UNIT 6 THERMAL CONTROL OF MICROORGANISMS

Structure

6.0 OBJECTIVES

After studying this unit, you should be able to:

- make you understand the principals of food preservation using high temperatures;
- explain various processes for thermal preservation;
- describe the terms associated with heat preservation; and
- discuss the causes of spoilage of heat processed products and common spoilage organisms.

6.1 INTRODUCTION

The minute living organisms, not visible to the naked eye and classified as microorganisms, are virtually everywhere. Those of primary medical interest are bacteria, viruses, spirochetes, rickettsia, molds, and yeasts. They flourish in the soil of the farms that grow our grains, fruits and vegetables, on the hides and feathers of our meat animals and on the fins and organs of the seafood we eat. Though there are innumerable genera and species of each class of microorganisms, not all are of medical significance or involved in disease processes. Many of these organisms can be beneficial. In fact the predominance are composed of those that are necessary to food production, friendly environments, and metabolic processes, examples being cheese/wine production, decomposition of organic matter, and digestion of food. Lactic acid bacteria in the dairy industry, yeasts in the baking and brewing industries, molds for specialty cheeses are examples of "domesticated" microorganisms. But in a many cases these microscopic flora create serious problems in our food supply. These problems fit into two categories. **Food spoilage** occurs when the food becomes unpalatable as the result of microbial growth. Products develop undesirable flavors, odors, appearances or textures via microbial action. The other, more dangerous problem is **food poisoning**, which occurs when the organisms present in food cause human illness or death. The microorganisms either produce a toxin or cause an infection, generally intestinal, when consumed. Those organisms that spoil product are typically called **spoilage organisms**, while those that can make people sick are referred to as **pathogens**. Therefore, to avoid both of these problems we need to understand the techniques which prevent their growth.

Food preservation has been around for a long time. The technique of food preservation may vary but the goal of food preservation has been the same **i.e. to keep the food in a stable condition over a period of time so that it will not spoil or make people sick.** There are various ways of food preservation, including chemical preservation, modified atmospheres, irradiation, low temperature preservation, preservation by drying and high temperature preservation.

6.2 THERMAL PRESERVATION OF FOODS

The most common method of killing microorganisms is to subject them to a heat treatment. High temperatures act by killing vegetative cells and also spores and denaturing the food enzymes. It may also act to destroy toxins produced by certain microorganisms.

The heat treatment used depends on the following factors. In order to safely preserve foods using heat treatment, the following must be known:

- What time-temperature combination is required to inactivate the most heat resistant pathogens and spoilage organisms in one particular food? The higher the temperature, the less time needed and vice versa. Heat destruction of microorganisms is a gradual phenomenon the longer is the treatment time at lethal temperatures, the larger is the number of microorganisms killed. As higher is treatment temperature the shorter is the time required to kill microorganisms and lower is heat induced damage to food products.

- What are the heat penetration characteristics in one particular food, including the can or container of choice if it is packaged?

- What are the types of micro-organisms present in the food material? The thermal death time of different microorganisms vary widely with the species. Different foods will support growth of different pathogens and different spoilage organisms so the target will vary depending upon the food to be heated.

- What is the concentration of the microorganisms? The higher the concentration, the more time is needed.

- What is the state of the microorganism? Spores are more resistant than vegetative cells. Organisms that have been stressed are more susceptible to heat.

- What is effect of heat on the product? Obviously, the temperatures required to kill microorganisms affect most food products.

- The degree of heat penetration also must be considered. Preservation processes must provide the heat treatment which will ensure that the remotest particle of food in a batch or within a container will reach a sufficient temperature, for a sufficient time, to inactivate both the most resistant pathogen and the most resistant spoilage organisms if it is to achieve sterility or "commercial sterility", and to inactivate the most heat resistant pathogen if pasteurization for public health purposes is the goal

- What is the effect of various environmental factors, such as pH and salts or solutes. Food acidity / pH value has a tremendous impact on the target in heat preservation/ processing.

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. Differentiate between spoilage organisms and pathogens?

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2. What is food preservation?

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3. Write various ways of food preservation?

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4. List important factors which need consideration in order to safely preserve foods using heat treatment?

