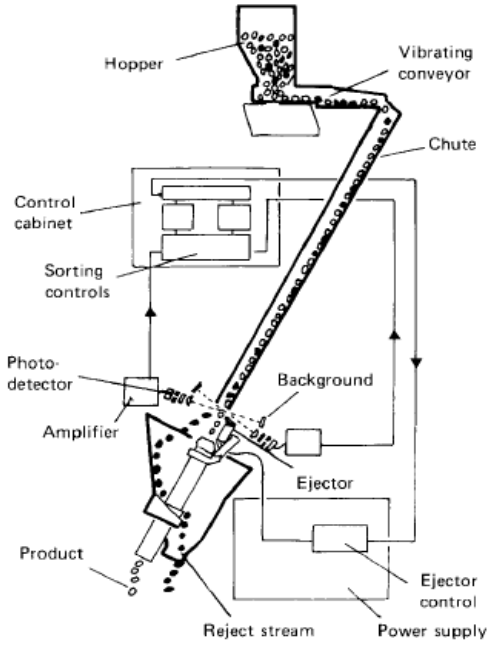


Fig. 12 Colour sorter

Grading

Grading is the unit operation involving separation of the materials in different homogenous groups according to their specific characteristics like size, shape, color and on quality basis. It saves time and energy in different processing operations, provides uniform treatment during processing and reduces the handling losses. Grading of fruits and vegetables is considered very important as it can fetch higher price to the grower. It also improves packaging, handling and other post-harvest operations. Therefore,

- Grading is assessment of a number of attributes to obtain an overall quality
- Classification into different quality fractions based on commercial usage
- Sorting may thus be a part of grading.
- Grading by trained operators
- More expensive than sorting
- Buying is based on Grade

Parameters of grading

- Size
- Shape
- Cleanliness
- Maturity
- Colour
- Weight
- Surface roughness
- Free from disease, mechanical, insect damage

Different types of grader

- Screen grader
- Barrel screen grader

- Diverging belt grader
- Roller grader
- Mass grading
- Optical grading
- Manual inspection

The grader based on size are of different types such as divergent roller type having inclination, expanding pitch type, inclined vibrating plate and counter rotating roller having inclination. Size variation in vegetables like potatoes, onions provides a base for grading them in different categories. Grading is also done based on weight, density and specific gravity of agricultural commodities.

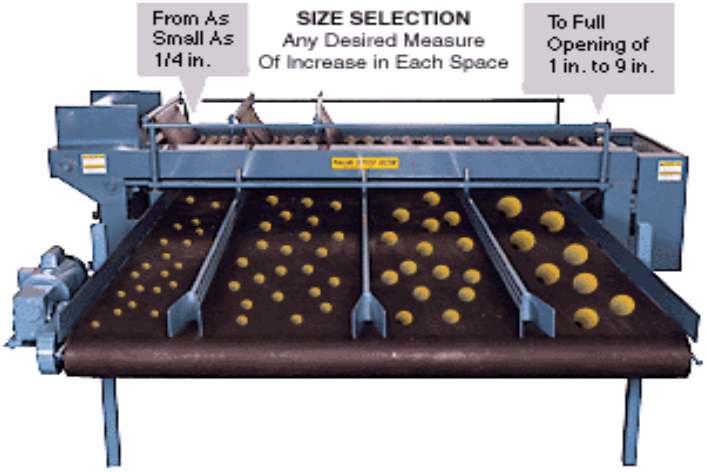


Fig. 13 Grading based on Size of Fruit and Vegetable

CHAPTER 5

Peeling, Size Reduction of fruits and vegetables

Peeling is used in the processing of fruits and vegetables to remove the unwanted or inedible material, and to improve the appearance of the final product.
The main considerations are :

- To minimize cost by removing as little of the underlying food as possible
- Reducing energy, labour and material costs to a minimum
- The peeled surface should be clean and undamaged

There are five main methods of peeling:

1. flash steam peeling
2. knife peeling
3. abrasion peeling
4. caustic peeling
5. flame peeling

Flash steam peeling

- Foods generally root crops are fed in batches into a pressure vessel which is rotated at 4–6 rpm.
- High-pressure steam (1500 kPa) is introduced and all food surfaces are exposed to the steam by the rotation of the vessel for a predetermined time, which differs according to the type of food.
- The high temperatures cause rapid heating of the surface layer (within 15–30 s) but the low thermal conductivity of the product prevents further heat penetration, and the product is not cooked.
- Texture and colour are therefore preserved.
- The pressure is then instantly released which causes steam to form under the skin, and the surface of the food 'flashes off'
- Most of the peeled material is discharged with the steam, and water sprays are needed only to remove any remaining traces. Flash steam peeler

Advantages

- consumes lower water,
- minimum product loss,
- good appearance of the peeled surfaces,
- a high throughput (up to 4500 kg/h) with automatic control of the peeling cycle,
- production of a more easily disposable concentrated waste.

Abrasion peeling

Food is fed onto carborundum rollers or placed into a rotating bowl which is lined with carborundum.
The abrasive surface removes the skin and it is washed away by a copious supply of water.

Advantages

- low energy costs as the process operates at room temperature,

- low capital costs,
- no heat damage
- good surface appearance of the food.
- Irregular product surfaces (for example ‘eyes’ on potatoes) may be used

Limitations

- a higher product loss than flash peeling (25% compared with 8–18% losses for vegetables)
- large volumes of dilute waste
- relatively low throughputs.

Caustic/ lye peeling

- A dilute solution of sodium hydroxide (named lye) is heated to 100–120ºC.
- In the lye peeling method, food is passed through a bath of 1–2% lye which softens the skin and the skin is then removed by high-pressure water sprays.
- Product losses are of the order of 17%.
- It causes changes in the colour of some products and incurs higher costs.
- A development of lye peeling is named dry caustic peeling.
- Food is dipped in 10% sodium hydroxide and the softened skin is removed with rubber discs or rollers.
- This both methods reduce water consumption and product losses and give a concentrated skin ‘paste’ which is more easily disposed of.

Flame peeling

- Developed for onions, this peeler consists of a conveyor belt which carries and rotates the
- food through a furnace heated to 1000ºC. The outer ‘paper shell’ and root hairs are
- burned off, and the charred skin is removed by high-pressure water sprays. Average
- product losses are 9%.

Size reduction of fruits and vegetables

There are four main types of size reduction equipment, classified in order of decreasing particle size:

1. slicing and flaking equipment
2. dicing equipment
3. shredding equipment
4. pulping equipment

Slicing and flaking equipment

Harder fruits such as apples are simultaneously sliced and de-cored as they are forcedover stationary knives fitted inside a tube. In similar design (the hydro cutter) foods areconveyed by water at high speed over fixed blades. More sophisticated slicers are able to cutvegetables into tagliatelle or garland shapes. Intermittent guillotine cutters are used to cutconfectionery products, such as liquorice. The blade advances with the product on theconveyor to ensure a square cut edge regardless of the conveyor speed or cut length. Thesize of the cut can be adjusted from the control panel, without mechanical adjustment or. Flaking equipment for flaked fish, nuts or meat is like slicingequipment. Adjustment of the blade type and spacing is used to produce the flakes.

Dicing equipment

For dicing, vegetables, fruits and meats are first sliced and then cut into strips by rotatingblades. The strips are fed to a second set of rotating knives which operate at right anglesto the first set and cut the strips into cubes.

Shredding equipment

- Typical equipment is a modified hammer mill in which knives are used instead of hammers to produce a cutting action.

- A second type of shredder, known as the *squirrel cage disintegrator, has two concentric cylindrical cages inside a casing.*
- *They are* fitted with knife blades along their length and the two cages rotate in opposite directions.
- Food is subjected to powerful shearing and cutting forces as it passes between them.

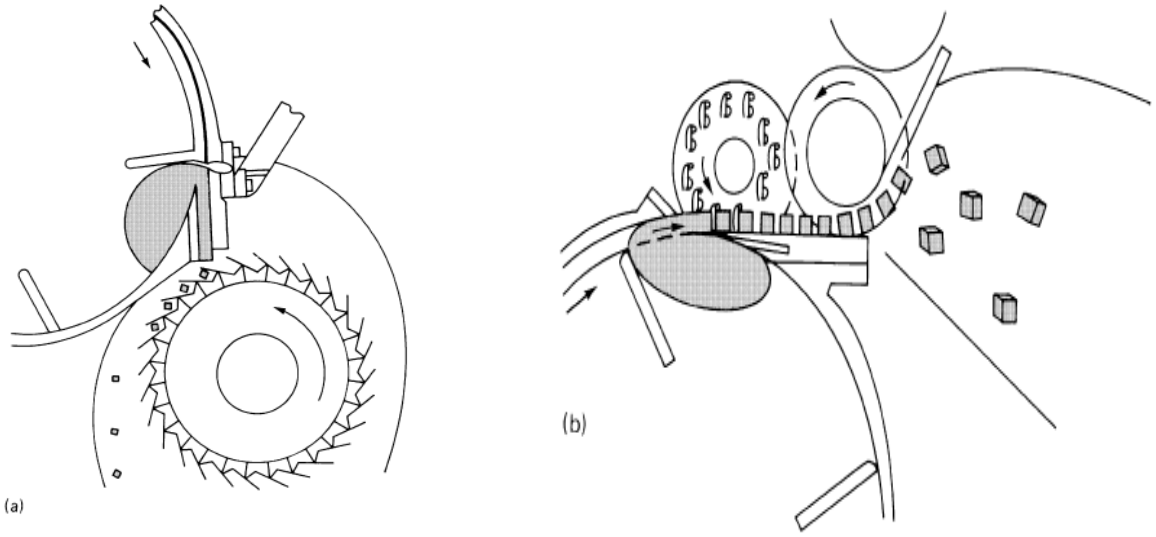


Fig. 14 Slicing and Dicing mechanism of Fruits and vegetables

Pulping equipment

- This uses a combination of compression and shearing forces for juice extraction from fruits or vegetables, for cooking oil production and for producing pure´ed and pulped meats. For example a rotary fruit crusher consists of a cylindrical metal screen fitted internally with high-speed rotating brushes or paddles.
- Grapes, tomatoes or other soft fruits are heated if necessary to soften the tissues, and pulp is forced through the perforations of the screen by the brushes. The size of the perforations determines the fineness of the pulp.
- Skins, stalks and seeds are discarded from the end of the screen. Other types of pulper, including roller presses and screw presses, are used for juice expression or cold extraction of cooking oils

Bowl chopper

Bowl chopper is used to chop harder fruits and vegetables into a pulp (for example for sausage meat or mincemeat preserve).

- A horizontal, slowly rotating bowl moves the ingredients beneath a set of high-speed rotating blades.
- Food may be passed several times beneath the knives until the required degree of size reduction and mixing has been achieved.

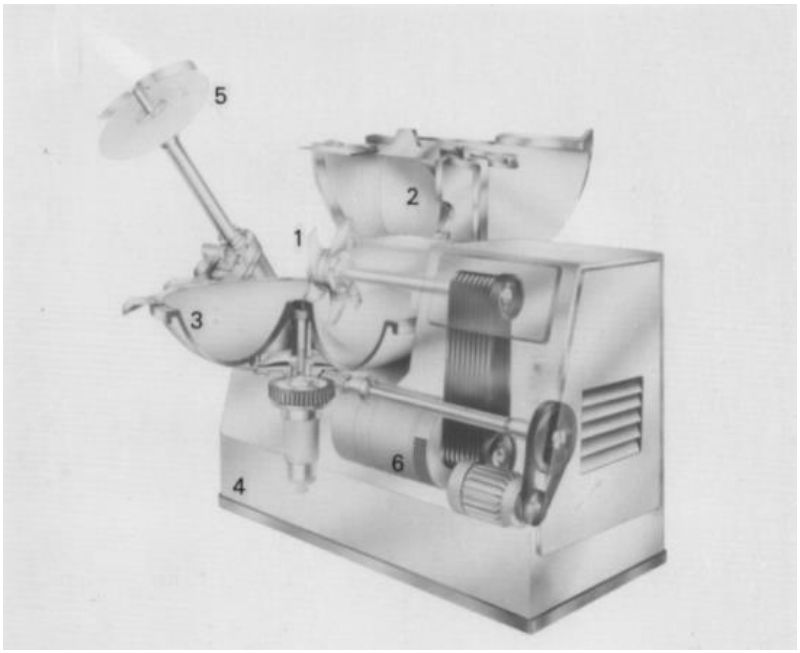


Fig. 15 Bowl chopper

1: cutting blades; 2: cover; 3: rotating cutter bowl; 4: casing; 5: rotating unloader disc; 6: main motor. (Courtesy of Hoegger Alpina Ltd.)

CHAPTER 6

Blanching of Fruits and Vegetables

Blanching serves a variety of functions, one of the main ones being to destroy enzymic activity in vegetables and some fruits, prior to further processing. As such, it is not intended as a sole method of preservation but as a pre-treatment which is normally carried out between the preparation of the raw material and later operations particularly heat sterilisation, dehydration and freezing. Blanching is also combined with peeling and/or cleaning of food, to achieve savings in energy consumption, space and equipment costs.
A few processed vegetables, for example onions and green peppers, do not require blanching to prevent enzyme activity during storage, but the majority suffer considerable loss in quality if blanching is omitted or if they are under-blanched. To achieve adequate enzyme inactivation, food is heated rapidly to a pre-set temperature, held for a pre-set time and then cooled rapidly to near ambient temperatures. The factors which influence blanching time are:

- type of fruit or vegetable
- size of the pieces of food
- blanching temperature
- method of heating.

Theory

The theory of unsteady-state heat transfer by conduction and convection, which is used to calculate blanching time. The maximum processing temperature in freezing and dehydration is insufficient to inactivate enzymes. If the food is not blanched, undesirable changes in sensory characteristics and nutritional properties take place during storage. In canning, the time taken to reach sterilising temperatures, particularly in large cans, may be sufficient to allow enzyme activity to take place. It is therefore necessary to blanch foods prior to these preservation operations. Under-blanching may cause more damage to food than the absence of blanching does, because heat, which is sufficient to disrupt tissues and release enzymes, but not inactivate them, causes accelerated damage by mixing the enzymes and substrates. In addition, only some enzymes may be destroyed which causes increased activity of others and accelerated deterioration.

The heat resistance of enzymes is characterised by D and z values. Enzymes which cause a loss of eating and nutritional qualities in vegetables and fruits include lipoxygenase, polyphenol oxidase, polygalacturonase and chlorophyllase. Two heat-resistant enzymes which are found in most vegetables are catalase and peroxidase. Although they do not cause deterioration during storage, they are used as marker enzymes to determine the success of blanching. Peroxidase is the more heat resistant of the two, so the absence of residual peroxidase activity would indicate that other less heat-resistant enzymes are also destroyed.

The factors that control the rate of heating at the centre of the product are:

- the temperature of the heating medium
- the convective heat transfer coefficient
- the size and shape of the pieces of food
- the thermal conductivity of the food.

Blanching reduces the numbers of contaminating micro-organisms on the surface of foods and hence assists in subsequent preservation operations. This is particularly important in heat sterilisation,, as the time and temperature of processing are designed to achieve a specified reduction in cell numbers. If blanching is inadequate, a larger number of micro-organisms are present initially and this may result in a larger number of spoiled containers after processing. Freezing and drying do not substantially reduce the number of micro-organisms in unblanched foods and these are able to grow on thawing or rehydration.
Blanching also softens vegetable tissues to facilitate filling into containers and removes air from intercellular spaces which increases the density of food and assists in the formation of a head-space vacuum in cans

Unsteady-state heat transfer by conduction and convection

When a solid piece of food is heated or cooled by a fluid, the resistances to heat transfer are the surface heat transfer coefficient and the thermal conductivity of the food. These two factors are related by the *Biot Number Bi:*

---- (1)

Where,

h (W m-2 K-1) heat transfer coefficient, the characteristic 'half dimension' (e.g. radius of a sphere or cylinder, half thickness of a slab) and *k (W m-1K-1) thermal*conductivity.

At small Bi values (Bi < 0.2):
The surface film is the main resistance to heat flow and the time required to heat the solid food is found using equation (2), using the film heat transfer coefficient *hs instead of U*

-----(2)

However, in most applications the thermal conductivity of the food limits the rate of heat transfer (Bi > 0.2). These calculations are complex, and a series of charts is available to solve the unsteady-state equations for simple shaped foods,

The charts relate the Biot number (Bi) the *temperature factor (the fraction of the temperature change that remains to be* accomplished (equation (3) and the *Fourier number Fo(a dimensionless number* which relates the thermal diffusivity, the size of the piece and the time of heating or cooling (equation 4).

