Food processing

1.1 Introduction

India has emerged a leading producer of certain food products such as buffalo meat, black tea, milk, and fruit and vegetables. The country is in possession of premium food products such as Basmati rice, Darjeeling tea and Alphonso mangoes to offer to the world.

1.2 Factors Influencing the Consumers to seek Processed Foods

Some of the factors which have led to the growth of processed foods in India are:

a) Emerging urban and rural middle class population with requisite purchasing power.
b) Socio-cultural changes, strongly influenced by the communication media.
c) Changing demographic pattern.
d) Increase in working women population.
e) Consumer competitiveness with alternate and substitute products, and
f) Entry of modern and self-service market outlets.

1.3 Constraints in Food Processing Sector

Despite being one of the largest producers of food items, only 2.0% of the total produce is processed as against an average of 40.0% in many developing and 70.0% in most developed countries. Moreover, because of the bottlenecks present in the supply chain, about 30.0% of the harvested produce is spoilt during distribution to the consumers.

The factors that have impeded the growth are summarized below:

a) Non-availability of the right quality of processable raw materials.
b) Seasonal excesses and scarcities of raw material causing wide fluctuations in the prices. c) High taxation.
d) Complicated administrative and legislative processes.
e) Streamlining of food laws.
f) Lack of interface between research institutions and the farmers and also between research institutions and the processors.
g) Indifference about the quality systems in the food processing sector.
h) Lack of awareness of intellectual property rights, and
i) Unpreparedness of the industry to meet the challenges posed by WTO agreement.

POST HARVEST PROCESSING

8.1 Introduction

Fruits and vegetables are important constituents of our diet and they serve as a vehicle of nutrients like vitamins, minerals, sugars and fiber. However, being harvested from farm or field they are prone to contain dirt, soil, bacterial contamination, extraneous matter making them unfit for direct consumption by consumers. Hence, processing interventions are necessary to make fruits and vegetables free from all the above mentioned materials. Also, their processing is required to increase their shelf life as well as to prepare a number of value added products from them. Fruits and vegetables are processed by various methods like low temperature, thermal treatment, concentration, freezing and irradiation. But prior to subjecting fruits and vegetables to such treatments, all fruits and vegetables undergo some preliminary operations. Each processing method is based on certain principles and each has its own advantages and disadvantages.

8.2 Post Harvest Preliminary Processing Operations

The preliminary processing operations of fruits and vegetables are sorting, grading, washing, peeling, sizing, blanching, etc. The importance of each operation is discussed below.

8.2.1 Sorting and grading

Sorting and grading are terms which are frequently used interchangeably in the food processing industry, but strictly speaking they are distinct operations. Sorting is a separation based on a individual physical properties of raw materials such as weight, size, shape, density, photometric property, etc. while grading is classification on the basis of quality incorporating commercial value, end use and official standards. The selection of fruits and vegetables is important from processing point of view for the manufacture a particular end product. The fruit should be ripe, but firm and evenly matured while vegetable should be tender and reasonably free from soil, dirt, etc. They should be free from blemishes, insect damage and malformation. Over ripe fruit is generally infected with microorganisms and would yield a poor quality finished product. After this preliminary sorting, the fruits and vegetables are graded. This is necessary to obtain a pack of uniform quality as regards size, colour, etc. It is done manually or with the help of grading machines.

8.2.2 Washing

The graded fruits and vegetables are washed with water in different ways, such as soaking and subsequent washing in running water or sprayed with water or dry air to remove surface adhering material. A thorough wash is very essential for improved microbiological quality of final product. Vegetables may preferably be soaked in a dilute solution (0.1%) of potassium permanganate or sodium hypochlorite solution to disinfect them. Agitation of the washing water is effected generally by means of compressed air or a force pump or propeller-type equipment. Among all, spray washing is the most efficient method.

