UNIT 2 HEAT APPLICATION

Structure

2.0 OBJECTIVES

After reading this unit, you should be able to:

- enumerate processes commonly used in processing of fruits and vegetables based on heat application;
- state difference between direct and indirect method of heat transfer;
- identify various types of heat exchangers;
- describe important features of process equipment used for blanching, pasteurization, sterilization and aseptic processing; and
- explain the principle of microwave and ohmic heat transfer.

2.1 INTRODUCTION

We have studied the basic principles of heat transfer in the previous unit. Now, in this unit, we will go through the heat application aspects in relation to processing of fruits and vegetables. The subject shall be of great interest to us as processes based on application of heat form the core of food preservation and processing operations. In fact, thermally processed foods constitute a large part of the industry. As a post-harvest technician or entrepreneur or food technologists, it is essential for us to know about type of heating processes and equipment available so that the twin objectives of preservation and value addition could be achieved effectively and efficiently. Further, understanding of some of the basic thermal processing principles will help in selecting the processing parameters which would ensure maximum retention of sensory and nutritional attributes.

The important conventional as well as new processes such as blanching, pasteurization, sterilization and aseptic processing, microwave, etc., along with associated equipments have been discussed in this unit. In most of these operations, the heat transfer takes place in the form of convection and conduction. Two different principles are used in heat application. In one case, the heating medium is mixed with product to be heated. This is called direct heating and is used: (a) to heat water – steam is injected directly into the water, and (b) application of direct heating in aseptic processing either through injection or infusion. The direct method of heat transfer is efficient for rapid heating. It does, however, involve mixing of the product with the heating medium, and this necessitates strict demand on the quality of the heating medium. Indirect heat transfer is the most commonly used in food processing operations. In this method, a partition is placed between the product and the heating or cooling medium. Heat is then transferred from the medium, through the partition into the product. Most of the heat exchangers in the industry are designed on this principle. General principles governing heat transfer and response of fruits and vegetables to heat energy can be applied to all heat processes but each type of thermal processes has separate objectives. Therefore, the heat application has been delineated in this unit on basis of the objectives of the heat process after introducing heat exchangers.

2.2 HEAT EXCHANGERS

A heat exchanger is a device that transfers heat from one fluid to another without allowing them to mix, i.e., to transfer heat by the indirect method. In food processing, the purpose is to heat or cool a liquid food in bulk.

The heat exchanger has two channels separated by a partition. Hot water flows through one channel and juice through the other. Heat transfer, in connection with food products, follows general law of heat and, therefore, can be calculated by the formula:

$Q = UA\,\Delta T$

Q = Rate of heat transfer (Btu/hr)

U = Overall heat transfer coefficient (Btu hr^{-1} ft^{-2} $^{o}F^{-1}$)

A = Heat transfer area between medium and product (ft^2)

ΔT = Difference in temperature of medium and product (temperature of high medium and temperature of product/ low temperature medium) (^{o}F)

(A true temperature difference is given by logarithm mean difference and is represented by Δ Tm = mean differential temperature.)

From the above equation, it may be said that heat transfer is increased by:

i) Temperature difference between the “warm” and the cold “media”. This is known as driving force;

ii) Greater available surface area – this means that a greater quantity of heat can be transferred if the area of the interface between medium and product is increased;

iii) Greater overall heat transfer coefficient (U Value) – more heat can be transferred if the U value is increased. This value is determined by several factors, including the flow rates of the media, the viscosity of the product, the shape of the heat transfer surface area and the material of which the partitions are made.

2.2.1 Practical Application of Principle of Heat Transfer

We know that food products are sensitive to temperature and agitation and this affects the capacity and efficiency of heat exchangers, for example, the higher temperature difference between the product and the heating medium may cause burning of certain food solids. Some of general principles for practical heat exchangers as outlined by Farrall (1976) are:

i) Rapid movement of the film of fluids on both sides of the heat transfer surface is important.

ii) Thorough and certain mixing of the film adjacent to the heat transfer area, with the body of the fluids is essential.

iii) Make use of the counter flow principle where possible, that is having the cold inlet product adjacent to the coldest outlet of the heating medium in a continuous system.

iv) Use as great a temperature difference as possible consistent with accurate temperature control and prevention of bad effects on the product treated.

v) Use as few intermediate cooling fluids or heating fluids as possible.

vi) Use as thin a sheet of heat transfer wall as possible consistent with proper mechanical strength.

vii) Use a heat transfer surface having good heat conductivity.

2.2.2 Types of Heat Exchangers

There are many types of equipment encountered in the food industry. The most important are the plate type, tubular type, scraped surface and vat type. The heating medium is usually either hot water or steam. A brief description is given below so that we may be able to use them effectively.

I. Tubular heat exchanger

The simplest type of tubular exchangers is the double pipe which consists of two concentric tubes with one fluid passing along the centre tube and the second fluid flowing in the annular space created between the tubes. Triple tube type employs three concentric tubes, with the product flowing through the intermediate passage and the heating or cooling medium flowing with counter current system in the other two passages, so that the product is surrounded on both sides. Today the tubular exchangers are not extensively used in food processing industries. The capital cost for these are low.

II. Scraped surface heat exchanger

The scraped surface heat exchanger is designed for heating and cooling of viscous, sticky and lumping products and for crystallization. This consists of a double-pipe exchanger with a central rotating shaft inside the inner pipe. Scraper blades are attached to the shaft and remove any material which builds up on the inner pipe wall. The second fluid flows in the annular space as in a conventional exchanger. The continual scrapping of the heat transfer surface ensures that higher heat transfer coefficients are obtained with highly viscous fluids.

III. Plate heat exchanger

One of the most popular type of heat exchanger is the plate system in which thin corrugated plates are stacked together to provide passage for the product and for the heating and cooling fluid. The advantages are:

i) High heat transfer surface area within a small plant volume.

ii) High heat transfer coefficients due to configuration of the plate surface.

iii) Easily cleanable either by opening it up or by CIP (cleaning in place) method.

iv) Versatile-addition of extra plates to increase surface area, ability to arrange a wide variety of flow patterns and several different fluids can flow through separate sections of the same heat exchanger, for example, allowing heating, cooling and heat recovery to take place in a simple unit.

v) Comparatively low in cost.

IV. Vat or tank heat exchanger

The flooded jacket, vat or tank is the simplest form of heat-exchanger, which is essentially a tank within a tank, with a space between the two that is flooded with water. The vat types of heat-exchangers are mainly used for batch pasteurization. For heating, a steam injection and mixing unit is employed and the agitator is provided for movement of the product over the heat exchanger surface.

Check Your Progress Exercise 1 ✍

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

1. Enlist factors affecting heat transfer.

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2. List the important components of a plate heat exchanger.

