Principles of Food Preservation

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Introduction

In this section we outline the principles, especially those of a microbiological nature, involved in the various methods of the food preservation. As a result of improved methods of preservation and transportation, out diet has become more varied and better balanced, perishable foods have been made available year-round instead of only seasonally, the preparation of meals has been made easier, and foods in general are being produced in a cleaner and more sanitary manner than before. In addition, these improved methods of preservation and transportation have made it possible for countries with excesses in certain commodities to help needs countries by providing food supplements of high quality.

Foods for human consumption can be divided into eight main groups, four of plant and four of animal origin, and several lesser groups. The eight main classes of foods are as follows:

Foods from plants	Foods from animals
Cereals and cereal products	Meats and meat products
Sugar and sugar products	Poultry and eggs
Vegetables and vegetable products	Fish and other seafood
Fruits and fruit products	Milk and milk products

➢ To the list of **foods of plant origin** **could be added spices** and other **flavoring materials**, **nutmeats**, and **fungi grown for food** (yeasts, molds, mushrooms, etc.).

➢ **Sodium chloride** is a mineral food, a flavoring material, an essential nutrient, and a chemical preservative.

➢ Some foods may be **fortified with minerals**, e.g., iron and calcium compounds added to flour.

➢ Some of the **coloring and flavoring materials** used in foods are synthetic.

➢ **Vitamins** usually are present in foods but **may be added or consumed separately** after chemical synthesis or production by microorganisms.

METHODS OF FOOD PRESERVATION

The chief methods of food preservation are as follows:

1. Asepsis, or keeping out microorganisms.
2. Removal of microorganisms.
3. Maintenance of anaerobic conditions, in a sealed, evacuated container.
4. Use of high/low temperatures.
6. Drying- this includes the tying up of water by solutes, hydrophilic colloids, etc.
7. Use of chemical preservatives either developed by microorganisms or added.
8. Irradiation.
9. Mechanical destruction of microorganisms by grinding, high pressures.
10. Combinations of two or more of the above methods.

PRINCIPLES OF FOOD PRESERVATION

In accomplishing the preservation of foods by the various methods, the following principles are involved:

1. Prevention or delay by microbial decomposition

a. By keeping out microorganisms (asepsis)
b. By removal of microorganisms, e.g., by filtration
c. By hindering the growth and activity of microorganisms, e.g., by low temperatures, drying, anaerobic conditions, or chemicals
d. By killing the microorganisms, e.g., by heat or radiation

2. Prevention or delay of self-decomposition of the food

a. By destruction or inactivation of food enzymes, e.g., by blanching
b. By prevention or delay of purely chemical reactions, e.g., prevention of oxidation by means of an antioxidant

3. Prevention of damage because of insects, animals, mechanical causes

The methods used to control the activities of microorganisms usually are effective against enzymatic activity in the food or chemical reactions. Methods such as drying and the use of low temperatures, however, permit auto-decomposition to continue unless special precautions are taken. For example, most vegetables are balanced (heated) to inactivate their enzymes before being frozen.

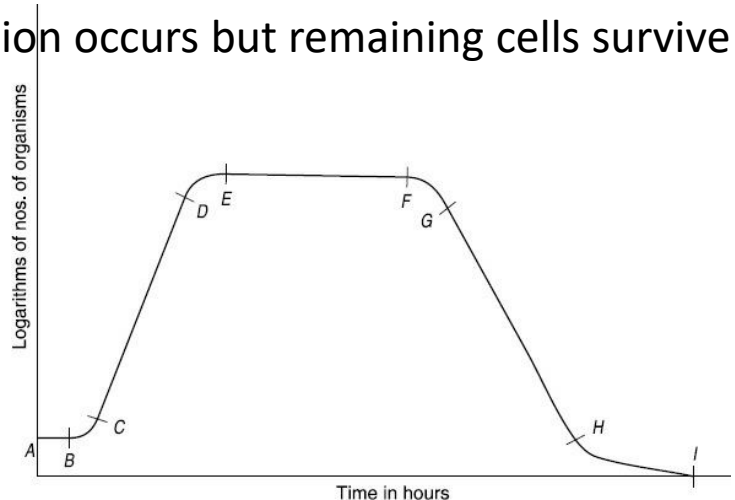
Delay of Microbial Decomposition

Many common methods of food preservation depend not on the destruction or removal of microorganisms but on delay in the initiation of growth and hindrance to growth once it has begun. A summary of the major preservation factors and their mode of action and achievement is presented in Table.