8.2.3 Size reduction

Fruits and vegetables are processed either as whole or into small pieces by size reduction. Size reduction involves peeling, coring and sizing. Peeling is done to remove unwanted or inedible material and to improve the appearance of the final product using a peeler (Fig. 8.1) while coring is done to remove central inedible portion using a corer (Fig. 8.2). There are five main methods of peeling. They are flash peeling (e.g. for root crops), knife peeling (e.g. for citrus fruits), abrasion peeling (e.g. for potato), caustic peeling (e.g. for guava, orange segments) and flame peeling (e.g. onion and garlic). Some of these are given below:

a. Hand peeling

Many of the fruits and vegetables are peeled and cut by hand with the help of special knives.

b. Peeling by heat

Some fruits and vegetables, particularly certain varieties of peaches and potatoes, are scalded in steam or boiling water to soften and loosen the skin, which is subsequently removed easily by hand. It usually involves exposing the fruit or vegetable to a temperature of 40: .C for 10-60 seconds where by the skin bursts and retracts facilitating its easy removal by means of pressure sprays. To achieve good results, the fruits and vegetables should be of uniform size and maturity. Using this method, there is practically no loss of flavour and the product is of uniform colour, free from any blemishes.

c. Lye peeling

Fruits and vegetables such as peaches, apricots, sweet orange, carrots, sweet potatoes, etc. are generally peeled by dipping them in boiling caustic soda or lye solution of 1 to 2 percent strength, for short periods, ranging from 0.5 to 2 minutes depending on the maturity of the fruit or vegetable. The hot lye loosens the skin from the flesh underneath. The peel is then removed easily by hand. Any traces of alkali is removed by washing the fruit or vegetable thoroughly in running cold water or preferably by dipping it for a few seconds in a very weak solution of hydrochloric or citric acid.

d. Flame peeling

It is used only for garlic and onion which have a papery outer covering. This is just burnt off.

Fig. 8.1 Fruit peeler

Fig. 8.2 Pineapple corer and its use

8.2.4 Blanching

Blanching refers to the mild heat treatment given to fresh produce such as vegetables to inactivate enzymes. Polyphenol Peroxidase (PPO) is most important groups of enzymes causing browning, off-flavour development in fruits and vegetables. PPO cause oxidation of phenolic compound namely Catechin, Gallic acid, Chlorogenic acid and Caffeic acids. Besides PPO certain peroxidase and pectic enzymes are also require inactivation. Pectic enzymes such as Pectin methyl esterase (PME) and Polygalacturonase (PG) are highly meat resistance and if failed to inactivate may lead to loss of cloud in citrus juices and serum separation in fruits and vegetables products, respectively. Their inactivation is the index of blanching. Blanching also improves colour, flavour and nutritional quality. Usually it is done with boiling water or steam for short periods, followed by cooling. In small scale industries, the fruit or vegetable to be blanched is placed in a wire of perforated basket, which is first dipped in hot water (88-99 C) for about 2-5 minutes. Microwave treatment is also used for blanching. Blanching requirement varies with different fruit or vegetable and depends upon relative enzyme concentration and maturity of commodity.

8.2.5 Ripening

Ripening before processing may be required for certain fruits such as avocado, banana, kiwifruit, mango, nectarine, papaya, peach, pear, plum, melons, etc. that are picked immature. Ethylene treatment can be used to obtain faster and more uniform ripening. The optimum temperature range for ripening is 15-25 C and within this range, the higher the temperature the faster the ripening. Relative humidity should be maintained between 90 and 95% during ripening. About 10 ppm ethylene in enclosed chamber is sufficient to initiate ripening. Ethylene is produced by the reaction between calcium carbide with moisture, mainly those involved in trade of fruits to hasten the ripening process. However, indiscriminate application may pose serious health hazards.

Commercially ethephon is used for the pre-harvest ripening of top fruits, soft fruits, tomatoes and coffee. It is also used to facilitate the harvest of fruit and berry crops (by loosening the fruits) and to accelerate post-harvest ripening. It is essentially a plant growth regulator with systemic properties. It penetrates into the tissues and is translocated. It decomposes into ethylene which is the active metabolite.

FREEZING: PRINCIPLE, METHODS AND APPLICATIONS

10.1 Introduction to Freezing

Freezing preservation is one of the most beneficial preservation methods. It involves, conversion of liquid content of food into ice crystals, which lowers down water activity and microbial growth is arrested due to cold shock. Pure water is frozen at 0^0C but since fruits and vegetables contain number of dissolved solids like sugars, acids, they freeze at below 0^0C.

