UNIT-11 METHODS OF FOOD PROCESSING – 1

Structure

11.1 INTRODUCTION

In the earlier unit we learnt about the principles and traditional methods of food processing. Now in the next two units we will find a detailed discussion on the different methods used today for food processing. Canning, dehydration, freezing, microwave processing, irradiation are common food processing methods used at home or at the industry level. Canning as a thermal processing method has been used for long. What does the process entail? What are the other thermal processing methods? These issues are discussed first in this unit, followed by a descriptive write-up on dehydration - one of the traditional methods of food processing. Freezing, microwave processing, irradiation and fermentation as other methods of food processing are taken up in the next unit.

Objectives

After studying this unit, you will be able to:

- enumerate the different methods of food processing
- enlist the different methods of thermal processing
- discuss the canning process and types of canned foods
- describe the different methods of dehydration

11.2 METHODS OF FOOD PROCESSING

Food is undeniably most vital to the survival of human beings. Hence, it must be processed using various scientific techniques. This is done to extend the shelf-life of foods as well as to ensure the quality and safety of the foods.

Over the years, several processing and preservation technologies have evolved, mostly by trial and error, for extending the storage life of food. As our scientific understanding of biological materials has accelerated in recent years so has the nature of the food industry, from a craft-based industry to a science-based manufacturing enterprise. Today, it is a big, dynamic, worldwide industry and undergoing continual change.

The fundamentals of food processing, as you may recall, involves the following two basic principles:

- Prepare the products fit for consumption.
- Destroy or inactivate pathogens found in food.

Based on these principles, the common unit operations for food processing include:

- Thermal processing: cooking, blanching, pasteurization, canning etc.
- Dehydration
- Cold preservation: refrigeration and freezing
- Fermentation
- Irradiation

We will learn about each of these operations in details, starting with thermal processing and dehydration in this unit.

11.3 THERMAL PROCESSING

Thermal processing *is the application of heat energy to the foods* with the following specific objectives:

- *Cooking:* Cooking is a primary process to make food more palatable and improve taste. This is not used as a preservation technique.
- *Blanching*: Blanching is defined as a mild heat treatment applied to tissue (usually plant) prior to freezing, drying or canning.
- *Pasteurization:* Pasteurization is a mild heat treatment to kill part of the microorganisms present in food. This process is usually combined with another preservation method. So primary objective of pasteurization is to kill pathogenic (milk) or spoilage (beers, fruit juices) microorganisms
- *Commercial Sterilization:* Sterilization is the most extreme heat treatment given for the preservation of food. Usually target organism is a heat resistant microorganism, most often a spore or schlerotia forming organism rather than a vegetative one (e.g. spore forming anaerobic bacteria – *Clostridium botulinum*)
- *Canning*: Canning is the process of applying heat to food that's sealed in a jar to destroy any microorganism that can cause food spoilage.

A brief description on each of the thermal processing method follows.

11.3.1 Cooking

All of us eat food either raw or in cooked form. Have you ever thought why we need to cook food? Cooking is a primary process to make food more palatable and improve taste. Note, this is not used as a preservation technique. You are aware of the various cooking methods used on day to day basis. At least six forms of cooking are available, namely:

1) Baking
2) Broiling
3) Boiling
4) Stewing
5) Roasting
6) Frying

While cooking, two preservation changes (at least) occur which include:

1. Destruction or reduction of microorganisms
2. Inactivation of enzymes

Other desirable changes that can occur during cooking include:

- Destruction of potentially hazardous toxins (endogenous, microbial)
- Alteration of color, flavor, texture
- Improved digestibility

11.3.2 Blanching

Blanching is used for variety of purposes. It is defined as *a mild heat treatment applied to tissue (usually plant) prior to freezing, drying or canning.* Why do we need to blanch foods?

Well, blanching is useful and its functions include:

- Inactivate most enzymes
- Some cleaning action
- Removes substances in some products
- Activates some enzymes (if controlled)
- Removes undesirable odors/flavors
- Softens fibrous material and decreases volume
- Expels air and respiratory gasses
- Preheating of product prior to canning

For frozen or dehydrated foods, major function is inactivation of enzymes, which can cause rapid changes in color, flavor and nutritive value. For canned products removing gases and preheating are very important to providing vacuum in can and proper sterilization.

Blanching as a pretreatment before drying has the following advantages:

- It helps in cleaning the material and reducing the amount of microorganisms present on the surface;

- It preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying;
- It shortens the soaking and/or cooking time during reconstitution.

Next, do you know how to blanch foods? There are different methods of blanching food as highlighted in Figure 11.1. The hot water blanch methodology is presented in box 1. What ever the method used, remember blanching is usually carried out at high temperature for a short time. Time of exposure, temperatures vary with type of product and further processing.

a. Hot water blanching <100°C

b. Steam blanching > 100°C

Figure 11.1 Methods of Blanching

Box 1: Hot water blanching

A suitable water-blanching method in traditional processing is as follows:

- The sliced material is placed on a square piece of clean cloth; the corners of the cloth are tied together;
- A stick is put through the tied corners of the cloth;
- The cloth is dipped into a pan containing boiling water and the stick rests across the top of the pan thus providing support for the cloth bag.

The average blanching time is 6 minutes. The start of blanching has to be timed from the moment the water starts to boil again after the cloth bag has been dipped into the pan. While the material is being blanched the cloth bag should be raised and lowered in the water so that the material is heated evenly. When the blanching time is completed the cloth bag and its content should be dipped into cold water to prevent over-blanching. 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.

During hot water blanching, some soluble constituents- water-soluble flavours, vitamins (vitamin

C) and sugars - are leached out. With potatoes this may be an advantage as inactivation of enzymes (catalase and peroxidase) makes the potatoes less prone to turning brown.

Next, can you name a few foods which are best blanched? Yes, green beans, carrots, okra, turnip and cabbage should always be blanched. On the other hand, blanching is not needed for onions, leeks, tomatoes and sweet peppers. You may have noticed that tomatoes are dipped into hot water for one minute when they need to be peeled but this is not blanching. Another practice you may have notices is to use or add sodium bicarbonate to the blanching water when okra, green peas and some other green vegetables are blanched. Have you wondered why? The chemical raises the pH of the blanching water and prevents the fresh green colour of chlorophyll being changed into pheophytin, which is unattractive brownish-green.

Finally, let us learn how to evaluate blanching efficiency? Normally, two of the more heat resistant plant enzymes, namely peroxidase and catalase are used to evaluate blanching efficacy. If both these enzymes are inactivated, it can be safely assumed that most other enzymes are also destroyed. Remember, blanching is a delicate processing step; time, temperature and the other conditions must be carefully monitored. Blanching time to inactivate enzymes are dependent on:

1. Type of food
2. Method or type of heating
3. Product size
4. Temperature of heating medium

In case of steam blanching, the food product is directly exposed to steam in place of using water as a medium for blanching, which avoids the loss of food soluble solids (flavours, vitamins, acids, sugars etc.) to blanching medium as well as solves the problem of disposing blanching medium after processing.

11.3.3 Pasteurization

You must be aware of the various pasteurized products available in the market. The most commonly used product being ‘milk’. Why do we need to pasteurize food? What does pasteurization entail? Let’s find out.

Basically, *pasteurization is a mild heat treatment to kill part of the microorganisms present in food.* So, the primary objective of pasteurization is to kill pathogenic (milk) or spoilage (beers, fruit juices) microorganisms. This process is usually combined with another preservation method. Typical other methods used in combination with pasteurization include:

1. Refrigeration as in the case of milk
2. Chemical additives - pickles, fruit juices
3. Fermentation (additives) - sauerkraut, cheeses
4. Packaging (anaerobic conditions) - beers, fruit juices

The severity of heat treatment for pasteurization depends on:

1. *Heat resistance of target microorganism*. Typical target organisms include *Coxiella burnetti*, a pathogenic rickettsia in milk, yeasts and molds - in high acid foods and fermented products and yeasts - in fermented beverages
2. *Sensitivity of product to heat treatment:* For many foods use of **H**igh **T**emperature **S**hort **T**ime (HTST) treatment is recommended, which destroys pathogenic microorganisms, but does not do too much damage to food quality.