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6.3 HEAT PRESERVATION PROCESSES

The most common type of food preservation by high temperatures is cooking. However, there are many more processes that involve the use of temperature above that of ambient air.

6.3.1 Sterilisation

By sterilisation we mean complete destruction of micro-organisms. Because of the resistance of certain bacterial spores to heat, this frequently means a treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent. It also means that every particle of the food must receive this heat treatment. If a can of food is to be sterilized, then keeping it at 121° C or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point. In such cases time needs to be increased.

6.3.2 Commercially Sterile Food Products

Sterile means free of life of every kind and is actually achieved under very limited conditions. The control of microorganisms in medicine, industry, sanitation, food, and feed service involves the acceptance that sterilization is most often not achievable without destroying or severely damaging the product. Only Low Acid Foods [LAF], having pH higher than 4.6, must be sterilized, because all microorganisms are able to grow in LAF. More acid products [pH equal/lower than 4.6] do not allow the growth of pathogenic spore forming bacteria. Then Sterilization is not required. Hence **Commercial Sterility** is a term commonly used in the canning industry meaning the condition achieved by the application of heat sufficient to render the processed product free from viable microorganisms (including those of known public health significance), capable of growing in the food under normal non-refrigerated temperatures at which the food is likely to be held during distribution and storage.

The process was developed by Nicolas Appert and published in 1810. All vegetative organisms that could grow in the food and cause spoilage under normal handling and storage conditions are destroyed. However **commercial sterile** foods may contain a small number of heat resistant bacterial spores, but they will not multiply under normal handling and storage conditions. Types of commercially sterile processes include canning, bottling, and aseptic processing. Commercial sterilization must make sure the numbers of surviving spores are at an acceptable level. The acceptable number of spores will depend on what type of damage they are capable of causing if they start to grow.

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. What is sterilization?

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2. What is commercial sterility? How commercial sterilization is different from sterilization?

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6.4 PASTEURIZATION

In the previous section you have read about strerilzation and commercially sterile foods. Now we will discuss milder heat treatment i.e. pasteurization. It is one type of preservation by heat that most people are familiar with. It is process of heating a liquid, particularly milk, to a temperature between 55 and 70 degrees C (131 and 158 degrees F), to destroy harmful bacteria. This process is named after the French chemist **Louis Pasteur**, who devised it in 1865 to inhibit fermentation of wine. Pasteur's aim was to destroy bacteria, molds, spores etc. He discovered that the destruction of bacteria can be performed by exposing them to certain minimum temperature for certain minimum time and the higher the temperature the shorter the exposure time required. Through this process, all of the bacteria (such as *E.coli, Lysteria*, and *Salmonella)* are not destroyed, it still exists in pasteurized products, but in very low concentrates. Refrigeration keeps the bacteria from further growth, very low. There are other bacteria that aren't harmful to humans, but they produce acids that turn the milk sour. They are called lactophilic because they consume the lactose in milk and produce acids. The extent of the pasteurization treatment required is determined by the heat resistance of the most heat-resistant enzyme or microorganism in the food. For example, milk pasteurization is based on *Mycobacterium tuberculosis* and *Coxiella burnetii*. These two organisms are the most heat resistant of pathogens that are not spore forming. Milk is a product that most people know is pasteurized. It is pasteurized by heating at a temperature of 63 degrees C (145 degrees F) for 30 minutes, rapidly cooling it, and then storing it at a temperature below 10 degrees C (50 degrees F).

Pasteurization is a comparatively low order of heat treatment, generally at a temperature below the boiling point of water. The more general objective of pasteurization is to extend product shelf-life from a microbial and enzymatic point of view. Pasteurization is frequently combined with another means of preservation - concentration, chemical, acidification, etc. Blanching is a type of pasteurization usually applied to vegetables mainly to inactivate natural food enzymes. Depending on its severity, blanching will also destroy some microorganisms.

Depending upon time and temperature treatment there are three kinds of pasteurization processes.

6.4.1 Low Temperature Long Time (LTLT)

Where pasteurization time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are as following: 63°C to 65°C for 30 minutes or 75° C over 8 to 10 minutes. Pasteurization temperature and time will vary according to:

- nature of product; initial degree of contamination;
- pasteurized product storage conditions and shelf life required.

In LTLT pasteurization 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.