10.2 Process of Freezing

During freezing the commodity cools down below their freezing point but don‟t freeze this phenomenon is called as ***super cooling***. It is shown by AB phase of curve (Fig. 10.1). At super cooled storage nuclei formation (***nucleation***) which is the first and most important step in ice-crystal formation in in freezing process. Here the temperature of water will be lower than 0^0C but it will remain in liquid form. At this stage, further lowering of temperature result in the formation of ice crystals. The second step is called ***crystal growth stage***. The release of heat of crystallization further enhances temperature (BC). Since food molecules contain substantial amount of soSlute hence, a progressive freezing occurs as depicted in Fig. 10.1. Various water molecules gathers around nuclei and due to subsequent addition, crystal growth occurs.

Nucleation may be either due to chance orientation of molecule or due to induction of nuclei from outside, but in fruits & vegetable mostly chance nucleation occur. In next step, crystal growth around these nuclei occurs and as a result of ice-crystal formation, heat of crystallization is generated, which cause increase in temperature of commodity. This T_{es} is shown by BC lines. So, time taken by freezing curve from initial cooling to E point of curve is known as ***thermal arrest time***. It determines how quick or slow freezing process is. After this point more ice crystal formation takes place and temperature lowers down.

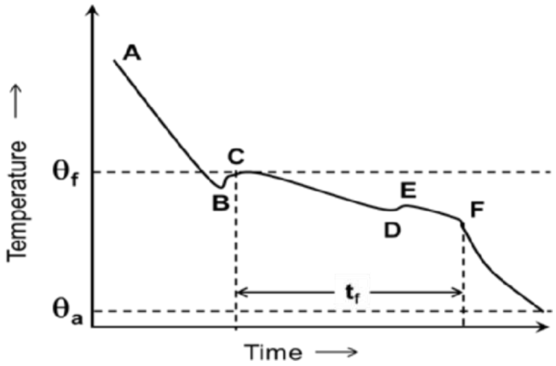

Fig. 10.1 Schematic diagram of freezing process

10.3 Advantages of Freezing

- No nutrient loss
- Retain freshness of commodity.
- Retain colour and flavor constituents.
- No microbial contamination.
- No respiration, hence longer shelf-life.

10.4 Effect of Freezing

Freezing process is divided into two broad categories *viz*. slow freezing and quick freezing.

a. ***Slow freezing***: when thermal arrest time is more than 30 min.
b. ***Quick freezing***: Thermal arrest time is less than 30 min.

In slow freezing, less number of nuclei is formed and as a result of slow freezing more concentrated solution is left in inter-cellular spaces which causes osmotic effect and liquid comes out from cells. This affects turgidity of cell and they collapse and on thawing cannot regain their original shape. Also, crystals forms are larger in size and pierce the cell membrane, puncture it and damage the cells. Whereas in quick freezing large numbers of nuclei are formed, hence having large numbers of crystals of smaller size evenly distributed within the cell and in the intercellular space. Since process is very quick, hence no concentration effect occur and commodities retain their original shape.

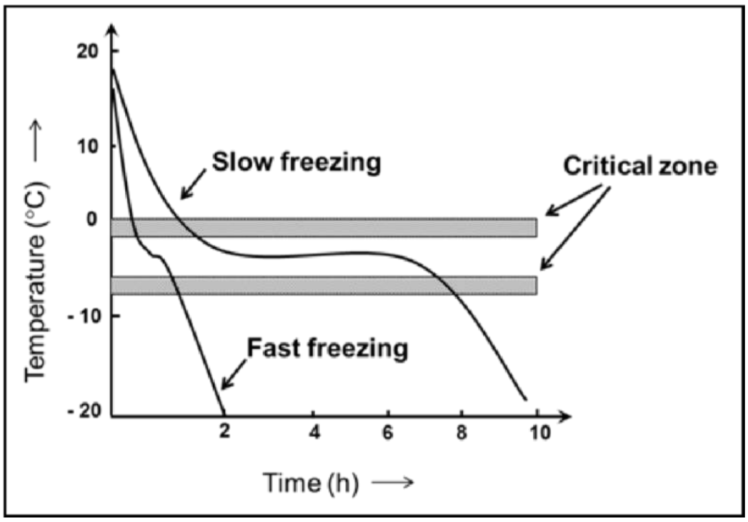

Fig. 10.2 Schematic diagram of temperature changes of food through the critical zone during freezing process

10.5 Freezing Methods

Mode of heat transfer in freezing food product is convection. Following points should be considered while selecting a freezing method:

a) Product dimension
b) Shape
c) Specific heat
d) Thickness of pieces
e) Freezing rate
f) Packaging
g) Food product components.