Further, there are a few other physical and chemical factors which influence the pasteurization process. These include:

a. Temperature and time;
b. Acidity of the products;
c. Air remaining in containers.

For pasteurizing two categories of processes may be used as indicated in figure 11.2

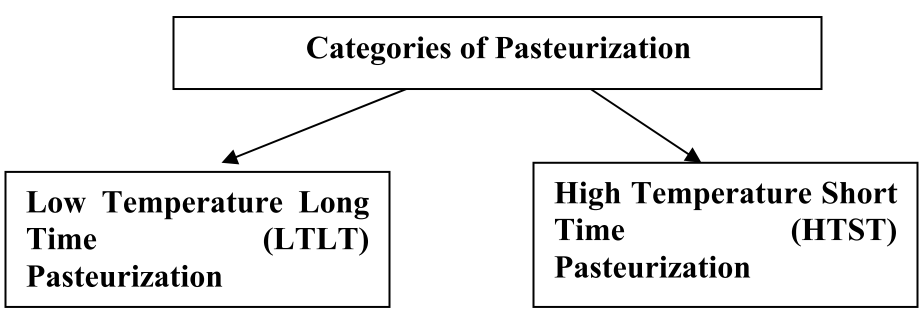


Figure 11.2 Categories of pasteurization

A discussion on each process follows:

a) *LTLT pasteurization*: In LTLT pasteurization, the pasteurization time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are used: *63 to 65°C over 30 minutes or 75° C over 8 to 10 minutes*.

In this first category of pasteurization processes it is possible to define three phases:

- Heating to a fixed temperature;
- Maintaining this temperature over the established time period (= pasteurization time);
- Cooling the pasteurized products: natural (slow) or forced cooling.

You would notice that, pasteurization temperature and time will vary according to:

- Nature of product; initial degree of contamination;
- Pasteurized product storage conditions and shelf life required.

b) *HTST pasteurization*: Rapid, high pasteurization is characterized by a pasteurization time in the order of seconds and temperatures of about 85° to 90°C or more, depending on holding time. Typical temperature/time combinations may be: *88°C for 1 minute; 100°C for 12 seconds; 121°C for 2 seconds*. While bacterial destruction is very nearly equivalent in low and in high pasteurization processes, the 121°C/2 seconds treatment give the best quality products in respect of flavour and vitamin retention. Such short holding times, however, require special equipment which is more difficult to design and generally is more expensive than the 63-65°C/30 minutes type of processing equipment.

In flash pasteurization the product is heated up rapidly to pasteurization temperature, maintained at this temperature for the required time, then rapidly cooled down to the temperature for filling, which will be performed in aseptic conditions in sterile receptacles. Taking into account the short time and rapid performance of this operation, flash pasteurization can only be achieved in continuous process, using heat exchangers. Industrial applications of pasteurization process are mainly used for the preservation of fruits and vegetable juices and especially for tomato juice.

The pasteurization of products packed in glass containers leads to a problem of a specific nature, which is referred to as ‘thermopenetration’. What is the thermopenetration concept? Let’s find out.

The thermopenetration problem is extremely important, especially in the case of the pasteurization of products packed in glass containers, because it is the determining factor for the success of the whole operation. During pasteurization it is necessary that a sufficient heat quantity is transferred through the receptacle walls; this is in order that the product temperature rises sufficiently to be lethal to microorganisms throughout the product mass.

The most suitable and practical method to speed up thermopenetration is the movement of receptacles during the pasteurization process. Rapid rotation of receptacles around their axis is an efficient means to accelerate heat transfer, because this has the effect, among others of rapidly mixing the contents. The critical speed of for this movement is generally about 70 rotations per minute (RPM). This enables a more uniform heating of products, reducing heating time and organoleptic degradation.

Heating may precede or follow packaging. It is convenient to separate heat preservation practices into two broad categories: one involves heating of foods in their final containers, the other employs heat prior to packaging. The latter category includes methods that are inherently less damaging to food quality, where the food can be readily subdivided (such as liquids) for rapid heat exchange. However, these methods then require packaging under aseptic or nearly aseptic conditions to prevent or at least minimise recontamination. On the other hand, heating within the package frequently is less costly and produces quite acceptable quality with the majority of foods and most of our present canned food supply is heated in the package. Tetra pack available in the market for fruit juices are the best example for aseptic packaging.

11.3.4 Commercial Sterilization

Sterilization is the most extreme heat treatment given in preservation of food by heat. Usually target organism is a heat resistant pathogenic microorganism, most often a spore or schlerotia forming organism rather than a vegetative one. Common examples include *Clostridium botulinum*-a spore forming anaerobic bacteria and Putrefactive anaerobe. The basic characteristics of these microorganisms are highlighted in box 1.

Clostridium botulinum	Putrefactive anaerobe (PA) 3679 and FS 1518 *Clostridium sporogenes*
• Can grow and produce toxin at pH > 4.6 • Obligate anaerobe, spore-forming, heat resistant pathogens. • Assumed to be ubiquitous in soil. • Has several strains. Types A and B are most heat resistant. • Ingestion of toxins produced them causes food poisoning. • Toxins are destroyed at 100°C for 10 minutes.	• Non-toxic facultative anaerobe. • Resistance to heat similar to *Clostridium botulinum.* • Generally used to determine safe thermal processes instead of *Clostridium botulinum.*

It is important to remember that bacterial destruction is a logarithmic function, complete destruction not probable to make food commercially sterile for extended shelf-life at room temperature. *Hence, only 90 % destruction is aimed and this is called commercial sterility.* Thermal conditions that are needed to produce commercial sterility depends on:

1. Nature of the food
2. Storage conditions post processing
3. Heat resistance of target organism
4. Heat transfer characteristics of food, container and heating medium
5. Initial load or quantity of organisms present

Of these, the nature of the food, primarily the pH of food, is the most significant determinant of how severely the food will be processed. Based on the pH, therefore, all foods can be divided into three categories as highlighted in Table 11.1.

Table 11.1: Classification of foods based on pH

High Acid Foods	**Low Acid Foods**	**Acid Foods**
Those foods with pH < 3.7 Thermal processes are based on the destruction of • yeasts and molds. • Spore former do not grow at pH < 3.	Those foods with pH > 4.5 *Examples:* Asparagus, beans, corn, potatoes, cauliflower, cantaloupe, watermelons, banana	Those foods with pH of 3.7 to 4.5 *Examples* include: Apples, blueberries, peaches, tomatoes, orange, grapefruits, grapes Thermal processes are based on the destruction of • *Bacillus coagulans* • *Bacillus polymyxa*

It is also important to note that to determine a heating process for a particular food, we must determine the:

A. Destructive effects of heating on target organism (and food), and

B. The rapidity of food heating up.

Most food components and microorganisms obey first order reaction kinetics, which means that the destruction rate is dependent on initial concentration. We can find a heat treatment, which will take care of the target microorganism while allowing only minimal quality damage to food components. To determine thermal resistance of a microorganism at a specific temperature, the following steps are required:

- Heat at constant "known" temperature for different times.
- Recover surviving cells.
- Plot survival curve - e.g. time versus number survivors.

As line transverses one log cycle of survivor number represents a 90% reduction in number of survivors - because this is a first order reaction - this % reduction remains constant i.e. for the next log cycle another 90% reduction occurs. The time required to reduce one-log cycle of survivor at a particular temperature is known as *D-value* at that temperature.

