Unit II - Topic 1

PHYSICAL METHODS-THERMAL PROCESSING

12.1 Introduction

Heat kills microorganisms by changing the physical and chemical properties of their proteins. When **heat** is used to preserve foods, the number of microorganisms present, the **microbial load** , is an important consideration. Various types of microorganisms must also be considered because different levels of resistance exist. For example, bacterial spores are much more difficult to kill than vegetative bacilli. In addition, increasing acidity enhances the killing process in food preservation.

12.2 High Temperature

Three basic heat treatments are used in food preservation: **pasteurization**, in which foods are treated at about 62°C for 30 minutes or 72°C for 15 to 17 s; **hot filling**, in which liquid foods and juices are boiled before being placed into containers; and **steam treatment** under pressure, such as used in the canning method. The heat resistance of microorganisms is usually expressed as the **thermal death time**, the time necessary at a certain temperature to kill a stated number of particular microorganisms under specified conditions.

12.3 Pasteurization

It is the process of heating a food-usually a liquid-to or below its boiling point for a defined period of time. The purpose is to destroy all pathogens, reduce the number of bacteria, inactivate enzymes and extend the shelf life of a food product. Pasteurization treatment is able to kill most heat resistant non spore forming organisms like *Mycobacterium tuberculosis* and *Coxiella burnetti*. Foods with a pH of less than 12.6, such as milk and spaghetti sauce, can be pasteurized. Permanent stabilitythat is, shelf life of about two years is obtained with foods that can withstand prolonged heating, such as bottled juices. There is a greater loss of flavour from foods that are exposed to a longer time-temperature relationship. Therefore, temporary stability (that is, limited shelf life) is only obtained with some foods where prolonged heating would destroy its quality. These foods, such as milk, usually require subsequent refrigeration. "High Temperature Short Time" (HTST) and "Ultra High Temperature" (UHT) processes have been developed to retain a food's texture and flavour quality parameters. Pasteurization is not intended to kill all microorganisms in the food. Instead pasteurization aims to reduce the number of viable pathogens so that they are unlikely to cause disease. Pasteurization involves a comparatively low order of heat treatment, generally at temperature below the boiling point of water. eating may be done by means of steam , hot water, dry heat or electric currents . Products are immediately cooled. Desired pasteurization can be achieved by a combination of time and temperature such as heating food to a low temperature and maintain for a long time i.e. LTLT -62.8°C for 30 minute (Figure 12.1), or by heating food to a high temp and maintain for a short time: HTST-71.7°C for 15 second(Figure 12.2).

Pasteurization is used when more rigorous heat treatment might harm the quality of the food product, as the market milk and for the main spoilage organisms which are not heat resistant, such as yeast in fruit juice. It also kills the pathogens .

12.3.1 Ultra heat pasteurization

In this process milk is heated to 120-138°C for 2-4 seconds and followed by rapid cooling. This treatment kills all the spoilage microorganisms. UHT pasteurized milk is packaged aseptically resulting in a shelf stable product that does not require refrigeration until opened.

12.4 Heat Resistance of Microorganisms and Their Spores

It is expressed in terms of their thermal death time (TDT).

12.4.1 Thermal death time (TDT)

It is the time taken to kill a given number of microorganisms or spores at a certain temperature under specified conditions.

12.4.2 Thermal death point

It is the temperature necessary to kill all the organisms in ten minutes.

Heat resistance of different microorganisms is different. Microorganisms are more heat resistant than their spores. Heat resistance of vegetative yeast is 50-58°C in 10-15 min and the ascospores is 60°C for 10-15 min. However, yeast and spores are killed by pasteurization.

12.5 Heat Resistance of Microorganisms

Heat resistance of mold is 60°C in 5 to 10 min and asexual spores are more heat resistance than the ordinary mycelium and require a temperature 5-10°C higher for their destruction. *Aspergillus, Muco,* ,*Penicillium* are more resistant than yeast. Heat resistance of bacteria and bacterial spores is different. Cells high in lipid content and capsule containing bacteria are harder to kill. Higher the optimal and maximal temperature for growth , the greater the resistance to killing.

12.6 Heat Resistance of Enzymes

Most of the food and microbial enzymes are destroyed at 79.4°C . Some hydrolases will retain a substantial levels of activity after an ultra high temperature treatment. Bovine phosphatase, if present, in processed milk indicates that the milk was not properly pasteurized.

12.7 D Value

It is the decimal reduction time, or the time required to destroy 90% of the organisms. Mathmatically, it is equal to reciprocal of the slop of the survivor curve and is a measure of the death rate of a microorganisms. When D is determined at 250°F, it is expressed as D_r.

12.8 Z Value

It refers to the degree F required to reduce TDT ten fold. Mathematically, this value is equal to the reciprocal of the slope of the TDT curve.

12.9 F Value

This value is the equivalent time, in min at 250°F, of all heat considered, with respect to its capacity to destroy spores or vegetative cells of a particular organisms or F is the time in minute required to destroy the microorganisms in a specified medium at 250°F.