10.5.1 Air freezing

This is an oldest method of freezing and utilizes cool air having a temperature of -18 to -40 °C as freezing method. Different types of air freezing are:

a) Tunnel freezing
b) Fluidized bed Freezing
c) Air blast freezing

Air-blast freezers recirculate air over foods at between -30 °C and -50 °C at a velocity of 1.5-6.0 ms^{-1}. The high air velocity reduces the thickness of boundary air films. Air flow is either parallel or perpendicular to the food and is ducted to pass evenly over all food pieces.

Air freezing may result in

- Excessive drying
- Costly
- More efficient & more rapid heat transfer

- Less product dehydration & less frequent requirement of frosting.
- Short freezing time so less moisture loss.

10.5.2 Plate freezing

Packaged or fresh commodities are placed over the surface of plate cooled by refrigerant in a cylindrical scraped – surface heat exchanges. Double plates are specially used in retail storage. Plate freezing is a slow freezing process and packages must be of uniform thickness.

10.5.3 Liquid immersion freezing

Certain liquids are used as refrigerant which are known as cryogens. Example: Liquid Nitrogen, Liquid NO_2, Liquid Ammonia, etc.

10.5.4 Cryogenic freezing

Freezers of this type use a change of state in the refrigerant (or cryogenic) to absorb heat from the freezing food. The heat provides the latent heat of vaporization or sublimation of the cryogen. The cryogen is in intimate contact with the food and rapidly removes heat from all surfaces to produce high heat transfer coefficients and rapid freezing. The two most common refrigerants are liquid nitrogen and solid carbon dioxide. The main advantages of cryogenic freezing are as follows:

- Short freezing time due to high heat transfer
- Reduction in flavor loss
- Reduction in drip loss
- Reduction in oxidative changes
- Improved texture of the product
- Suitable for freeze sensitive products

The main disadvantage of cryogenic freezing is relatively high cost of cryogens.

10.6 Changes Associated With Ice Formation

10.6.1 Volume changes

The volume of ice is 9% greater than pure water when water is transformed into ice at 0°C, and hence upon freezing there is expansion of foods. However, few exceptions also exist. For example, highly concentrated sucrose solution. The degree of expansion depends upon (a) composition, (b) fraction of water that fails to freeze, and (c) temperature range.

- ***Moisture*** High moisture contents in foods produce greater changes in volume.
- ***Cell arrangement in fruits and vegetables*** Fruits and vegetables have intercellular air spaces which absorb internal increases in volume without large changes in their overall size.
- ***Concentration of solutes*** High concentrations reduce the freezing point and foods do not freeze or expand at commercial freezing temperatures.

- ***Freezer temperature*** It determines the amount of ice and hence the degree of expansion.
- ***Temperature range*** Observed changes depend upon the temperature range to which food product is exposed.

    a. Cooling of the specimen: contraction
    b. Ice formation: Expansion
    c. Cooling of ice-crystals: contraction
    d. Solute crystallization: contraction

- ***Crystallized components***: These include ice, fats and solutes, contract when they are cooled and this reduces the volume of food.

10.6.2 Concentration of non-aqueous system

During freezing water freezes first. So nearly all the dissolved substances are therefore concentrated in the diminished quantity of water. So in some manner it is similar to dehydration. Unfrozen phases have changed physico-chemical properties like pH, titrable acidity, ionic strength, viscosity, freezing point, or potential. Dissolved gases will be removed/expelled from the space. Water structure & water-solute interaction may be drastically increased, macromolecules will come together and many detrimental reactions may occur. As freezing progresses, concentration of a particular solute increases and eventually reaches or exceeds their respective saturation concentration crystallization

DRYING: PRINCIPLE, METHODS AND APPLICATIONS

11.1 Introduction

Drying and dehydration of fruits and vegetables is an age old method to preserve these products. Removal of the water (75-90%) present in fresh commodity results in reduction in the water activity and ultimately resistance against most of the deteriorative agents. The removal of water is carried out by the application of heat and this heat is usually supplied in the form of solar energy or artificially generated hot air. Removal of moisture and exposure of heat often results in poor textural attributes, loss in nutritive value (vitamins), discolouration and loss of flavouring components. Although both drying and dehydration are interchangeably used, drying is referred to removal of water to an equilibrium moisture content while dehydration is removal of water to an almost bone dry condition.