This is a typical batch method where a quantity of milk is placed in an open vat and heated to 63°C and held at that temperature for 30 min. Sometimes filled and sealed bottles of milk are heat-treated in shallow vats by that method and subsequently cooled by running water.

6.4.2 High Temperature Short Time (HTST)

HTST 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 are as follows:

- 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. This is the most widely used process. The "hold time" is typically 125°C to pasteurize milk. This process is a continuous method and a "hold tube" is used. The "hold tube" is the tubing in the system that transports the milk after the point where the product is heated. The tubing is sized so that it takes 15-20 seconds for the product to travel all the way through it. When it reaches the end, if the temperature is at 125°C or hotter, it is considered pasteurized. It is then cooled and put in storage. The warm milk passes through the cooling section where it is cooled to 4° C or below by coolant on the opposite sides of the thin, stainless steel plates. The cold, pasteurized milk passes on to a storage tank filler for packaging.

6.4.3 Ultra High Temperature (UHT) Processing Treatments

In this method, milk is exposed to a brief, intense heating, normally to temperatures in the range 135-140 °C but for a very short time, a second or less. The treatment kills all microorganisms that would otherwise spoil the product. The process depends upon a fairly complicated *sterilizer/aseptic filling* design. The two stages of effective heat sterilization followed by aseptic filling represent an integral system. Frequently the packaging material for UHT milk is cardboard which must be chemically sterilized prior to the filling operation

This method is used mainly for coffee creamers and boxed juices with the exception of Europe. They pasteurize milk in this way. After this is done, there is no need to refrigerate, because it sterilizes the product. Sometimes the products can have a "cooked" taste that can be detected after being brought to such a high temperature.

Industrial applications of pasteurization process are mainly used as a means of preservation for milk and fruits and vegetable juices and specially for tomato juice.

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. Name the scientist who invented Pasteurization. In which food material this process is used the most?

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2. Why pasteurization of milk is important?

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3. What are the factors responsible for microbial inactivation during pasteurization?

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4. Does pasteurization kill all the bacteria in the product?

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5. Name the organisms on which milk pasteurization time and temperature is based?

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6. Why HTST pasteurization is better treatment than LTLT?

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6.5 PRESERVATION BY MOIST HEAT

Moisture levels of the food material are a definite influencing factor in the shelf life of food. Moist heat readily kills viruses, bacteria, and fungi by denaturing enzymes whereas dry heat kills by oxidation of cell contents. There is a correlation between the percent of water and the effectiveness of heat to kill microorganisms. Moist heat is a more effective sterilizing agent than dry heat because the moisture increases the rate of heat penetration. Moist heat requires less heat (temperature or time) than dry heat (121°Cfor 10 min of moist heat is equivalent to about 30 min at 200°C dry heat).

For this reason a lot of sterilization procedures use super heated steam that provides moist heat. Temperature over 100^0C requires heating under elevated pressure, (like in a pressure cooker) 121^0C require 100 kpa extra pressure. It is important that no air pockets are allowed to develop when a product being sterilized with steam. In air pockets food is exposed to dry heat and thus the time /temperature is not enough. Moist heat denatures proteins which destroys essential enzyme activities.

Endospores are much more resistant to heat than are vegetative cells. For this reason, moist heat sterilization is aimed at ensuring that endo spores are killed.

Terms Associated with Heat Preservation

Scientists use different terms to refer the effect of moist heat on the preservation of food. These terms include thermal death time, D-value, and z-value.

6.5.1 Thermal Death Time (TDT)

Thermal death time is the amount of time that is necessary to kill a specific number of microbes at a specific temperature. This value is obtained by keeping temperature constant and measuring the time necessary to kill the amount of cells specified.