The sterility index is represented by F value. This index often has a subscript representing the specific temperature and a superscript indicating the z value of the particular organism (F temperature change required to change the thermal death time by a factor of 10) thus represents the F value of *C. botulinum* at 121.1 (250°F). The temperature of 121°C is usually used as a reference temperature and is always indicated as "Fo". Since similar first order reactions occur for various food nutrients and qualities, a similar procedure can be used to analyze their loss as "thermal resistance curves". Another useful system for representing temperature response by biological systems is the Q value, which is the change in reaction rate for a 10°C temperature change.

The F value for *C. botulinum* is the time required to reduce by 12 D the number of viable spores and this has become the Standard Heat Process for foods which have the potential to have *C. botulinum* outgrowth (i.e. pH > 4.5). For a temperature of 121°C,

Fo = 12 D = 2.45 minutes = Sterilizing Value.

This is the **12 D concept** for canning operations. Thus if there were 10^{12} spores present in a can of food and it received a 12 D process, then there would be only 1 spore left. There are some food spoilage organisms that are more thermally resistant than *C. botulinum*. For foods that contain these microorganisms and for foods with pH > 4.5, processors typically process to 5 D. This would give a probability of loss due to spoilage of less than 1 can per 1000 for normal contamination.

While on the topic of sterilization, we also need to highlight that the following two methods of heat sterilizing foods are employed.

1. Foods can be heat sterilized then placed into a sterile container - aseptic processing
2. Foods can be placed into a non-sterile container then the entire container is processed - conventional canning

These steps are commonly done at the food canning establishments, where the actual processing is done. We will learn more about the canning process in the next sub-section.

Before we move on to canning, we need to emphasize here that like thermal destruction of microorganisms, thermal destruction of enzymes is also carried out during sterilization. Heat process for enzymes are carried out for the inactivation of enzymes. While enzymes or microorganisms are killed, the quality attributes of the food are also being destroyed or lost in a similar logarithmic manner. Ideally, if a troublesome enzyme is to be inactivated, heating the food product just enough to disrupt it without too much damage to the desirable quality attributes is preferred.

Check Your Progress Exercise 1

1. Fill in the blanks:

(i) The two basic principles of food processing are-------------------- and ---------------------- .

(ii) The application of heat energy to foods is referred to as ---------------------------------- .

(iii) Any two changes that occur in food on cooking are --- and -- .

(iv) --------------------- is the determining factor for the success of pasteurization process.

(v) Change in reaction rate for a 10^0C temperature change is referred to as ---------------------

2. What do you understand by the term blanching? What are the functions of blanching?

----

3. List a few benefits of blanching.

----

4. What do you mean by the term ‘pasteurization’? Also, explain the types of pasteurization.

----

5. List a few of thermal conditions required to produce commercial sterility.

Let us learn about the canning process.

11.3.5 Canning

You must have seen the markets flooded with canned products. Can you name a few of such products? Yes the canned juices, canned aerated drinks or the canned fruits etc. Have you ever given a thought to how canning of foods is done? Well read the following section and get to know all about canning and its uses.

It is in 1795 that *Nicolas Appert* (1749-1841), French cook-confectioner (figure 11.2), developed a process to preserve food during several months. The principle was to condition food products thermetically and to sterilise them with heat (100°C). The process was called canning and is defined as *a process for conservation of food and its nutritional qualities for long duration at ambient temperature, obtained by a process associating a heat treatment and a waterproof packing*. In simple terms*, canning is the process of applying heat to food that's sealed in a jar/can to destroy any microorganism that can cause food spoilage.*

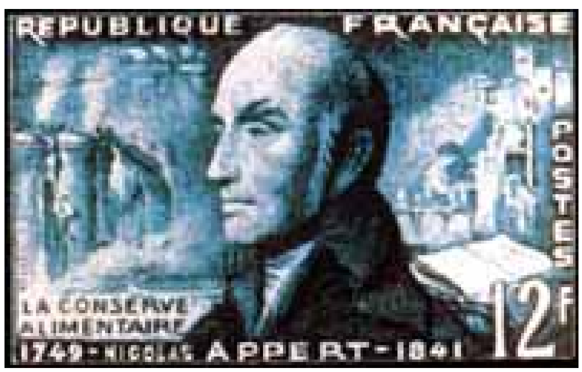


Figure 11.2: Nicolas Appert

Based on *Appert's* methods of food preservation the packaging of food in sealed airtight tin-plated wrought-iron cans was first patented by an Englishman, *Peter Durand*, in 1810. A can of roast veal taken on *Parry's* voyage to the Arctic in 1824 is highlighted in figure 11.3.

Figure 11.3: Can of Roast Veal

Since Parry's voyage in 1824, there are an enormous variety of canned foods available today, which differ both in terms of type of ingredients and method of processing used. The main types are as follows:

Types of canned foods:

1. Some foods form convection currents when being heated inside a can and so are heated faster since self-mixing - as foods become more viscous this mixing action is reduced (e.g. fruit juices, milk, brine packed vegetables, syrup packed fruits, gravies)
2. Some foods can only be heated by conduction - no currents are formed and heat must be passed from one molecule of food to the next toward the center - these foods heat very slowly (e.g. Thick purees, mash packs, layered products like spinach)
3. Some foods change modes during heating from convection to conduction - foods which contain large amount of starch which gels on heating - gives "broken heating curve" (e.g. cream style corn, condensed soups)

For conduction heated food, the slowest heating point "cold point" is the geometric center of the can. For convection heated food, the slowest heating point is along the vertical axis near the bottom of the can.

Let us next learn about the process of canning.
(refer to Figure)

Process of Canning

The basic principles of canning have not changed dramatically since *Nicholas Appert* and *Peter Durand* developed the process. Heat sufficient to destroy microorganisms is applied to foods packed into sealed, or "airtight" containers. The canned foods are then heated under steam pressure at temperatures of 240-250°F (116-121°C). The amount of time needed for processing is different for each food, depending on the food's acidity, density and ability to transfer heat. For example, tomatoes require less time than green beans, while corn and pumpkin require far more time.

Canning uses metal or glass containers into which food is placed and sealed under reduced atmospheric pressure. Food does not completely fill the container; a *headspace i*s required for expansion of food during heating. The headspace cannot be more than 10% of the total container volume. The containers are then processed in steam or hot water at temperatures above 115°C after which they are cooled. The cooking vessels required for these high temperature cooks must be capable of handling steam at pressures in excess of 1 atmosphere (14.7 psi). To have a steam environment at a temperature greater than 100°C elevated pressures are used.

Still Retorts are used in canning plants for heating foods in glass containers or different sizes of cans. These retorts are usually cylindrical in shape and may be oriented vertically or horizontally with a heavy lid or door on top or at one end. Containers are loaded in layers into perforated retort baskets or crates. This may be done manually or by machine. Filled crates are placed into the retorts, the lid is closed and steam is introduced. Water with steam injection is used for glass containers since they cannot handle the heat stress. An overriding air pressure maintains enough pressure so that the water does not “boil” at temperatures greater than 100°C. Temperature in a retort is regulated by means of a steam automatic valve. At the end of the “cook” cycle, the retort is showered/flooded with cold water (metal cans) or injected with cold water just below the surface of the hot water (glass jars). The containers are removed once they are cooled.
The sequence of operations employed in canning are highlighted in the next section. This will give you a good idea as to what canning as a procedure involves.

Sequence of operations employed in Canning

In a simplified manner, the main operations employed in canning can be described as follows:

Food preparation	Preparation procedures will vary with the type of food. For fruit, washing, sorting, grading, peeling, cutting to size, pre-cooking and pulping operations may be employed.
Can/receptacle	This may be carried out manually or by using sophisticated filling machinery. The ratio of liquid to solid in the can must be carefully controlled and the can must not be overfilled. A headspace of 6-9 mm depth (6-8% of the container volume) above the level of food in the can is usual.
Vacuum production	This can be achieved by filling the heated product into the can, by heating the can and contents after filling, by evacuating the headspace gas in a vacuum chamber, or by injecting superheated steam into the headspace. In each case the can end is seamed on immediately afterwards.
Thermal processing	The filled sealed can must be heated to a high temperature for a sufficient length of time to ensure the destruction of spoilage micro-organisms. This is usually carried out in an autoclave or retort, in an environment of steam under pressure.
Cooling	The processed cans must be cooled in chlorinated water to a temperature of 37°C. At this temperature the heat remaining is sufficient to allow the water droplets on the can to evaporate before labeling and packing.
Labeling and packing	Labels are applied to the can body and the cans are then packed into cases.