Mode of action	Preservation factor	Mode of achievement
Inactivation of microorganisms	Heat	Pasteurization Sterilization
	Radiation	Radicidation Radurization Radappertization
Inhibition or slowing of growth of microorganisms	Cool	Chill Freeze
	Restrict water (reduce water activity)	Dry Add salt Add sugar Add glycerol Add other solutes or use combinations of the above
	Restrict oxygen	Vacuum pack Nitrogen pack
	Increase carbon dioxide	CO_2 pack
	Acidity	Add acids Lactic fermentation Acetic fermentation
	Alcohol	Fermentation Fortification
	Add preservatives	Inorganic (e.g., sulphite, nitrite Organic (e.g., sorbate, benzoate, parabens, etc.) Antibiotics (e.g., nisin) Smoke
Restriction of access of microorganisms to product	Microstructure control	Emulsion (w/o)
	Decontamination	Ingredients Packaging materials, e.g., by chemicals (HCl, H_2O_2) heat, irradiation (ionizing or X; nonionizing)
	Aseptic or clean handling	Superclean processing Aseptic processing
	Packaging	Aseptic or clean packaging

Growth Curve of Microbial Cultures

Whenever microorganisms are added to a food and conditions are favorable, the organisms will begin to multiply and will pass through a succession of phases. This curve ordinarily is divided into phases
(1) the initial lag phase *(A to B), during which there is no growth or even* a decline in numbers,
(2) the phase of positive acceleration *(B to C), during which the rate of* growth is continuously increasing,
(3) the **logarithmic or exponential phase of growth (*C to D),*** during which the rate of multiplication is most rapid and is constant,
(4) the phase of **negative acceleration (*D to E), during which the rate of multiplication is decreasing,***
(5) the maximal* stationary phase (*E to F), where numbers remain constant,
(6) the accelerated death phase (F to *G),*
(7) the ***death phase or phase of decline (G to H), during which numbers decrease at a*** faster rate than new cells are formed, and
(8) the **survival phase (*H to I), during which no cell*** division occurs but remaining cells survive on endogenous nutrients.



Applications to Food Preservation

Especially important in food preservation (**i.e., prevention of spoilage**) is the **lengthening, as much as possible, of the lag phase and the phase of positive acceleration**. This can be accomplished in different ways:

1. By introducing as few spoilage organisms as possible, i.e., by reducing the amount of contamination; the fewer organisms present, the longer the lag phase.

2. By avoiding the addition of actively growing organisms (from the logarithmic phase of growth). Such organisms might be growing on unclean containers, equipment, or utensils that come in contact with foods.

3. By one or more unfavorable environmental conditions: unfavorable foods, moisture, temperature, pH, or O-R potential, or presence of inhibitors. The more unfavorable the conditions, the longer the delay of the initiation of growth.

4. By actual damage to organisms by processing methods such as heating or irradiation. Thus, for example, bacteria or their spores subjected to sub lethal heat treatments have been found to require a better culture medium for growth than do the unheated organisms. Often a combination of methods for delaying the initiation of growth is enough to give a food the desired storage life.

Prevention of Microbial Decomposition

Microbial decomposition of foods will be prevented if all spoilage organisms are killed (or removed) and recontamination is prevented. Merely stopping the multiplication of microorganisms, however, does not necessarily prevent decomposition, for viable organisms or their enzymes may continue to be active.

Vegetative cells of organisms in their logarithmic phase of growth are least resistant to lethal agencies, and they are more resistant in their late lag or maximal stationary phase of growth.

ASEPSIS

In nature there are numerous examples of asepsis, or **keeping out microorganisms**, as a preservative factor. The inner tissues of healthy plants and animals usually are free from microorganisms, and if any microorganisms are present, they are unlikely to initiate spoilage. If there is a protective covering about the food, microbial decomposition is delayed or prevented. Examples of such coverings are the shells of nuts, the skins of fruits and vegetables, the husks of ear corn, the shells of eggs, and the skin, membranes, or fat on meat or fish.

Following are some examples of **aseptic methods in industries-**

- Packaging of food
- In dairy industry
- In canning industry
- In the meat packing industry

REMOVAL OF MICROORGANISMS

For the most part the removal of microorganisms is not very effective in food preservation, but under special conditions it may be helpful. Removal may be accomplished by means of

a. filtration
b. centrifugation (sedimentation or clarification)
c. washing
d. trimming.

The liquid is filtered through a previously sterilized **“bacteriaproof”** filter made of sintered glass, diatomaceous earth, unglazed porcelain, membrane pads, or similar material, and the liquid is forced through by positive or negative pressure. This method has been used successfully with fruit juices, beer, soft drinks, wine, and water.

Maintenance of anaerobic condition.

Preservation by use of High Temperatures

Introduction

- The killing of microorganisms by heat is supposed to be caused by the **denaturation of the proteins and especially by the inactivation of enzymes required for metabolism**.