6.5.2 D-Value

The term D-value refers to decimal reduction time. This is the amount of time that it takes at a certain temperature to kill 90% of the organisms being studied. Thus after an organism is reduced by 1 D, only 10% of the original organisms remain. The population number has been reduced by one decimal place in the counting scheme. When referring to D-values it is proper to give the temperature as a subscript to the D. For example, a hypothetical organism is reduced by 90% after exposure to temperatures of 149°C for 2 minutes, Thus the D-value would be written as D_{300F} = 2 minutes. Several parameters help us to do thermal calculations and define the rate of thermal lethality. The D-value is a measure of the heat resistance of a microorganism. It is the time in minutes at a given temperature required to destroy 1 log cycle (90%) of the target microorganism. (Of course, in an actual process, all others that are less heat tolerant are destroyed to a greater extent). For example, a D-value at 72°C of 1 minute means that for each minute of processing at 72°C the bacteria population of the target microorganism will be reduced by 90%. D-values vary according to the temperature, species of microorganisms, number of initial population, and other factors that may affect thermal resistance. In the illustration below, the D-value is 14 minutes (40-26=14 min.) and would be representative of a process at 72°C.

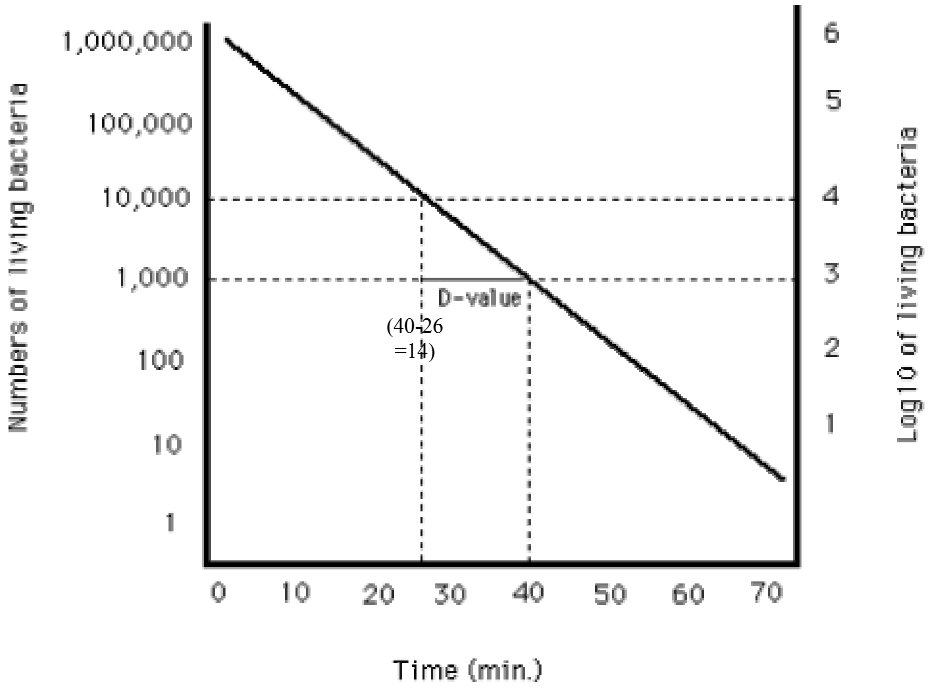

Figure 6.1: The D-value

6.5.3 Z-Value

The Z-value reflects the temperature dependence of the reaction. It is defined as the temperature change required to change the D-value by a factor of 10. While the D-value gives us the time needed at a certain temperature to kill an organism, the Z-value relates the resistance of an organism to differing temperatures. In the illustration below the Z-value is 10°C.