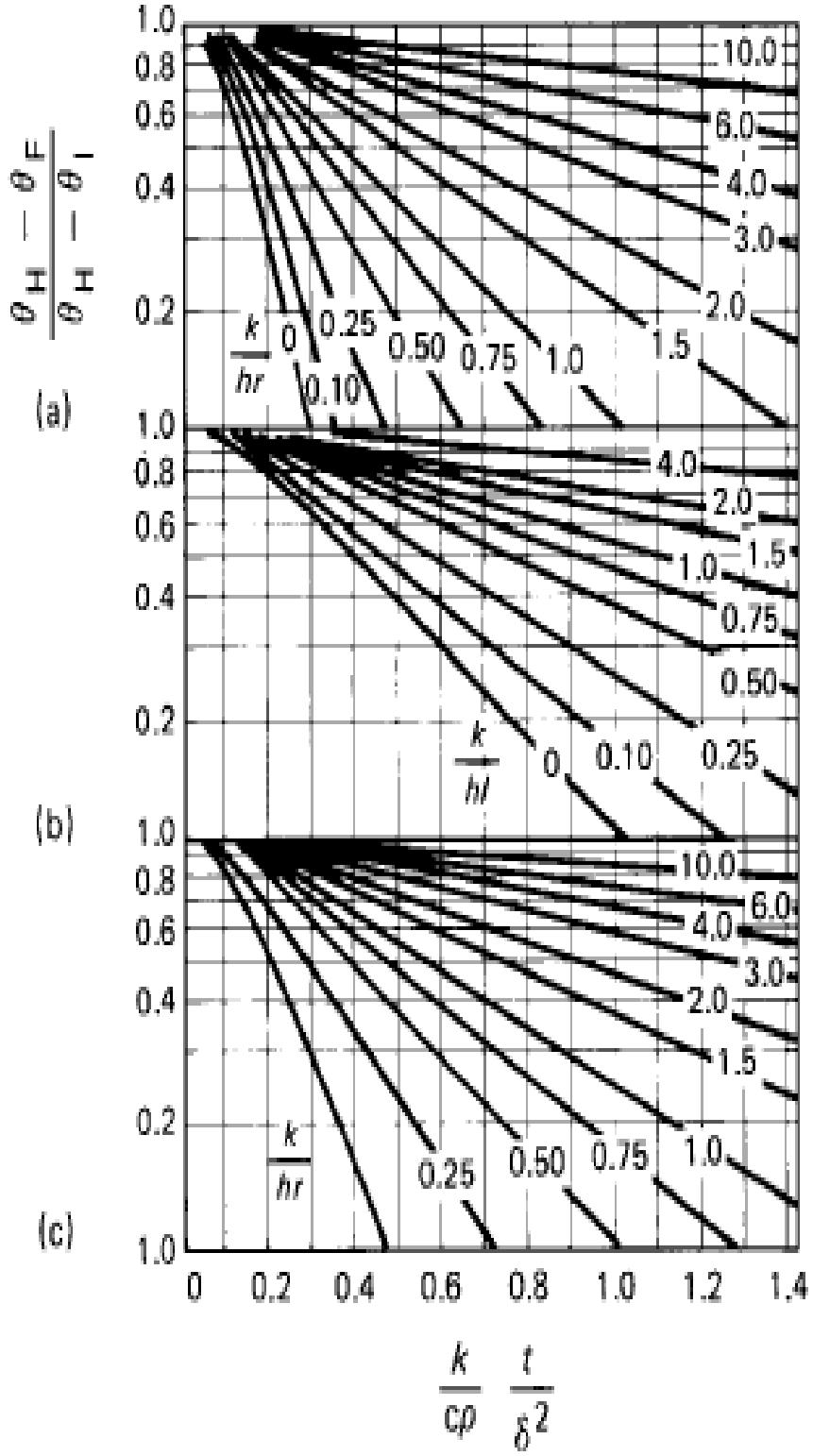


Fig. 16 Chart for unsteady-state heat transfer: (a) sphere; (b) slab; (c) cylinder
(Henderson and Perry (1955)

Equipment

- The two most widespread commercial methods of blanching involve passing food through an atmosphere of saturated steam or a bath of hot water. Both types of equipment are relatively simple and inexpensive. Microwave blanching is not yet used commercially on a large scale.

Steam blanchers

- In general this is the preferred method for foods with a large area of cut surfaces as leaching losses are much smaller than those found using hot-water blanchers.
- At its simplest a steam blancher consists of a mesh conveyor belt that carries food through a steam atmosphere in a tunnel. The residence time of the food is controlled by the speed of the conveyor and the length of the tunnel. Typically, a tunnel is 15m long and 1-1.5mwide.

In conventional steam blanching, there is often poor uniformity of heating in the multiple layers of food. The time-temperature combination required to ensure enzyme inactivation at the centre of the bed results in over heating of food at the edges and a consequent loss of texture and other sensory characteristics.

Hot-water blanchers

- There are a number ofdifferent designs of blancher, each of which holds the food in hot water at 70-100^0 C for a specified time and then removes it to a dewatering-cooling section.
- In the widely used *reel blancher,* food enters as slowly rotating cylindrical mesh drum which is partly submerged in hot water.
- The food is moved through the drum by internal flights. The speed of rotation and length control the heating time.

Table 8 Advantages and limitations of conventional steam and hot-water blanchers

Equipment	Advantages	Limitations
Conventional steam blanchers	Smaller loss of water-soluble components, Smaller volumes of waste and lower disposal charges than water blanchers, particularly with air cooling instead of water, Easy to clean and sterilise	Limited cleaning of the food so washers also required. Uneven blanching if the food is piled to high on the conveyor. Some loss of mass in the food.
Conventional hot-water blancher	Lower capital cost and better energy efficiency than steam blanchers	Higher costs in purchase of water and charges for treatment of large volumes of dilute effluent (Chapter 26).Risk of contamination by thermophilic bacteria.

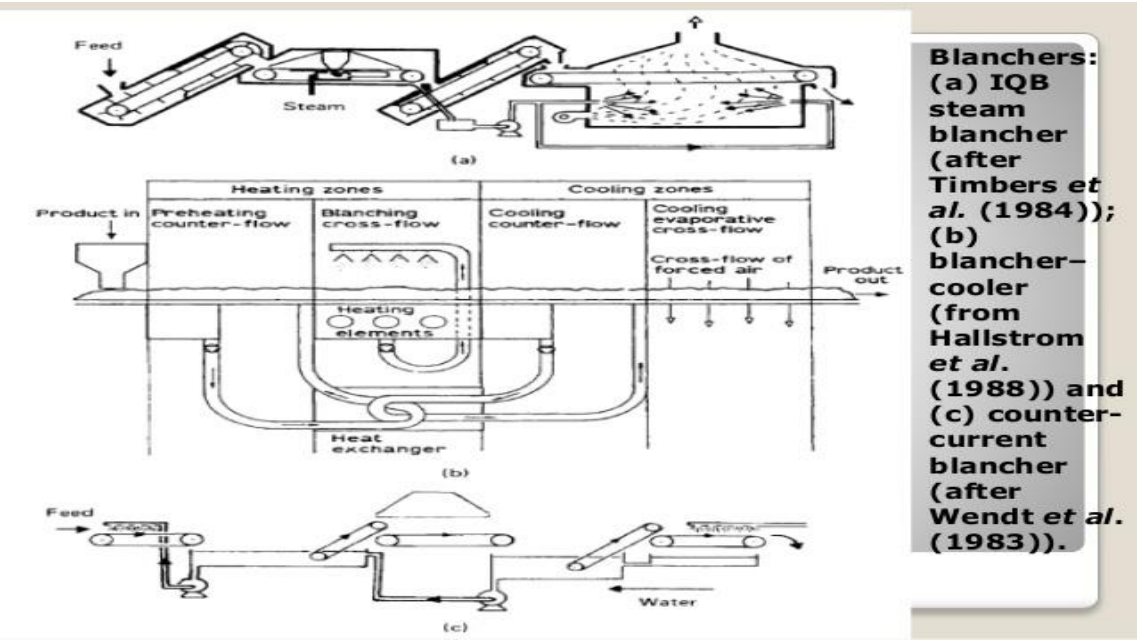


Fig. 17 Different set-ups of Blanching machine

Blanching Effect on foods

- The heat received by a food during blanching inevitably causes some changes to sensory and nutritional qualities.
- However, the heat treatment is less severe than for example in heat sterilization, and the resulting changes in food quality are less pronounced.
- In general, the time-temperature combination used for blanching is a compromise which ensures adequate enzyme inactivation but prevents excessive softening and loss of flavour in the food.

Nutrients

- Some minerals, water-soluble vitamins and other water-soluble components are lost during blanching. Losses of vitamins are mostly due to leaching, thermal destruction and, to a lesser extent, oxidation.
- The extent of vitamin loss depends on a number of factors including:
- The maturity of the food and variety
- Methods used in preparation of the food, particularly the extent of cutting, slicing or dicing
- The surface-area-to-volume ratio of the pieces of food.
- Method of blanching
- Time and temperature of blanching (lower vitamin losses at higher temperatures for shorter times)
- The method of cooling
- The ratio of water to food (in both water blanching and cooling).

Colour and flavour

- Blanching brightens the colour of some foods by removing air and dust on the surface and thus altering the wavelength of reflected light.
- The time and temperature of blanching also influence the change in food pigments according to their D value.
- Sodium carbonate (0.125% w/w) or calcium oxide are often added to blancher water to protect chlorophyll and to retain the colour of green vegetables.
- Enzymatic browning of cut apples and potatoes is prevented by holding the food in dilute (2% w/w) brine prior to blanching.

Table 9 Effect of blanching methods on ascorbic acid losses in selected vegetables

Treatment	Loss (%) of ascorbic acid		
	Peas	Broccoli	Green beans
Water blanch-water cool	29.1	38.7	15.1
Water blanch-air cool	25.0	30.6	19.5
Steam blanch-water cool	24.2	22.2	17.7
Steam blanch-air cool	14.0	9.0	18.6

Losses of ascorbic acid are used as an index of food quality, and therefore the severity indicator of blanching When correctly blanched, most foods have no significant changes to flavour or aroma, but under-blanching can lead to the development of off-flavors during storage of dried of frozen foods. Calcium chloride (1-2%) is therefore added to blancher water to form insoluble calcium pectate complexes and thus to maintain firmness in the tissue.

CHAPTER 7

Canning of Fruits and vegetables

Canning is defined as preservation of foods in hermetically sealed containers and usually implies heat treatment as the principal factor in prevention of spoilage.Canning was invented by Nicholas Appert in 1910 so also termed as Appertization.

Foods that are canned

- **Low Acid foods:** Meat, fish, poultry, dairy fall into a pH range of 5.0 to 6.8. This large group is commonly referred to as the low acid group.
- **Acid foods:** With pH values between 4.5 and 3.7. Fruits such as pear, oranges, apricots and tomatoes fall in this class.
- **High acid foods:** Such as pickled products and fermented foods. The pH values range from 3.7 down to 2.3, also jams and Jellies are in this classification.

Canning Processing

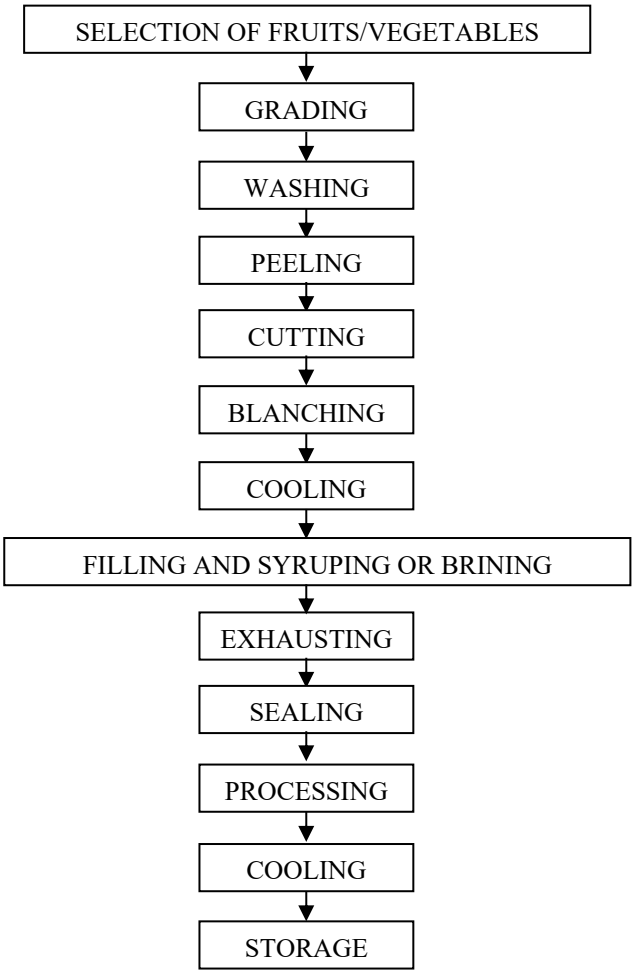


Fig. 18 Flowchart of Canning Process

Canned mango slices

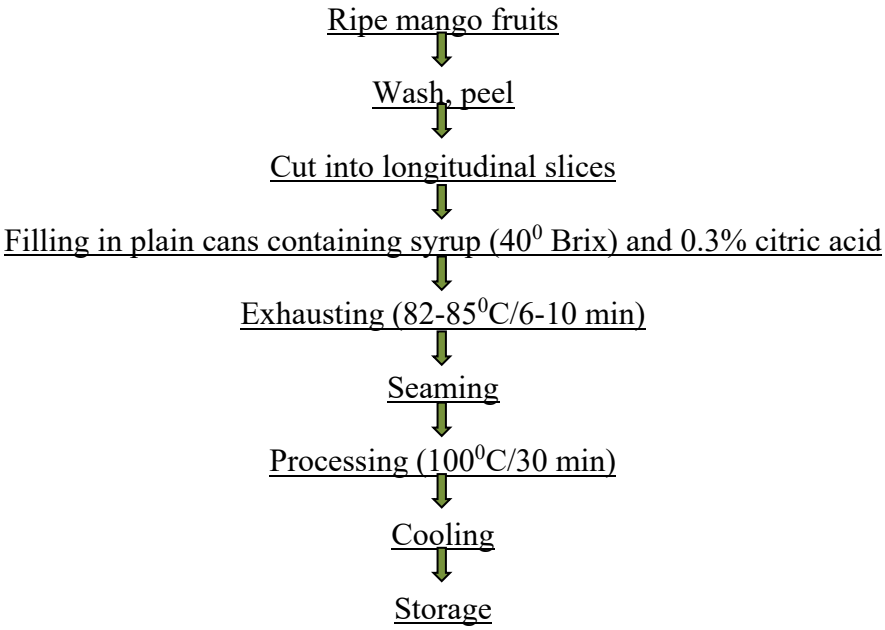


Fig. 19 Flowsheet of Canning Process of mango slices

Selection of fruits and vegetables

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

Grading

- The selected fruits and vegetables are graded according to size and colour to obtain uniform quality.
- This is done by hand or by macines such as screw grader and roller grader.
- Fruits like berries, plums and cherries are graded whole.
- While peaches, pears, apricots, mangoes, pineapples, etc., are generally graded after cutting into pieces or slices.
- **Washing**
- It is important to remove pesticide spray residue and dust from fruits and vegetables.
- One gram of soil contains 1012 spores of microorganisms. Therefore, removal of microorganisms by washing with water is essential.
- Fruits and vegetables can be washed in different ways. Root crops that loosen in soil are washed by soaking in water containing 25 to 50 ppm chlorine (as detergent).
- Other methods of washing are spray washing, steam washing, etc.

Peeling

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

- Hand Peeling
- Steam Peeling
- Mechanical Peeling
- Lye Peeling

2. Cutting

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

Blanching

- Blanching is usually done in case of vegetables by exposing them to boiling water or steam for 2 to 5 minutes, followed by cooling.
- Inactives most of the plant enzymes which cause toughness, discoloration (polyphenol oxidase), mustiness, off-flavour (peroxidase), softening and loss of nutritive value.
- Reduce the number of microorganisms by as much as 99%.

Cooling

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

Filling

- Before filling, cans are washed with hot water and sterilized
- Automatic, large can-filling machines are used in advanced countries but choice grades of fruits are normally filled by hand to prevent bruising in India. Hand filling is the common practice.
- After filling, covering with syrup or brine is done and this process is called syruping or brining. Headspace left inside ranges from 0.32 cm to 0.47 cm.

Exhausting

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

- Corrosion of the tinplate and pin holing during storage is avoided.
- Minimizes discoloration by preventing oxidation.
- Helps in better retention of vitamins particularly vitamin C.
- Prevents building of cans when stored in hot climate or at high altitude.
- Reduces chemical reaction between the container and the contents
- Prevents development of excessive pressure and strain during sterilization

Exhausting methods:

- Thermal exhausting (Steam Vacuum)
- Mechanical Exhausting (Machine Vacuum)

Sealing

- Immediately after exhausting the cans are sealed airtight by means of a can sealer.
- In case of glass jars a rubber ring should be placed between the mouth of the jar and the lid, so that it can be sealed airtight.

- During sealing the temperature should not fall below 74^0C.

Processing

Heating of foods for preserving is known as processing. The cans must be processed (heat treated) immediately after closing (hermetic sealed) at suitable time and temperature

Food to be canned is threatened on the one hand by bacterial spoilage (if under processed) and on the other by danger of lower the nutritive quality by overheating.

- Vegetative bacteria are killed at 80^0C/30 min.
- Spore formers at a temp.110^0/30 min.
- For destroying the spores 121^0C/3 min.

Cooling

- Immediately after processing, the cans are cooled in water to a temperature of 36ºC to 42ºC to avoid thermophilic spoilage or can rust.
- If the cans are cooled much below 36ºC, they may not dry thoroughly and rusting well result.
- If the cans are cased at temperatures much over 42ºC, thermophilic spoilage may occur.

Storage

After labeling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place,

- The outer surface of the cans should be dry as even small traces of moisture sometimes induce rusting.
- Storage of cans at high temperature should be avoided, as it shortens the shelf-like of the product and often leads to the formation of hydrogen swell.



Fig. 20 Steps of Canning process

Spoilage of canned products

- Soft Swell: A can that is bulged on both ends, but not so tightly that the ends can't be pushed in somewhat with a thumb press.
- Hard Swell: A can that is so tightly bulged on both ends that the ends can't be pressed in.
- Flipper: A can whose end normally looks flat, but "flips out" when struck sharply on one end.
- Springer: A can with on e end bulged out. With sufficient pressure, this end will flip in, but the other end will flip out.
- Leaker: A can with a crack or hole in the container that has caused leakage.

Containers for packaging of canned products

Both tin and glass containers are used in the canning industry, but tin containers are preferred.

Tin containers

- Tin cans are made of thin steel plate of low carbon content, lightly coated on both sides with tin metal.
- It is difficult to coat the steel plate uniformly and during the process of manufacture small microscopic spots are always left uncoated, although the coating may appear perfect to the eye.
- The contents of the can may react with these uncoated spots resulting in discolouration of the product or corrosion of the tin plate.
- It is necessary, therefore, to coat the inside of the can with some material (lacquer) which prevents discolouration but does not affect the flavor or wholesomeness of the contents. This process is known as "lacquering".

Types of cans:

1. 3 piece cans and 2 piece cans, depending on the structure.
2. Aluminum cans and steel cans, depending the material.