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2.3 BLANCHING

As you know that blanching is a heat treatment applied to tissue systems of fruits or vegetables, primarily to inactivate natural food enzymes, prior to canning, freezing or drying. Most blanching operations are accomplished by putting the product in contact with either hot water or steam for an appropriate time. Blanching is not indiscriminate heating. Too little is ineffective, and too much damages the fruits/vegetables. The time is dependent on the objectives of the process, i.e., whether enzymes are to be inactivated or whether partial cooking is desired. It involves: i) heating food to a preset temperature, ii) holding for a preset time, and iii) cool rapidly to ambient temperature. The blanching of vegetables is most often done in hot water or steam containing calcium or magnesium salts to check chlorophyll degradation. Calcium brines or colloidal thickness are used in blanching of fruits for firming them. The blanching is not recommended for frozen fruits after thawing as it results in undesirable changes in texture and flavour. The adequacy of blanching is known through the catalase or the peroxidase test. The peroxidase system is most commonly used and we know that a negative peroxidase test is necessary to prevent the development of undesirable characteristics in the finished product.

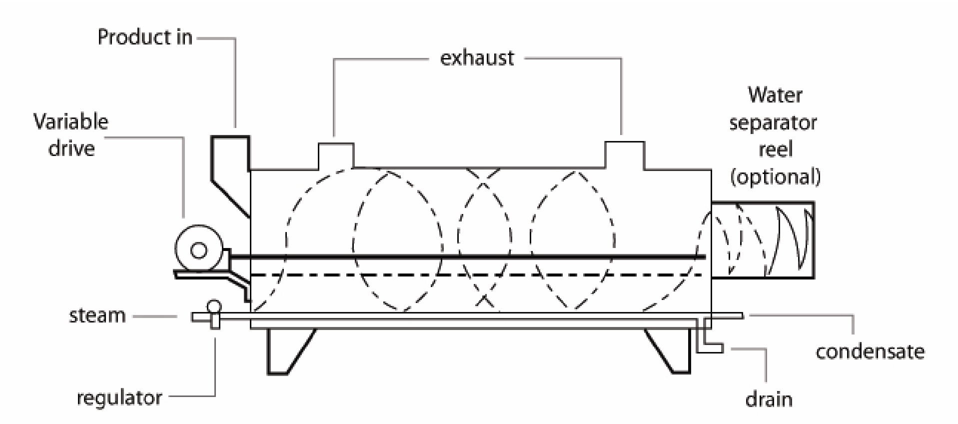
2.3.1 Process Equipment

Rotary hot water and steam blanchers are common process equipment and are shown in Figure 2.1 (a) and (b), respectively. They are available with variable speed drive. The rotary hot water blancher receives the product through a valve just above the drive end. The product is conducted into a spiral unit which conveys it to the opposite end. In the case of the hooded live steam blancher which has a perforated wire belt, the blancher serves as a conveyor making it very adoptable to the system.

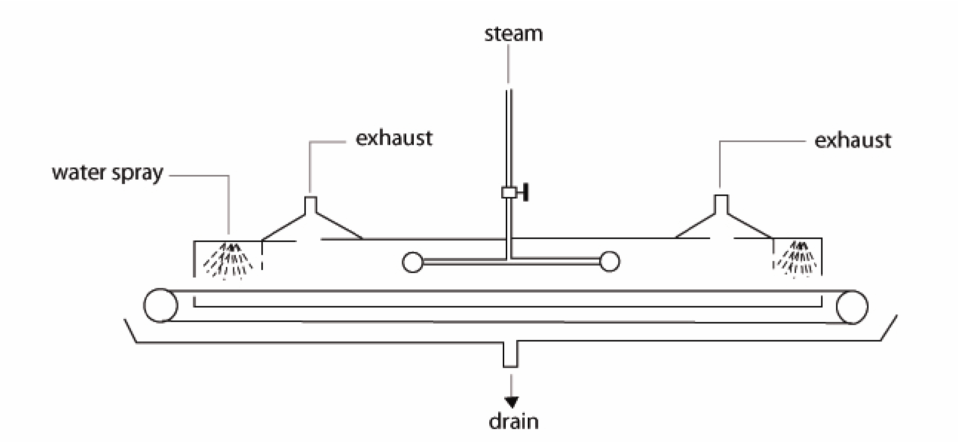
The steam blancher consists of a metal frame with galvanized sheet metal forming the steam chamber. The unit is frequently equipped with both water and steam sprays to increase its versatility as a scolder/blancher. The lower belt of the hooded chamber is pitched to a separate drain outlet for removal of condensate. A typical commercial steam blancher is approximately 20 ft. long, 4 ft. wide and 4 ft. high. A typical water blancher would be around 6 ft. in height with an overall length of 21 ft. In general steam blanching results in greater retention of water-soluble nutrients due to less leaching loss. With leafy vegetables, such as spinach, care must be taken not to overload the belt since upon heating these products tend to wet and mat. Heat transfer through this mat is very slow and under blanching could occur.

The advantages of steam blanchers are: smaller loss of water soluble components, smaller volume of waste, lower disposal charges and easy to clean and sterilize. The disadvantages associated with a steam blanchers are: limited cleaning of food, higher capital cost, uneven blanching, some mass loss in food and poor energy efficiency. At the same time, the advantages of hot water blanchers are lower capital cost and better energy efficiency. The disadvantages are loss of water soluble components, higher cost of water and disposal of effluent and risk of contamination.

A thermal screw may also be used to steam blanch products. Here, the product is conveyed in a trough by a closely fitting helical screw. Steam injected at regular interval is used to heat the product. Similar designs use hot water as the transfer medium, and this reduces abrasion and damage to sensitive products such as mushroom.



(a)



(b)

Figure 2.1: Blanchers. a) Water type rotary blancher; b) steam blancher for leafy products

We should select a size of blancher which will handle the line capacity without being over crowded. Do you know that one of the serious mistakes made by the operator is overloading. As an operator, we have to ensure maintenance of the unit on a regular basis and check that automatic controls are performing well. The use of a check thermometer to ascertain the accuracy of the one installed on the unit is a good practice.

Check Your Progress Exercise 2 ✍

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

1. Draw a diagram of water type rotary blancher.

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2. What are the advantages of steam blancher?

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2.4 PASTEURIZATION

Pasteurization is the term usually applied to preservation of liquid products like pulps or juices by heat. We know that this thermal treatment primarily inactivates the disease causing microorganisms present in the foods. The process i) kills non-spore forming bacteria, ii) inactivates enzymes, and iii) destroys yeasts and moulds. It is suitable for short time preservation because it reduces the number of fermentative microorganisms that contribute to the acidification of juice, at the expense of sugars. The processing details have already been discussed in earlier units and we know that the time-temperature treatment depends on i) the heat resistance of the particular vegetative or pathogenic organism, and ii) the sensitivity of product quality to heat.