So now you can appreciate how interesting and scientific this whole process of canning is. In the end, can you also suggest what are the advantages of canning food? Try listing them down and tally your responses with the advantages listed herewith.

The main advantages of canned foods are: (a) they are safe and hygienic and have reasonably good nutritional value; (b) they are economical as the entire contents can be eaten, whereas

30~50% of fresh food cannot be eaten due to perishing and loss in weight; and (c) they come in a wide assortment, from main dishes to side dishes and desserts, and have utility value; and (d) they keep for a long period.

With canning, we come to the end of the thermal processing method.

11.4 DEHYDRATION

The technique of drying is the oldest method of food preservation practiced by mankind. The removal of moisture, which is actually dehydration or drying, prevents the growth and reproduction of microorganisms causing decay and minimizes many of the moisture mediated deterioration reactions. Further, removal of moisture brings about substantial reduction in weight and volume, thus minimizing packing, storage and transportation costs and enable storability of the product under ambient temperatures. The sharp rise in energy costs has promoted a dramatic upsurge in interest in drying worldwide over the last decade.

What then is dehydration? What is the theory/principle behind this method of processing? How are foods dehydrated? These are a few aspects which we will learn about now in this section..

Theory/Principle of Drying

Drying can be defined as the application of heat under controlled conditions to remove the majority of the water normally present in a food by evaporation. The main purpose of dehydration is to extend the shelf life of foods by a reduction in water activity (a_w). This will inhibit microbial growth, however the processing temperature will not normally be sufficient to cause inactivation, thus care will needed to be taken with the product on subsequent rehydration. Drying does cause deterioration in the eating quality and nutritive value of the food. The role of the food engineer is to design a plant that will minimize such detrimental effects while obtaining efficient drying rates. Typical foods that are important commercially include; sugar, coffee, milk, potato, flour, beans, pulses, grains, nuts, breakfast cereals, tea and spices.

From our discussion above, it is clear that dehydration deals with reduction in the moisture content of foods. In this context, therefore, understanding where and how the water is present, and assessment of moisture content in foods becomes crucial. These are the aspects discussed in the next section.

11.4.1 Expression of Moisture Content

Moisture content, you would realize, is expressed in one of two ways i.e dry weight basis (dwb) or wet weight bases (wwb). Moisture content is calculated using the following formula:

$$m.c.(m) = \frac{\text{mass of water}}{\text{mass of sample}} \text{ x } 100$$

where mass of sample can be made up of water and dry matter or solids. Thus

$$m.c.(m) = \frac{\text{mass of water}}{\text{mass of water} + \text{solids}} \text{ x } 100$$

On a dry weight basis, moisture is calculated as

$$M = \frac{\text{mass of water}}{\text{mass of solids}}$$

The mechanism content on wet basis can be converted to dry basis vice versa using the following equations:

$$\text{m} = \frac{100\text{M}}{1+\text{M}} \text{ or } \text{M} = \frac{\text{m}}{100\,(1 - \text{m}/100)}$$

Moisture content (w.w.b.) is most often used in food composition tables, whereas moisture (d.w.b.) is more often encountered with sorption isotherms and drying curves. You will learn about sorption isotherms in Unit , Block of this course. Next, how to determine the moisture content of foods? The amount of water in a food is most easily determined by taking a representative sample of the food and drying it in an oven to constant mass.

Next crucial aspect to learn, in the context of dehydration, is about the types of water present in food. This information will help you understand the mechanism of drying, which is discussed in the next section. So read it carefully.

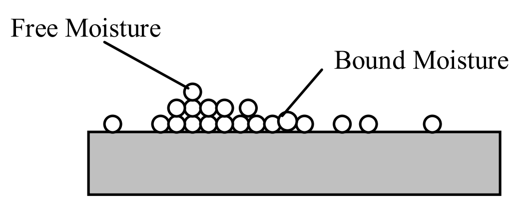
11.4.2 Classification of Types of Water Found in Food

Water may be present in several different forms in the food as highlighted herewith:

Water of hydration: This moisture is chemically bound to the constituents of the material and in most cases would not be considered in moisture content determinations. It is considered to be an integral part of the material.

Bound Water: Water which is in some way bound to the food so that it exerts a vapour pressure less than that of pure water. It can often be thought of as the first layer of water molecules attached to a surface.

Free Water: Water which is bound by such minute forces, that its vapour pressure is equal to the vapour pressure of pure water. It can be found as free water, in cavities and wide capillaries. This can often be thought of as the second and subsequent layers of moisture attached to a surface. The heat of adsorption of this moisture is equal to the normal heat of vaporisation of water at the same temperature.



Absorbed Moisture: It is the moisture that has passed through cell walls and entered the cytoplasm of the cell. It is this form of water that is believed to account for the hysteresis between the sorption and desorption equilibrium moisture content isotherms, described later.

The absorption of water by an organic, chemically inert material is a complex process which is not entirely understood. This complexity becomes much greater when biological materials are involved. This complexity is due principally to the fact that water may be present in several different forms as highlighted above.

With the basic understanding of moisture content and dehydration in general, let us now look at the mechanism of drying.

11.4.3 Mechanism of Drying

Drying as a mechanism, you will realize, involves the removal of free moisture from the surface and also moisture from the interior of the material. How does this mechanism work? When hot air is blown over a wet food, heat is transferred to the surface, and the latent heat of vaporisation causes water to evaporate. Water vapour diffuses through a boundary film of air and is carried away by the moving air. This creates a region of lower water vapour pressure at the surface of the food, and a water vapour pressure gradient is established from the moist interior of the food to the dry air. This gradient provides the driving force for the removal of water from the food. Water moves to the surface by the following mechanisms:

1) Liquid movement by capillary forces.
2) Diffusion of liquids, due to differences in concentration of solutes in different regions of food.
3) Diffusion of liquids that are adsorbed in layers at surfaces of solid components of the food.
4) Water vapour diffusion in air spaces within the food caused by vapour pressure gradients.

So you have seen that dehydration involves the application of heat to vapourise water and some means of removing water vapour after its separation from the food. Hence it is a combined/simultaneous (heat and mass) transfer operation for which energy must be supplied. A current of air is the most common medium for transferring heat to a drying tissue and convection is mainly involved. In order to assure products of high quality at a reasonable cost, dehydration must occur fairly rapidly.

Four main factors affect the rate and total drying time, which include:

- The properties of the products (the moisture content, surface area to volume ratio, surface temperature and rate of moisture), loss especially particle size and geometry;
- The geometrical arrangement of the products in relation to heat tansfer medium (drying air);
- The physical properties of drying medium/ environment;

- The characteristics of the drying equipment/drier (the dry bulb temperature, relative humidity).

Other factors which influence the rate of drying include:

1) The fat content of the food-Higher fat contents generally result in slower drying as moisture is trapped within the food.
2) The method of preparation- Cut surfaces loose moisture more rapidly than through skin.
3) The amount of food placed in a drier in relation to its size- In a given drier, faster drying is achieved with smaller quantities of food.

So far we have looked at the concept, theory and mechanism of dehydration. A wide variety of techniques/methods are employed world over for dehydrating foods. The next section presents a review on these methods/techniques.

11.4.4 Drying Techniques and Methods

Several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of food products including fruit and vegetables. While *sun drying* of fruit crops is still practiced for certain fruit such as prunes, figs, apricots, grapes and dates, *atmospheric dehydration* processes are used for apples, prunes, and several vegetables. *Continuous processes* as tunnel, belt trough, fluidised bed and foam-mat drying are mainly used for vegetables. *Spray drying* is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture / high sugar fruits like peaches, pears and apricots.