1. 3-piece cans consisting of three components of
   - A bottom lid,
   - A cylindrical body
   - A top lid a lid with a lip [an opening] and

   2-piece cans consisting of two components of
   - A body integrated with a bottom lid and
   - A lid with a lip (an opening).

2. Aluminum cans and steel cans:
   - Depending upon material.

To prevent the discoloration lacquering is done.

Two types of lacquers:

Acid resistant

- Can coated with this, called R-enamel or A.R cans.
- Meant for high acid food commodity (raspberry, strawberry, apricot etc.)

Sulphur resistant

- Can coated with it know as C-enamel of S.R cans.
- Meant for low acid foods (peas, corn, beans)

CHAPTER 8

Chilling of fruits and vegetables

Chilling is the unit operation in which the temperature of a food is reduced to between -1ºC and 8ºC. It is used to reduce the rate of biochemical and microbiological changes, and hence to extend the shelf life of fresh and processed foods. It causes minimal changes to sensory characteristics and nutritional properties of foods and, as a result, Chilled foods are perceived as being convenient, easy to prepare, high quality and fresh like.

Chilled foods are grouped into three categories according to their storage temperature range as follows:

- 1. -1ºC to +1ºC (fresh fish, meats, sausages and ground meats, smoked meats and breaded fish).
- 2. 0ºC to +5ºC (pasteurized canned meat, milk, cream, yoghurt, prepared salads, sandwiches, baked goods, fresh pasta, fresh soups and sauces, pizzas, pastries andunbaked dough).
- 3. 0ºC to +8ºC (fully cooked meats and fish pies, cooked or uncooked cured meats, butter, margarine, hard cheese, cooked rice, fruit juices and soft fruits).

Theory

The rate of biochemical changes caused by either micro-organisms or naturally occurring enzymes increases logarithmically with temperature. Chilling therefore reduces the rate of enzymic and microbiological change and retards respiration of fresh foods.

- The time needed to destroy 90% of the micro-organisms (to reduce their numbers by a
- Factor of 10) is referred to as the *decimal reduction time or D value (5 min in Fig. 1.13).*
- *D* values differ for different microbial species, and a higher *D value indicates*

greater heat resistance

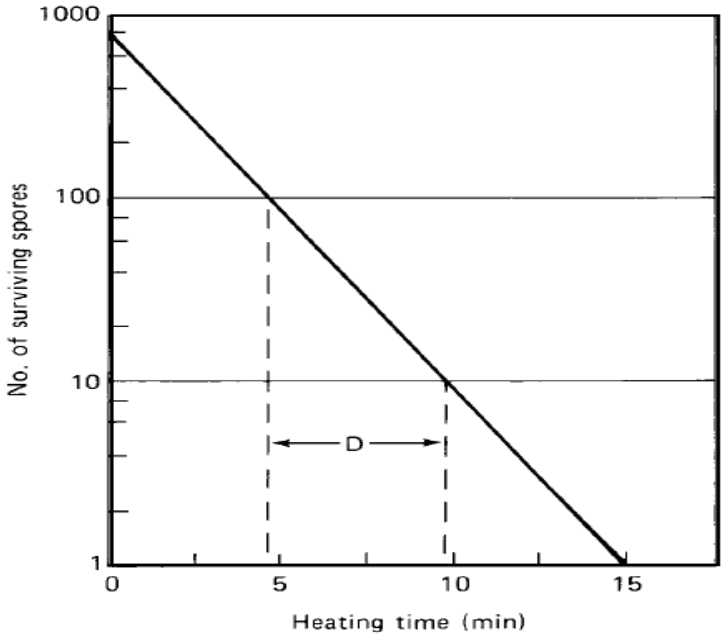
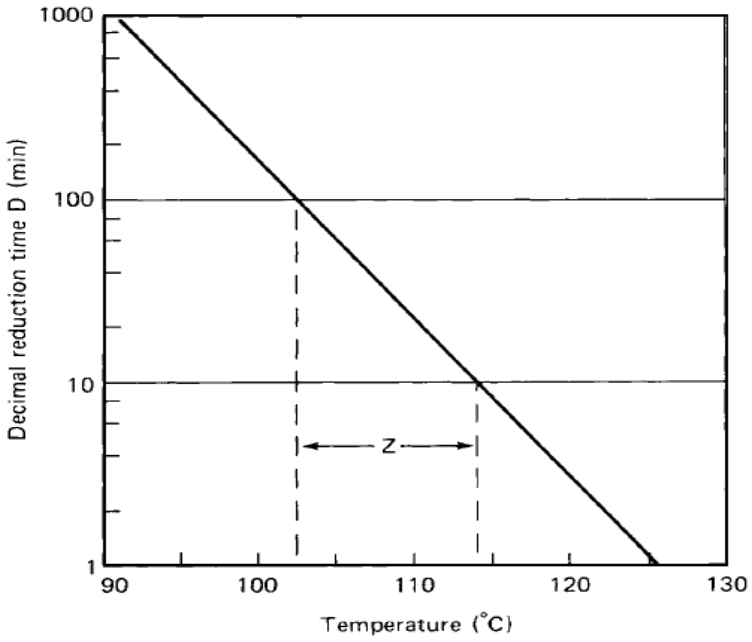


Fig. 21 Death Rate Curve

- The slope of the TDT curve is termed the *z* value and is defined as the number of degrees Celsius required to bring about a ten-fold change in decimal reduction time (10.5ºC in Fig. 1.14).
- The *D value and z value are used* to characterize the heat resistance of a micro-organism and its temperature dependence respectively.



TDT curve. Microbial destruction is faster at higher temperatures (for example 100 min at 102.5°C has the same lethal effect as 10 min at 113°C).

Fig. 22 Decimal reduction Time Vs. Temperature curve

The factors that control the shelf life of fresh crops in chill storage include the following things.

- Type of food and variety or cultivar
- Part of the crop selected (the fastest growing parts have the highest metabolic rates and the shortest storage lives)
- Condition of the food at harvest (for example the presence of mechanical damage or microbial contamination, and the degree of maturity)
- Temperature of harvest, storage, distribution and retail display.
- Relative humidity of the storage atmosphere, which influences dehydration losses

Chilling Equipments

1. Mechanical refrigerator
2. Cryogenic systems

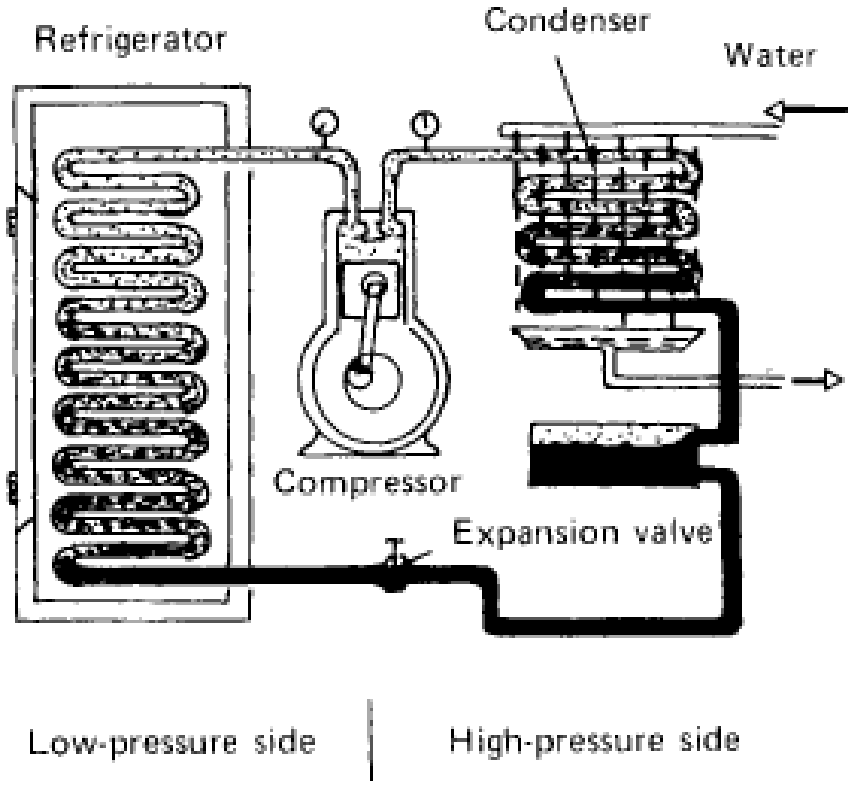


Fig. 23 Mechanical compression-expansion refrigeration system

CHAPTER 9

Freezing of Foods

Freezing is the unit operation in which the temperature of a food is reduced below its freezing point and a proportion of the water undergoes a change in state to form ice crystals.

- The immobilization of water to ice and the resulting concentration of dissolved solutes in unfrozen water lower the water activity (*aw) of the food*
- Preservation is achieved by a combination of low temperatures, reduced water activity and, in some foods, pre-treatment by blanching.
- There are only small changes to nutritional or sensory qualities of foods when correct freezing and storage procedures are followed

The major groups of commercially frozen foods are as follows:

• fruits (strawberries, oranges, raspberries, blackcurrants)
• vegetables (peas, green beans, sweetcorn, spinach, sprouts and potatoes)
• fish fillets and seafoods (cod, plaice, shrimps and crab meat) including fish fingers, fish cakes or prepared dishes with an accompanying sauce
• meats (beef, lamb, poultry) as carcasses and meat products (sausages, beefburgers, reformed steaks)
• baked goods (bread, cakes, fruit and meat pies)
• prepared foods (pizzas, desserts, ice cream, complete meals and cook–freeze dishes).

Theory

1. During freezing, sensible heat is first removed to lower the temperature of a food to the freezing point.
2. In fresh foods, heat produced by respiration is also removed.This is termed the *heat load, and is important in determining the correct size of freezing* equipment for a particular production rate.
3. Most foods contain a large proportion of water which has a high specific heat (4200 J/ kg K) and a high latent heat of crystallisation (335 kJ/ kg). A substantial amount of energy is therefore needed to remove latent heat, form ice crystals and hence to freeze foods.
4. The latent heat of other components of the food (for example fats) must also be removed before they can solidify, but in most foods these other components are present in smaller amounts and removal of a relatively small amount of heat is needed for crystallisation to take place.
5. Energy for freezing is supplied as electrical energy, which is used to compress gases (refrigerants) in mechanical freezing equipment or to compress and cool cryogens

If the temperature is monitored at the thermal centre of a food (the point that cools most slowly) as heat is removed, a characteristic curve is obtained.

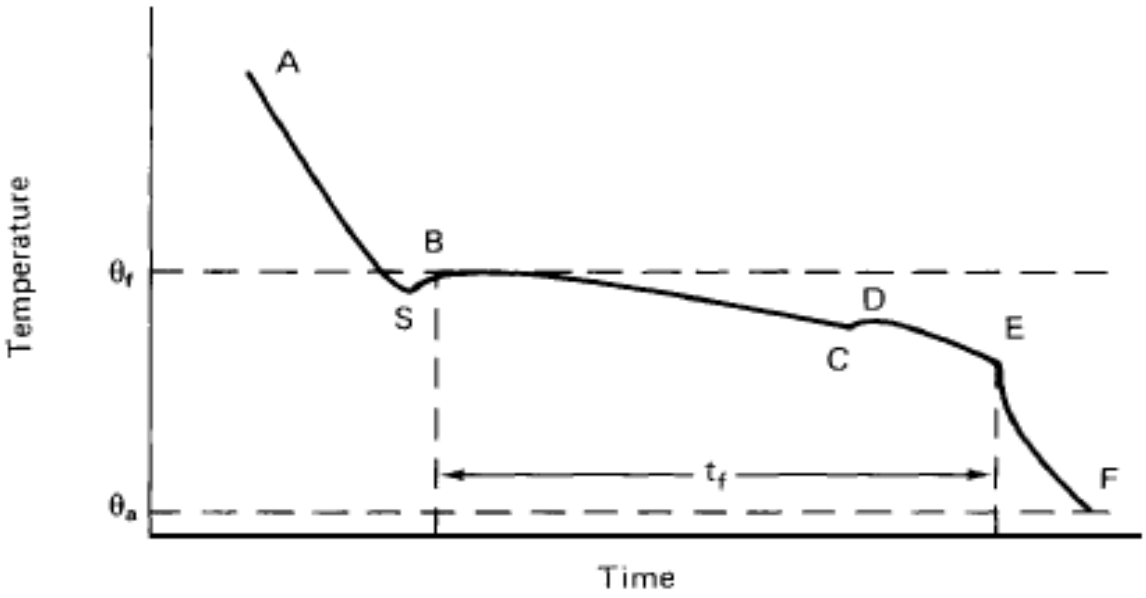


Fig. 24 Time-Temperature profile data during freezing of food

The six components of the curve are as follows

i. AS- The food is cooled to below its freezing point , with the exception of pure water, is always below 0ºC. At point S the water remains liquid, although the temperature is below the freezing point. This phenomenon is known as *super cooling and may be as much as 10ºC below the freezing point.*

ii. SB- The temperature rises rapidly to the freezing point as ice crystals begin to form and latent heat of crystallization is released.

iii. BC- Heat is removed from the food at the same rate as before, but it is latent heat being removed as ice forms and the temperature therefore remains almost constant. The freezing point is gradually depressed by the increase in solute concentration in the unfrozen liquor, and the temperature therefore falls slightly. It is during this stage that the major part of the ice is formed.

iv. CD- One of the solutes becomes supersaturated and crystallizes out. The latent heat of crystallization is released and the temperature rises to the eutectic temperature for that solute.

v. DE- Crystallisation of water and solutes continues. The total time *tf taken (the freezing plateau) is determined by the rate at which heat is removed.*

vi. *vi.* EF- The temperature of the ice–water mixture falls to the temperature of the freezer. A proportion of the water remains unfrozen at the temperatures used in commercial freezing; the amount depends on the type and composition of the food and the temperature of storage. For example at a storage temperature of -20ºC the percentage of water frozen is 88% in lamb, 91% in fish and 93% in egg albumin.

Ice Crystal formation

- The freezing point of a food may be described as 'the temperature at which a minute crystal of ice exists in equilibrium with the surrounding water'.

- However, before an ice crystal can form, a nucleus of water molecules must be present. *Nucleation therefore* precedes ice crystal formation.
- There are two types of nucleation:
  - ✓ Homogeneous nucleation (the chain orientation and combination of water molecules), and
  - ✓ heterogeneous nucleation (the formation of a nucleus around suspended particles or at a cell wall).

Heterogeneous nucleation is more likely to occur in foods and takes place during super cooling. The length of the super cooling period depends on the type of food and the rate at which heat is removed.

Table: Water Content and Freezing Point Temperature of selected Foods

Food	Water content (%)	Freezing point (°C)
Vegetables	78–92	−0.8 to −2.8
Fruits	87–95	−0.9 to −2.7
Meat	55–70	−1.7 to −2.2
Fish	65–81	−0.6 to −2.0
Milk	87	−0.5
Egg	74	−0.5

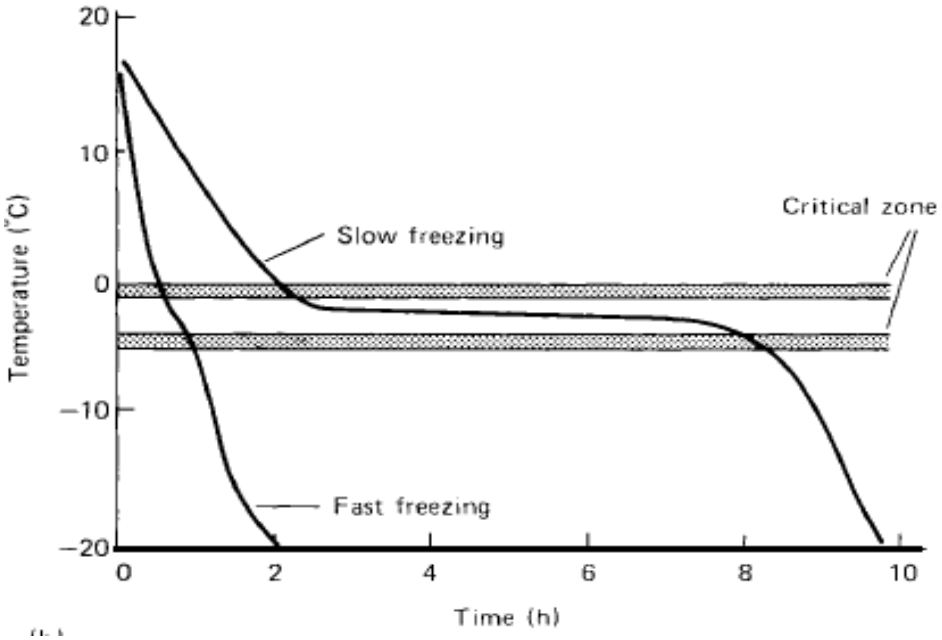


Fig.25 Slow freezing Vs. Quick freezing

Calculation of freezing time

During freezing, heat is conducted from the interior of a food to the surface and is removed by the freezing medium. The factors which influence the rate of heat transfer are:

- the thermal conductivity of the food
- the area of food available for heat transfer
- the distance that the heat must travel through the food (size of the pieces)
- the temperature difference between the food and the freezing medium
- the insulating effect of the boundary film of air surrounding the food
- packaging, if present, is an additional barrier to heat flow.

The freezing time for cubes of food is calculated using:

$$t_f = \frac{\lambda \rho}{\theta_f - \theta_a}\left[\frac{L}{6}\left(\frac{1}{h}+\frac{x}{k_1}\right)+\frac{L^2}{24k_2}\right] \qquad 21.1$$

where t_f (s) = freezing time, L (m) = length of the cube, h (W m^{-2}K^{-1}) = surface heat transfer coefficient, θ_f (°C) = freezing point of the food, θ_a (°C) = temperature of the freezing medium, λ (J kg^{-1}) = latent heat of crystallisation, ρ (kg m^{-3}) = density of the food, x (m) = thickness of the packaging, k_1 (W m^{-1}K^{-1}) = thermal conductivity of the packaging, k_2 (W m^{-1}K^{-1}) = thermal conductivity of the frozen zone, 6 and 24 are factors which represent the shortest distance between the centre and the surface of the food. Other shapes require different factors; these are 2 and 8 for a slab, 4 and 16 for a cylinder and 6 and 24 for a sphere. Derivation of the equation is described by Earle (1983).