2.4.1 Process Equipment

Since pasteurization is normally done at temperature less than 100° C, solid food particles can be pasteurized in the same type of equipment as that used for blanching. A water bath is the simplest pasteurization equipment for acid food products. Packaged food products are placed in steel tanks for heating with hot water. At the end of process cold water is added for cooling. A continuous water bath pasteurizer is used in pickle industry and in fruit processing. The equipment consists of a long tank through which the product moves on a belt.

Continuous water spray equipment is used for pasteurizing fruit juices. In this unit, the product is conveyed on a belt through several temperature zones where water is sprayed onto the containers. The zones are first pre-heat, second pre-heat, pasteurization, pre-cool and final cool. Do remember that glass containers be processed with care to avoid thermal shock.

For fruit, fruit juices, and tomatoes, the continuous, agitating, atmospheric cooker is widely used. Operation of the unit is similar to the continuous, agitating, pressure cooker wherein the cans are screw conveyed through the unit. The unit operates at atmospheric pressure with either steam, hot water, or a combination of steam and hot water as the heating medium. Processing rates of up to 20-250 cans/minute can be achieved.

Pasteurization of unpackaged liquid is commonly done in indirect heat exchanger and High Temperature Short Time (HTST) processing is preferred for high throughputs (Figure 2.2). The nutrient loss is less. This procedure makes use of a plate heat exchanger with three sections for heating, regeneration, and cooling, respectively, a holding tube to pasteurization temperature for the required time and a flow diversion value to ensure that liquid which has not reached the desired temperature is not discharged as finished product. It is important to ensure that rapid cooling occurs in order to prevent quality deterioration and to ensure a uniform residence time. The temperature time treatment for some of the food products is given in Table 2.1.

Table 2.1: Temperature/time treatment in pasteurization

Food Product	Temp (°C)	Time (Seconds)
Milk	72	15
Tomato Juice	118	60
Fruit Juice	88	15
Soft Drink	95	10

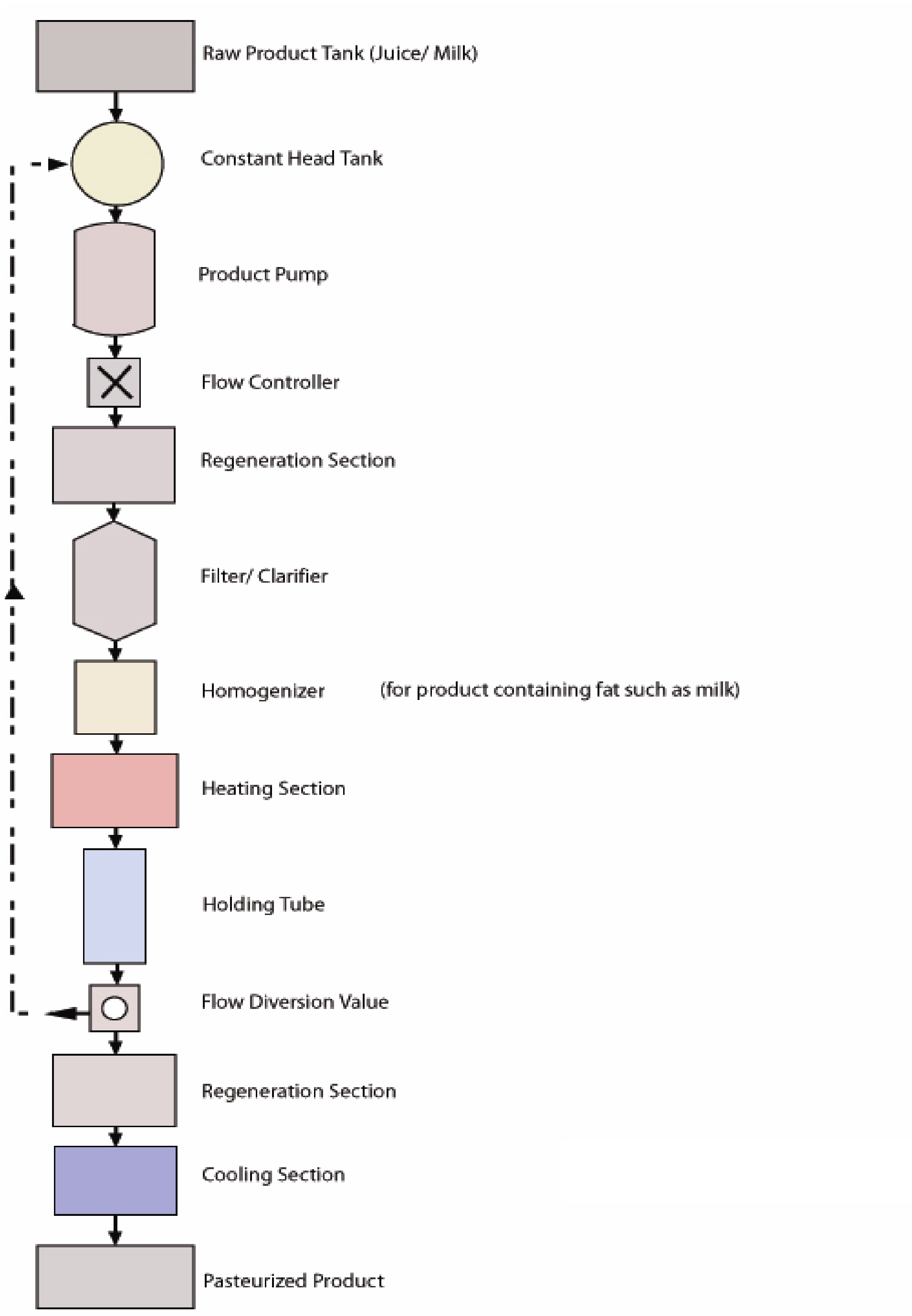

Figure 2.2: Flow diagram of pasteurization process

Check Your Progress Exercise 3

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

1. Draw a line diagram of HTST pasteurization.

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2. Write pasteurization temperature and time combination for fruit juice and tomato juice.

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2.5 STERILIZATION

Sterilizing a product means exposing it to sufficiently high temperature and for a sufficiently long time that may kill all micro-organisms. In contrast to pasteurization, commercial sterilization is intended to give long shelf life (in excess of six months) to foods by destroying both microbial and enzyme activities. The products that are difficult to sterilize are low in acid and often high in protein and contain spore bearing bacteria. Sometimes severe heat treatment results in substantial changes in nutritional and sensory qualities of food. Therefore, optimum time temperature schedules are to be worked out for each product for better quality and shelf life. Sterilized products have excellent keeping quality.

There are two basic methods for sterilization (i) heating the food after it has been placed in a container (known as “in-container”), and (ii) heating and cooling the food and then packaging it aseptically (aseptic packaging). This subsection deals about sterilization process. The traditional retorting of canned foods is an example of sterilization process.