Well then we have a wide variety of methods to choose from. Which method to select for which product? This choice is crucial. Factors on which the selection of a particular dryer/ drying method will depends include:

- Form of raw material and its properties;
- Desired physical form and characteristics of dried product;
- Necessary operating conditions;

- Operation costs.

Primarily, there are three basic types of drying process:

- Sun drying and solar drying;
- Atmospheric drying including batch (kiln, tower and cabinet dryers) and continuous (tunnel, belt, belt-trough, fluidised bed, explosion puff, foam-mat, spray, drum and microwave);
- Sub-atmospheric dehydration (vacuum shelf/belt/drum and freeze dryers).

The scope is expanded to include low temperature, low energy process like osmotic dehydration.

As far dryers are concerned, one useful division of dryer types separates them into air convection dryers, drum or roller dryers, and vacuum dryers. Using this breakdown, Table 11.2 indicates the applicability of the more common dryer types to liquid and solid type foods.

Table 11.2 Common dryer types used for liquid and solid foods

Dryer type	Usual food type
Air convection dryers	
Kiln	pieces
cabinet, tray or pan	pieces, purées, liquids
Tunnel	pieces
continuous conveyor belt	purées, liquids
belt trough	pieces
air lift	small pieces, granules
fluidized bed	small pieces, granules
Spray	liquid, purées
Drum or roller dryers	
Atmospheric	purées, liquids
Vacuum	purées, liquids

Vacuum dryers	
vacuum shelf	pieces, purées, liquids
vacuum belt	purées, liquids
freeze dryers	pieces, liquids

Let us learn about the different drying methods now.

Types of Drying Processes for the Dehydration of Foods

You have learnt earlier that there are three basic types of drying processes – sun and solar drying, atmospheric drying, which includes techniques like batch and continuous processes, and sub-atmospheric dehydration. Let us learn about these processes.

Sun and Solar Drying

The use of solar energy to preserve the food items is probably the oldest form of food reservation and is still practiced today for foods such as raisins. Sun and solar drying of fruits and vegetables is a cheap method of preservation because it uses the natural resource/ source of heat i.e. sunlight. The advantages of the process are that the energy is free, renewable and non-polluting. On the other hand, the disadvantages are that it can be very labour intensive, suffers from a lack of control and is prone to deterioration by biochemical reactions or microbiological or insect infestation.

Sun/solar drying method can be used on a commercial scale as well at the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period. The fresh crop should be of good quality and as ripe (mature) as it would need to be if it was going to be used fresh.

Note, poor quality produce cannot be used for natural drying. Different lots at various stages of maturity (ripeness) must NOT be mixed together; this would result in a poor dried product. Some varieties of fruit and vegetables are better for natural drying than other; they must be able to withstand natural drying without their texture becoming tough so that they are not difficult to reconstitute. Some varieties are unsuitable, because they have irregular shape and there is a lot of wastage in trimming and cutting such varieties.

As a general rule plums, grapes, figs, dates are dried as whole fruits without cutting/slicing. Some fruit and vegetables, in particular bananas, apples and potatoes, go brown very quickly when left in the air after peeling or slicing; this discoloration is due to an active enzyme called poly-phenoloxidase. To prevent the slices from going brown they must be kept under water until drying can be started. Salt or sulphite in solution give better protection. However, whichever method is used, further processing should follow as soon as possible after cutting or slicing.

As a food scientist, what should interest us is to learn about the process of sun/solar drying as such. The mechanism of sun and shade drying and the use of specific solar dryers has been described in Box 3 herewith.

Box 3: Sun and solar drying- method

Sun drying

As discussed earlier, the main problems for sun drying are dust, rain and cloudy weather. Therefore, drying areas should be dust-free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover. In order to produce dust-free and hygienically clean products, fruit and vegetable material should be dried well above ground level so that they are not contaminated by dust, insects, livestock or people. All materials should be dried on trays designed for the purpose; the most common drying trays have wooden frames with a fitted base of nylon mosquito netting. Mesh made of woven grass can also be used. Metal netting must NOT be used because it discolours the product. The trays should be placed on a framework at table height from the ground. This allows the air to circulate freely around the drying material and it also keeps the food product well away from dirt. Ideally the area should be exposed to wind and this speed up drying, but this can only be done if the wind is free of dust. With 80 cm x 50 cm trays, the approximate load for a tray is 3 kg; the material should be spread in even layers. During the first part of the drying period, the material should be stirred and turned over at least once an hour. This will help the material dry faster and more evenly, prevent it sticking together and improve the quality of the finished product. Products for sun drying should be prepared early in the day; this will ensure that the material enjoys the full effect of the sun during the early stages of drying. At night the trays should be stacked in a ventilated room or covered with canvas. Plastic sheets should NEVER be used for covering individual trays during sun drying. Dry or nearly dry products can be blown out of the tray by the wind. However, this can be protected by covering the loaded tray with an empty one; this also gives protection against insects and birds.

Shade drying

Shade drying is carried out for products which can lose their colour and/or turn brown if put in direct sunlight. Products which have naturally vivid colours like herbs, green and red sweet peppers, chilies, green beans and okra give a more attractive end-product when they are dried in the shade. The principles for the shade drying are the same as of sun drying. The material to be dried requires full air circulation. Therefore, shade drying is carried out under a roof or thatch which has open sides; it CANNOT be done either inside conventional buildings with side walls or in compounds sheltered from wind. Under dry conditions when there is a good circulation of air, shade drying takes little more time than is normally required for drying in full sunlight

However, beside this there has been much research to develop simple systems that could be used in developing countries and areas where obtaining other energy sources is limited. The simplest way of carrying out solar drying is to lay the material on the ground in the sun. However this leaves the product open to the spoilage reactions described earlier. Simple structures, such as the solar dryers, can be cheaply built which will enhance the drying conditions. Information on this follows.

Solar Dryers

There are many different designs for solar dryers, these range from simple cabinet dryers, convection dryers, shelf dryers to more complicated semi-artificial dryers that include some form of heat storage device. Typical foods that would be dried using solar dyers include bananas, barley, coffee beans, pepper, peanuts, sweet potato, tea and wheat.

A simple solar dryer can be built and the main parts of the solar dryer being;

1. Drying space, where the material to be dried is placed and where the drying takes place.
2. Collector to convert solar radiation to heat.
3. Auxiliary energy source (optional).
4. Means for keeping drying air in flow. Could be a chimney or a fan.
5. Heat storage unit (optional).
6. Measuring and control equipment (optional).

The drying process can be improved slightly by using some form of heat storage for when sunlight is not incident on the dryer as this means the drying period can be extended using surplus energy and some degree of temperature control may be utilised. Efforts to improve the solar drying process have included the use of forced air circulation and combination with other drying processes, such as conventional drying processes and osmotic drying.

Check Your Progress Exercise 2

1. Define the following:

(a) Canning

(b) Dehydration

----

2. List the sequence of canning operations.

----

3. Give a few advantages of the canned foods.

----

4. What is the main principle behind drying?

----

5. Mention a few factors that affect drying rate and total drying time.

So far we learnt about solar/sun drying method. Now have a look at the atmospheric and sub-atmospheric drying methods. A brief review of the different methods follows.

Tray and Tunnel Dryers: Tray and tunnel dryers are widely used in the food industry. In both cases the material being dried is supported on multiple trays, with the hot air being directed at high speed between and across the surfaces. Tray dryers operate in batch mode. However, two or more of the larger versions of this dryer may be linked to provide semi-continuous operation.

Tunnel dryers provide a natural extension to this concept and are continuous. The tunnel dehydrator is by far one of the most flexible systems, which is in commercial use. In its simplest form it consists of a rectangular tunnel which will accommodate trucks containing the trays on which the product to be dried is uniformly spread.