Equation (21.1) may be rearranged to find the heat transfer coefficient as follows:

$$h = \frac{L}{6}\left[\frac{t_f(\theta_f - \theta_a)}{\lambda \rho} - \frac{Lx}{6k_1} - \frac{L^2}{24k_2}\right] \qquad 21.2$$

CHAPTER 10

Drying and Dehydration

- Application of heat under controlled conditions to remove majority of water normally present in a food by evaporation or by sublimation.
- excludes mechanical separations & membrane concentration, evaporation and baking, these normally remove much less water than dehydration.

Main purpose of Drying

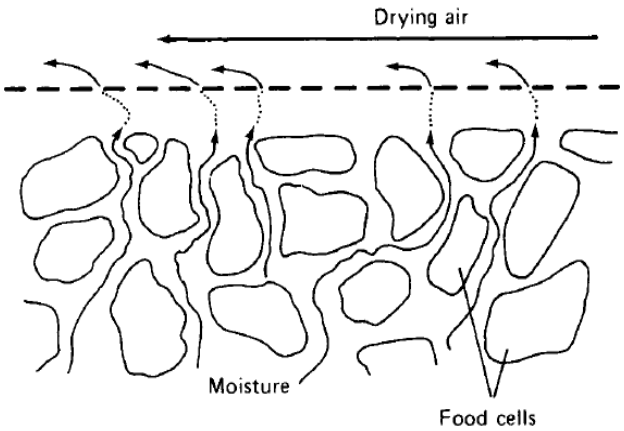
- To extend the shelf life (reduction of water activity, aw), inhibits microbial growth & enzyme activity
- reduction in weight & bulk of food
- provides convenient product, easily handled ingredients.
- deterioration of eating quality & nutritional value.
- selection of appropriate drying conditions for individual foods.

Theory

- • Dehydration involves simultaneous application of heat & removal of moisture from foods (except for osmotic dehydration).
- **Factors control rate at which foods dry:**
- – those related to processing conditions
- – those related to nature of food
- – those related to drier design.
- (e.g. Hot air drying: **air temperature; humidity; air velocity**)

Mechanism of drying

When hot air is blown over a wet food, water vapour diffuses through a boundary film of air surrounding the food & is carried away by the moving air. A water vapour pressuregradient is established fromthe moist interior of food tothe dry air. It provides the 'driving force'for water removal from food.



Movement of moisture during drying.

Fig. 26 Mechanism of drying

Boundary film is a barrier to heat transfer & water vapour removal during drying.
• Thickness of the film by air velocity if the velocity is low, the boundary film is thicker reduces heat transfer coefficient & rate of water vapour removal.

- The faster the air, the thinner the boundary film& the faster the rate of drying.

• Water vapour leaves the surface of food & increases humidity of the surrounding air reduction in the water vapour pressure gradient & rate of drying.

Rate of Drying:

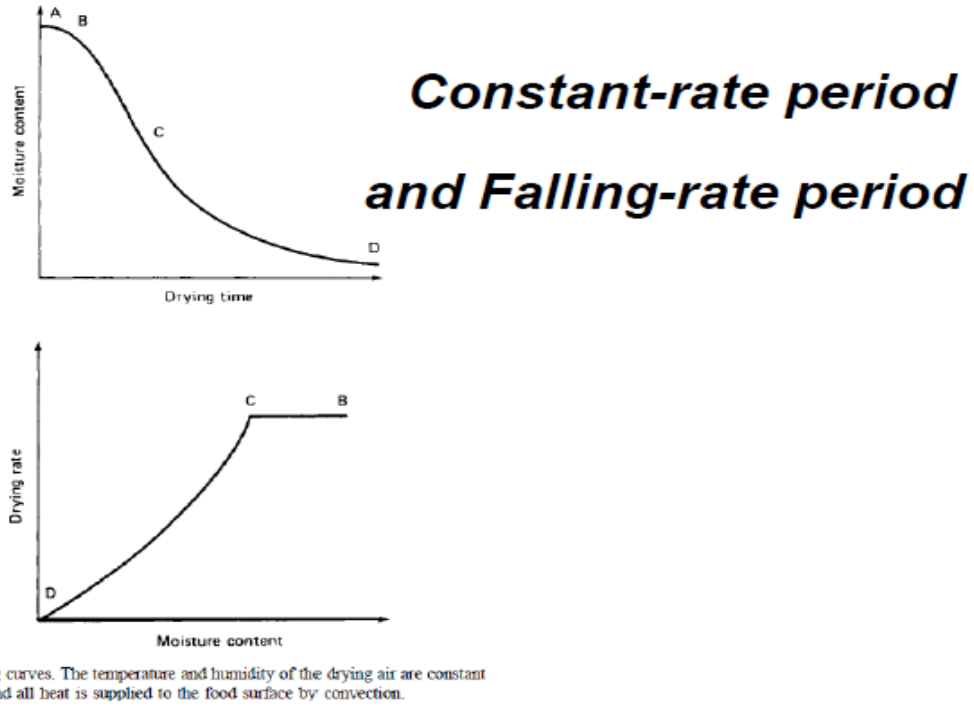


Fig. 27 Rate of drying

Drying Techniques

- Sun or solar drying
- Drum drying
- Spray drying
- Foam mat drying
- Convection air & Superheated steam (tray, tunnel)
- Osmotic drying
- Microwave
- Freeze drying

Sun and Solar drying

It is the most widely practiced drying method. Foods are simply laid out in fields or on roofs or other flat surfaces and turned regularly until dry. Most sophisticated methods (solar drying) collect solar energy and heat air, which in turn is used for drying.

Solar Tunnel Dryer

Example – Technical Data :

Size	: 18 x 2 m
Collector area	: 16 m2
Drying area	: 20 m2
Air flow rate	: 400 – 1200 m^3/hour
Drying air temperature	: 30 – 80°C

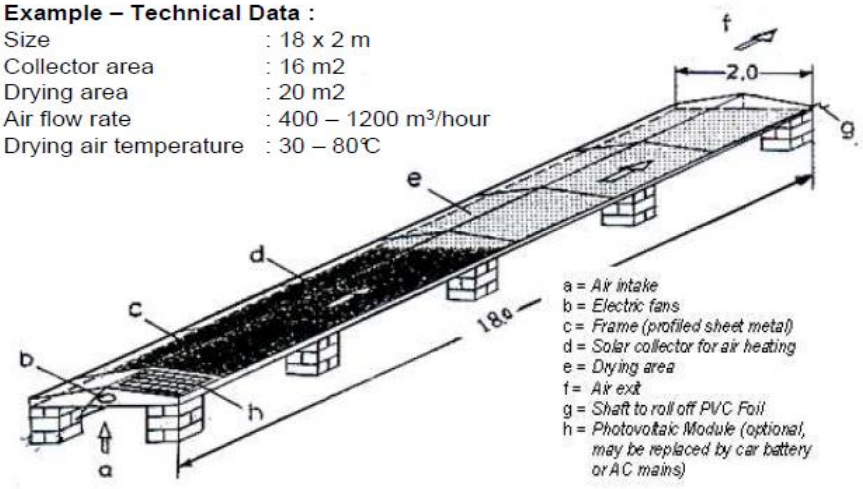


Fig. 28 Solar Tunnel drying

Sun and solar drying

- the most widely practised
- foods are simply laid out in fields or on roofs or other flat surfaces and turned regularly until dry.
- More sophisticated methods (solar drying) collect solar energy and heat air, which in turn is used for drying.
- Solar driers:
  - direct natural-circulation driers (a combined collector and drying chamber)
  - direct driers with a separate collector
  - indirect forced-convection driers (separate collector and drying chamber).

Cabinet driers (tray driers)

- insulated cabinet fitted with shallow mesh or perforated trays, each of which contains a thin (2–6 cm deep) layer of food.
- Hot air is blown through a system of ducts & baffles to promote uniform air distribution
- low capital & maintenance costs; flexible in operation for different foods.
- relatively poor control & produce more variable product quality as food dries more rapidly on trays nearest to the heat source.

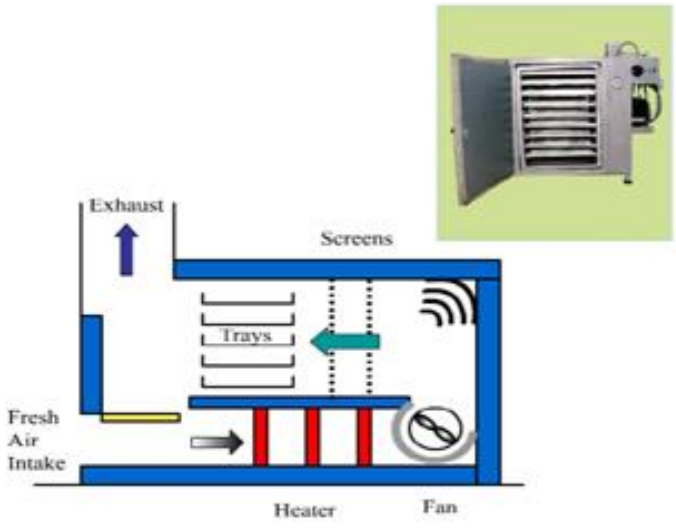


Fig. 29 Cabinet Tray drying

Drying using heated surfaces

- Slurries of food are deposited on heated steel drum.
- Heat is conducted from hot surface through food
- Moisture is evaporated from the exposed surface.
- Resistance to heat transfer:

  → thermal conductivity of food.

  → partly dried food lifts off the hot surface forming a barrier layer of air between the food & drum.

Tunnel driers

- Layers of food are dried on trays; stacked on trucks move semi continuously through an insulated tunnel, having one or more types of air flow
- Food is finished in bin driers.
- Dry large quantities of food in a relatively short time
- Superseded by conveyor drying & fluidised bed drying

  Higher energy efficiency, reduced labour costs & better product quality.

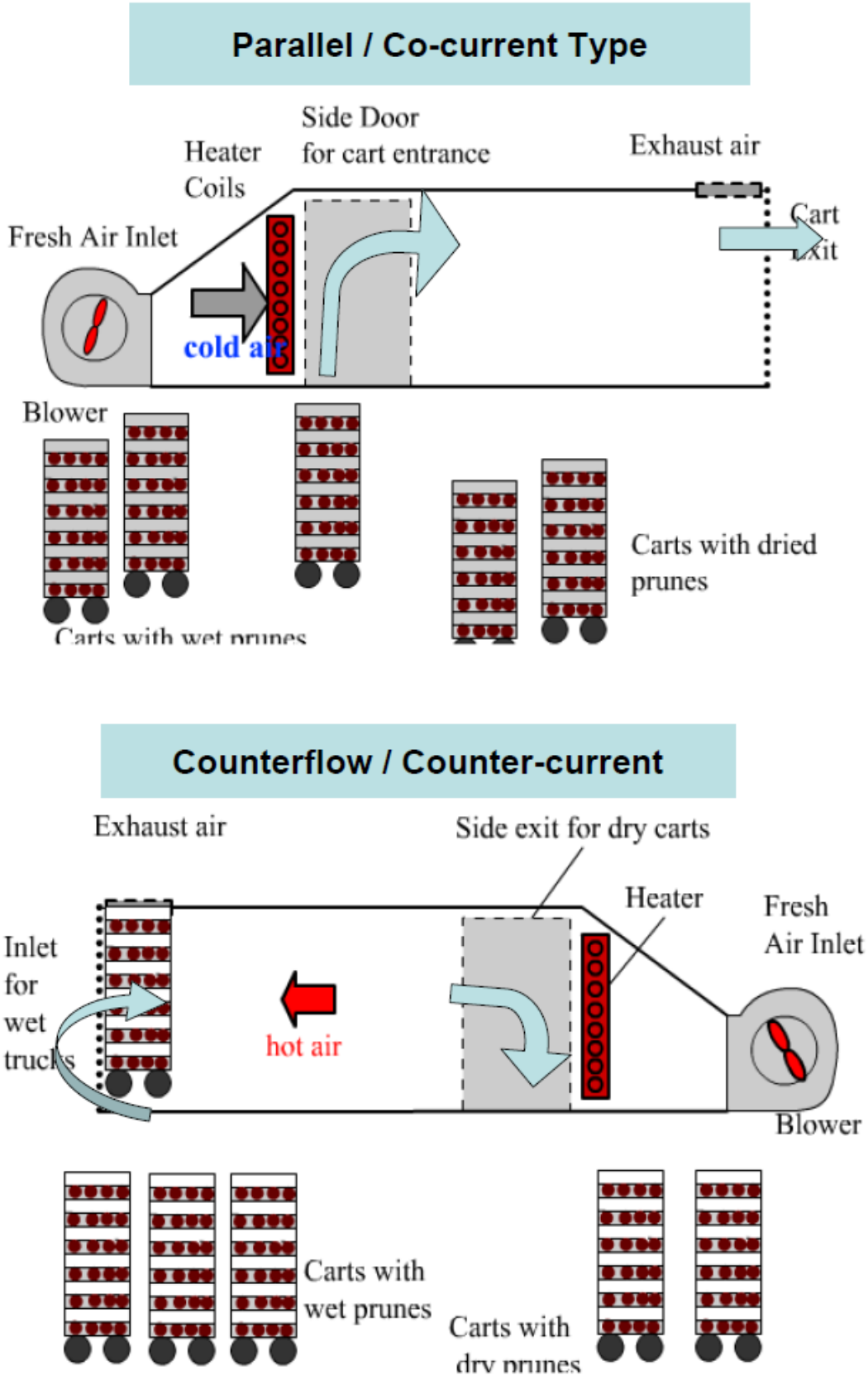


Fig. 30 Tunnel Dryers (Parallel and Counter flow types)

Osmotic Dehydration

Osmotic dehydration, also called as dewatering and impregnation soaking (DIS) process, was pioneered by James D. Ponting in 1966. It is a water removal process that involves the soaking of foods, mostly fruits and vegetables in hypertonic salt or sugar or in a combined solution, to reduce the water content while increasing the soluble solid content.

- Osmotic dehydration is undertaken to reduce the product water activity in minimal processing, which is carried out either at atmospheric pressure or at vacuum conditions.
- The raw material is placed in concentrated solutions of soluble solids with higher osmotic pressure and lower water activity.
- Water moves through the selective permeable membrane with much greater ease than in the dissolved substances.
- The last two mass transfers occur mainly because of diffusion. This counter current mass flow is due to the water and solute gradients across the cell membrane.
- This process continues till the osmotic potential on two processes reaches equilibrium.
- In an ideal osmotic solution, a semi-permeable membrane would be permeated by the solvent molecules but not by the solute molecules.
- In fruits and vegetables, the cell wall membranes are living biological units and selective permeable, which can stretch and expand under the influence of growth and turgor pressure generated inside the cells.
- These cellular membranes, which are composed mainly of parenchymatous cells, freely allow the solvent molecules to pass through, but they also allow, to a lesser degree, the passage of some of the solute molecules.
- Such membranes are called as differentially permeable, rather than semi-permeable.
- Osmotic dehydration may result in 40-50% decrease in initial volume, if properly performed.

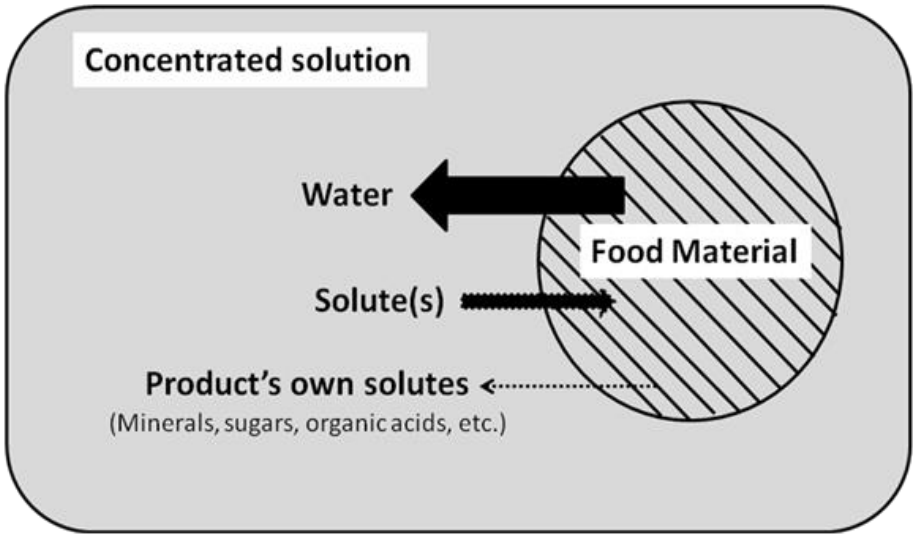


Fig. 31: Mechanism of Osmotic dehydration of fruits and vegetables

Factors affecting osmotic dehydration

1. Nature of the product
2. Processing temperature
3.Operating conditions: osmosis, diffusion, flux interactions and shrinkage

Different steps of preparation for drying

Selection of raw material

- Good quality raw material is of prime importance. Immature or over mature fruits and vegetables often result in poor quality product.
- over mature green peas result in less sweet and starchy dried product with poor rehydration characteristics. Similarly high specific gravity fully mature potatoes with low reducing sugar content are desirable because they are large, mealy and less prone to browning or yellowing during dehydration.

Washing

- On commercial scale raw material is dumped in large tanks for some time and then sprayed with a jet of water. Alternatively, it may cleaned in a stream of running water.
- To remove the traces of pesticides, colouring material commonly dilute acids may also be added in washing water.
- Addition of chlorine-based compounds is permitted to certain level for washing purpose to improve the microbiological quality of the finished product.
- **Peeling, trimming and sizing**
- A number of peeling processes are available on commercial level. Trimming is done to remove unwanted parts.