A number of processing steps are carefully designed to check all these adverse effects of drying. Some of the new technologies have been introduced in recent years to produce a wholesome and nutritive product. Partial dewatering by osmosis and impregnation soaking process before drying saves energy during drying and improves quality of dried product. Osmotic dehydration is gaining popularity, as the dehydrated product is more stable during storage due to low water activity by solute gain and water loss. The low water activity resulted in fewer rates of chemical reactions avoiding deterioration of the food. Osmotic dehydration in many cases is employed to increase sugar to acid ratio of acidic fruits, thereby to improve the taste, texture and appearance of dried product. The processing steps involve in drying of fruits and vegetables are summarized here.

11.2 Why Drying of Foods?

- Water activity is defined as the ratio of vapour pressure of food to that of the vapour pressure of pure water at a constant temperature. Reduction in water activity (a_w) so control/check over chemical and microbiological changes (deterioration).
- Reduction in weight, size and volume of food material. Hence bulk transportation becomes easier and cheaper.
- Packaging requirements are simple and cheap.
- Facilitate further processing. Example: grain drying for flour.

11.2.1 Water content in foods

Water is present in food as free or/and bound water. **Free water** is defined as water within a food that behaves as pure water. Unbound water is removed during the constant rate period of drying, when the nature of food does not have a great effect on the drying process.

Bound water can be defined as water that exhibits a lower vapour pressure, lower mobility and greatly reduced freezing point. So, bound water molecules have different kinetic and thermodynamic properties than ordinary water molecules. The a_w as affected by the extent of bound water is given in Table 11.1:

Table 11.1 Water activity as affected by the extent of bound water

Extent of bound water	Water activity (a_w)
Tightly bound water	< 0.3
Moderately bound water	0.3 to 0.7
Loosely bound water	> 0.7
Free water	~ 1.0

11.3 Mechanism of Drying

When hot air is blow over a wet food, heat is transferred to the surface and latent heat of vaporization causes water to evaporate. Water vapours diffuse through a boundary film of air and is carried away by the moving air. This create a region of lower water vapour pressure gradient is established from the moist interior of the food to the dry air. The gradient provides the "**driving force**" for water removal from the food.

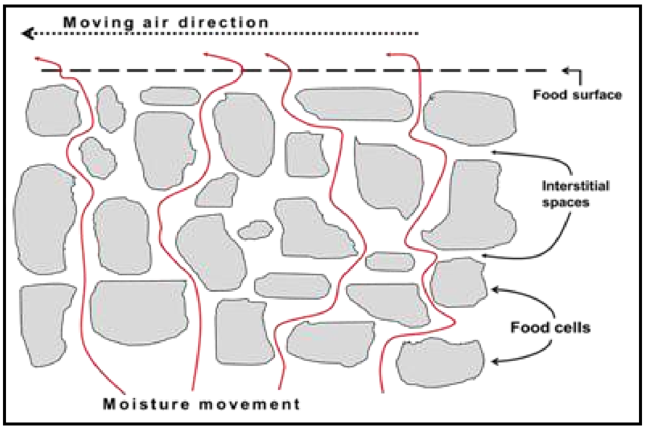

Fig 11.1 Schematic diagram of movement of moisture in the interstitial spaces of food cells during drying in fruits and vegetables

1. Liquid movement by capillary force.
2. Diffusion of liquids, caused by concentration gradient.
3. Diffusion of liquids, which are absorbed in layers at the surfaces of solid components of the food.
4. Water vapour diffusion in air spaces within the food caused by vapour pressure gradients.
5.