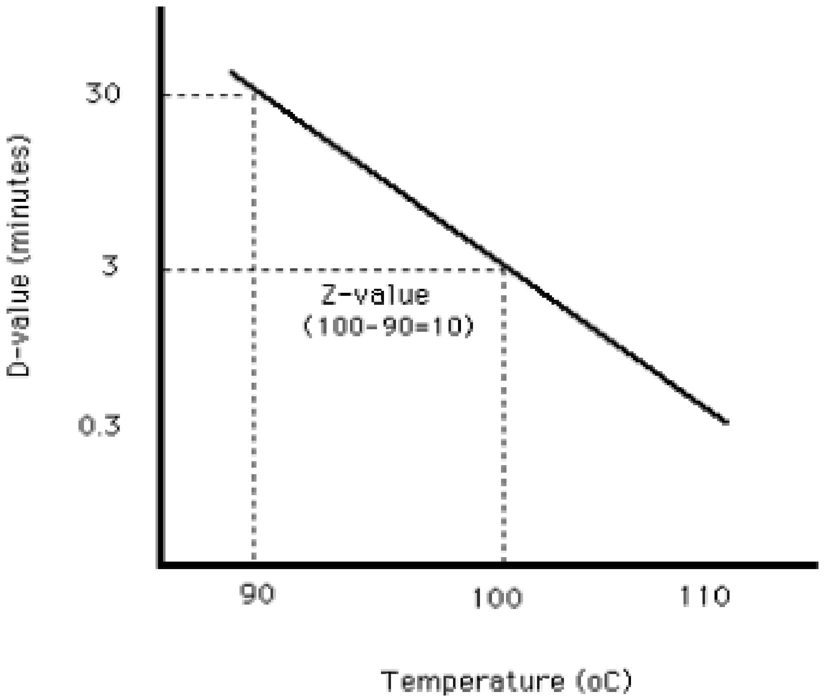

Figure 6.2: The Z-value

The Z-value allows us to calculate a thermal process of equivalency, if we have one D-value and the Z-value. So, if it takes an increase of −12°C to move the curve one log, then our Z-value is 10. So then, if we have a D-value of

4.5 minutes at 66°C, we can calculate D-values for 71°C by reducing the time by 1 log. So, our new D-value for 71°C is 0.45 minutes. This means that each -12°C increase in temperature will reduce our D-value by 1 log. Conversely, a -12°^{0}C decrease in temperature will increase our D-value by 1 log. So, the D-value for a temperature of 60°^{0}C would be 45 minutes.

Reactions that have small Z-values are highly temperature dependent, whereas those with large Z-values require larger changes in temperature to reduce the time. A Z-value of 10°C is typical for a spore forming bacterium. Heat induced chemical changes have much larger Z-values that microorganisms, as shown below:

	Z (°C)	**D121(min)**
bacteria	5-10	1-5
enzyme	30-40	1-5
vitamins	20-25	150-200
pigment	40-70	15-50

Figure 6.3 illustrates the relative changes in time temperature profiles for the destruction of microorganisms. Above and to the right of each line the microorganisms or quality factors would be destroyed, whereas below and to the left of each line, the microorganisms or quality factors would not be destroyed. Due to the differences in Z values, it is apparent that at higher temperatures for shorter times, a region exists (shaded area) where pathogens can be destroyed while vitamins can be maintained. The same holds true for other quality factors such as colour and flavour components. Thus in milk processing the higher temperature, shorter time (HTST) process (72°C/16 sec) is favoured compared to a lower temperature longer time (batch or vat) process since it results in a slightly lower loss of vitamins and better sensory quality.