- Sizing is done to develop uniform product and it also facilitates subsequent unit operation. Increase in surface area causes faster drying.

Pre-treatments

Blanching

- Blanching is mild heat treatment primarily done to inactivate the naturally occurring enzymes like polyphenol peroxidases that catalyze the oxidation of phenolic substances, resulting in production of brown coloured compounds.
- Blanching improves the colour of dried products, aids to rapid reconstitution of dried product,
- it also increase drying rate and expels dissolved oxygen and improve bacteriological quality of the finished product.

Sulphiting

- Sulphur dioxide and sulphites (usually sodium metasulphite or potassium metabisulphite) are well known anti-browning agents.
- The blanched or checked fruits or vegetables are exposed to fumes of sulphur dioxide by burning sulphur powder in an enclosed chamber or can be dipped in Sulphur salt.

Drying

- Drying of the fruits and vegetables is usually carried out in cabinet dryer.
- The temperature, velocity and the humidity of the air are important for drying process. The temperature varies from 55-80^{o}C.
- Some vegetables those are light, cylindrical or spherical like peas are dried in fluidized bed dryer. This improves the rehydration characteristic and the nutritive value of the product, as it take lesser time and more uniform drying.

Flow chart of Osmotic Drying of Onions

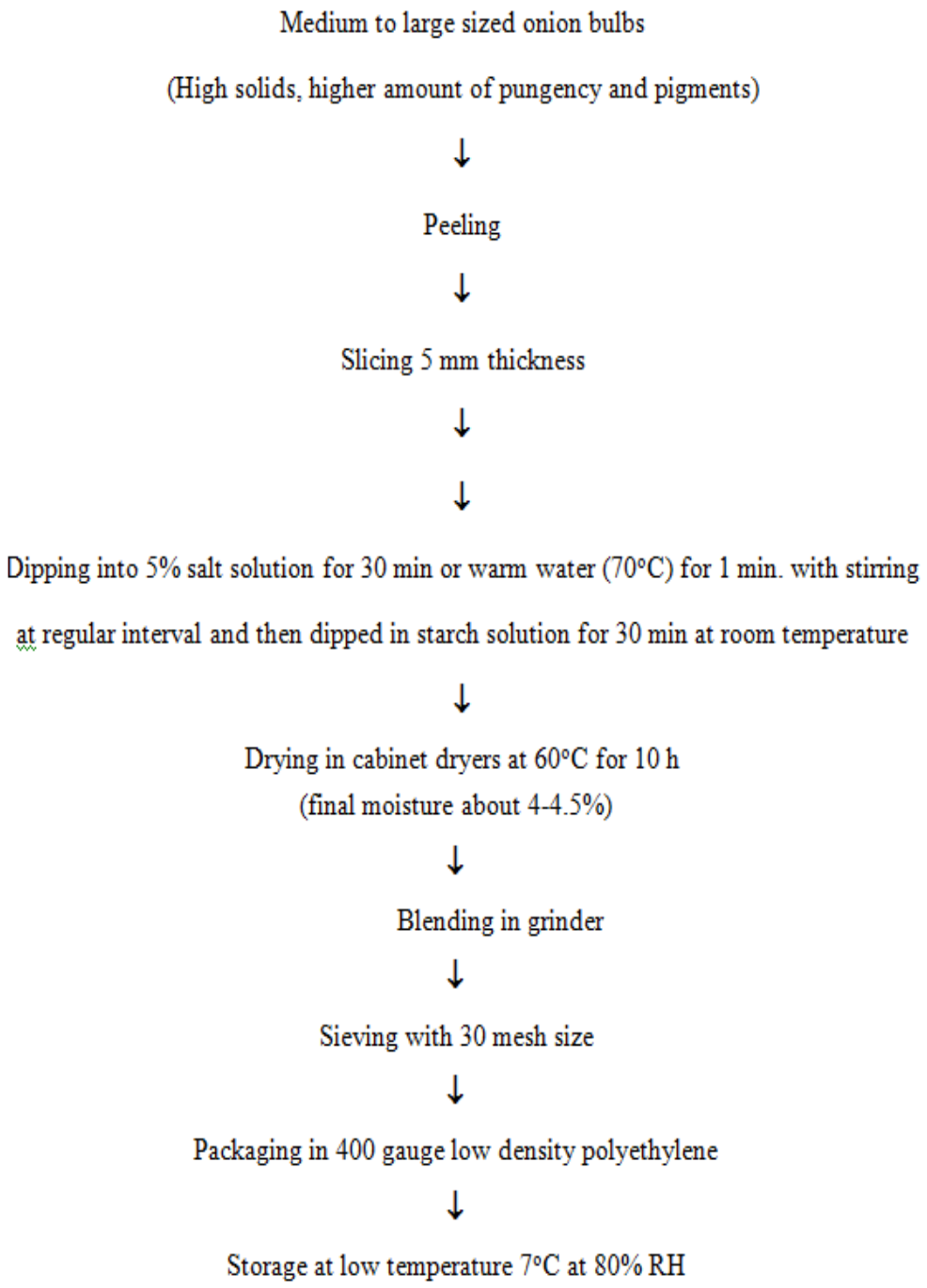


Fig. 32 Flow chart of Osmotic Drying of Onions

Flow chart of Osmotic Drying of Cauliflowers

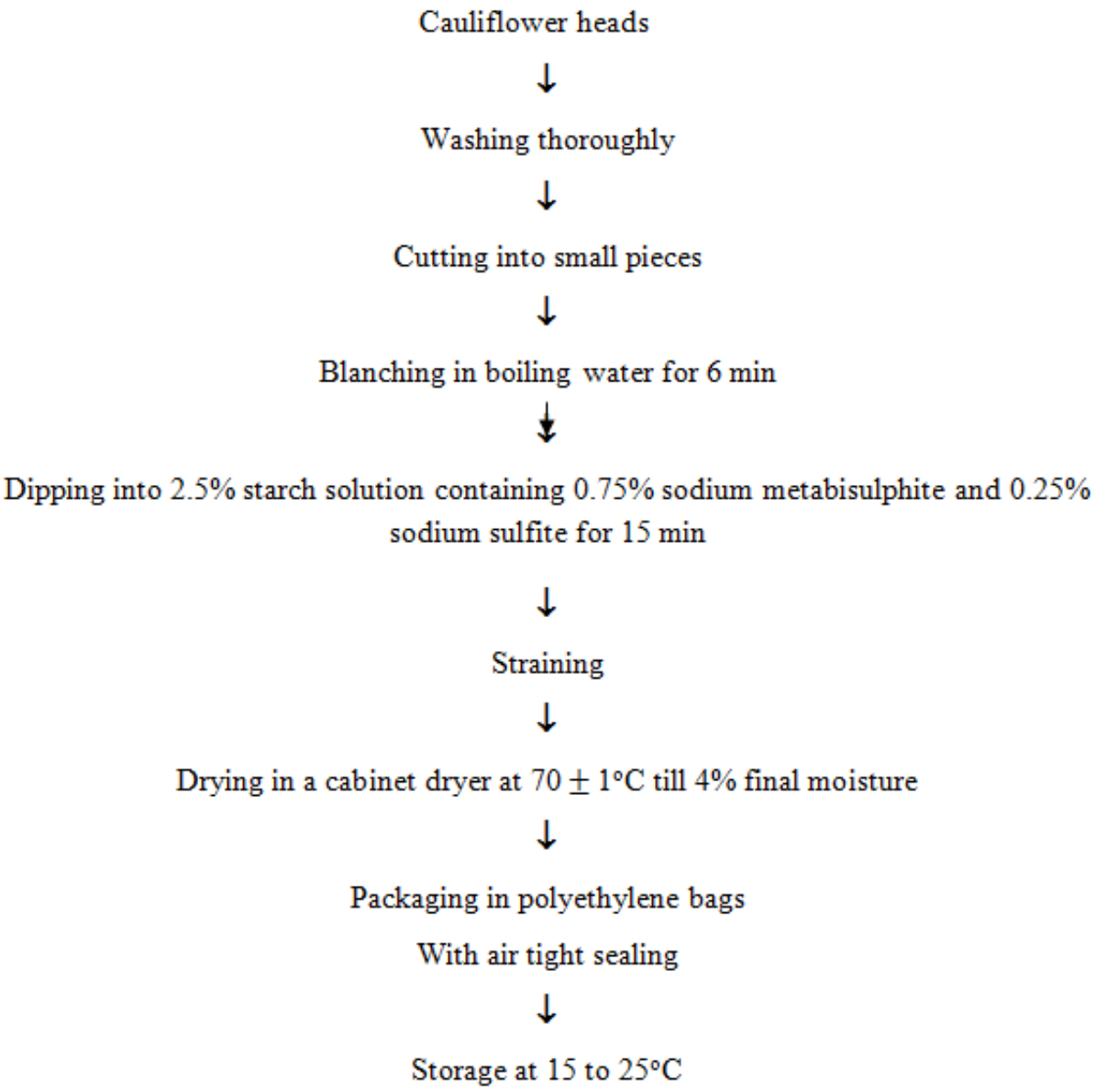


Fig. 33 Flow chart of Osmotic Drying of Cauliflowers

CHAPTER 11

Material Handling and Transportation

Most common types of mechanical devices for handling of fruits and vegetables
1. Belt conveyor
2. Bucket elevator
3. Screw conveyor
4. Pneumatic conveyor

The following principles should be taken into account:

The conveying device is to be selected according to the characteristics of the products.
The stability of the conveyor must be ensured under normal and climatic conditions.
The capacity of conveying and speed rating should be maintained at specified limits.
The deadload of the conveyor should be low in relation to the weight of transported products.
Possibility of Use of gravity should be taken into consideration
capacity of the conveying equipment should match with the capacity of processing unit.
Spillage of conveying products should be avoided.
Pollution due to noise or dust should be avoided.

Belt conveyors
It 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 or some other
enclosed shapes for conveying bulk materials.
Parts:
Belt
Drive mechanism,**Fig. 41 Belt Conveyor**
End pulleys
Idler
Loading and discharge devices

Capacity (m3/h) = area of c.s. x belt-speed, m/min x 60

Handling equipment for processing
The pattern of movement of materials during processing should be as simple as possible to avoid the risk of contamination of processed foods by raw foods and to attain the other benefits. Cross-contamination is a major concern for all food processors, but especially for those that produce 'high-risk' foods.
There is no single 'model' layout for plant and equipment, but five patterns are commonly used:
1. **Straight line** – for relatively simple processes containing few pieces of equipment
2. **Serpentine** (or 'zig-zag') – where the production line is increased for a given floor area by 'bending back' on itself
3. **U-shaped** – used when a process is required to place the finished **product in the same general area as the starting point**

4. **Circular** – used when a part-processed or finished product is required in exactly the same place where it started 5. odd-angle – where there is no recognisable pattern, but where short flow lines are needed between a group of related operations, where handling is mechanised or where space limitations will not permit another layout.

It is important that all equipment which is used to handle foods is designed to be easily cleaned to reduce the risk of product contamination.

The principles of sanitary equipment design are incorporated into good practice guides can be summarised as follows:

• equipment surfaces that are in contact with food should be inert to the food being processed and must not migrate to, or be absorbed by, the food

• surfaces should be smooth and non-porous to prevent accumulations of food and bacteria

• surfaces should either be accessible for cleaning and inspection, or able to be easily disassembled for manual cleaning and inspection. If cleaned without disassembly, it should be demonstrated that results are similar to manual cleaning

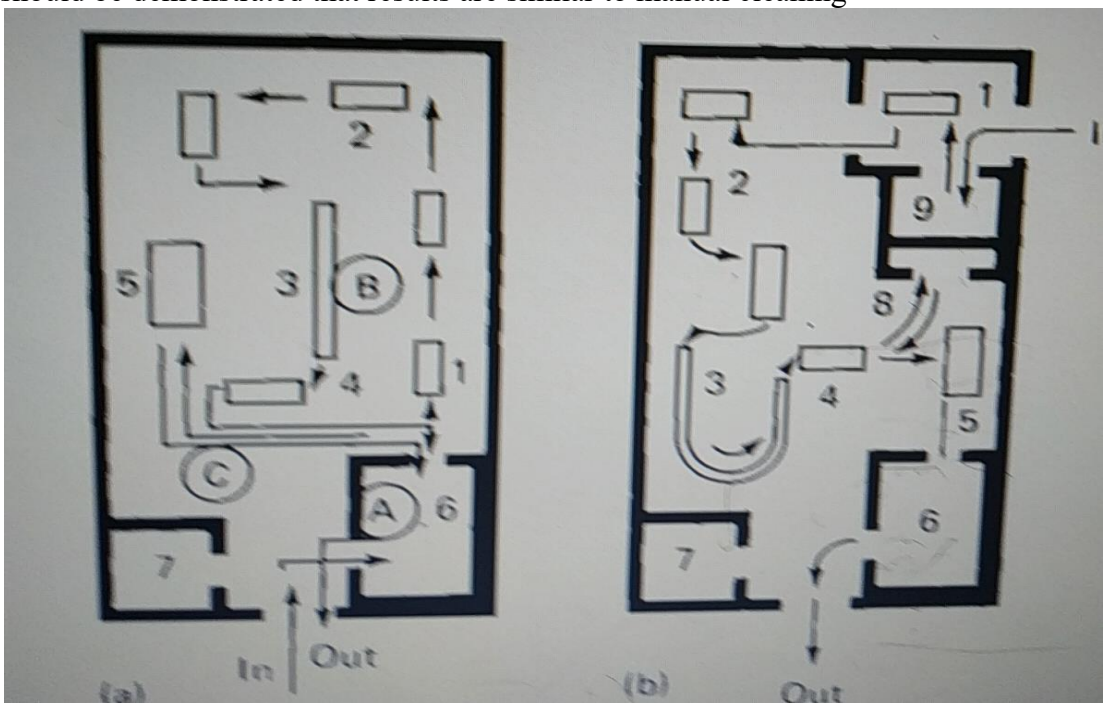


Fig. 34 Examples of factory layouts for materials handling: (a) correctly designed and (b) incorrectly designed: 1, cleaning; 2, peeling and preparation; 3, inspection; 4, packaging; 5, freezing; 6, cold store; 7, office; 8, overflow cold store; 9, raw material cold store. Note the following faults in design (a): A, raw material, partly processed product and finished product in same cold store; B, adjacent inspection of prepared food and washing of raw material; C, confused and excessive materials handling

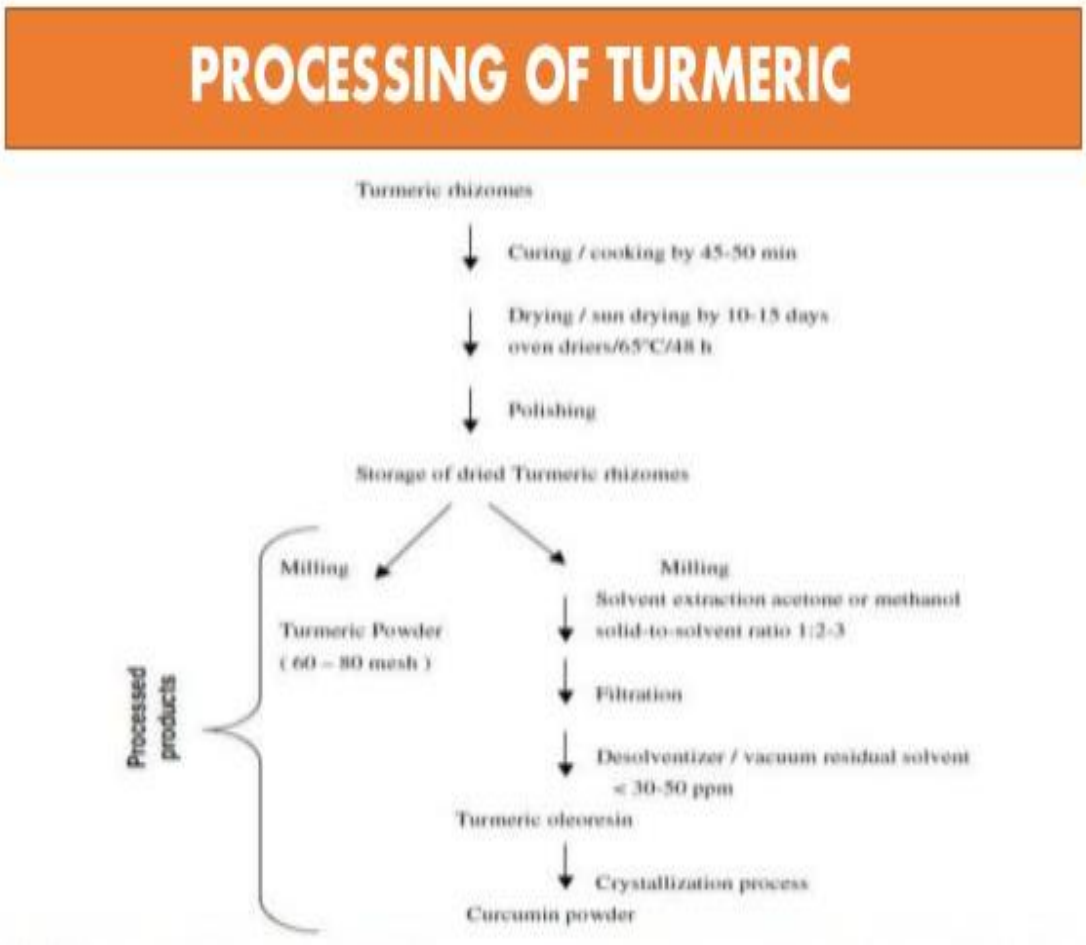
Roller conveyors and skate wheel conveyors are usually unpowered, but roller conveyors may also be powered. The rollers or wheels are either horizontal, to allow packed foods to be pushed along, or slightly inclined (e.g. a fall of 10 cm in a length of 3 m) to allow packs to roll under gravity. Rollers are stronger than wheels and therefore able to carry heavier loads, but their greater inertia means that they are more difficult to start and stop, and they are more difficult to use around corners. Additionally, the build up of materials on the rollers and bearings causes increased friction, which increases power consumption and maintenance costs.