2.5.1 Process Equipment

The Batch Retort: The batch operated retorts are either horizontal or vertical. The basic feature of a vertical retort is given in Figure 2.3. It consists of a pressure vessel, usually cylindrical and a basket or grate into which individual cans are placed. The various layers of cans are separated by grids which allow thorough circulation of steam. The retort is supplied with steam, cold water and compressed air. Inlets are fitted with globe valves and the outer outlets with gate valves. At the bottom of the retort, a steam spreader is connected to the steam inlet to ensure uniform distribution of stream inside the retort. The drain is fitted to the base of the retort to remove the condensate during heating and cooling cycles. A vent, with a valve, is provided on the body of the retort. It is intended to purge the air flow between the cans during the initial part of the come-up period. The retort instrument packet is fitted with a petcock which acts as a permanent bleeder; mercury in glass thermometer; an additional place for a check thermometer; a temperature-sensing probe connecting to the recording thermometer; and a pressure gauge. An additional petcock and a pressure safety valve are on the lid. The retorts are strong enough to withstand the pressure of air, besides that of steam pressure, i.e., a working pressure of 2.8-3.5 kg/cm^2 (40-50 psig). The retorts should be located in a sufficiently large area to enable easy operation. The floor should be resistant to wear, well-drained, and impervious to water. The free space between the retort should be at least 50 cm.

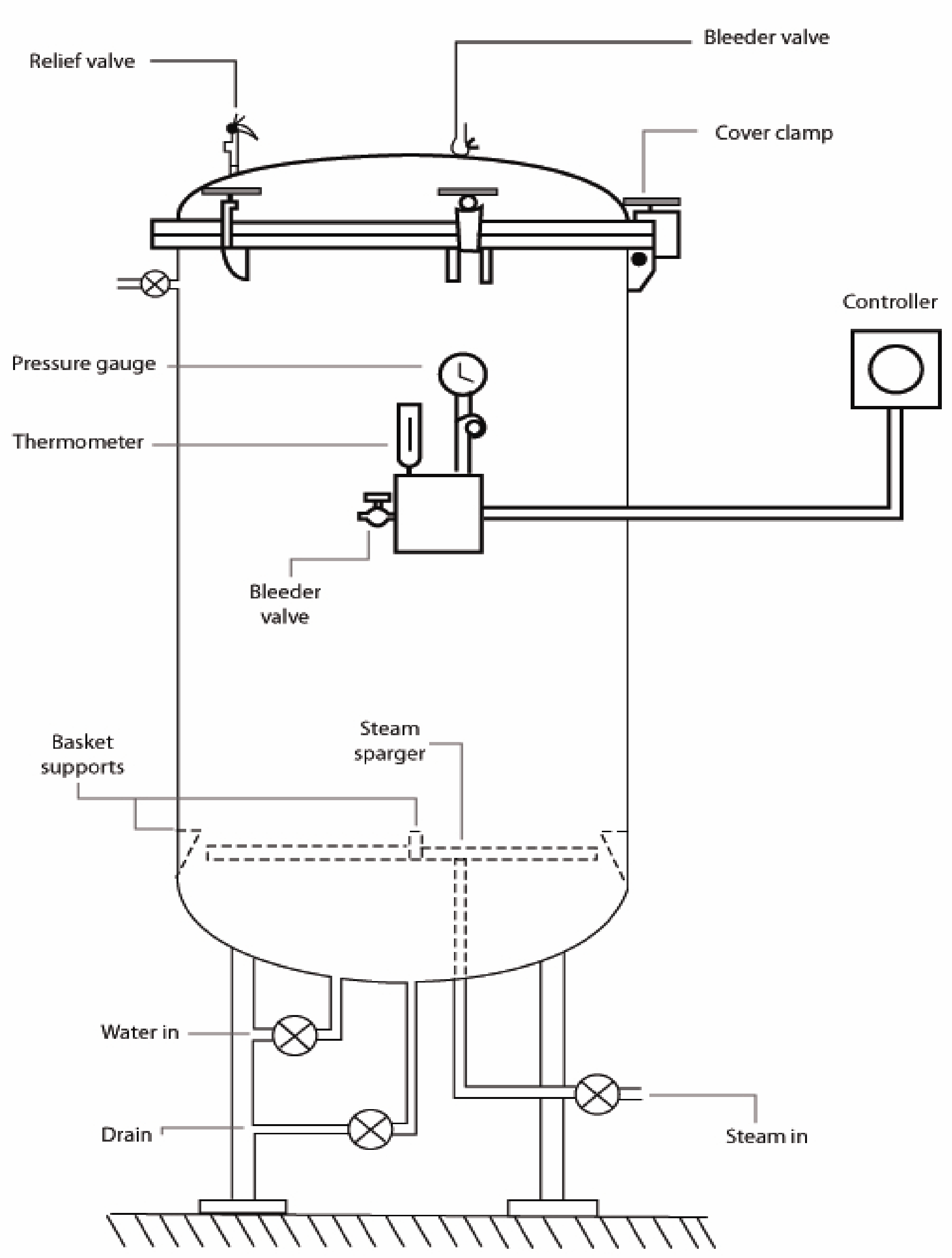

Figure 2.3: Basic layout for a vertical retort

Steam is an excellent heat medium because of its ability to condense on container surface releasing large amounts of latent heat. The main enemy of efficient heating in a closed vessel (e.g. a retort) using saturated steam is the presence of entrapped air especially that trapped in the small spaces between containers in the load. The presence of air reduces the temperature and tends to insulate the cans giving lower rates of heat transfer. This means that in order to bring about efficient and uniform heating, air must be purged, or as it is, referred to in the industry 'venting' from the retort at the start of the process. This is achieved by introducing high velocity steam into the retort. The rotary retorts ensure agitation and give adequate heating and acceptable processing times.

Retort operation is a specialized job. As a technician, you should be well trained in its operation and ensure proper processing. The basic operating procedure is as follows: The cans are placed in a basket which is lowered into the retort and then steam is introduced. Time is allowed for any condensed water to drain away before a drain valve at the base of the retort is closed.

Acidic products, for example canned fruits, require a milder heat treatment and use steam at atmospheric temperature, while the high temperature is required for less acidic foods and need heat to be supplied by steam at pressures greater than atmosphere. The steam is introduced at high speed for venting. After a short period, the vent valve is closed and the retort is brought up to temperature by allowing the steam pressure to rise to a pre-set level. After processing for the required time, the steam flow is stopped and the cooling water flow is started. As the temperature of the can's content rises the vapour pressure inside the can increases. During the heating cycle increase in pressure is balanced by the steam pressure outside the can, however, during the cooling cycle this internal pressure is balanced by admitting compressed air simultaneously. Cooling continues in retort until the temperature falls to about 40°C after which retort is opened and the cans are removed.

Check Your Progress Exercise 4

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

1. Draw a labelled diagram of a Vertical Retort.

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2. What is venting?

