High-Temperature Food Preservation:

The use of high temperatures to preserve food is based on their destructive effects on microorganisms. Depending on the temperature and time of heating, microbial cells and spores can be heat-shocked, sublethally injured, or dead. Heat-shocked cells achieve some resistance to subsequent heating and sublethally injured cells and spores retain the ability to repair and multiply.
Heat injury, bacterial cells show loss of permeability and increased sensitivity to some compounds to which they are normally resistant. **Sublethally injured cells** seem to suffer injury in the cell membrane, cell wall, DNA, ribosomal RNA and some important enzymes (denaturation). **Death** occurs from damages in some vital functional and structural components. Death of bacterial spores results from the inability of a spore either to germinate or to outgrow.

Heat treatments employed in processing foods:

1- Low-Heat Processing or Pasteurization

The temperature used for low-heat processing or pasteurization is below 100ºC. Pasteurization by use of heat implies either the destruction of all disease-producing organisms (for example, pasteurization of milk) or the destruction or reduction in the number of spoilage organisms in certain foods, as in the pasteurization of vinegar. The pasteurization of milk is achieved by heating as follows:
63°C for 30 minutes (Low Temperature, Long Time [LTLT])
72°C for 15 seconds (High Temperature, Short Time [HTST])
These treatments are equivalent and are sufficient to destroy the most heat resistant of the nonspore- forming pathogenic organisms *Mycobacterium tuberculosis* and *Coxiella burnetii.*

Milk pasteurization temperatures are sufficient to destroy, in addition, all yeasts, molds, gram negative bacteria, and many gram positives. The two groups of organisms that survive milk pasteurization are placed into one of two groups: thermodurics and thermophiles. **Thermoduric organisms** are those that can survive exposure to relatively high temperatures but do not necessarily grow at these temperatures. Ex: The non sporeforming organisms belong to the genera *Streptococcus* and *Lactobacillus.*

Thermophilic organisms are those that not only survive relatively high temperatures but require high temperatures for their growth and metabolic activities. Ex: The genera *Bacillus* and *Clostridium* .

2- High-Heat-Processed Foods

The process involves heating foods at or above 100ºC for a desired period of time. The temperature and time of heating are selected on the basis of product characteristics and the specific microorganisms to be destroyed. Low-acid or high-pH ($pH > 4.6$) products are given treatment to destroy *Cl. botulinum* spores (the most resistant spores of a pathogen). However, the products can have viable spores of thermophilic spoilage bacteria (e.g., *Bacillus stearothermophilus, B. coagulans, Cl. thermosaccharolyticum*, and *Desulfotomaculum nigrificans*. As long as the products are stored at or below 30ºC, these spores will not germinate. If the products are temperature abused to 40ºC and above even for a short time, the spores will germinate. Subsequent storage at or below 30ºC will not prevent outgrowth and multiplication of these thermophiles to cause food spoilage.
For high-acid or low-pH ($pH \leq 4.6$) products, such as tomato products, fruit products, and acidified foods, a much lower heat treatment is used. Because *Cl. botulinum* spores cannot germinate or grow at this low pH. The sporeformers that can germinate and grow in low pH products (e.g., *B. coagulans*) and the aciduric nonsporeforming bacteria (e.g., *Lactobacillus* and *Leuconostoc* spp.), yeasts, and molds that can grow at low pH are relatively heat sensitive. These products are generally heated at 100ºC for a desirable period of time.
Commercial sterility is also obtained by heating a food at very high temperatures for a short time. This process is designated as ultrahigh temperature (UHT) processing.

Canned foods are sometimes called "commercially sterile" to indicate that no viable organisms can be detected by the usual cultural methods or that the number of survivors is so low as to be of no significance under the conditions of canning and storage. Also, microorganisms may be present in canned foods that cannot grow in the product by reason of undesirable pH, oxidation-reduction potential (Eh), or temperature of storage.
The processing of milk and milk products can be achieved by the use of ultrahigh temperatures (UHT). The UHT treatment include very high temperatures (in the range 140-150 ºC) and short time (a few seconds) necessary to achieve commercial sterility . UHT-processed milks have higher consumer acceptability than the conventionally heated pasteurized products, and because they are

commercially sterile, they may be stored at room temperatures for up to 8 weeks without flavor changes.

*FACTORS AFFECTING HEAT RESISTANCE IN MICROORGANISMS

Equal numbers of bacteria placed in physiologic saline and nutrient broth at the same pH are not destroyed with the same ease by heat. Some 12 factors or parameters of microorganisms and their environment have been studied for their effects on heat destruction, and are presented below.

1-Water

The heat resistance of microbial cells increases with decreasing humidity, moisture, or water activity (a_w). Dried microbial cells placed into test tubes and then heated in a water bath are more heat resistant than moist cells of the same type.

2- Fat

In the presence of fats, there is a general increase in the heat resistance of some microorganisms(Table 1).This is sometimes referred to as fat protection and is presumed to increase heat resistance by directly affecting cell moisture.