‘Air-cushioned’ conveyors overcome these problems by carrying materials on a film of air blown into tubular trough sections by a small fan.

Chain conveyors are used to move churns, barrels, crates and similar bulk containers by placing them directly over a driven chain, which has protruding lugs at floor level. Monorail conveyors are used for moving meat carcasses or boxed poultry carcasses on an overhead track. Screw conveyors comprise a rotating helical screw inside a metal trough. They are used to move bulk foods such as flour and sugar, or small-particulate foods including peas and grain.
The main advantages are the uniform, easily controlled flowrate, the compact cross-section without a return conveyor and total enclosure to prevent contamination. They may be horizontal or inclined but are generally limited to a maximum length of 6 m as above this, high friction forces result in excessive power consumption.
Vibratory conveyors cause a small vertical movement to food to raise it a few millimeters off the conveyor, and forward movement to transport it along the conveyor. The amplitude of vibration is adjusted to control the speed and direction of movement and this precise control makes vibratory conveyors useful as feed mechanisms for processing equipment.
There are many designs of elevators, but two common types are bucket and magnetic elevators: bucket elevators consist of metal or plastic buckets fixed between two endless chains. They have a high capacity for moving free-flowing powders and particulate foods. The shape and spacing of the buckets and the speed of the conveyor (15–100 m/min) control the flow rate of materials.
Magnetic elevators are used for conveying cans within canneries. They have a positive action to hold the cans in place and are thus able to invert empty cans for washing, and they produce minimal noise.
In general, conveyors and elevators are best suited to high-volume movement, where the direction of flow of materials is fixed and relatively constant. They can also be used as a reservoir of work-in-progress.
Pneumatic conveyors consist of a system of pipes through which powders or small particulate foods, such as salt, flour, peas, sugar, milk powder, coffee beans, etc., are suspended in recirculated air and transported at up to 20–35 m s1. The air velocity is critical; if it is too low, the solids settle out and block the pipe, whereas if it is too high, there is a risk of abrasion damage to the internal pipe surfaces.
Generation of static electricity by movement of foods is a potential problem that could result in a dust explosion when conveying powders, and is prevented by earthing the equipment, venting, or explosion containment and suppression techniques. Pneumatic conveyors cannot be overloaded, have few moving parts, low maintenance costs and require only a vacuum pump or a supply of compressed air at around 700 x 103 Pa.

CHAPTER 12

Processing of Spices and Condiments





Turmeric boiler



Large scale turmeric



Turmeric polisher

MACHINERIES OF TURMERIC



Fig: Turmeric grinding Machine

Rs. 8.5 Lakh/ Unit(s)



Fig : Turmeric Polishing Machines



Fig : Turmeric powder making machine

Source : https://dir.indiamart.com/impcat/ginger-paste-machine.html [Last accessed : 3 April,2019]

PROCESSING OF GINGER



Source: https://www.bing.com/images/search?view=detailV2&id=D2A3E978C4703960269DC1D9EBB4229A8FF9EBC4&thid=OIP.PRK4wXSkmhBosAgXnqO1wQHaCa&mediaurl=http%3A%2F%2Fwww.rajturnkey.com%2Fimages%2Fginger_processing_plant.jpg&exph=195&expw=600&q=rocessing+chart+of+ginger&selectedindex=8&ajaxhist=0&vt=0&eim=1,6[Last accessed : 3 April,2019]

1.SORTING



- It involves separating the good rhizomes from the shrivelled ones and extraneous matter (dry shoot and grass stumps, pebbles and sand).

2.WASHING

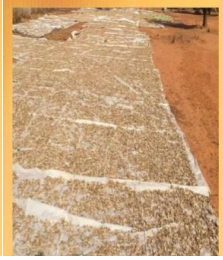
- Harvested rhizomes are kept soaked in water overnight and rubbed well to clean them.
- After cleaning, they are removed from the water.
- The outer skin is then scraped off with a bamboo splinter or wooden knife having pointed ends



6.CLEANING& GRADING



1.SUN DRYING



2.DEHYDRATOR







Ginger Washing and Peeling Machine **Ginger Slices/Flakes Machine**

Unit operations of Chilli





Chilli dry cleaning



Chilli deseeding machine



Chilli drying machine



Chilli powder milling machine

CHAPTER 13

Pack House Technology

Packing houses serve as a collection centre for fruits and vegetables prior to distribution and marketing. The houses can be simple packing sheds with a limited equipment and minimal operations or a large complex that is well equipped and with facilities for specialized operations. The types of operation carried out vary with different commodities and market requirements. Produce that are destined for export or supermarket outlets are often subjected to elaborate operations compared to local markets.

Sorting and Trimming

Freshly harvested fruits and vegetables are sorted for uniformity in size, shape and varietal characteristics. Damaged, discoloured and decayed parts are removed to make the produce more attractive and prevent infection from the diseased parts.

Washing

Washing is necessary to remove extraneous materials from the field such as dirts, chemicals and latex. This is usually done before storage or immediate retailing of the produce. In order to r educe the incident of decay, chlorine is often added to the wash water.

Drying

Drying is done to remove excessive moisture from the surface of the produce. Excessive drying should be avoided to prevent wilting, shrinking and water loss.

Waxing

Waxing is done on certain types of fruits and vegetables such as ginger, tomato, citrus and melons to reduce water loss, thereby reducing shriveling. In addition to that, the application of edible wax will enhance the appearance of the produce.

Curing

Injured and bruised surfaces of root, rhizome and tuberous crops are allowed to heal by holding them at ambient temperatures for a few days. Curing initiates the formation of periderm layers at wound areas, thereby reducing moisture loss and microbial infection. Sufficiently cured vegetables can be stored for a longer period.

Chemical Treatments

Fungicides and growth regulators are commonly used to reduce decay and undesirable growth respectively. The use of chemicals should be closely supervised and within the recommended levels for human consumption.

Grading

Fresh fruits and vegetables are classified into groups according to a set of recognized criteria of quality and size, with each bearing an accepted name and size grouping.

Packaging

Produce are packed in suitable containers to provide protection against mechanical and biological damages during transportation and subsequent handling operations. Packaging materials should be of accepted standards with regard to strength, ruggedness and resistance to pressure. Packages should have adequate ventilation so that produce will not warm up as a result of heat arising from respiration. Excessive ventilation, however, may result in wilting.

Pre-cooling

Pre-cooling is an essential step prior to storage at low temperatures. It is the rapid removal of field heat from the produce to reduce the rate of respiration, microbial activity and refrigeration load. Pre-cooling can be done with chilled water, ice or cool air (forced air cooling), whereby the

produce is cooled to the half cooling temperature.

Storage

Storage at low temperatures has been an effective mean of extending the shelf-life of fresh fruits and vegetables. It also enables orderly marketing and distribution of produce in time of peak production. Temperature requirements for different produce may vary depending on variety, location, stage of maturity and other factors. It is important to note that cool storage is a tool used to maintain quality but not to improve it.

Transportation

Proper handling of the produce during transportation is essential to reduce losses to a minimum and to maintain their quality from the farm to the packing house and from packing house to market. The used of refrigerated trucks to transport highly perishable and high value produce will maintain their quality over an extended duration. In non ventilated vans, temperature of the fruits or vegetables rises quickly, increasing respiration and decay.

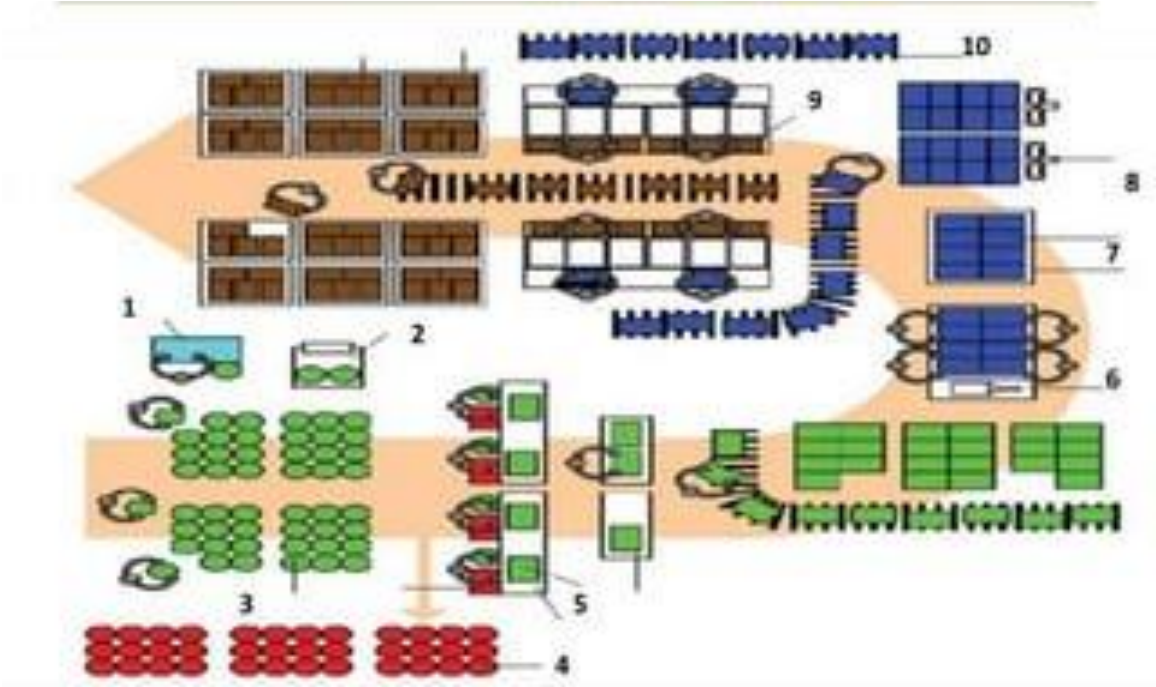


Fig.35 Pack House Layout (U-shape)

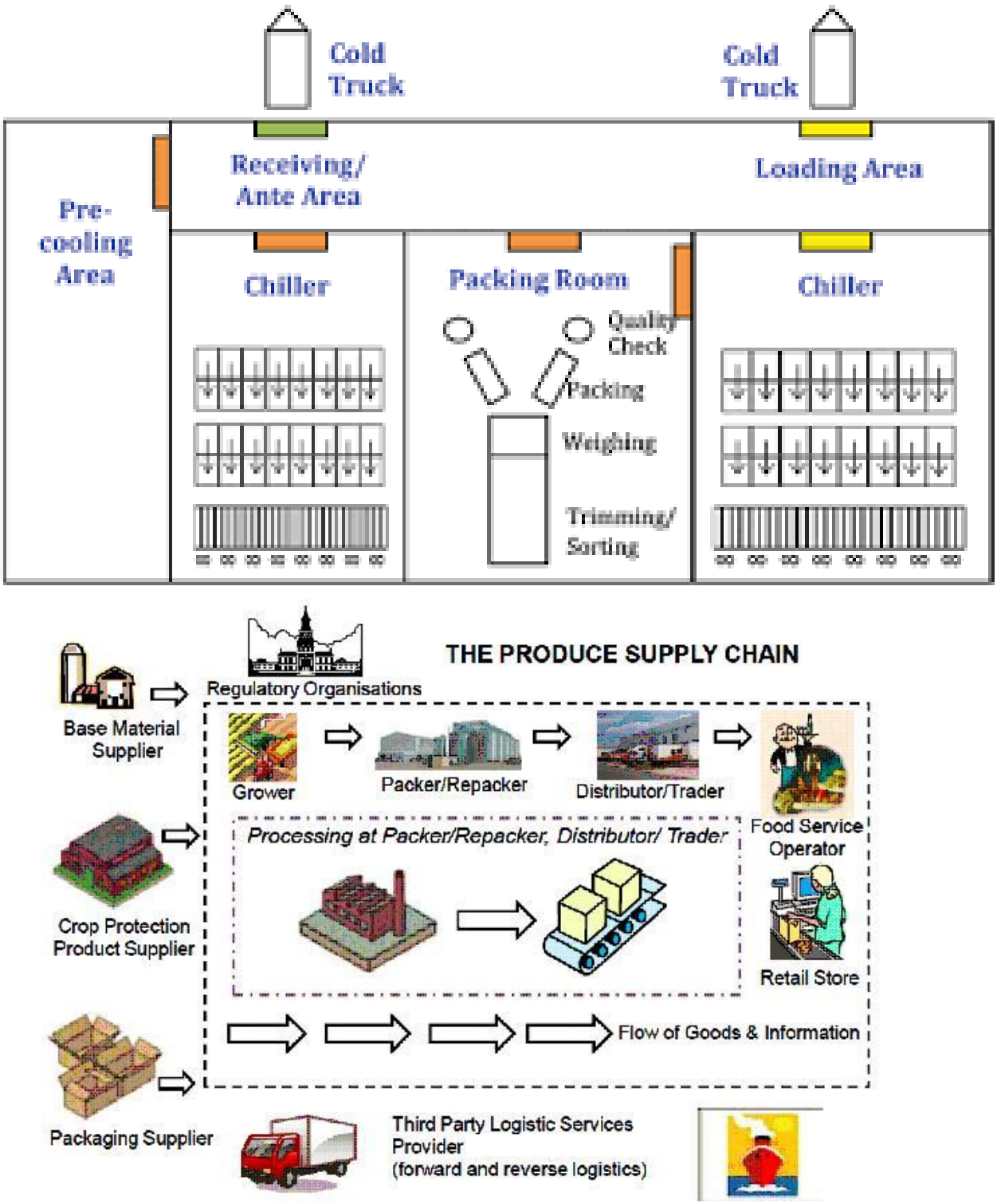


Fig. 36 Pack House Layout and Supply Chain

CHAPTER 14

Packaging of Fruits and Vegetables

The purpose of packaging of food involves:

1- Product containment
2- Preservation and quality
3- Presentation and convenience
4- Protection during distribution and processing
5- Provide storage history

Product Containment

- The first function of packaging is its capability of containment.
- The primary purposes of packaging are containment and protection.
- Liquids, semi liquids, and powders, as well as bulk solids, cannot be marketed without suitable containers.
- Containment refers to holding goods in a form suitable for transport, whereas protection refers to safekeeping goods in a way that prevents significant quality deterioration

The second function of packaging is **to control the local environmental conditions to enhance storage life and safety**.

- The main purpose of food packaging is to protect the product from surroundings and maintain the quality of the food throughout the product's shelf life.
- Product shelf life is controlled by three factors:
    - 1-product characteristics,
    - 2-property of packaging material
- storage and distribution conditions of individual package .
- Reactions causing deterioration in foods include enzymatic, chemical, physical, and microbiological changes. Additional problems include insects, pests, and rodents.

Nutritional Quality

- Include peroxidation of polyunsaturated fats and destructive oxidation of nutrients such as ascorbic acid,
- Fatty acid peroxides are well established as causing health problems.
- As antioxidative nutrients such as vitamins C and E are lost.
- Carotenoid pigments can also be oxidized, leading to loss of color as well as loss of their beneficial effects in the body.
- Lipid hydroperoxides can also result in the formation of aldehydes and other compounds with off-flavors. In addition to light barriers, use of UV absorber in the packaging material can decrease lipid oxidation.

Among all other functions of packaging, the protection of foodstuffs against light plays a key role particularly during storage, transport, and sales display.

Barrier Properties

- To achieve the best from packaging , it is important to know product characteristics, properties of individual package, storage, and distribution conditions.
- Barrier properties include permeability of gases (such as O_2, Co_2, N_2, and C_2H_4), water vapor, aromas, and light. These are vital factors for maintaining the quality of foods.

- packaging materials cannot be chosen solely on the basis of their barrier properties.
- Factors such as process ability, mechanical properties and chemical resistance and interaction with product and Environmental factors, such as temperature, relative humidity, and light intensity must also be taken into account

- Now various types of active substances can be incorporated into the packaging material to improve its functionality and give it new or extra functions.
- Such **Active packaging technologie**s and **Antimicrobial Packaging** and ***Edible Film*** are designed to extend the shelf life of foods, while maintaining their nutritional quality and safety.

Presentation and Convenience

- Food labels are intended by law to provide the information that consumers need to be able to make the necessary decisions about those purchases of food.
- It is important to display the product in an attractive manner to the potentialbuyer.
- A cleverly designed and beautifully produced packaging can help sell a product, which is an essential ingredient of an effective marketing campaign.
- The packaging helps in distinguishing products on the shelf, which is a traitespecially important when marketing low-fat or nutritional products.
- For a package to be effective, it must present the product well and should do its own publicity.
- Eating styles, such as ready-to-eat meals, snacks, and microwaveable ready meals, have been changed over the years, which need innovation in packaging.
- Packaging should meet the future demand of meeting eating style of the society.
- For children, the packaging might represent innovation or fun.

Protection during Distribution and Processing

The fourth function is to protect the product during transit to the consumer.Packaging is part of the distribution process necessary to deliver goods to the consumer and facilitate handling and transportation.

It also has affected international trade by making shipping of food products possible, allowing seasonal products to be more accessible out of season.

Packaging can handle better when there are challenges in food distribution chain, such as heat, humidity, or dew.

It is important to be aware of the distribution challenges and designing of package to suit it.

In case of prepacked product, it should have the ability to stand the severity or type of process conditions such as flexible packaging during canning, microwaveable foods, ovenable, and retortable foods.

Irradiated foods are usually prepacked prior to treatment by ionizing radiation.

Protective packaging is a term applied to packaging primarily designed to protect the goods, rather than for appearance or presentation.

Provide Storage History

- Time-temperature indicator (TTI) is effective for predicting microbial concentrations and other parameters of food quality during shipping and storage.