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2.6 ASEPTIC PROCESSING AND PACKAGING

Aseptic processing and packaging is a remarkable technological advancement over traditional retort processing. It is the process by which micro-organisms are prevented from entering into the package during and after packaging. It is achieved by filling a sterilized package with a sterile food product within the confines of a hygienic environment. The packaged product could be stored without the need for refrigeration or preservatives for periods up to one year. Aseptically packaged products include milk, juices, tomato soups, sauces, broths, soy beverages, etc. The production of these products is constantly increasing in the country.

2.6.1 The Aseptic Process

The aseptic process is a technique for processing liquid food products by exposing them to brief intense heating. Sterility is the key word in the process and involves the same principles as discussed with respect to sterilization. Since very high temperatures are employed (125 °C to 145 °C), the process is also referred to as Ultra High Temperature (UHT). The holding time of the product at high temperature is very short (3 to 15 seconds) and therefore, thermal stress on the product is less while ensuring safety. This rapid heating and cooling process also reduces the energy use and nutrient losses associated with conventional sterilization. Processing at high temperature usually requires that the process be based on enzyme inactivation rather than microbial destruction. The process involves:

i) Sterilization of the product in sterile equipment;
ii) Pre-sterilized containers;
iii) Aseptic environment for filling of the sterile product into the sterile package; and
iv) Sterile packaging.

The advantages of the UHT processing are (i) higher quality (ii) increased shelf life (iii) easy adaptability to many size containers from single serving (200 ml.) to thousands of litres of bulk pack, and (iv) cheaper packaging material. The disadvantages are (i) higher cost (ii) sophisticated control and maintenance of plant, and (iii) higher skill level on the part of operators and maintenance personnel.

2.6.2 Process Equipment

UHT plants are often designed with great product flexibility in order to enable processing of a wide range of products in the same plant. Both low acid products (with pH values above 4.5) and high acid products (with pH values below 4.5) can be treated in UHT plant. However, only low acid products require UHT treatment in order to become commercially sterile as spores can grow in a low acid environment. Spores cannot develop in high acid products such as juice and the heat treatment is, therefore, only intended to kill yeasts and moulds. Normal high-temperature pasteurization is sufficient to make high end products commercially sterile. The UHT plants are classified according to the method of heating. The options are consolidated in Table 2.2.

Table 2.2: Types of UHT plants

Sl. No	Type of plant	Options available
1.	Direct Heating (Product and the heating media are in direct contact)	Steam injection (steam into product) Steam infusion (product into steam)
2.	Indirect Heating (Heat transfer surface between the product and the heating media)	▪ Plate, ▪ Tubular and ▪ Scraped surface heat exchangers

i) **Direct Heating:** There are two main methods for aseptic processing by direct methods: by injecting pressurized steam into product or by injecting product into steam (steam infusion). Both systems work on the principle that the steam comes into contact with the product, it will condense and give up some latent heat causing the product to heat up very quickly. The steam has to be of satisfactory quality, i.e., derived from drinking water. Simplified flow sheets for direct steam injection and steam infusion are shown in Figure 2.4 and 2.5, respectively. The basic principle for both systems is to pass the product from a balance tank to a pre-heating and final heating system, usually by a plate heat exchanger at 75-80°C. The product then passes through the main product pump to the steam injection or infusion system. The mixture then flows through a holding tube (2-4 seconds) which enters tangentially into the vacuum chamber. The product passes on an aseptic path – pump, homogenizer, cooler and storage tank – to aseptic package. Steam injection is most suitable for low viscosity homogeneous products such as milk and juice. Steam infusion is for more gentler and sensitive products.

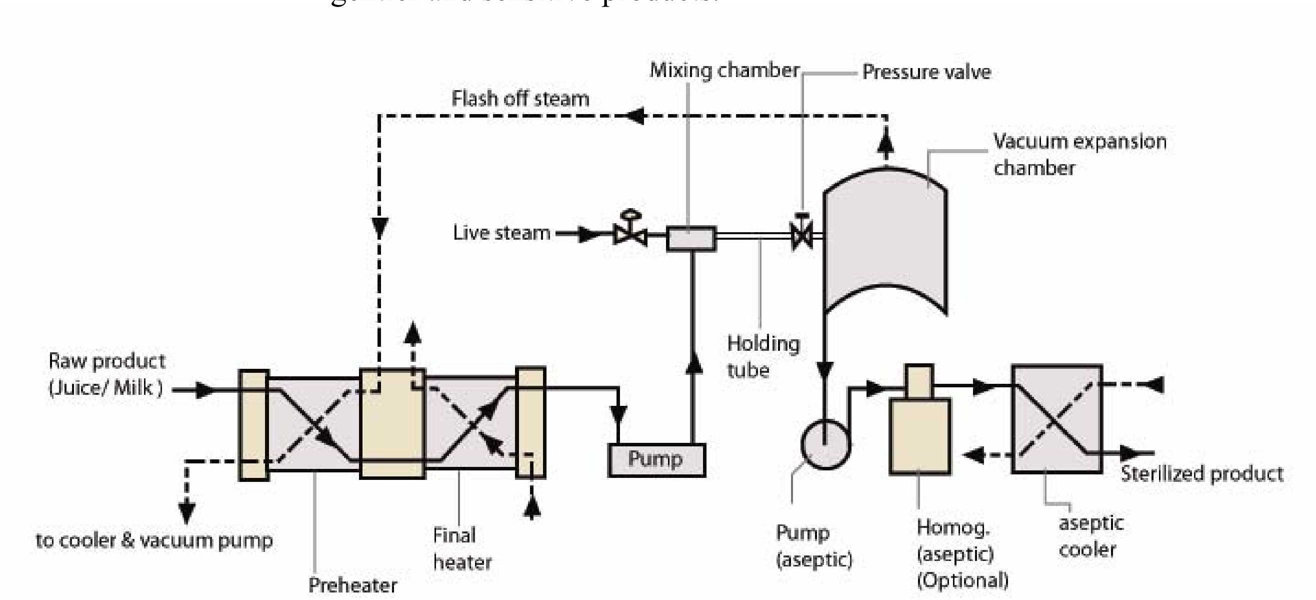

Figure 2.4: Diagram of an ultra-high temperature heating plant using direct heating (steam injection)