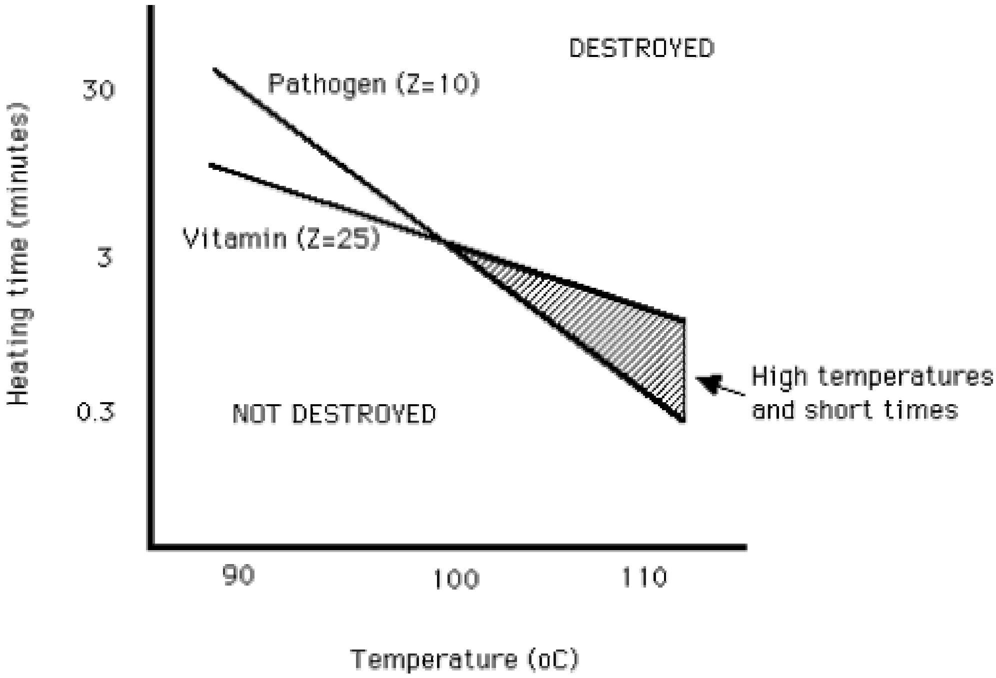

Figure 6.3: The relative changes in time temperature profile

Alkaline phosphatase is a naturally-occurring enzyme in raw milk which has a similar Z value to heat-resistant pathogens. Since the direct estimation of pathogen numbers by microbial methods is expensive and time consuming, a simple test for phosphatase activity is routinely used. If activity is found, it is assumed that either the heat treatment was inadequate or that unpasteurized milk has contaminated the pasteurized product.

6.5.4 12-D Concept

Canned foods are susceptible to the spores of the organism *Clostridium botulinum*. This is the organism that causes botulism. Their bacterial spores can survive many heat treatment processes. However, in modern food production, canned foods are subjected to a time/temperature process that will reduce the probability of the survival by the most heat-resistant *C. botulinum* spores by 12 logs or 12-D at 250F (the temperature used in the calculation of most commercial 12-D processes is 250F, and the D-value for this organism at 250F is 0.21 minutes). This process is based on the assumption of the number of surviving spores in one can. If it is assumed that a container had one million spores per can the heat treatment needed to reduce the number to one in one million i.e. from 10^6 to 10^{-12} involves a reduction of twelve decimal places i.e. from 1,000,000 to 0.0000001

6.5.5 F-Value

If we assume that there are 10 surviving spores in one can, then we can calculate the time for a 12-D process to occur by using the following formula:

- $F_0 = D_{250F}$ (log a − log b), where a = initial population and b = final population.
- So F_0 = (0.21min.) (log 10^1 − log 10^{-11}), we move down 12 log values (1 − (−11)) = 12.
- So, F_0 = (0.21min.) (1 − (−11)), or 0.21 × 12 = 2.52 minutes.

Simply put, (D-value at 250F) × (12) results in a 12-D process.

The killing effect of a time / temperature combination is referred to as the **F-value.**

F = 1 is heat killing effect equivalent to 1 min at 121°C.

The F-value required to achieve a 12D cook depends on the resistance of the particular type of bacteria. One of the most resistant species is *Bacillus stearothermophilus* which is 5 or 6 time more resistant than *C. botulinum.*

A 12-D cook for *Cl. botulinum* may require an F value of 2.52
A 12-D cook for *B. stearothermophilus* may require F = 18

From food safety angle, the microorganisms of greatest concern are *Salmonella* sp., *Clostridium perfringens*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter sp*., and *E. coli*, all of which have much lower z values and consequently should achieve a 12D process in a shorter time. *Bacillus* of the most heat resistant strains of bacteria known.

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. Why moist heat is a more effective sterilizing agent than dry heat?

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2. Define D-value and Z-value. How these terms are inter-related?

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3. What is the principal of 12D concept?

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4. Define F-value?

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6.6 MICROBIOLOGY OF THERMALLY PROCESSED FOOD

As you can now very well understand the heat is an important way of preserving foods. Still some thermally processed foods undergo spoilage due to chemical or biological reasons. The most important chemical spoilage of canned foods is the hydrogen swell produced as a result of action of food acids with the metals. Biological spoilage of thermally processed foods by microorganisms may result either from the survival of organisms after the heat treatment or leakage of the container permitting entrance of the microorganisms. Surviving organisms may be vegetative cells or spore formers depending upon the heat treatment. Acid foods are processed at temperature around $100^{O}C$ which result in the killing of all vegetative cells of bacteria, yeasts and molds. Only bacterial spores may survive *stearothermophilus* is a non-pathogenic organism that has been shown to be one but these do not grow in acid foods. On the other hand, meat, vegetables and milk are processed at low temperatures. This may eliminate vegetative cells but not the spores, which germinate later and cause spoilage. Microorganisms that enter through leaks during cooling need not necessarily be heat resistant.