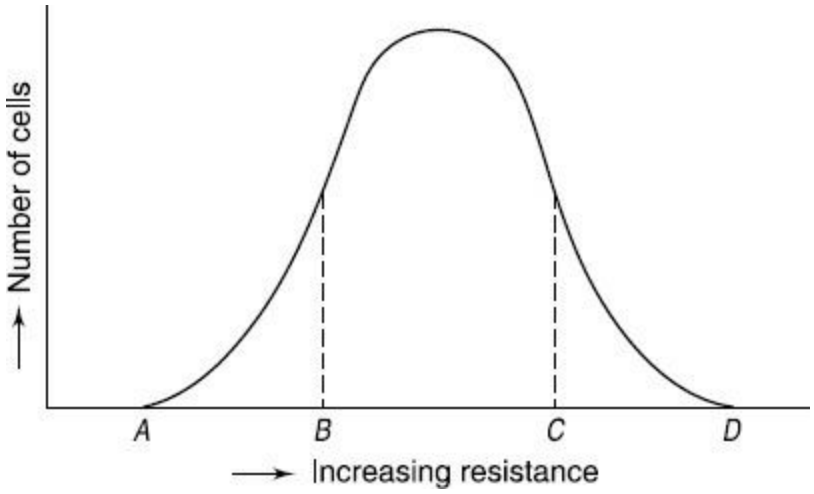
- The heat treatment necessary to kill organisms or their spores varies with the **kind of organism**, its **state**, and the **environment during heating**.

- Depending on the heat treatment employed, only some of the vegetative cells, most or all of the cells, part of the bacterial spores, or all of them may be killed.

- The heat treatment selected will depend on the kinds of organisms to be killed, other preservative methods to be employed, and the effect of heat on the food.

FACTORS AFFECTING HEAT RESISTANCE (THERMAL DEATH TIME)

- Cells and spores of microorganisms differ widely in their resistance to high temperatures.
- There are **differences in heat resistance within a population of cells** or spores, as illustrated by the frequency distribution curve in Figure.
- A **small number of cells have low resistance** (points A to B); **most of the cells have a medium resistance** (points B to C); and a **small number have high resistance** (points C to D).
- Conditions of growth may favor one or the other of these groups, and, by selection, cultures that are more or less heat-resistant than usual can be produced.



Heat resistance

Certain factors are known to affect the **heat resistance of cells** or spores and must be kept in mind when microorganisms are compared and when heat treatments for the destruction of an organism are considered.

The chief known factors are as follows:

1. The temperature time relationship

The time for killing cells or spores under a given set of conditions decreases as the temperature is increased. This is illustrated in Table by the results of **Bigelow and Esty** (1920) with 115,000 spores of flat sour bacteria per milliliter in corn juice at pH 6.1.

Temperature, C	Thermal death time, or time to destroy all spores, min
100	1,200
105	600
110	190
115	70
120	19
125	7
130	3
135	1

2. Initial concentration of spores (or cells)

The more spores or cells present, the greater the heat treatment necessary to kill all of them. Bigelow and Esty heated spores of a thermophile from spoiled canned food in corn juice at pH 6.0 at 120 C, with the results shown in Table.

Initial concentration of spores, number/ml	Thermal death time, or time required to kill all spores, min at 120 C
50,000	14
5,000	10
500	9
50	8

3. Previous history of the vegetative cells or spores

The conditions under which the cells have been grown and spores have been produced and their treatment thereafter will influence their resistance to heat.

a. Culture medium- The medium in which growth takes place is especially important. The effect of the nutrients in the medium, their kind, and the amount vary with the organism, but in general the better the medium for growth, the more resistant the cells or spores. The presence of an adequate supply of accessory growth factors usually favors the production of heat resistant cells or spores.

b. Temperature of incubation- The temperature of growth of cells and the temperature of sporulation influences their heat resistance. In general, **resistance increases as the incubation temperature is raised toward the optimum** for the organism and for many organisms increases further as the temperature approaches the maximum for growth. *Escherichia coli, for* example, is considerably more heat-resistant when grown at 38.5 C, which is near its optimal temperature, than at 28 C.

Temperature of incubation, C	Time to kill at 100 C, min
21 – 23	11
37 (optimum)	16
41	18

c. Phase of growth or age- The heat resistance of vegetative cells varies with the stage of growth and of spores with their age. Bacterial cells show their **greatest resistance during the late lag phase** but almost as **great resistance during their maximum stationary phase**, followed by a decline in resistance. The cells are **least resistant during their phase of logarithmic growth**. Very young (immature) spores are less resistant than are mature ones. Some spores increase in resistance during the first weeks of storage but later begin to decrease in resistance.

d. Desiccation- Dried spores of some bacteria are harder to kill by heat than are those kept moist, but this apparently does not hold for all bacterial spores.