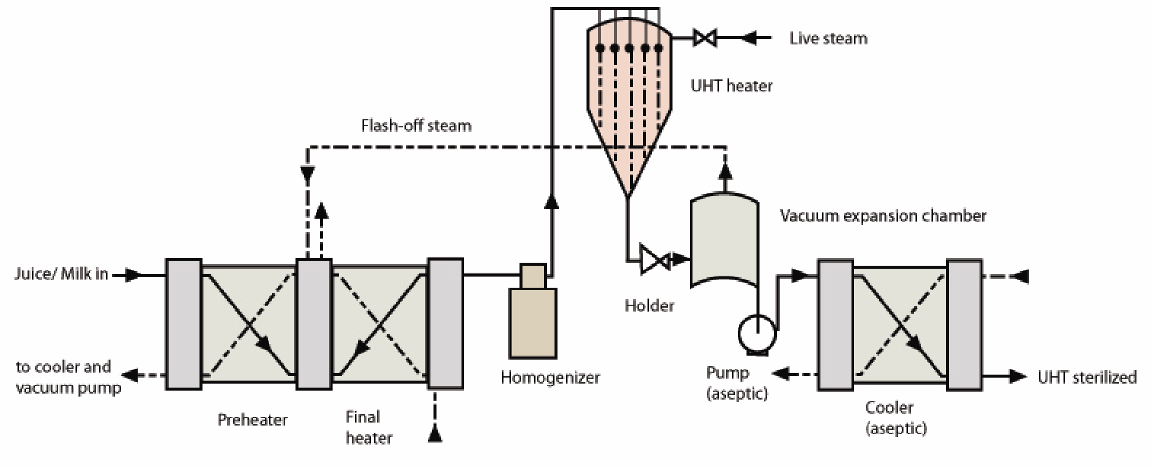

Figure 2.5: Diagram of a UHT plant using direct heating of product in a steam space (steam infusion)

ii) **Indirect UHT Plant:** UHT heating plants using indirect heating method rely on having a heat transfer surface between the product and the heating media. There are three main types of indirect heating system, viz. plate heat exchanger, tubular heat exchanger and scraped surface heat exchanger. Each system has benefits as well as drawbacks depending on the product process requirement. A simplified flow sheet for an indirect UHT plant is shown in Figure 2.6. UHT plants of the indirect heating types are built for capacities up to 30,000 l/h.

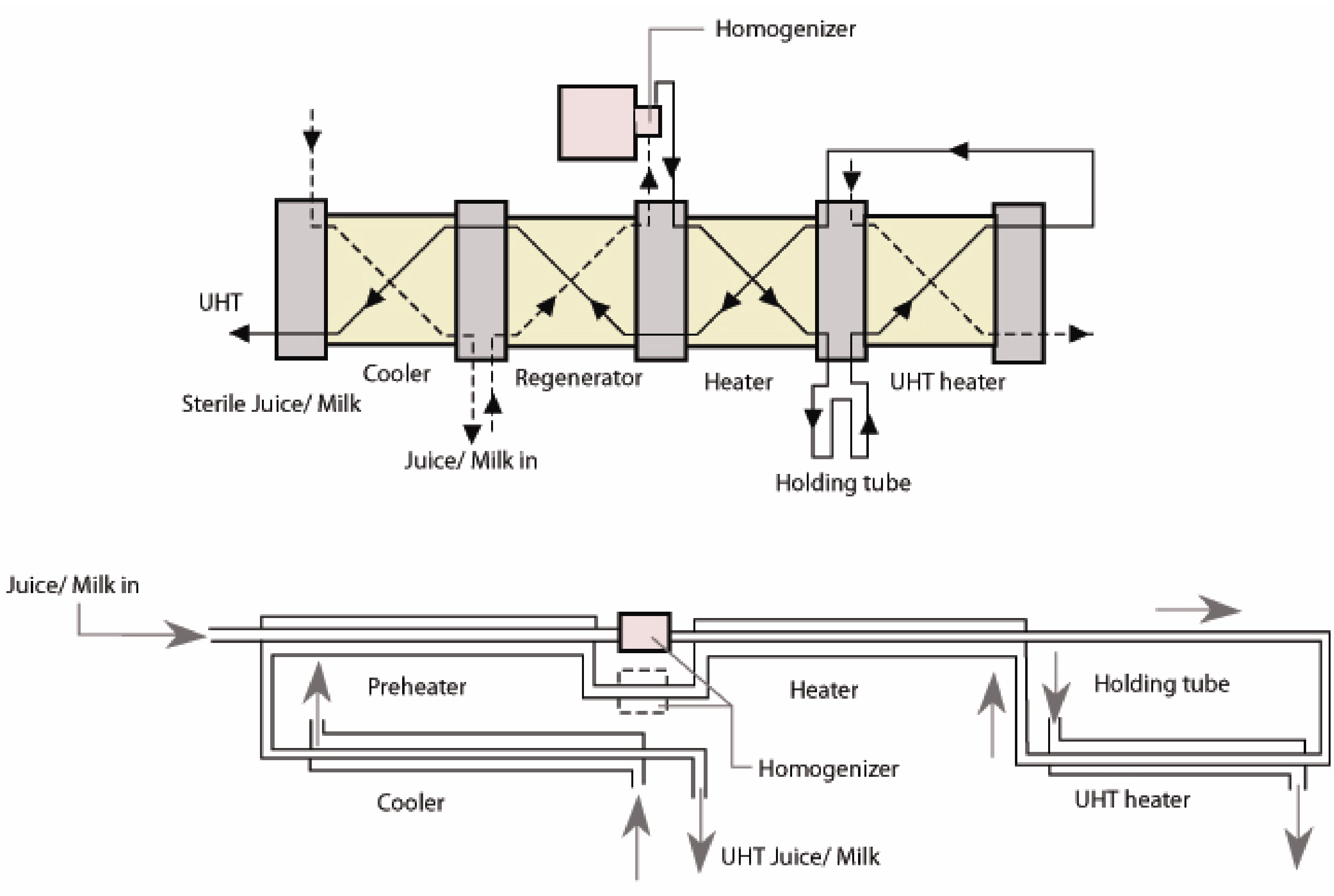

Figure 2.6: Diagrammatic representation of UHT heating plants using indirect heating methods

2.6.3 Aseptic Packages

There are several different forms of packages that are used in aseptic processing such as cans, laminates, flexible pouches, thermoformed plastic containers, tetrapack, etc. Tetrapack, a revolutionary package, is a laminate of three materials: high-quality paperboard, polyethylene and aluminium. Each material plays a critical role in achieving the unique benefits of the aseptic package. Paper (70%) provides stiffness, strength and the efficient brick shape to the package. Polyethylene (24%) on the innermost layer forms the seals that make the package liquid-tight. A protective coating on the exterior keeps the package dry. Aluminium (6%) is the silver material we see on the inside of the aseptic package. This ultra-thin layer of foil forms a barrier against light and oxygen, eliminating the need for refrigeration and preventing spoilage without using preservatives. The aseptic package contains a total of six layers in this order: polyethylene, paper, polyethylene, aluminium foil, polyethylene and polyethylene. The processing steps involved in formation of a package are: sterilization of roll and, formation of package, filling and sealing in sterile environment.

Check Your Progress Exercise 5

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

1. What are the advantages of UHT Processing?

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2. Draw a line diagram of the direct UHT steam injection plant.

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3. Enlist the packaging materials forming the common aseptic package.