11.3.1 Phases of drying

1. Initial warm up period
2. Constant drying rate period
3. Falling drying rate period

In hygroscopic food material more than one falling rate period occurs. In the first period plane of evaporation moves inside the food and water diffuses through the dry solids to the drying air. It ends when plane of evaporation reaches to the centre of food and the partial pressure of water falls below the saturated water vapourpressure. Second falling rate period occurs when the partial pressure of water is below the saturated vapour pressure and the drying is by desorption. Falling rate period is the longest period during drying of food product.

Equilibrium moisture content (EMC) occurs when dry spots develop at the surface so less area exposed to dry air and evaporation decreases.

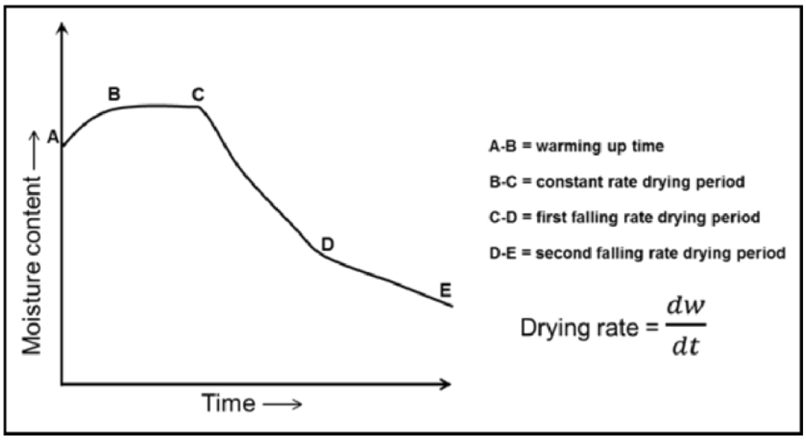

Fig 11.2 Schematic diagram of change in moisture content with time (drying rate)

There are 4 resistances to heat transfer in drying:

1. Resistance to external heat transfer
2. Resistance to internal heat transfer
3. Resistance to external mass transfer
4. Resistance to internal mass transfer

11.4 Drying Time

Drying time is the total time required for removal of water from food material. Drying time ***during constant rate period*** is inversely proportional to wet bulb depression while drying rate is directly proportional to wet bulb depression.

$$\text{Drying time (t)} = \frac{(w_i - w_t) \times \rho_s \times L \times d}{h \times (T_a - T_w)}$$

where, w_i = initial moisture content, w_t = moisture content at time t, ρ_s = bulk density of solid, L = latent heat of vapour, d = thickness of material, h = surface heat transfer coefficient, T_a = dry bulb temperature of hot air, T_w = wet bulb temperature of air, $(T_a\text{-}T_w)$ = Wet bulb depression

If velocity of air is increased, *h* and hence drying rate will increase and drying time is decreased.

Total drying time is the time required to attain critical moisture content ($w_t = w_C$)

Drying time ***during falling rate period*** is decided by predominantly by diffusion and to some extent by capillary action.

Drying time (t) due to diffusion = $\frac{4\,d^2}{\pi^2\,D} ln\left(\frac{8}{\pi^2}\left(\frac{w_c - w_e}{w - w_e}\right)\right)$ where, D = liquid diffusivity

w_e = equilibrium moisture content

Drying time (t) due to capillary = $\frac{\rho \times d \times L \times (w_c - w_e)}{h \times (T_a - T_w)} \times ln\left(\frac{w_c - w_e}{w - w_e}\right)$

if, $w_i < w_c$ it is falling rate $w_i > w_c$ it is constant rate

11.5 Factors Affecting Drying Rate

The factors that affect drying rate are external and internal factors.

The external factors are:

- Dry bulb temperature
- Relative humidity
- Air velocity
- Surface heat transfer coefficient Internal factors are:

- Surface to volume ratio
- Surface temperature
- Rate of moisture loss
- Composition i.e. moisture, fat

11.6 Effects of Drying on Foods

11.6.1 Shrinkage

During drying as moisture is removed and food material becomes smaller in size. This also affects bulk density (weight per unit volume) of food material. Slow drying results in development of internal stress. These rupture compress and permanently distort the relatively rigid cells, to give the food a shrink / shrivelled appearance. Such food material on rehydration absorbs water more slowly. Gelatinization of starch, denaturation of proteins, and crystallization of cellulose also affect rehydration characteristics. Rapid drying improves textural characteristics such as wettability, sinkability, dispersibility and solubility.