Table 1: The Effect of the Medium on the Thermal Death Point of *Escherichia coli*

Medium	Thermal Death Point (0C)
Cream	73
Whole milk	69
Skim milk	65
Whey	63
Bouillon (broth)	61

Note: Heating time: 10 minutes

3-**Salts**

The effect of salt on the heat resistance of microorganisms is variable and dependent on the kind of salt, concentration and other factors. Some salts have a protective effect on microorganisms, and others tend to make cells more heat sensitive. It has been suggested that some salts may decrease water activity and thereby increase heat resistance by a mechanism similar to that of drying, whereas others may increase water activity (e.g., Ca2+ and Mg2+) and,consequently, increase sensitivity to heat. It has been shown that supplementation of the growth medium of *Bacillus megaterium* spores with $CaCl_2$ yields spores with increased heat resistance, whereas increased phosphate content decreases heat resistance.

4-Carbohydrates

The presence of sugars causes an increase in the heat resistance of microorganisms suspended. This effect is at least in part due to the decrease in water activity caused by high concentrations of sugars.

5-Proteins

Proteins in the heating have a protective effect on microorganisms. Consequently, high-protein-content foods must be heat processed to a greater degree than low-protein-content foods in order to achieve the same end results.

6-pH

Microorganisms are most resistant to heat at their optimum pH of growth, which is generally about 7.0. As the pH is lowered or raised from this optimum value, there is a consequent increase in heat sensitivity. Advantage is taken of this fact in the heat processing of high-acid foods, where less heat is applied to achieve sterilization compared to foods at or near neutrality.

7-Numbers of Organisms

The larger number of organisms, the higher degree of heat resistance (Table 2). It has been suggested that the mechanism of heat protection by large microbial populations is due to the production of protective substances excreted by the cells. Because proteins are known to offer some protection against heat, many of the extracellular compounds in a culture would be expected to be protein in nature and, consequently, capable of affording some protection.

Table 2: Effect of Number of Spores of *Clostridium botulinum* on Thermal Death Time at 100°C

Number of Spores	Thermal Death Time(min)
72,000,000,000	240
1,640,000,000	125
32,000,000	110
650,000	85
16,400	50
328	40

8-Age of Organisms

Bacterial cells tend to be most resistant to heat while in the stationary phase of growth and less resistant during the logarithmic phase. Heat resistance has been reported to be high also at the beginning of the lag phase but decreases to a minimum as the cells enter the log phase. Old bacterial spores are reported to be more heat resistant than young spores.

9-Growth Temperature

The heat resistance of microorganisms tends to increase as the temperature of incubation increases, and this is especially true for sporeformers. Ex: cultures of microorganisms grown at 44°C was found to be approximately three times more resistant than cultures grown at 35°C .

10-Inhibitory Compounds

A decrease in heat resistance of most microorganisms occurs when heating takes place in the presence of heat-resistant antibiotics, SO_2, and other microbial inhibitors. The use of heat plus antibiotics and heat plus nitrite has been found to be more effective in controlling the spoilage of foods than either alone. The practical effect of adding inhibitors to foods prior to heat treatment is to reduce the amount of heat that would be necessary if used alone .

11-Time and Temperature

The longer the time of heating, the greater the killing effect of heat. The higher the temperature, the greater the killing effect of heat. As temperature increases, time necessary to achieve the same effect decreases. Also important is the size of the heating vessel or container and its composition (glass, metal, plastic). It takes longer to effect pasteurization or sterilization in large containers than in smaller ones, and containers with walls that do not conduct heat as readily as others.

12-Effect of Ultrasonics

The exposure of bacterial endospores to ultrasonic treatments just before or during heating results in a lowering of spore heat resistance.

*Thermal Destruction of Microorganisms:

-Thermal Death Time (TDT)

Thermal Death Time (TDT) is the time necessary to kill a specific number of microbial cells or spores at a specific temperature. By this method , the temperature is kept constant and the time necessary to kill all cells is determined.

-Thermal Death Point (TDP):

Temperature required to kill agiven number of microorganisms in afixed time, usually 10 minutes. Here temperature is unknown.

- Decimal Reduction Time (*D* Value)

The *D* value is the time in minutes required to destroy 90% or 1 log of microorganisms.

Ex: The 12*D* concept is used in heat processing of high-pH foods (pH > 4.6, lowacid foods such as corn, beans, and meat) to destroy the most heat-resistant spores of the pathogenic bacteria *Clostridium botulinum*. It means that the products are given heat treatment to reduce the population of *Cl. botulinum* spores by 12 log cycles. The 12*D* value at *D*121.1ºC is ca. 2.8 or ca. 3.0 min.

-*Z* Value

The *Z* value, which indicates the temperature (ºC or ºF) required to change the *D* value (or TDT) to transverse by 1 log. A value of *Z* = 10 in ºC implies that if the *D* value of bacterial spores at 100ºC is 50 min, at 110ºC it will be 5 min, and at 120ºC it will be 0.5 min.

In developing heat-processing conditions of a food, *D* and *Z* values are used to obtain desirable destruction of microorganisms (cells and spores).

- *F* Value

The *F* value is used to express the time (min) necessary to completely destroy a specific number of microbial spores or vegetative cells at a temperature (121.1ºC for spores and 60ºC for vegetative cells).