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2.7 HOT PACK OR HOT FILL

The terms Hot Pack or Hot Fill or Hot-Fill-Hold-Cool Process or Flash Pasteurization refer to the filling of previously pasteurized or sterilized foods, while still hot, into clean but not necessarily sterile containers, under clean but not necessarily aseptic conditions. The hermetically sealed containers are then inverted and held for an adequate time (1-3 minutes) to sterilize the lid as well as the containers. The hot-filled containers are then cooled either in a water-spray tunnel or by immersing in a tank containing chlorinated cold water. Rapid cooling is essential to retain the colour, flavour and nutrients. In yet another practice followed in some western countries, the head space is flushed with steam or nitrogen to minimize the residual oxygen. A schematic diagram of hot-fill system is shown in Figure 2.7.

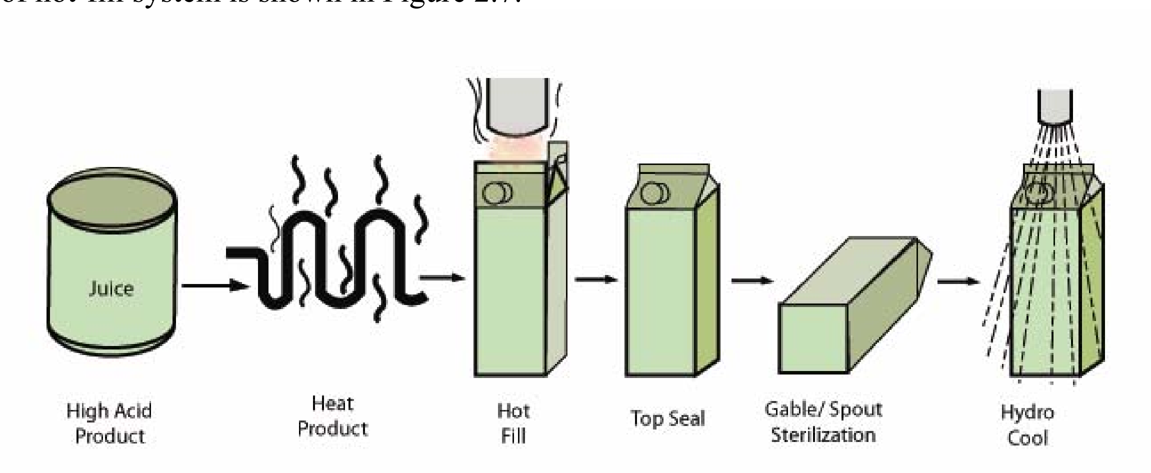

Figure 2.7: Hot-fill system – A schematic diagram

Hot-pack is more effective with acid foods, as at pH below 4.5 *Clostridium botulinum* will not grow or produce toxin. Hot pack with low acid foods (above pH 4.5) is not possible unless the product is recognized as being only pasteurized and will be stored under refrigeration. However, hot pack treatment could be combined with some additional means of preservation such as very high sugar content. The temperature and time for pasteurization and hot filling depend upon the specific product's pH and other food characteristics. It is essential that the definite temperature and time must be adhered for hot pack processing to be effective.

Check Your Progress Exercise 6 ✍

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

1. What do you understand by Hot Pack or Hot Fill Process?

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2. Draw a schematic diagram of hot-fill process.

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2.8 MICROWAVE AND OHMIC HEATING

We are familiar with microwave ovens, their use and popularity is increasing constantly. In microwave heating, a high frequency field is passed through the food, stimulating the vibrational frequencies of chemical bonds to heat the material. Microwave and ohmic heating are known as heat generation methods where heat is generated by the material *in situ* as a result of interaction with an external field.

2.8.1 Microwave Heating

Microwaves are electromagnetic waves of radiant energy, differing from such other electromagnetic radiations as light waves and radio waves primarily in wavelength and frequency. The microwave frequency ranges from 300 MHz. to 300 GHz. corresponding to wavelength in the range of 0.001-1 m, and is positioned somewhat close to FM radio and television broadcasting brands. Microwaves, like light, travel in straight lines. They are reflected by metals, pass through air and many, but not all types of glass, paper and plastic materials, and are absorbed by several food constituents including water.

When microwaves pass into foods, water molecules and other polar molecules tend to align themselves with the electric field. But the electric field reverses 915 or 2450 million times per second (MHz.). The molecules attempting to oscillate at such frequencies generate intermolecular friction which quickly causes the food to heat. In microwave, heat is generated quickly and quite uniformly throughout the mass. .

The use of microwave energy in food processing can be classified into six unit operations: heating, baking and (pre) cooking, tempering, blanching, pasteurization and sterilization, and dehydration.

The most commonly used type of microwave generator is an electronic device called a magnetron. A magnetron is a kind of electron tube within a magnetic field which propagates high frequency radiant energy. The microwave field is transmitted to the oven cavity / tunnel via an antenna placed inside the wave guide. Industrial oven is either a larger version of the domestic oven and is used for batch processing (e.g. tempering) or for continuous processes, taking the form of tunnel with food conveyed on belt inside an enclosure.

A major use of microwave in the food industry is tempering and thawing of frozen foods, especially meat, fish, butter and fruit. Tempering raises the temperature of frozen foods to around – 4°C and thus allows other operations such as cutting to be carried out much faster. Microwave tempering has a number of advantages over conventional methods as it takes minutes rather than days, reduces labour costs and requires a smaller space than the conventional refrigerated storage room. Microwaves have been used for pasteurization of ready meals, further developments are needed to use them in commercial sterilization.

2.8.2 Ohmic Heating

In ohmic heating, an electric current is passed through a food material which then heats as a result of its inherent electrical resistance. The process involves the passage of low frequency alternating current (50 or 60 Hz.) through the product. The electrical energy is transformed into thermal energy. The extent of heating depends on the uniformity of the electrical conduction throughout the product and its residence time in the heater. A typical layout of an aseptic processing system using ohmic heaters is shown in Figure 2.8.