6.6.1 Spoilage by Thermophilic Bacteria

Under processing of low acid foods result in spoilage by thermophilic (microorganisms which require high temperature, more than 45°C for their growth) bacteria such as *Bacillus coagulance, Bacillus stereothermophilus*. These microbes produce heat resistant endospores than can survive 121°C for 4-5 minutes. These organisms produce acid without gas. This is known **as flat sour spoilage**. Some times In Low and medium acid foods the cans swell due to production of carbon dioxide and hydrogen by *Clostridium thermosaccharolyticum*. This is known as **thermophilic spoilage**. **Sulphide spoilage** is caused by *Clostridium nigrificans* in low acid foods. Spores of this bacterium are not very heat resistant and their presence is indicative of under processing. Spoilage is indicated by the the presence of H_2S and blackening of material. Sources of all these material are generally, the plant equipment, sugar, starch, soil etc.

6.6.2 Spoilage by Mesophilic Organisms

Mesophilic microorganisms are those microorganisms which grow best at temperature 25-45°C. Spoilage of canned foods by mesophilic organisms is indicative of under processing and is caused by species of Bacillus, Clostridium, Yeast and fungi. *Clostridium butyricum* and *C. pasteurianum* produce a butyric acid type of fermentation in acid or medium acid foods with swelling of the container by the production of CO_2 and H_2. Other species of *Clostridia* may produce H_2S causing can to swell. These putrefactive anaerobes (Micro organism that grow in the absence of oxygen) generally grow in low acid foods such as peas corn, meat, poultry etc. but some times may also spoil medium acid foods.

Some *Bacilli* such as *Bacillus subtilis* and *B. mesentroides* have been found to grow in poorly evacuated cans of sea foods, meat and milk. The gas forming Bacilli (B.polymyxa, B. macerans) are also reported to cause spoilage of canned peas, spinach, peaches and tomatoes.

The presence of non spore forming bacteria in canned food is an indicative of leak or under processing. *Streptococcus thermophilus*, *Pseudomonas*, *Micrococcus* and *proteus* have also been reported to cause spoilage of thermally processed products. Molds, yeast and their spores are destroyed at pasteurization temperature. Their presence is indicative of under processing or leakage. Spoilage of canned fruits and fruit products by yeasts may result in CO_2 production and spoilage of cans. Film yeast and fungi grow on the surface and cause degradation of the product.

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 probable reasons for biological spoilage of thermally treated foods?

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2. Name two thermophilic microorganisms responsible for flat sour spoilage.

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3. What is thermophilic spoilage?

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4. What do you understand about sulphide spoilage of low acid foods?

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5. Name some mesophilic bacteria responsible for spoilage of thermally treated foods.

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6.7 LET US SUM UP

Thermally processed foods are those that have been i) heated in hermetically sealed container ii) have been filled hot into a container which is then closed and cooled. The purpose of these processes is to destroy pathogenic microorganisms and those that might grow and cause spoilage of the particular food. The food that are commercially sterile are those that will not support microbial growth when exposed to the usual temperatures during storage, transport and marketing. However, they may not be completely free of microorganisms. Pasteurization is heat treatment to inactivate some microorganisms. Thermally processed foods may get spoiled due to under processing or leakage.

6.8 KEY WORDS

Thermophilic	:	Microorganisms which grow at temperature above 45°C.
Mesophilic	:	Microorganisms which grow at temperature 25-45°C.
Under processing	:	Lower time or temperature treatment.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check You Progress Exercise 1

1. Your answer should include the following points:

   - Microorganisms that spoil product are typically called **spoilage organisms**.
   - Microorganisms that can make people sick are **pathogens**.

2. Your answer should include the following points:

   - to keep the food in a stable condition over a period of time
   - to prevent it from spoilage or making people sick.

3. Your answer should include the following points:

   - chemical preservation
   - modified atmospheres
   - irradiation
   - low temperature preservation
   - preservation by drying
   - high temperature preservation.

4. Your answer should include the following points:

   - Time-temperature combination
   - heat penetration characteristics of particular food
   - the type of micro-organisms present in the food material
   - the thermal death time of different microorganisms
   - type of food
   - concentration of the microorganisms
   - state of the microorganism
   - effect of heat on the product
   - the degree of heat penetration
   - food acidity / pH value.