Conveyor (or Band) Dryers: In the conveyor (or band) dryer, the product is distributed on a moving belt, typically of a perforated plate, that passes through a tunnel like structure in which vertical airflow is strictly controlled. With the exception of transfer operations (or occasional deliberate stirring of the bed), the individual particles remain fixed in position with respect to one another.

This type of drying system is very similar to the tunnel system except that the material is conveyed through the hot air system on a continuous moving belt. The system has the advantage that the high cost of handling products both before and after drying using trays is substantially reduced. This drying system is used for downstream operations such as cereal puffing.

Rotary Dryers: Rotary dryers are widely used to dry relatively large throughputs of granular products and by products in a number of industries, including the food industry. Rotary dryers are characterised by a slowly rotating cylindrical drum, which is normally inclined at a small angle (0 - 5°) to the horizontal. The product to be driedis introduced into the upper end and dried product is withdrawn at the lower end. There are a number of different types of rotary dryer; one of the most common is the cascading rotary dryer. Typical food products dried in rotary dryers include fish scraps, wheat residues, cocoa beans, nuts, cooked cereals, flour, sugar and spent grains.

Fluidized, Torbed and Agitated Bed Dryers

Fluidization occurs when a flow of fluid upwards through a bed of particles (ranging from fine powders to particulate foods such as diced carrots) reaches sufficient velocity to support the particles without carrying them away in the fluid stream. The bed of particles then assumes the characteristics of a boiling liquid, hence the term fluidization. The fluid responsible for fluidization may be a gas or air the choice of which will confer different properties on the fluidizing system.

Fluidized bed dryers can be used for either of the following situations:

a) Finish or final drying of products partially dried by other techniques; for example, blueberries dried osmotically are then dried at 170°C for 4 minutes in a high temperature fluidized bed.

b) Drying foods completely - examples of this include the drying of grains, soybeans, peas, beans and vegetables.

The complete drying of foods in fluidized beds may be carried out either by the use of a “high temperature short time” process or by a more gradual process at a lower temperature. Delicate fruits such as blueberries are dried by the HTST process (170°C for 8 minutes), whereas oil seeds are dried over a longer period of time (55-65°C for 4 hours). This longer, cooler process is required so that the quality of the oil and the germination characteristics of the grain are not affected.

Torbed Dryer, on the other hand, is a variation of the fluidized bed dryer. This is designed for use with particulate foods. Torbed dryers are used to dry hazelnuts, carrots, mushrooms, beef dices and shrimps. Grated cheese can also be dried in fluidized beds.

The distinction between *agitated bed* and *fluidized bed drier* is a narrow one, since in each case an upward velocity of air sufficient to support the food particles is applied. In the case of the former the bed is less vigorously stirred than in the latter. It is necessary with driers of this type to decrease the air velocity as the particle dries in order to prevent the particles being lost from the system. The final drying is accomplished using bins.

The fluidized bed principle represents an important advance that can be used for a wide range of particulate materials. Apart form the commercial drying of peas, beans and diced vegetables it is also used for drying potato granules, onion flakes and fruit pieces.

Explosion puffing: Explosion puffing has been recognized as one of the most significant developments in dehydration technology. In explosion puffing, partially dehydrated pieces from a preliminary stage drying are heated in a closed rotating cylindrical container known as a 'gun' until the internal pressure has reached a predetermined value. When this point has been reached the gun is discharged instantly to atmosphere. During this process a certain amount of water is vaporized but, more important, the explosive or flashing conditions cause a highly porous network of capillaries to be developed within the particles. This porosity enables the final dehydration to be achieved much more rapidly (approximately twice) than would have been the case with conventionally dried products. It also bestows on the product the ability to reconstitute extremely rapidly.

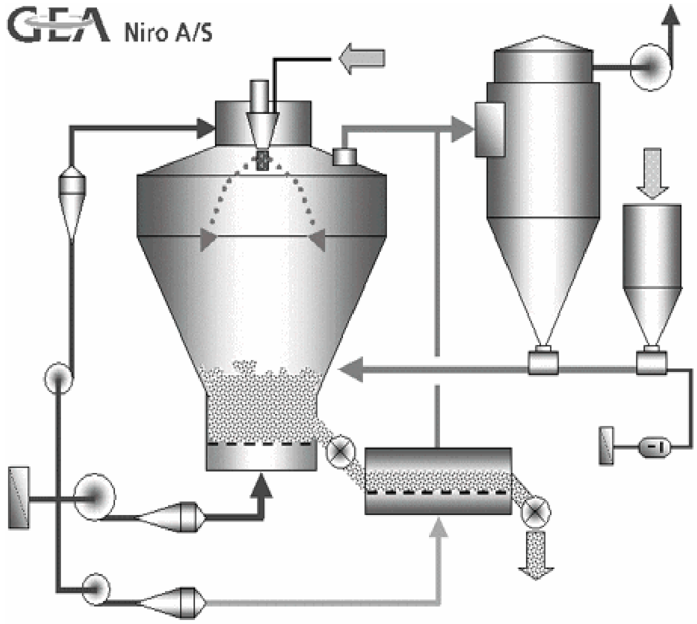
Vacuum Puff Drying: The vacuum puff process has been developed for drying liquids under vacuum. The development of processes for drying liquids under vacuum came from the observations made on the freeze drying of orange juice concentrate. The rate of drying of the product in the liquid state was double that in the frozen state (freeze drying) and the dried product had a highly porous structure, which exhibited good rehydration properties. This was due to the fact that under vacuum conditions the liquid tends to foam and produce a film structure, which dries to give a highly porous solid.

Foam Mat Drying: This process is a development of the vacuum puffing but, instead of employing a vacuum to foam the material, it is initially foamed by suitable agents and then subjected to drying under atmospheric pressure. The equipment required for this is similar to the continuous band drier described previously, without the vacuum facilities.

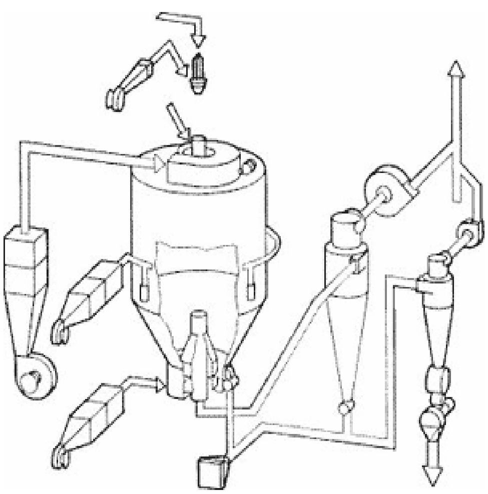
Microflake-T dehydration: This technique involves the drying of a continuous sheet of foam 20 mm thick on a continuous stainless steel belt. The later is heated from below by steam and above by a high velocity air stream and drying times are reported to be about one tenth of the standard process.

Spray Drying: Spray drying is a unique drying process since it involves both particle formation and drying. It is most suitable for drying of liquid foods such as milk, fruit juices etc. The feed is converted into small droplet with the help of a nozzle or atomizer and then droplets are dried in a drying chamber when they come in contact with hot air. The product is separated from hot air by a cyclone separator and collected. The characteristics of the resultant powder can be controlled and powder properties can be maintained constant throughout a continuous operation. With the designs of spray dryers available, it is possible to select a dryer layout to produce either fine- or coarse-particle powders, agglomerates or granulates.