12.10 Thermal Death Time Curve

Mean viable counts determined at intervals of 5 minute are as follows-

Time Mean viable count 5 3120.0 10 65.015 19.0

Time of heating in min is plotted on semi-log paper along the linear axis and the number of survivors is plotted along the log scale to produce the TDT curve .

12-D concept: It is the time temperature process that will reduce the most heat resistant *Cl. botulinum* spores by 12 log cycles. Processing of food for 2.52 min at 250°C reduces *Cl. botulinum* spores to 1 spore in 10^{12} containers

12.11 Effect of Pasteurization

The positive effects of pasteurization are the destruction of pathogenic microorganisms to increase the safety of market milk for human consumption, improved keeping qualityandinactivation of certain naturally occurring enzymes.

The negative effects are: certain preformed products of microbial origin are not inactivated during pasteurization, e.g. Staphylococcal toxins and aflatoxins. There is small loss of native aroma particularly in case of fruit juices. In case of milk, it destroys the natural microbicidal property of milk by inactivating different natural occuring antimicrobial substances and the rennet coagulation time also increases.

12.12 Blanching

It is a kind of pasteurization generally applied to fruits and vegetables , primarily to inactive natural food enzymes. It is a common practice when such food products are to be frozen, since frozen storage itself would not completely arrest enzyme activity. Peroxidase and catalase are the most heat resistant enzymes; the activity of these enzymes is used to evaluate the effectiveness of a blanching treatment. If both are inactivated then it can be assumed that other significant enzymes also are inactivated. The heating time depends on the type of fruit or vegetable, method of heating, the size of fruits or vegetable or the temperature of the heating medium.

Rapid changes in colour, flavor and nutritive value occur as a result of enzyme activity. Blanching is a slight heat treatment, using hot water or steam, that is applied mostly to vegetables before canning or freezing. The main objectives of blanching are to inactivate enzymes, to remove the tissue gases, to clean the tissue, to increase the temperature of the food. Blanching is also used before canning for different reasons, because enzymes will inevitably be destroyed during canning. Blanching induces a vacuum in canned goods, and it is also used to control the fill into containers (for example, spinach).

12.13 Sterilization (Retorting)

Sterilization destroys all pathogenic and spoilage microorganisms in foods and inactivates enzymes by heating. All canned foods are sterilized in a retort (a large pressure cooker) and called commercial sterilization which indicates that no viable organisms are present. This process enables food to have a shelf life of more than two years. Foods that have a pH of more than 4.6, such as meat and most vegetables must undergo severe heating conditions to destroy all pathogens. These foods are heated under pressure to 121°C for varying times. Severe conditions are applied primarily to ensure that *Clostridium botulinum* spores are destroyed during processing. These spores produce the deadly botulinum toxin under anaerobic conditions (that is, where there's no oxygen). The spores are destroyed by heat or are inhibited at pH values of less than 4.6 Therefore, a food with a pH of less than 4.6 that is packaged anaerobically, such as spaghetti sauce, doesn't need to undergo such a severe heat treatment. The destruction of vegetative and sporeforming organism and pathogens is secondary objective of commercially sterilized foods.

Nicolas Appert , a Parisian confectioner by trade, established the heat processing of foods as an industry in 1810. The food product is washed, sorted, and graded and then subjected to steam for three to five minutes. This last process called blanching, destroys many enzymes in the food product and prevents further cellular metabolism. The food is then peeled and cored, and diseased portions are removed. For canning, containers are evacuated and placed in a pressurised steam steriliser, similar to an autoclave at 121°C. This removes especially *Bacillus* and *Clostridium* spores. If canning is defective, foods may become contaminated by anaerobic, bacteria which produce gas. These are species of *Clostridium*, and coliform bacteria (a group of Gram-negative non spore-forming rods which ferment lactose to acid and gas at 32°C in 48 hours).

Canning cooking fruits or vegetables, sealing them in sterile cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of pasteurization. High-acid fruits like strawberries require no preservatives to can and holding for only a short boiling cycle, whereas marginal fruits such as tomatoes require longer boiling and addition of other acidic elements. Many vegetables require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened. Lack of quality control in the canning process may allow ingress of water or micro-organisms. *Clostridium botulinum* produces an acute toxin within the food and may lead to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Food contaminated in this way include Corn, beef and Tuna.

In canning process heat is applied to food that is sealed in a jar in order to destroy any microorganisms that can cause food spoilage. Proper canning techniques stop this spoilage by heating the food for a specific period of time and killing these unwanted microorganisms. During the canning process, air is driven from the jar and a vacuum is formed as the jar cools and seals.

Water-bath canning and pressure canning are two approved methods of canning.

12.14 Water-Bath Canning

This method sometimes referred to as *hot water canning*, uses a large kettle of boiling water (Figure 12.4). Filled jars are submerged in the water and heated to an internal temperature of 212°F for a specific period of time. This method is used for processing high-acid foods, such as fruit, items made from fruit, pickles, pickled food, and tomatoes.