- It helps in ensuring proper handling and provides a gauge of product quality for sensitive products in which temperature control is imperative to efficacy and safety.
- TTI could be used in chilled foods to identify the temperature abuse during storage and distribution.
- TTIs are tags that can be applied to individual packages or shipping cartons to visually indicate whether a product has been exposed to time and temperature conditions that adversely affect the product quality.
- According to the response mechanisms, TTIs can be divided into three groups:
- (i) biological, (ii) chemical, and (iii) physical systems
- There are two issues to be considered:
- One is the economics.
- The other issue is knowledge of the food product.

Ideal Packaging

- Zero toxicity
- High product visibility
- Strong marketing appeal
- Ability of moisture and gas control
- Stable performance over a large temperature range
- Low cost and availability
- Suitable mechanical strength (i.e., strength in compression, wear, and puncture characteristics)
- Easy machine handling and suitable friction coefficient
- Closure characteristics, such as opening, sealing and resealing, pouring
- Ability to include proper labeling
- Resistance of migration or leaching from package
- Protection from loss of flavor and odor
- Controlled transmission of required or unwanted gases

Packaging Categories
1- Primary packaging
2- Secondary packaging
3- Transit packaging
wrapping used to bundle the boxes or crates
for transport and distribution.
Transit packaged products are placed in shipping containers for long-distance transportation and distribution

Selecting the right material
Material selection is based on:
- technical properties (strength, flexibility, etc.)
- fitness for purpose (moisture barrier, cushioning, etc.)
- availability, manufacturing capability, cost,
- environnmental impact, regulations

Types of Packaging

Packaging can be classified in a number of ways but the most important one is by stages of distribution.

- Consumer/unit packaging
- Direct bulk/ transport packaging

Consumer Packaging

Package in which consumer receives the produce is called consumer packaging.

Small in size and designed to hold ½ dozen – 1 dozen fruits or ½ kg to 2 kg of vegetables

This mainly depends upon:

- Type of produce
- Expected transport and storage time
- Required shelf life
- Packaging material costs
- Cost of packaging
- Market requirement

Types of Consumer Packaging

Flexible Plastic Films

- Most common and favoured retail packs.
- Low density polyethylene (LDPE), high density polyethylene (HDPE), , PVC (Poly vinyl Chloride) and PP (Polypropylene) bags are most suited.
- Mostly used as pouches with holes
- Film bags are clear, allowing for easy inspection of the contents, and readily accept high quality graphics.
- Low material and packaging cost.





Net Bags

- Stretches and accommodates all size and shapes
- Provide desired ventilation and allow free air.
- Suitable for citrus fruits, onions, potatoes etc.
- HPDE and polyamide
- Cost effective
- Attractive display





Tray

- Tray packs made of foamed polystyrene/ PVC/PP are overwrapped with heat shrinkable or stretch films.
- A tight wrap immobilizes fruits and keep them apart.
- Avoids abrasion and bruising
- Trays provide cushioning effect
- Attractive display





Punnets

- Clear plastic punnets are ideal option for packaging of fresh fruits and vegetables.
- Punnets are light weight, offers excellent clarity.
- PET, PVC or PP
- Each punnet has small holes carefully positioned throughout (produce can breathe)
- Lid can be fixed securely onto the punnet, for protection/ retail purposes.





Shrink Wrap

- Packs individual produce
- Controls moisture loss
- Shrink wrapping has been used successfully to package potatoes, sweet potatoes, apples, onions, sweet corn.
- Reduce shrinkage, protect the produce from disease.
- Reduce mechanical damage and provide a good surface for stick-on labels
- LDPE or LLDPE
- Attractive display.





Types of Bulk Packaging

Wooden Boxes

- Use to move produce from field or orchard to packing house.
- Sturdy, rigid and have very high stacking strength.
- Efficient palletization
- Advances in material handling have reduced their use to a few specialty items, apples, stone fruit etc.
- Occupy more space, nails cause injuries, deforestation





Corrugated Fibre board Boxes (CFB)

- Most commonly used shipping containers
- Manufactured in many different styles and weights
- Low cost to strength and weight ratio.
- Smooth and non-abrasive surface
- Good cushioning characteristics
- Excellent printability
- Easy to set up and collapsible for storage
- Reusable and recyclable
- Absorb moisture from surrounding air (cold temperatures + high humidity) and can reduce strength of container
- Laminated with LDPE, PP or PVC

Pulp Container

- They are made from recycled paper pulp
- Cushioning material
- Pulp containers are available in a large variety of shapes and sizes and are relatively inexpensive in standard sizes.
- Arranged inside CFB boxes
- They can absorb surface moisture from the product,
- Biodegradable and recyclable.





Plastic Crates

- Usually made up of HDPE or polypropylene (PP) by injection moulding.
- Replaced wooden crates
- Good resistant properties to weather, ultraviolet degradation and shock damages.
- Durable and can last many years
- Designed in such a way that they can nest inside each other when empty to facilitate transport
- Stackable, stack-nest/ collapsible.

Sacks

- Flexible shipping containers used for vegetables.
- Commonly used materials are cotton, jute, woven plastics (HDPE/PP).
- Cost effective
- High strength, reusable and requires little space for empties
- Poor stackability, low protection against puncture, compression, vibration and impact injuries





Glass

Advantages:

- Glass containers used to be and still are considered a prestigious means of packaging, and serve for the most expensive wines, liqueurs, perfumes, and cosmetics.
- It is highly inert, impermeable to gases and vapors, and amenable to the most diverse shaping. It is an excellent oxygen barrier and completely neutral in contact with foods
- It has the advantage of transparency, but where required it can be given different desired colors.
    - It has complete as well as selective light protection properties

Disadvantages:

- Fragility, heavy mass, and high energy requirement duringmanufacturing.
- The main uses of glass for packaging are in milk bottles, condiments, baby foods, instant coffee, and drinks.
- Glass is not used for frozen products, or for ground or roasted coffee because of breakage costs and the difficulty of vacuum flushing.

Pulp products

- Pulp products are widely used in food packaging in the form of different kinds of paper, paperboard, laminates, and corrugated board.
- The main advantages of paper are its low cost, low mass, relatively high stiffness, and excellent printability;
- the main disadvantage is its high sensitivity to moisture, reflected in close dependence on the relative humidity of the environment.
- The basic raw material for papermaking is cellulose.

Timber

Wood is commonly used in box construction, but the use of wood for individual packaging (such as cigars) has decreased since the advent of plastics. Examples of timber for packaging are cases, boxes, and casks for long-distance transport.

Cardboard

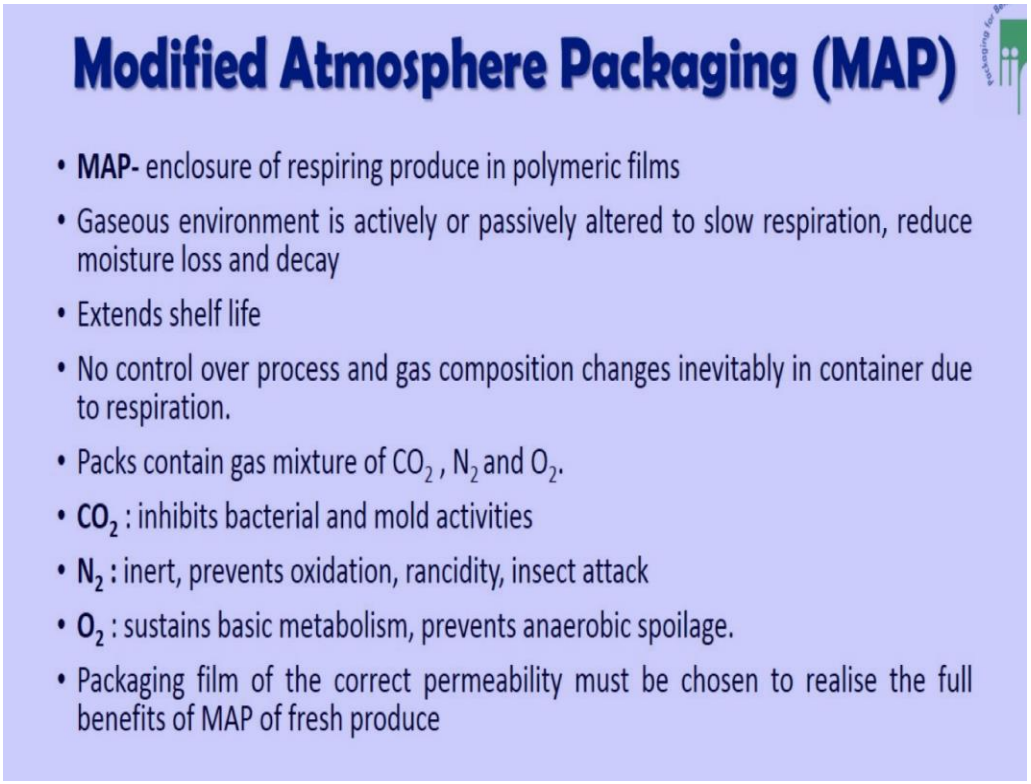
Choosing a carton for a specific job depends on the capacity of the carton to meet the requirements for that job.

CHAPTER 15

Modified and Controlled Atmospheric Packaging

Modified Atmospheric packaging

- The modification of the atmosphere generally implies a reduction of O2 content or an increase of the CO2 concentration, but in some cases changing the level of carbon monoxide (CO),ethylene, ethanol, or other compounds in the atmosphere can also contribute to shelf-life extension.
- After closing the package, the respiration of the product will cause a decrease in the oxygen content and an increase in the carbon dioxide content.
- The course of the atmosphere modification is determined by three interacting processes: respiration of the commodity, gas diffusion through the commodity, and gas permeation through the film. Each of these processes is in turn strongly influenced by several commodity- and environment-generated factors.
- Strict temperature control in the distribution chain would be a prerequisite for optimal use of MAP in practice.



- Several new technologies offer the packer opportunities to modify the atmosphere inside the shipping package during distribution.

➢Controlled atmosphere packaging (CAP)

➢Modified atmosphere packaging (MAP)

➢Edible coatings and films

➢Antimicrobial packaging

➢Smart/intelligent packaging

Controlled Atmosphere Packaging (CAP)

- CAP- Extend shelf life by altering gaseous environment in and around the product.
- Perishable foods like meat, poultry, fish, and fruits like apple, pears and some vegetables.
- Requires strict control of quality and storage temperatures (to ensure the safety and quality of products).
- CAP actively and continuously "senses" package conditions and responds to changes in those conditions by means of gas absorbers or emitters, humidity regulators.

Active packaging



- Sachets and Pads
  - O_2 Absorbers
    - Oxidation of iron powder, ascorbic acid, catechol, glucose oxidase
    - 0.01% removal < 0.3 to 3 % in vacuum
    - Depends on Nature, a_w , O_2 dissolved, shelf life, initial O_2 in package, and Permeability



  - CO_2 Absorbers/Emitters
    - $Ca(OH)_2$ + Fe – Absorbent
    - Ascorbic acid with $FeCO_3/NaOH_3$ – Emitters



  - Ethylene Adsorbers
    - $KMnO_4$ toxic – perlite, alumina, silica gel, etc
  - Ethanol Emitters
    - 55% ethanol + 10 % water adsorbed to SiO_2 in EVA
  - Moisture/Water Absorbers
    - Drip Absorbent pads – polyacrylate, copolymers of starch



Vacuum Packaging

- Vacuum packaging (VP) may be regarded as a special type of MAP, since part of the normal headspace is removed, leaving an altered initial atmosphere that is not controlled after packaging.
- In this system, the initial gas composition is that of normal air, but because of the reduced partial gas pressure, the amount of O2 available at the start of storage is about one-third of the normal amount.
- As with MAP, the lower O2 content stabilizes the postharvest product quality by slowing down the metabolism of the produce and the growth of spoilage microorganisms.

Vacuum Packaging

- Product is packed in a vacuum condition
- Vacuum packaging offers an extensive barrier against corrosion, oxidation, moisture, dirt, fungal growth, etc

Increases the shelf life upto 30 days

Ripening takes 7 to 10 days after opening the bags.

No residual effect of fungicide

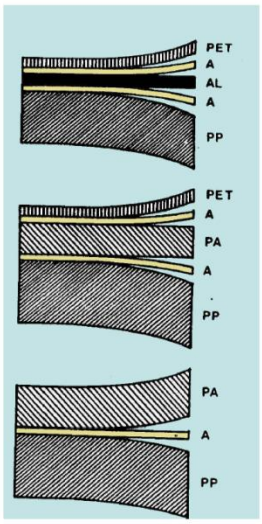


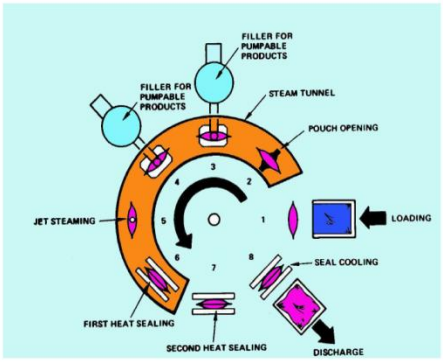







Retort pouches





Rice and pasta; Soups and stews; Sauces and gravies; Meat and chicken; Seafood; Fruits and vegetables; Baby food; Pet food


Non – foil pouch


Foil bearing plastic pouch

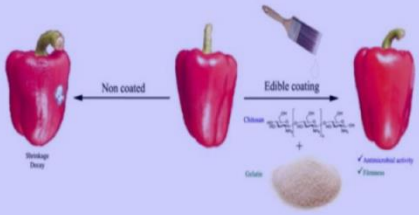

Ready-to-eat sauces


Ready-to-eat meals


Ready-to-cook sauces

Edible Coatings and Films

- Environment friendly technology
- Good barrier (moisture, CO2, O2 & ethylene)
- Additional protective coating
- Act as a micro MAP
- Prevent browning and decrease microbial activity (antimicrobial & antioxidant additives)
- Extend shelf life.



Edible Coatings and Films

- Edible coating materials are generally made up of polysaccharides, proteins and lipids.
- Edible coatings are mainly divided into three classes:

➢ **Hydrocolloids**: e.g., polysaccharides, proteins and alginate

➢ **Lipids:** e.g., fatty acids, acryl glycerides and waxes

➢ **Composites:** e.g., protein/protein, polysaccharides/ protein, lipid/polysaccharides

Types of Edible Coatings and Films

Coating material	Functions
Guar gum	Antimicrobial
Soybean gum, Jojoba wax, Glycerol and Arabic gum	Overall quality
Shellac +/- Aloe vera gel	Keeping quality
Chitosan, Zein	Antioxidant, H_2O barrier
Beeswax, Coconut and Sunflower oil	Antimicrobial, antioxidant quality
Chitosan, Methyl cellulose	Antimicrobial, antioxidant, CO_2,/O_2 /H_2O barrier
Pectin-base	Overall quality
Aloe vera gel	Overall quality
Agar, chitosan, acetic acid (combined)	Antimicrobial, CO_2,/O_2 barrier
Whey protein, rice bran oil	H_2O barrier, Overall quality
Alginate and Gellan-based	CO_2,/O_2 /H_2O barrier

Antimicrobial Packaging

- Next generation packaging (microbial inhibiting + barrier properties)
- Inhibits growth of pathogenic and spoilage microorganisms
- Extends shelf life
- **Antimicrobial agents:**
- **Natural antimicrobial agents:** extracts of spices, oils, chitosan, bacteriocins, enzymes.
- **Chemical antimicrobial agents:** Benzoic acid, sorbic acid

Smart/Intelligent Packaging

- Sensor technology
- Packaging- "senses and informs"
- Package function switches on and off in response to changing external/internal conditions,
- Communicates status of product



- Highly value added feature
- Monitors vibration, acidity, shock, humidity, light, heat, chemicals, virus or bacteria
- Devices: Integrated circuits, Time temperature integrators, radio frequency identification tags



- Advanced form of data information carrier and requires cyber security
- Fresh-cut fruits and vegetables

CHAPTER 16

Quality standards and safety

Quality: The characteristics of a material which meets the customer's requirements and is acceptable. The quality of a material varies in accordance with its intended use.

Food quality: The characteristics of a food that is acceptable to consumers. It includes the external factors such as appearance, texture, and flavor, factors such as federal grade standards for eggs and internal factors such as chemical, physical and microbial.

The combination of attributes or characteristics of a product will have significance in determining the degree of acceptability of that product to the consumer. Hence more the degree of acceptability, the higher would be the quality and vice versa.

Food Quality assurance: It is the precision and accuracy by which the various requirements for quality are measured and controlled to provide a commodity which satisfies the wants of a consumer is known as quality assurance. This provides internal and external confidence that a food industry fulfils the requirement for quality.

In the manufacturing of food products, quality is an important requirement, because consumers are susceptible to any form of contamination that might occur during the manufacturing process. Most of the consumers generally depend on manufacturing and processing standards, specially to know the type of ingredients present, due to dietary, nutritional requirements, or medical conditions. Quality assurance has become a necessary component of the food service business with the adoption of analysis and control systems for food safety.

The main purpose:

- To provide consumers with good quality foods.
- To prevent Poor handling of foods and spoilage due to microbial contamination.
- To prevent the presence of hazardous chemicals in foods due to lack of control in the usage of pesticides.
- To prevent the addition of food additives in excess and use of wrong additives.
- To prevent food adulteration which defrauds the customer, decreases nutritive value of food and causes harm.
- To reduce naturally occurring toxins in food.

Quality system: This refers to the organization structure, responsibility, procedures, processes and resources needed to implement a comprehensive quality management programme.

Food toxicity: The presence of undesirable non nutritional substances resulting in potential health risks of different characteristics and magnitude to persons consuming them. The undesirable constituents that affect the food quality include toxicants that are present naturally or

Food quality control: A programmed and coordinated activity of authentic organizations to maintain and improve the quality of food products

Safety: The relative certainty that a substance will not cause harm or injury.

Food safety: Thebasic concept offood safety is that when food is consumed either fresh or processed will not harm the consumer so long as intended guidelines are followed in the preparation. Food becomes potentially harmful whenever it has been exposed to hazardous agents and intended use guidelines have not been followed.
Food safety is a multi sectorial activity which demands good coordination between:

- Central and state ministries
- National institutes and laboratories
- Trader and food industries
- NGOs
- Consumers
- International organizations

Food standards:A body of rules or legislation defining certain criteria, such as composition, appearance, freshness, source, sanitation, maximal bacterial count, purity, maximum concentration of additives, and so on, which the food must fulfill to be suitable for distribution or for sale.