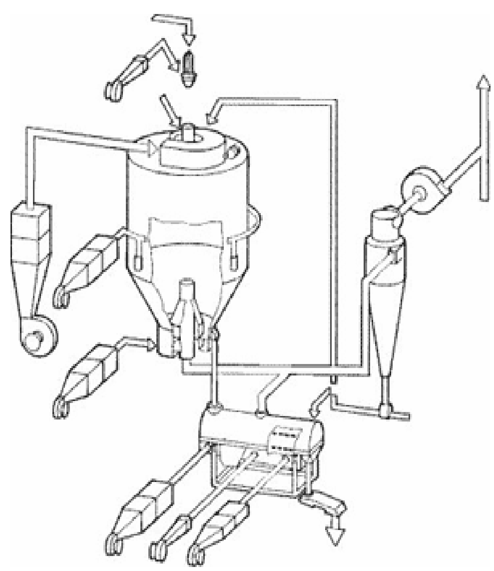
Spray drying involves the atomisation of feed into a spray, and contact between spray and drying medium resulting in moisture evaporation. The drying of the spray continues until the desired moisture content in the dried particles is achieved, and the product is recovered from the air. There are various types of spray dryers such as two stage dryers, three stage dryers, multi stage dryers and compact spray dryers. Figure 11.1 illustrates the different spray dryers.



Multi stage spray dryer



Two stage spray dryer



Compact spray dryer

Figure 11.1: Different types of spray dryers

Foam Spray Drying: This is an extension of spray drying and involves the use of gases dissolved under pressure prior to spraying. The main advantage is that the density of the product is reduced by half and the dried particles are hollow spheres surrounded by thick walls of dried material. The foam process produces particles having many internal spaces and relatively thin wall.

Roller Drying (Drum drying): One of the important techniques for drying liquid food products is the roller drier. Like spray drying, roller drying can only be used for liquid products, which can either have a low viscosity or be highly viscous to paste like. Roller dryer is also called drum drying. The metal rollers are heated from inside with condensing steam and the product dries as a thin film by contact with the cylinder surface. While spray drying is done purely by vaporisation, evaporation is the main process in roller drying since the saturated vapour pressure is equal to the atmospheric pressure. The product to be dried is spread as a thin film on to the surface of the hot drum and after one revolution is scraped off by a knife, in the form of flakes, scales or powder. A large part of the roller dried whole milk powder is destined for chocolate manufacture. Roller drying is extensively used for the manufacture of 'instant' potato products, potato flakes, and also for all liquid food products including infant foods, fruit products, eggs, milk and beverages.

Freeze Drying: The Techniques of freeze-drying have been developed over the past half-century for the purpose of preserving certain biological materials, which are costly to produce, and which are highly unstable. Perhaps its most notable successes have been in the preservation of human plasma for transfusion purposes and in the preservation of the early samples of penicillin during the war. Today it has numerous applications in the pharmaceutical industry, but it falls far short of requirements for the food industry. The cost of the process is also still too high to make it a practical proportion for many of the cheaper foods.

In this method of removal of water the product is frozen and the temperature maintained below the triple point of the constituent aqueous solutions so that the water vapour can be sublimed from the frozen state. There is, therefore, a direct transfer from solid to vapour without the ice melting and passing through the liquid phase. The process is carried out under high vacuum to provide a high vapour diffusion potential and is accelerated by supplying heat in some convenient form, either radiant, conductive or from microwaves. It is generally considered that as a means of dehydration. It produces a dried product of the highest quality and therefore is potentially an extremely attractive method.

The major aspects of the mechanism of freeze drying are:

(a) The removal of vapour from the subliming ice front within the material,
(b) The removal of vapour from between the food particles,
(c) The supply of heat to the food particles,
(d) The supply of heat to the ice within the food particles

The conventional freeze drying unit consists of a vacuum chamber into which trays of the material to be dried can be placed, and a source for supplying heat to the material so that the sublimation process can be accelerated. The usual method is to arrange the trays on or between the heated plates, which are either electrically heated or internally heated with steam. The vacuum is produced either with a mechanical pump, suitable steam ejectors, or refrigerated condensers.

Other Types of Drying: There are many other dryer types available, such as;

- Osmotic Drying
- Impingement Drying
- Microwave and Dielectric Drying
- Superheated Steam Drying
- Electrohydrodynamic Drying

So far we have learnt about the dehydration process and the different methods which can be used and are in use in the food industry for dehydration of foods. Next, we shall look at yet another form of preservation method i.e. concentration.

11.5 PRESERVATION BY CONCENTRATION

First what do we mean by concentration. Concentration is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation or thermal evaporation process.

But, why do we need to concentrate foods. Foods are concentrated for many of the same reasons that they are dehydrated; concentration can be a form of preservation but this is true only for some foods. Concentration reduces weight and volume and results in immediate economic advantages. Nearly all liquid foods which are dehydrated, need to be concentrated before they are dried. This is because in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment. Further, increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.

Foods are also concentrated because the concentrated forms have become desirable components of diet in their own right. Thus, fruit juices plus sugar with concentration becomes jelly. The more common concentrated fruit and vegetable products include items as fruit and vegetable juices and nectars, jams and jellies, tomato paste, many types of fruit purées used by bakers, candy makers and other food manufacturers.

The level of water in virtually all concentrated foods is in itself more than enough to permit microbial growth. Yet while many concentrated foods such as non-acid fruit and vegetable purées may quickly undergo microbial spoilage unless additionally processed, such items as sugar syrups, jellies and jams are relatively "immune" to spoilage; the difference of course is in what is dissolved in the remaining water and what osmotic concentration is reached.

Removal of water by concentration also increases the level of food acids in solution (particularly significant in concentrated fruit juices). While the preservation effects of food concentration are important, the main reason of most food concentration is to reduce food weight and bulk. Tomato pulp, which is ground tomato devoid of the skins and seeds, has a solid content of only 6 % and so a 3.78 liter can would contain only 230 g of tomato solids. Concentrated to 32% solids, the same can would contain 1.38 kg of tomato solids or six times the value of product. For a manufacturer needing tomato solids such as producer of soups, canned spaghetti or frozen pizza the saving from concentration are enormous.

So you realize how concentration as a method of preservation is useful in the food industry. Further, we would also like to know how the process of concentration is carried out. A brief discussion on the different methods of concentration which are used at the home or industrial level follows.

11.5.1 Methods of concentration

We define the concentration process as one that starts with a liquid product and ends up with a more concentrated, but still liquid and still pumpable concentrate as the main product from the process.

In most cases, it is essential that the product be subject to minimal thermal degradation during the concentration process, requiring that temperature and time exposure must be minimized. This and other requirements brought on by the physical characteristics of the processed product have resulted in the development of a large range of different evaporator types. An evaporator, as you may have realized, is generally used to concentrate the liquid food products. Some of the common evaporators frequently used in food industry include falling film evaporators, rising film evaporators, forced circulation evaporators and plate evaporator. We shall not go into the details of the functioning of these evaporators, but you should know that in almost all evaporators the heating medium is steam, which heats a product on the other side of a heat transfer surface.

Here, however, we would like to bring to your notice some of the simple techniques one can use for evaporation during concentration process. These include:

a. *Solar concentration:* As in food dehydration, one of the simplest methods of evaporating water is with solar energy. A typical example of this method is production at farm level in developing countries of fruit pastes/leathers (such as apricot or plum pastes).

b. *Open Kettles:* Some foods can be satisfactorily concentrated in open kettles that are heated by steam. This is the case for jellies and jams, tomato juices and purées and for certain types of soups. High temperatures and long concentration times should be avoided in order to reduce or eliminate damage. It is also necessary to avoid thickening and burn-on of product to the kettle wall as these gradually lower the efficiency of heat transfer and slow the concentration process. However, when the process is under control, this type of evaporation is still highly recommended for small scale operations in developing countries. It is a quite widely used system, mainly for jellies, jams and marmalades.

c. *Vacuum evaporators:* It is common to construct several vacuumised vessels in series so that the product moves from one vacuum chamber to the next and thereby becomes progressively more concentrated in stages. With such an arrangement the successive stages are maintained at progressively higher degrees of vacuum, and the hot water vapour produced by the first stage is used to heat the second stage, the vapour from the second stage heats the third stage and so on. In this way maximum use of heat energy is made. Such system is called a multiple effect vacuum evaporator. It is a widely used system for concentrated tomato paste.

d. *Freeze Concentration:* This process has been known for many years and has been applied commercially to orange juice. However, high processing costs due largely to losses of juice occlude [unclear] to the ice crystals, have limited the number of installations to date.