12.15 Pressure Canning

Pressure canning uses a large kettle that produces steam in a locked compartment (Figure 12.5). The filled jars in the kettle reach an internal temperature of -240 °C under a specific pressure (stated in pounds) that is measured with a dial gauge or weighted gauge on the pressure-canner cover. A pressure canner should be used for processing vegetables and other low-acid foods, such as meat, poultry and fish.

12.16 Drying

One of the oldest methods of food preservation is by drying, which reduces water activity sufficiently to delay or prevent bacterial growth. Drying is done to produce concentrated form of foods, inhibits microbial growth and autolytic enzymes, retains most nutrients. Drying can cause loss of some nutrients, particularly thiamine and vitamin C. Sulphur dioxide is sometimes added to dried fruits to retain vitamin C, but some individuals are sensitive to this substance.

Most types of meat can be dried. This is especially valuable in the case of pig meat, since it is difficult to keep without preservation. Many fruits can also be dried; for example, the process is often applied to apples, pears, bananas, mangos, papaya, and coconut and grapes . Drying is also the normal means of preservation for cereal grains such as wheat, maize, oats, barley, rice, millet and rye. Drying is an excellent way of preserving several of the seasonal fruits for use during the off season. There are several types of dryers which are used. These include: drum dryer, cabinet dryer, tunnel dryer, rotary dryer, spray dryer and solar dryer. The basic methods of drying involves ai r and contac t dr ying under atmospheric pressure . In this cas e the heat is transferred through the food either from heated air or heated surfaces, and the resulting water vapour is removed with the air current . Solar drying, sun drying, drum and spray drying all use this technique.

Advantages of drying are many

i) Long Shelf Life – Since most microorganisms responsible for food spoilage are unable to grow and multiply in the absence of moisture, spoilage due to microbial degradation is limited in dried foods. Furthermore, enzymes which catalyse undesirable changes in foods need moisture to be effective.

ii) Reduced Weight – This results in reduced transportation, storage and shipping costs.

iii) Convenience – The production of convenience items with novelty appeal for niche markets makes drying an attractive option.

iv) Concentration of nutrients – The removal of most of the water from a food results in a highly concentrated source of nutrients.

v) No refrigeration is required for dried products – Savings in energy and storage costs together with the long shelf life provide a lucrative processing alternative for tropical countries.
Disadvantages of Drying

Disadvantages of Drying are few and mainly relate to oxidation, which usually accompanies drying. This results in losses of micronutrients such as carotene and ascorbic acid and minimal loss in protein as a result of browning reactions. Reduced consumer appeal is often linked with the latter. There might also be changes in flavour and texture if drying is not properly controlled, particularly with regard to maximum temperatures.

12.17 Microwave Sterilization

Microwave sterilization is a thermal process. A microwave oven (Figure 12.6) works by passing non ionizing microwave radiation, usually at a frequency of 2.125 GHz (a wavelength of 12.212 cm), through the food. Microwave radiation is between common radio and infrared frequencies. Microwave heating takes place due to the polarization effect of electromagnetic radiation at frequencies between 300 MHz and 300 GHz. It delivers energy to the food package under pressure and controlled temperature to achieve inactivation of bacteria harmful for humans. Most processed foods today are heat treated to kill bacteria. Prolong exposure to high heat often diminishes product quality. Microwaves interact with polar water molecules and charged ions. The friction resulting from molecules aligning in rapidly alternating electromagnetic field generates the heat within food. Since the heat is produced directly in the food, the thermal processing time is sharply reduced. The colour, texture and other sensory attributes of foods processed by microwave sterilization are often better compared with those of conventionally retorted foods while meeting microbial safety requirements. US Federal Communication Commission (FCC) allocates 915 MHz and 21250 MHz bands for industrial and domestic microwave heating applications. The microwave sterilization technology using the combination of 915 MHz microwave and conventional heating to improve heating uniformity. Microwave ovens use electromagnetic radiation to excite water molecules in food. The actual waves penetrate only about 10 inches from the source of the radiation. Within the food, the waves only penetrate 3/12 to 1 inch on all sides. As a result, the actual ovens must be limited in size. Heat is produced within the food by the friction of water molecules, which spreads to the centre of the food by conduction. Small portions are cooked rapidly in microwave ovens. As the quantity of food increases, however, the efficiency is lost.

Microwave heating has also found applications in the food industry, including tempering of frozen foods for further processing, pre-cooking of bacon for institutional use and final drying of pasta products. In those applications, microwave heating demonstrates significant advantages over conventional methods in reducing process time and improving food quality.

The shelf life of a product is determined by its microbiological safety and sensory attributes. In general, microwave sterilization can achieve the same reduction of bacterial population as conventional retorting. Products intended for microwave sterilization are usually packaged in plastic trays or pouches. The ability of plastics to withstand oxygen permeation will affect the organoleptic or sensory acceptance of the product during storage. Normal shelf life expectancy of microwave-sterilized products pre-packaged in plastic containers or pouches is 2-3 years or longer. With innovative plastic technologies coming to the market, the new generations of plastics may increase the expected shelf life even longer.