Food standards protect consumers from being cheated and also provide information in making food choices.
Justification for food standard is three fold:

- To prevent the transmission or cause of the disease.
- To limit the sale of unsatisfying product.
- To simplify the marketing of food.

Food Risk: It is the likelyhood of an occurrence of a hazardous event after the consumption of a food due to the presence of hazardous materials.

Food hazard: It is a biological, chemical or physical agent in, or condition of, food reasonably likely to cause illness or injury or an adverse health effect in the absence of its control.

chemical contaminants or environmental contaminants or toxins released by microbial growth.

Specifications for raw materials

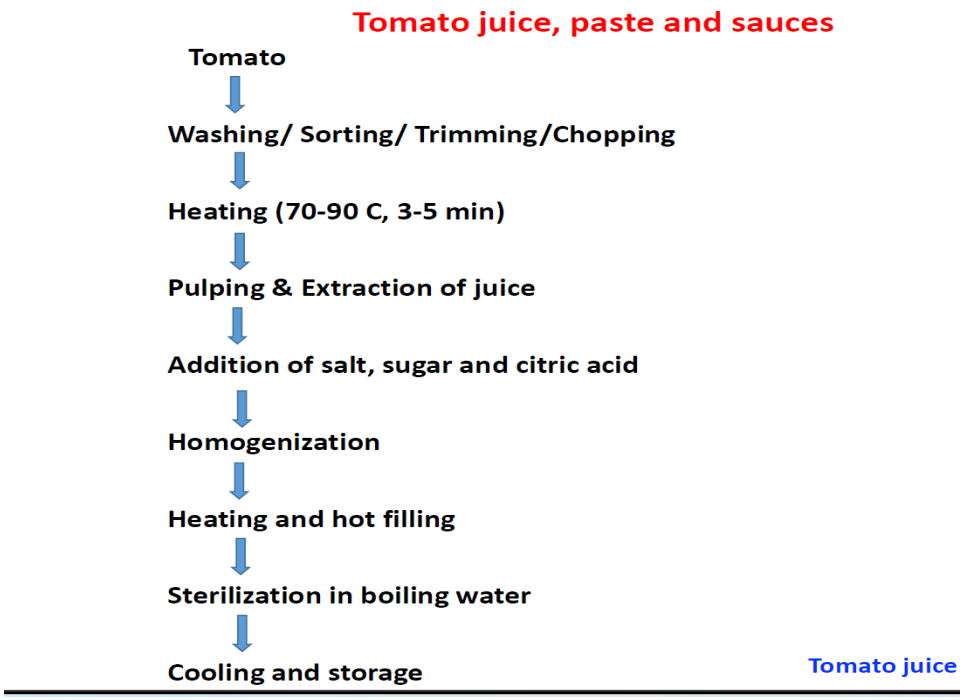
Specifications for fruits and vegetables

- Free from punctures or other significant physical damage sustained during harvesting or post harvest handling.
- clean, practically free of any visible foreign matter, soil, dust, chemical residues or other visible foreign matter.

- The produce must be practically free from insects, mites or any other pests. The presence of pests can detract from the commercial presentation and acceptance of the produce.
- The produce must be free from damage caused by insects, mites or any other pests that affects the fruit flesh. Pest damage affecting the flesh makes the produce unfit for consumption.
- The produce should be free of abnormal external moisture. This provision applies to excessive moisture, for example, free water lying inside the package but does not include condensation on produce following release from cool storage or refrigerated vehicle. However, a certain amount of external moisture may be necessary for quality preservation and is allowed.
- Produce should be free of any foreign smell and/or taste. This refers particularly to produce which have been stored on badly kept premises or have travelled in a badly maintained vehicle, especially produce which has acquired strong smell from other produce stored on the same premises or travelling in the same vehicle. It does not refer to any smell emanating from products used in conformity with the regulations for their use to improve keeping properties.

FSSAI specifications for beverages

Product	Minimum % of total soluble solids in final product (w/w)	Minimum % of fruit juice in final product (w/w)
Unsweetened juice	Natural	100
Fruit syrup/Sharbat	65	25
Crush	55	25
Squash	40	25
Fruit nectar (excluding orange and pineapple)	15	20
Orange and pineapple nectars	15	40
Cordial	30	25
Sweetened juice	10	85
Lime/lemon RTS beverage	10	5
Ready-to-serve beverage/ drink	10	10
Fruit juice concentrate	32	100
Synthetic syrup/sherbet	65	-
Sweetened Mango pulp/ puree	15	**10**
Sweetened fruit pulp/ puree other than mango	6 (exclusive of added sugar)	**10**



Food safety and Standard Acts

Food processing industry in India isgoverned by several laws in the areas ofsanitation, licensing and other necessarypermits that are required to start up and runa food business. Initially, the food safety ofIndia was under the Prevention of FoodAdulteration Act, 1954 (PFA). However, achange to the PFA was felt needed, and in 2006, it was replaced by the Food Safety andStandards Act, 2006 (FSSA). The FSSAcombines various acts and orders that werepreviously handled by various ministriesand departments related to food.The FSSA specifically replaced eight lawsthat were in operation before theenforcement of the FSSA:

- PFA
- Fruit Products Order, 1955
- Meat Food Products Order, 1973
- Vegetable Oil Products (Control)Order, 1947
- Edible Oils Packaging (Regulation) Order, 1998
- Solvent Extracted Oil, De oiledMeal, and Edible Flour (Control)Order, 1967
- Milk and Milk Products Order,1992
- Essential Commodities Act, 1955(in relation to food).

The preamble to the FSSA states that itseeks to 'consolidate the laws relating tofood and to establish the Food Safety andStandards Authority of India for layingdown science based standards for articles offood and to regulate their manufacture, storage, distribution, sale and import, toensure availability of safe and wholesomefood for human consumption'. To thiseffect, the Act established an independentstatutory authority – the Food Safety andStandards Authority of India (FSSAI).

Food Safety and StandardsAuthority of Indi, The FSSAI acts as a single reference pointfor all matters relating to food safety andstandards, by moving from multi-level, multi-departmental control to a single lineof command.

Functions of the FSSAI

The FSSAI is mandated by the FSSA toperform the following functions:

• Framing of regulations to lay downthe standards and guidelines inrelation to articles of food, andspecifying an appropriate system ofenforcing various standards thusnotified

• Laying down mechanisms andguidelines for accreditation ofFood Safety and Standards in India certification bodies engaged incertification of food safetymanagement systems for food businesses

• Laying down procedure and guidelines for accreditation of laboratories and notification of theaccredited laboratories

• Providing scientific advice andtechnical support to centralgovernment and state governmentsin the matters of framing the policyand rules in areas that have a direct or indirect bearing on food safetyand nutrition

• Collecting and collating data onfood consumption, incidence and prevalence of biological risk, contaminants in food, residues ofvarious contaminants in foodproducts, identification of emergingrisks and introduction of a rapidalert system

• Creating an information networkacross the country so that the public, consumers, Panchayats and son receive rapid, reliable and objectiveinformation about food safety andissues of concern

• Providing training programs forpersons who are involved or intendto become involved in foodbusinesses

• Contributing to the development ofinternational technical standards forfood and SPS standards

• Promoting general awareness aboutfood safety and food standards.

The FSSAI functions under theadministrative control of the Ministry ofHealth and Family Welfare. Thecomposition of the FSSAI is specifiedunder the FSSA, and its work is supportedby state food safety authorities. The mainpositions and institutions are:

Members of the FSSAI

• Food safety commissioner – Everystate is legally mandated to appointa food safety commissioner forimplementation of food safetystandards.

• Food safety officers – The foodsafety commissioners are mandatedto appoint food safety officers for agiven area, and assign to them thetask of performing functions underthis Act. The powers of the foodsafety officers include collectingsamples of food articles and gettingthem tested, seizing articles thatappear to be in violation of the lawand inspecting places where anyarticle of food is manufactured.

• Food analysts – Food analysts arealso appointed by the food safety commission and are tasked withcarrying out an analysis on any foodsample collected by the food safetyofficer, or by any purchaser of thatfood product.

• Designated officer – Every districtmust have one designated officer. That person has the authority toissue, revoke or renew a licence fora food business, or to prohibit thesale of any food article that violatesany provision of the Act. Thisofficer could also sanctionprosecution of any food business operator or recommend the same tothe food safety commissioner.

• Laboratories – The FSSAI cannotify laboratories and researchinstitutions for the purpose ofcarrying out testing of food samplesby appointed food analysts. Inaddition to state laboratories, theFSSAI also notifies privatelaboratories for the purpose ofcarrying out food safety tests, basedon their accreditation by theNational Accreditation Board forTesting and CalibrationLaboratories (NABL). It can alsonotify referral laboratories, to whichan appeal could be referred fromany of the state or accreditedlaboratories.

Food Safety and StandardsRegulations, 2011

Under the FSSAI, six regulations wereimplemented on 5 August 2011, coveringthe interests of food business operators' andconsumers. These regulations are the:
• Food Safety Standards (FSS)(Licensing and Registration)Regulation, 2011
• FSS (Packaging and Labelling) Regulation, 2011
• FSS (Food Product Standards andFood Additives) Regulation, 2011,Part I & Part II
• FSS (Prohibition and Restriction onSales) Regulation, 2011
• FSS (Contaminants, Toxins andResidues) Regulation, 2011
• FSS (Laboratory and SamplingAnalysis) Regulation, 2011.

Popular grade standards for foodproducts in India
Grading standards, popularly known inIndia as AGMARK GRADES, cover 213commodities in the categories of food grainand by-products, fruit and vegetables, spices and condiments, edible nuts, oilseeds, vegetable oils and fats, oil cakes, essential oils, pickles, fibre crops, forestproduce, livestock, dairy and poultryproducts. These standards were formulatedand notified under the AgriculturalProduce (G&M) Act 1937, by theDirectorate of Marketing and Inspection (DMI), under the Ministry of Agricultureand Farmer's Welfare, Government ofIndia. DMI has also prepared list ofcommon adulterants and simple screeningtests for their detection in food. The standards are denoted by an AGMARKlogo on the packages. Adherence to thesestandards by the trading communities isvoluntary except for blended vegetable oilsand fat spreads. Traders wishing to markettheir products with AGMARK certificationobtain a licence from DMI. Under theprovisions of the Act, the traders mustensure purity of raw material, hygienicprocessing conditions and adherence tograde standards depicted on the packages. Traders have their products tested inlaboratories by qualified personnel. Theofficials of DMI check the standards bytaking market samples, and periodicallycheck the records of the laboratories of thetraders. Thus, the quality of food productsis monitored by DMI, as has been the practice since 1935. Consumers rely on the quality and safety ofproducts marked with the AGMARK logoon the packages. However, owing to ashortage of manpower, the intensity ofquality checks by DMI is low; hence, consumer confidence in AGMARK products is diminishing. To regain themarket share of AGMARK products, thereshould be frequent and stringent checks, and quick action on traders not adhering tothe grade standards.The AGMARK product range covers mostfood items, and would ensure the safety ofconsumers if the provisions of the schemewere properly implemented. There could bean advantage in aligning the standards andregulatory provision of AGMARK withFSSAI.
The primary objective of this project was tounderstand food safety and standards inIndia to identify possible interventionsfor increasing food safety and bilateraltrade between India and Australia.Food safety is a shared responsibility ofgovernment, private firms and households.Any public standard-setting process thatdoes not invite private sector input andperspective would be highly flawed.Keeping this in mind, all the stakeholders were consulted who are involved in the foodvalue chain, to understand the food safetystandards in India. A field survey of women was conducted in the chosen surveyarea, street food vendors and modernretailers (those involved in the meat andvegetable value chains).

The objectives and approach were to:
• document and content analysis ofthe Food Safety Standards Rule (2011)
• evaluate general food safety standards followed by women in the metropolitan cities of Delhi (the capital of India) and Hyderabad
• evaluate food safety and standardsfollowed by the street food vendorsin Delhi and Hyderabad
• evaluate food safety and standardsfollowed by the meat and vegetablevalue chains

• increase awareness of food safetyissues to increase bilateral trade.

FOOD SAFETY AND STANDARDS ACT, 2006

- An Act to consolidate the laws relating to food and to establish the Food Safety and Standards Authority of India for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for human consumption and for matters connected therewith or incidental thereto.



FOOD SAFETY AND STANDARDS AUTHORITY OF INDIA (FSSAI)

A Statutory Body governing the Food Safety of the country

MANDATE:

Ensure availability of safe and wholesome food for human consumption

ROLE OF FSSAI:

- Creating Information Dissemination Network across the country about food safety
- Capacity Building for various stakeholders
- Contribute to development of International Technical Standards for Food products, Sanitary and Phyto-Sanitary Standards
- Promote general awareness about Food Safety and Food Standards
- Procedure and guidelines for Risk Analysis methodologies, food safety plans etc.
- Collect and collate data on food consumption, Incidence and Prevalence of biological risk, Contaminants in food, Residues of contaminants in food and introduction of rapid alert system

SafeFood3 Solutions

Various Good Practices

Good practices directly conected to food issues

- ✓ good agricultural practice (**GAP**)
- ✓ good catering practice (**GCP**)
- ✓ good housekeeping practice (**GKP**)
- ✓ good hygiene practice (**GHP**)
- ✓ good laboratory practice (**GLP**)
- ✓ good manufacturing practice (**GMP**)
- ✓ good retail practice (**GRP**)
- ✓ good storage practice (**GSP**)
- ✓ good transport practice (**GTP**)

GHP

Good Hygiene Practice refer to procedures that must be undertaken and hygiene conditions that have to be fulfilled and monitored at all stages of production or trade in order to guarantee food safety.

Good Hygiene Practice consists of practical procedures and processes that return the processing environment to its original condition (disinfection or sanitation programmes); keep building and equipment in efficient operation (maintenance programme); control of cross-contamination during manufacture (usually related to people, surfaces, the air and the segregation of raw and processed product).





LOCATION, LAYOUT & FACILITIES

Location & surroundings
Layout & design of food establishment premises
Equipment & containers
Facilities

- Water Supply
- Drainage & Waste disposal
- Personnel facilities and toilets
- Air quality and ventilation
- Lighting

GMP

Good Manufacturing Practice denotes all the actions that must be undertaken and conditions to be fulfilled in order to ensure that production of food, wrapping materials and other materials expected for contact with food, is executed in proper way to guarantee safe end products and safe food for human consumption.

Good Manufacturing Practice consists of practical procedures and processes that ensure quality system, provide consistent manufacture and control of products by qualitative criteria and conformity assessing criteria with intended purpose as required by the marketing authorisation and specification of the product. It is part of the quality assurance which ensures that food products are consistently produced and controlled to the quality standards appropriate to their intended use.







Principles of HACCP



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Codex Alimentarius Commission ...!!!

- The Codex Alimentarius Commission
- Created in 1963 by FAO and WHO to develop food standards & guidelines
- Codes of practice under the Joint FAO/WHO Food Standards Programme.
- To protect health of the consumers and ensuring fair trade practices in the food trade throughout world.

Foundation of HACCP

Pre Requisite Program:

- Documented PRP's - for the production of safe & wholesome food.

Selection of raw materials:

- A list of raw materials, ingredients, additives, chemicals & product contact materials.

Product and Process design:

- A product hazard assessment - includes evaluation of raw materials, process aids, storage and distribution.

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Foundation of HACCP

Process control:

- A flow diagram of process with CCP's identified.

CCP plan:

- Review of CCP records and signature by a member of management daily.
- Corrective actions detailed in writing during CCP failure.
- Records should be kept in a corrective action or deviation file.
- Corrective actions should be effective in preventing recurrence of the problem.
- Person monitoring CCP should be aware of the critical limits and corrective actions.

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Codex HACCP 12 steps & 7 Principles methodology …!!!



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1. Conduct a hazard identification and risk assessment

List all potential hazards associated with each step

- What can go wrong ?
- Is it likely to occur ?
- Could it cause an adverse health effect ?
- How can we control it ?
- Is this the best approach ?

- For each identified food safety hazards acceptable levels shall be determined & recorded.
- These levels must meet the requirements as laid down in laws and regulations and defined by customers.

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2. Risk assessment

Risk assessment

Likelihood / Probability

Severity		High (3)	Medium (2)	Low (1)
	High (3)			Control measures
	Medium (2)		Control measures	Control measures
	Low (1)	Control measures	Control measures	Control measures

Control Measure

- Any *activity* that can be used to *prevent , eliminate or reduce* to an acceptable level a food safety hazard.

3. Establish Critical Limits

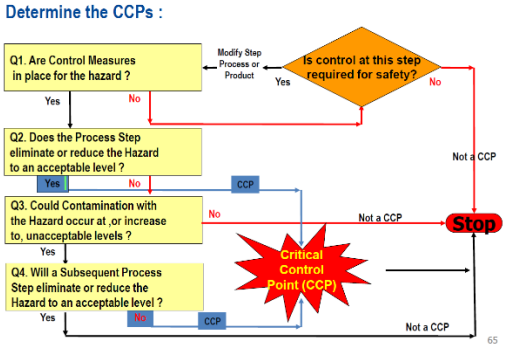
- Establish *target levels* and *tolerance* for **Critical Limits** which must be met to ensure each CCP is under control

4. Establish a Monitoring system

- Establish a *monitoring system* to *ensure control* of the CCP by *scheduled testing* or observations.

- Monitoring Procedures:
  - Who?
  - What ?
  - When?
  - Where?
  - How?

5. Determine the critical Control Points

6. 

6. Establish Verification Procedures

- Establish verification procedures, consisting of:
  - Verification of monitoring
  - Verification of Corrective action

7. Establish Documentation

- Establish *documentation* concerning all *procedures and records*

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POST HARVEST EQUIPMENTS