Equipped with the knowledge of how to concentrating foods, with or without evaporators, let us next learn about the applications of evaporators in food and dairy Industry, where concentration is carried out. This is highlighted in Table 11.3.

Table 11.3: Some representative applications of evaporators in food and dairy industry, where concentration is carried out

Milk products	**Fruit juices**
Whole & skim milk	Orange & other citrus juices
Condensed milk & Cream	Apple & other pomaceous juices
Buttermilk	Mixed juices, Tropical fruit juices Coconut milk
Milk permeate & proteins	
Sweet whey & sour whey	**Other applications**
Whey permeate & protein	Baby food
Lactose solutions	Egg white
Vegetable juices	Fermentation liquids
Tomato juice	**Hydrolyzates**
Carrot juice	Hydrolyzed whey
Beetroot juice	Hydrolyzed milk
Grass juice	Soup seasoning
Extracts	Protein hydrolyzate
Meat & bone extract	**Organic Natural Products**
Coffee & tea extract	Fermentation broths
Hop extract	Glue & gelatine
Malt extract	Emulsions
Yeast extract	Extracts

Pectin	Stick water
High-protein juices	Organic effluents
Soya whey	Blood
Yeast extract	
Fodder yeast	

Finally before we end our discussion on concentration, let us look at the effect of concentration on physical/nutritional quality of food.

11.5.2 Changes due to Concentration Process

Obviously concentration that exposes food to 100°C or higher temperatures for prolonged periods can cause major changes in organoleptic and nutritional properties. Cooking of foods and darkening of colour are two of the more common heat induced results, which must be kept under control during a well designed process with an efficient evaporator which is still "safe”.

Microbial destruction is another type of change that may occur during concentration and will be largely dependent upon temperature. Concentration at a temperature of 100 °C or slightly above will kill many microorganisms but cannot be depended on to destroy bacterial spores. When the food contains acid, such as fruit juices, the extent of inactivation will be greater but again sterility is unlikely. On the other hand, when concentration is done under vacuum many bacterial types not only survive the low temperatures but also multiply in the concentrating equipment. It is therefore necessary to stop frequently and sanitize low temperature evaporators and where sterile concentrated foods are required, to resort to an additional preservation treatment.

Check Your Progress Exercise 3

1. What do you understand by the term ‘concentration’?

   ----

2. Give a few reasons why do we need to concentrate foods.

   ----

3. List some of the simple techniques used for evaporation during the concentration process.

11.6 LET US SUM UP

In this unit, you studied the various methods of food processing. You learnt that food being most vital for the survival of human beings must be processed using scientific techniques. In this context, you learnt in a great detail about thermal processing i.e., cooking, blanching, pasteurization, sterilization and canning; dehydration and various drying techniques.

Another aspect which was considered in this unit was the preservation by means of concentration. In this, the main focus was on the various methods of concentration and the changes that occur in food as a result of concentration.

11.7 GLOSSARY

Bound water : Water which is in some way bound to the food so that it exerts a vapour pressure less than that of pure water.

Concentration : An operation used to remove a liquid from a solution, suspension or emulsion by boiling off some of the liquid.

Conduction : The transfer of energy through a medium without bulk movement of the medium itself.

Convection : A process of transfer or transmission, as of heat and electricity, by means of circulation of currents in liquids or gases resulting from changes of temperature and other causes.

Dry bulb temperature : Air temperature as indicated by an ordinary thermometer.

Food Preservation : A process by which certain foods are prevented from getting spoilt for a long period of time. It preserves the colour, taste and nutritive value of the food.

Food Processing	**:** Conversion of raw materials and ingredients into a consumer food product.
Free Water	**:** Water which is bound by such minute forces, that its vapour pressure is equal to the vapour pressure of pure water.
Heat of vaporization	**:** Heat required to overcome the molecular forces of attraction between the particles of a liquid, and bring them to the vapour state, where such attractions are minimal.
Organoleptic properties	**:** Relating to qualities (as taste, colour, odour, and feel of a substance that stimulate the sense organs.
Relative humidity	**:** Ratio of the quantity of water vapour present in the air to the highest amount possible at a given temperature, expressed as a percentage.
Sanitize	**:** To make less offensive or more acceptable by killing all living including bacteria and algae.
Still retorts	**:** Cylindrical glass containers used in canning plants for heating foods.
Latent heat of Vaporization	**:** The amount of heat energy required from the environment to change the state of a liquid to a gas.
Water activity	**:** Ratio of vapour pressure of a food to the vapour pressure of pure water.

11.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(i) Preparation of the products fit for consumption and destruction or inactivation of pathogens found in food.

(ii) Thermal processing

(iii) Any two of the following: Destruction/reduction of microorganisms; Inactivation of undesirable enzymes; Destruction of hazardous toxins; Alteration of colour, flavor, and texture; Improved digestibility.

(iv) Thermopenetration

(v) Q value

2. The functions of blanching are listed as (any five):

- Inactivate most enzymes
- Cleaning action
- Removes substances in some products
- Activates some enzymes
- Removes undesirable odors/ flavours
- Softens fibrous material and decreases volume
- Expels air and respiratory gases
- Preheating of product prior to canning

3. A few benefits of blanching are:

- cleaning the material and reduce the amount of microorganisms present on surface
- Preserving natural colour in dried products
- Shortening the soaking/ cooking time during reconstitution

4. Pasteurization is a mild heat treatment to kill a part of the microorganisms present in food. There are two categories of pasteurization. These are:

a) LTLT: In this, the pasteurization time is in the order of minutes and related to the temperature used. To typical temperature/time combinations are used: 63-65^{o}C over 30 minutes or 75^{o}C over 8-10 minutes.

b) Rapid, high or flash Pasteurization: It is characterized by a pasteurization time in the order of seconds and temperatures of about 85^{o}C to 90^{o}C or more, depending on the holding time. Typical temperature/time combinations may be: 88^{o}C for 1 minute; 100^{o}C for 12 seconds; and 121^{o}C for 2 seconds. The 121^{o}C for 2 seconds treatment gives the best quality products in respect of flavour and vitamin retention.

5. Thermal conditions required to produce commercial sterility are: nature of the food, storage conditions during post processing; heat transfer characteristics of food, container and heating medium; and initial load or quantity or organisms present.

Check Your Progress Exercise 2

1.

a) Canning is a process for conservation of foods and its nutritional qualities for along duration at ambient temperature, obtained by a process associating a heat treatment and a water proof packing.

b) Dehydration is a technique that involves the application of heat to vapourise after its separation from the fruit/vegetable tissues. It is a combined/simultaneous transfer operation for which the energy must be supplied.

2. The sequence of canning operations are as: food preparation, filling of can/receptacle, vaccum production, thermal processing, cooling, labeling and packing.

3. The advantages of canned foods are safe and hygienic and high nutritional value, economical, availability in a wide assortment and have utility value and can be kept for a long period

4. The main purpose of drying is to extend the shelf-life of foods by a reduction in water activity (a_w). This will inhibit microbial growth, however, the processing temperature will not normally be sufficient to cause inactivation, thus care is needed to be taken with the product on subsequent rehydration.

5. A few factors that affect the drying rate and total drying time are:

- Properties of the products
- Geometrical arrangement of the products
- Physical properties of drying medium/environment
- Characteristics of drying equipment

Check Your Progress Exercise 3

1. Concentration is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid.

2. The reasons to concentrate foods are:

a) it is a form of preservation

b) it reduces weight and volume and results in immediate economic advantages.

c) Concentrated forms have become desirable components of the diet.

3. The simple techniques used for evaporation during the concentration process are solar concentration, open kettles, vaccum evaporation and freeze concentration.