Check You Progress Exercise 2

1. Your answer should include the following points:

   - complete destruction of micro-organisms.

2. Your answer should include the following points:

   - the condition achieved by the application of heat sufficient to render the processed product free from viable microorganisms
   - capable of growing in the food under normal non-refrigerated temperatures at which the food is likely to be held during distribution and storage

- Unlike sterilization here the food is not completely free of microorganisms.

Check You Progress Exercise 3

1. Your answer should include the following points:

   - process created by Louis Pasteur
   - aimed to destroy bacteria, molds, spores etc.
   - discovery about the destruction of bacteria by exposing them to certain minimum temperature for certain minimum time
   - the higher the temperature the shorter the exposure time required.
   - process applied to milk.

2. Your answer should include the following points:

   - Public Health Aspect – to make milk and milk products safe for human consumption by destroying all bacteria that may be harmful to health (pathogens)
   - Keeping Quality Aspect – to improve the keeping quality of milk and milk products. Pasteurization can destroy some undesirable enzymes and many spoilage bacteria. Shelf life can be 7, 10, 14 or up to 16 days.

3. Your answer should include the following point:

   - extent of microbial inactivation depends on the combination of temperature and holding time.

4. Your answer should include the following points:

   - Through pasteurization all of the bacteria are not completely destroyed, it still exists in pasteurized products, but in very low concentrates.
   - Refrigeration keeps the bacteria from further growth, very low.

5. Your answer should include the following points:

   - thermal death time studies for the most heat resistant pathogens found in milk
   - *Coxiella burnetii* and *Mycobacterium tuberculosis* are the most heat resistant non spore forming pathogens.

6. Your answer should include the following points:

   - bacterial destruction is very nearly equivalent in LTLT and in HTST pasteurization processes but
   - HTST treatment give the best quality products in respect of flavour and vitamin retention.

Check You Progress Exercise 4

1. Your answer should include the following points:

   - moisture increases the rate of heat penetration.
   - Moist heat requires less heat (temperature or time) than dry heat
   - 121°C for 10 min of moist heat is equivalent to about 30 min at 200°C of dry heat.

2. Your answer should include the following points:

   - D-value is the amount of time that it takes at a certain temperature to kill 90% of the organisms being studied.
   - Z value is defined as the temperature change required to change the D-value by a factor of 10.
   - D-value gives us the time needed at a certain temperature to kill an organism
   - Z-value relates the resistance of an organism to differing temperatures.

3. Your answer should include the following points:

   - process based on the assumption of the number of surviving spores in one can.
   - canned foods subjected to a time/temperature process that will reduce the probability of the survival of the most heat-resistant *C. botulinum* spores by 12 logs i.e. from 1,000,000 to 0.0000001.

4. Your answer should include the following point:

   - killing effect of a time / temperature combination.

Check You Progress Exercise 5

1. Your answer should include the following point:

   - Under processing or leakage may be the cause of spoilage of thermally treated foods.

2. Your answer should include the following point:

   - *Bacillus coagulance* and *Bacillus stereothermophilus.*

3. Your answer should include the following point:

   - In Low and medium acid foods the cans swell due to production of carbon di oxide and Hydrogen by *Clostridium thermosaccharolyticum*.

4. Your answer should include the following points:

   - caused by *Clostridium nigrificans* in low acid foods.
   - Spores of *Clostridium nigrificans* are not very heat resistant and their presence is indicative of under processing.

- Spoilage is indicated by the the presence of H_2S and blackening of material.
- Sources of all these material are generally, the plant equipment, sugar, starch, soil etc.

5. Your answer should include the following points:

- *Clostridium nigrificans*
- *C. pasteurianum*
- *Bacillus subtilis*
- *B. mesentroides*
- *B.polymyxa*
- *B. macerans*
- *Streptococcus thermophilus*
- *Pseudomonas*
- *Micrococcus* and *Proteus.*

6.10 SOME USEFUL BOOKS

1. Adams, M.R. and Moss, M.O. (2000) Food Microbiology. Royal Society of Chemistry, Cambridge, U.K.

2. Jay, J.M. (2000) Modern Food Microbiology, Van Nostrand Company, New York.