11.6.2 Case hardening

Formation of impervious layer over the surface of a dried food product characterized by inner soft and outer hard layer resulting in inadequate drying. It always occurs in food products rich in solutes and when initial drying temperature is very high. During the initial high temperature solute particles comes out and deposit at the surface resulting of building up of an impermeable layer which prevents further moisture removal. It can be prevented by using lower drying temperature.

11.6.3 Browning

Browning refers to change in the colour of food material to light to dark brown colour. This change in colour may occur by any of the three methods given below.

- Residual enzymatic browning: the residual enzymes especially in vegetables such as polyphenol oxidases cause oxidation that result in the change of colour.
- Maillard‟s reaction: it is the reaction between the amino group of proteins and reducing sugars of carbohydrates in presence of heat. This type of browning is most common in dried foods.
- Caramelization: it is the conversion of sugars only into dark coloured compounds in presence of heat.

11.7 Types of Drying

a. Hot Air drying: It includes spray drying, tray drying, fluidized bed drying, etc. In spray drying a fine dispersion of pre-concentrated food (40-60% moisture) is "atomized" to form fine droplets and then sprayed into a co-or counter-current flow of heated air at 150-300 C in a large drying chamber. Tray driers consist of an 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 at 0.5-5.0 m/s through a system of ducts and baffles to promote uniform distribution over and/or through each tray.

b. Microwave drying: It involves use of microwaves.

c. Freeze drying: It is also known as “lyophilization” and is usually used for drying heat sensitive food material by freezing the material and then reducing the surrounding pressure to allow the frozen water to sublimate directly from the solid phase (ice) to gas phase (water vapour).

f. Osmotic drying: This is explained in section 11.8

11.8 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.

11.8.1 Mechanism of osmotic dehydration

In osmotic dehydration process, a solid product of high moisture content is immersed in a concentrated solution (mainly of sugar or salt), which initiates three types of counter-current mass transfer. The diagrammatic presentation of osmotic dehydration is given in Fig. 11.3.

- Water outflow from the product to the surroundings solution as a result of osmosis through a semipermeable membrane.
- Solute transfer, from the solution to the product.
- Leaching out of the water-soluble component along with water from the product to the solution.

The last two mass transfers occur mainly because of diffusion. This counter current mass flow is due to the water and solute activity gradients across the cell‟s 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.