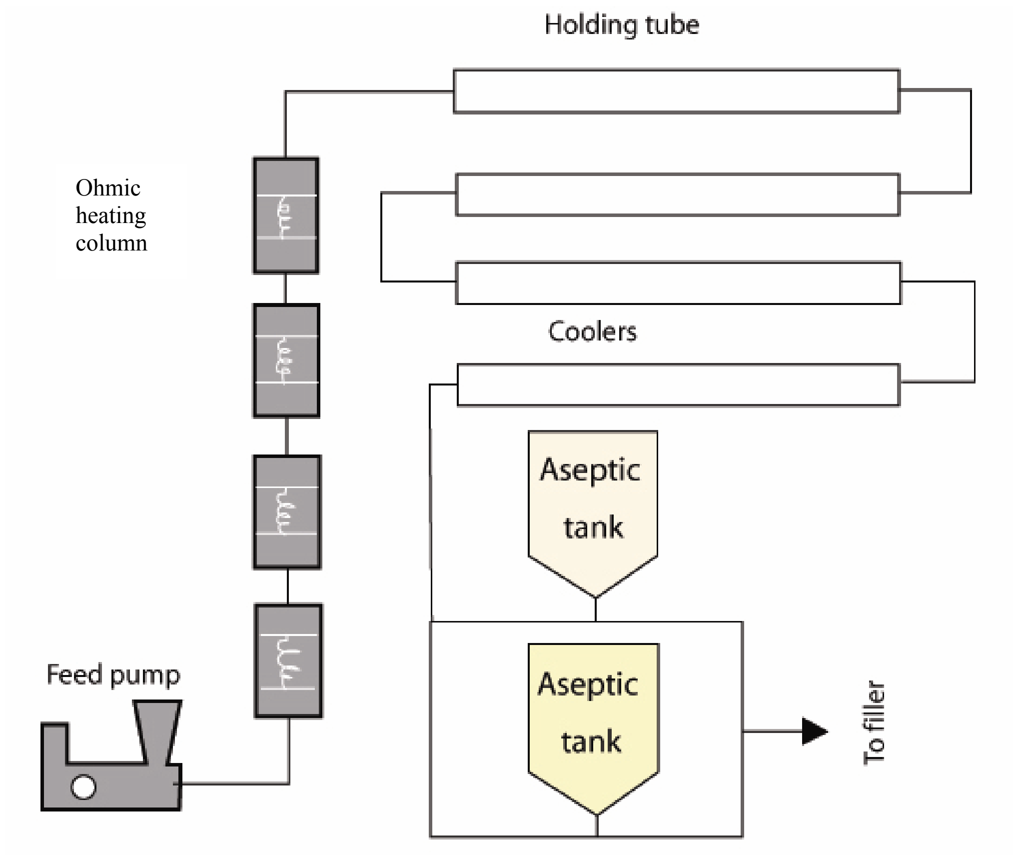

Figure 2.8: Schematic diagram of a continuous-flow ohmic heating process

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Check Your Progress Exercise 7

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

1. State the principle of microwave heating and its major use in food industry.

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2. What is ohmic heating?

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2.9 LET US SUM UP

The principles of heat transfer are widely used in food processing industries. The common processes based on heat application are blanching, pasteurization, sterilization and aseptic processing. The types of heat exchangers used in these processes may include plate, vat, tubular or scraped surface. Plate heat exchangers are quite common due to various advantages such as high heat transfer surface area within a small plant volume, high heat transfer coefficient, versatility, and low cost.

Rotary hot water and steam blanchers are commonly used equipment for blanching, and size of the blancher should be in proportion to line capacity of the plant. Plate heat exchangers are usually employed for pasteurization of unpackaged liquid. The raw product passes through regeneration, heating, holding and cooling sections. After heating and holding to a stipulated temperature-time combination, the pasteurized product is chilled immediately through regeneration and cooling section. Sterilization is more severe heat treatment employed to have longer shelf life (in excess of six months) of food products and the traditional retorting of canned foods is an example of sterilization process. The entrapped air should be vented from the retort at the start of process for efficient and uniform heating. Aseptic processing and packaging is a technological advancement wherein sterilization is obtained by employing Ultra High Temperature (UHT) (125° C to 145° C) for very short time. The UHT plants could be (i) direct steam injection, (ii) direct steam infusion, and (iii) indirect UHT plant with plate/tubular/scraped surface heat exchanger. Hot pack or hot fill, effective with acid foods, involves filling of previously pasteurized or sterilized foods, while still hot into clean containers.

The new techniques microwave and ohmic heating are known as heat generation methods where heat is generated by the material *in situ* as a result of interaction with an external field.

2.10 KEY WORDS

Aseptic packaging : It is a process by which micro-organisms are prevented from entering into the package during and after packaging. An aseptic process is achieved by filling a sterilized package with a sterile food product within the confines of a hygienic environment.

Blanching : Blanching is a heat treatment applied to tissue systems of fruits or vegetables primarily to

		inactive natural food enzymes prior to canning, freezing and drying.
Commercially sterile	:	The terms are used wherein all pathogenic and toxin forming organisms have been destroyed in the product.
Heat exchanger	:	A device that transfers heat from one fluid to another without allowing them to mix.
Pasteurisation	:	A form of thermal processing, which uses moderate degree of heat treatment generally at temperatures below the boiling point of water, for short time preservation. It inactivates bacteria and disease producing organisms of importance in specific food stuff.
Sterilisation	:	Complete destruction of micro-organisms by powerful heat treatment.
UHT	:	Ultra High Temperature (UHT) is a technique for processing liquid food products by exposing them to intensive heating for a short time.

2.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer may include the following points:

1.
   - Temperature difference between heating and cooling media
   - Surface area for heat transfer
   - Heat transfer coefficient

2. Important components of plate heat exchangers: Head frame, guide bar, follower, end support, carrying bar, hinged distance piece, tightening screw device, detachable ratchet spanner, bank of plates, connector grid with inlet and outlet bosses.

Check Your Progress Exercise 2

Your answer may include the following points:

1. Please refer Figure 2.1a.

2.
   - Smaller loss of water soluble components
   - Smaller volume of waste
   - Lower disposal charges
   - Easy to clean and sterilize

Check Your Progress Exercise3

Your answer may include the following points:

1. Please refer Figure 2.2.
2. Fruit Juice –88°C / 15 seconds
   Tomato Juice –118°C / 60 seconds

Check Your Progress Exercise 4

Your answer may include the following points:

1. Please refer Figure 2.3.

2. - Entrapped air tends to insulate the cans and gives lower rates of heat transfer.
   - Air is purged out from the retort at the start of process for uniform heating. This is achieved by introducing high velocity steam into the retort.

Check Your Progress Exercise 5

Your answer may include the following points:

1. - Higher product quality
   - Increased shelf life
   - Easily adaptable to many size containers

2. Please refer Figure 2.4.

3. The aseptic package laminate consists of (a) paper board, (b) polyethylene, and (c) aluminium.

Check Your Progress Exercise 6

Your answer may include the following points:

1. The process includes rapidly heating the juice in a heat exchanger and filling containers with the hot juice (around 95°C) followed by sealing and inverting, thus pasteurizing the container. It should be followed by rapid cooling.

2. Please refer Figure 2.6.

Check Your Progress Exercise 7

Your answers should include the following points:

1. A magnetron in the oven generates electromagnetic waves (microwave). In the electromagnetic field generated in the oven, there is a rapid reversal of change (at either 915 or 2450 mega hertz). When microwaves penetrate a food, the dipolar molecules of water that are present oscillate about their axes in response to this reversal of change. Heat is generated in the food itself as a result of rapid oscillation.

The major use of microwave in the food industry is tempering and thawing of frozen foods.

2. The ohmic heating is a process where heat is generated in the product by passing an electric current. The heat is produced due to resistance created by the product during passage of current.

2.12 SOME USEFUL BOOKS

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