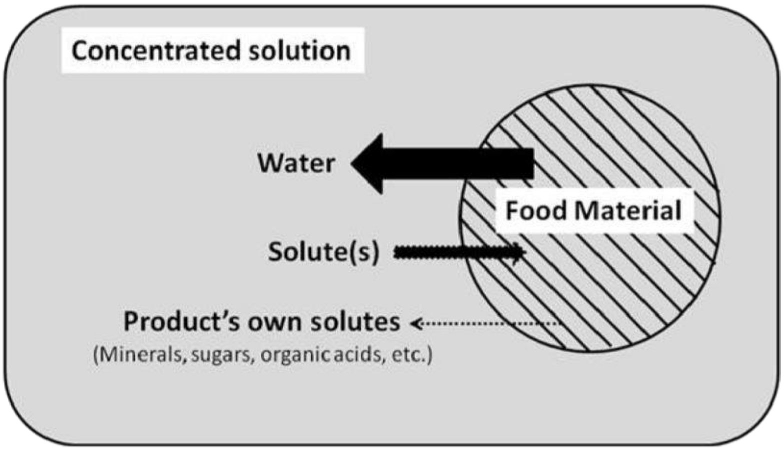

Fig.11.3 Diagrammatic presentation of Osmotic Dehydration

11.8.2 Osmotic agents and their requirements

Osmotic agent must have lower water activity (a_w), good solubility, constant concentration during processing, and it should be cheap. However, non-toxicity, inertness to food constituent and good sensory attributes is other added attraction, while selecting any osmotic agent. These are number of compounds available, satisfying above mentioned criteria, like, sucrose, glucose syrups, invert sugar, corn syrups, honey, and humectants such as sorbitol and glycerol. The kind of sugar utilized strongly affects the kinetics of water removal, and by increasing the molecular weight of osmotic substance, larger water removal could be achieved with little uptake of solutes. Low molecular weight substances (glucose, fructose, sorbitol etc.) favour the sugar uptake because of the high velocity of penetration of the molecules so that solid enrichment instead of dehydration is the main effect of the process. Sodium chloride (NaCl) is an excellent osmotic agent for vegetables and other animal derived products, but its use with fruits is restricted because of alteration in taste and bleaching of colour. Addition of NaCl to osmotic solution increased the driving force for drying owing to the a_w lowering capacity of salt. Synergistic effects between sugar and salt have also been observed. The use of blends comprising two or more solutes seems to be an attractive alternative.

11.8.3 Factors affecting osmotic dehydration

In any type of food product, many mechanisms can be acting at the same time, the relative contribution of which depends upon the following:

1. Nature of the product

2. Processing temperature

3. Operating conditions such as osmosis, diffusion, flux interactions and shrinkage.

11.9 Manufacturing Steps Involved In Drying of Fruits And Vegetables

11.9.1 Selection of raw material

The major cost involve in drying operation is the price of raw material. Hence good quality raw material is of prime importance. Immature or over mature fruits and vegetables often result in poor quality product. For example 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.

11.9.2 Washing

Before further processing raw materials should be thoroughly washed to remove the adhering dirt, dust and other foreign particles. 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. Water for this purpose must be of potable quality. To remove the traces of pesticides, colouring material commonly used nowadays to impart shining; some of the chemicals like dilute acids may also be added in washing water. Addition of sanitizers like chlorine based compounds is permitted to certain level for washing purpose. These sanitizers improve the microbiological quality of the finished product.

11.9.3 Peeling, trimming and sizing

Fruits and vegetables are either dried as whole or undergo size reduction before drying. 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.

11.9.4 Pre-treatments

In order to improve the quality of finished product fruits and vegetables they are invariable subjected to many pre-treatments. Some of the pre-treatments are summarized here.

11.9.4.1 Checking

Checking is an operation in which fruits specially raisins, prunes are dipped for a brief period in hot solution of alkali. This cause removal of waxy layer and it also improve the drying rate.

11.9.4.2 Blanching

Blanching is mild heat treatment given to some fruits and majority of vegetables primarily to inactivate the naturally occurring enzymes. These enzymes belong toperoxidase group like polyphenol peroxidases that catalyze the oxidation of phenolic substances, resulting in production of brown coloured compounds. The cell wall degrading enzymes, catalase (off-flavour), and ascorbic acid oxidase also get inactivated during blanching process. Blanching improves the colour of dried products, it aids to rapid reconstitution of dried product, it also increase drying rate, it also expels dissolved oxygen and it also improve bacteriological quality of the finished product.

11.9.4.3 Sulphiting

Sulphur dioxide and sulphites (usually sodium metasulphite or potassium metabisulphite) are well known antibrowning agents. The sulphur dioxide gas competes withperoxidases for the active sites and prevents the oxidation of phenolic substances. In many products that contain anthocyanin as major pigment, the colour of the product turned blue when exposed to acidic conditions. In such fruits or vegetables sulphur dioxide treatment may prove beneficial. The blanched or checked fruits or vegetables are exposed to fumes of sulphur dioxide by burning sulphur powder in an enclosed chamber. This is most widely used method of sulphuring. However, they can be dipped in solution of some sulphur salt. Proper penetration of sulphur dioxide is important to prevent internal darkening during drying. In fuming process, the sulphur dioxide absorption is faster as compared dipping. However the absorption is more uniform in later.

11.9.5 Drying

Drying of the fruits and vegetables is usually carried out in cabinet dryer. The material is loaded over perforated aluminium trays and dried using hot air. The temperature, velocity and the humidity of the air are important for drying process. It usually varies from commodity to commodity. A lower drying temperature is generally used for fruits, as there may be chances of case hardening. The temperature varies from 55-80^{o}C. To create perforation initially temperature is maintained towards higher side and them it is reduced. 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.