4. Composition of the substrate in which cells or spores are heated

The material in which the spores or cells are heated is so important that it must be stated if a thermal death times is to have meaning.

a. Moisture- Moist heat is a much more effective killing agent than dry heat, and as a corollary dry materials require more heat for sterilization than moist ones. In the bacteriological laboratory about 15 to 30 min at 121 C in the moist heat of an autoclave will effect sterilization of ordinary materials, but 3 to 4 hr at 160 to 180 C is necessary when the dry heat of an oven is employed. Spores *of Bacillus subtilis* are killed in less than 10 min in steam at 120 C, but in anhydrous glycerol 170 C for 30 min is required.

b. Hydrogen-ion concentration (pH)- In general, cells or spores are **most heat resistant** in a substrate that is at or **near neutrality**. An increase in acidity or alkalinity hastens killing by heat, but a change toward the acid side is more effective than a corresponding increase in alkalinity. Spores of *B. subtilis* heated at 100 C in 1:15 m phosphate solutions, adjusted to various pH values, gave the results shown in Table.

pH	Time to survival, min
4.4	2
5.6	7
6.8	11
7.6	11
8.4	9

(1) **Low-acid foods,** with a pH above 5.3, including such foods as peas, corn, lima beans, meats, fish, poultry, and milk .

(2) Medium-acid foods, with a pH between 5.3 and 4.5, including such foods as spinach, asparagus, beets, and pumpkin.

(3) Acid foods, with a pH between 4.5 and 3.7, including such foods as tomatoes, pears, and pineapple.

(4) High-acidfoods, with a pH of 3.7 and below, including such foods as berries and sauerkraut.

c. Other constituents of the substrate- The only **salt present** in appreciable amounts in most foods is sodium chloride, which in low concentrations has a protective effect on some spores. **Sugar** seems to protect some organisms or spores but not others. The **optimal concentration for protection varies** with the organism: it is **high for some osmophilic** organisms and low for others, high for spores and low for non osmophilic cells. The protective effect of sugar may be related to a resulting decrease in a*w. A reduced aw does result in an* increase in observed heat resistance.

HEAT RESISTANCE OF MICROORGANISMS AND THEIR SPORES

The heat resistance of microorganisms usually is expressed in terms of their **thermal death time,** which is defined as the time it takes at a certain temperature to kill a stated number of organisms (or spores) under specified conditions.

This sometimes is referred to as the **absolute thermal death time** to distinguish it from the majority thermal death time for killing most of the cells or spores present and the **thermal death rate**, expressed as the rate of killing.

Thermal death point now used little is the temperature necessary to kill all the organisms in 10 min.

Heat Resistance of Yeasts and Yeast Spores

In general the ascospores of yeasts need only 5 to 10 C more heat for their destruction than the vegetative cells from which they are formed.

Most ascospores are killed by 60 C for 10 to 15 min; a few are more resistant, but none can survive even a brief heating at 100 C.

Both yeasts and their spores are killed by the pasteurization treatments given milk (62.8 C for 30 min or 71.7 C for 15 sec).

Heat Resistance of Molds and Mold Spores

- Most molds and their spores are killed by moist heat at **60 C in 5 to 10 min**, but some species are considerably more heat-resistant.

- The **asexual spores are more resistant** than ordinary mycelium **and require a temperature 5 to 10 C higher** for their destruction in a given time.

- **Sclerotia are especially difficult to kill by heat**. Some can survive a heat treatment of 90 to 100 C for a brief period and have been known to cause spoilage in canned fruits. It was found that 1,000 min at 82.2 C or 300 min at 85 C was necessary to destroy sclerotia from a species of *Penicillium*.

Heat Resistance of Bacteria and Bacterial Spores

The heat resistance of vegetative cells of bacteria **varies widely** with the species, from some of the delicate pathogens that are easily killed to **thermophiles** that may require several minutes at 80 to 90 C. A **few general statements** can be made about the heat resistance of vegetative cells of bacteria:

(1) cocci usually are more resistant than rods, although there are many notable exceptions,

(2) the higher the optimal and maximal temperatures for growth, the greater the resistance to heat is likely to be,

(3) bacteria that clump considerably or form capsules are more difficult to kill than those which do not,

(4) cells high in lipid content are harder to kill than are other cells.

A few examples of thermal death times of bacterial cells are shown in table below.

Table- Thermal Death Times of Bacterial Cells

Bacterium	Time, min	Tem, C
Neisseria gonorrhoeae	*2-3*	50
Salmonella typhi	*4.3*	60
Staphylococcus aureus	*18.8*	60
Escherichia coli	*20–30*	57.3
Streptococcus thermophilus	*15*	70-75
Lactobacillus bulgaricus	*30*	71

Table- Thermal Death Times of Bacterial Spores.

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Spores of Time to kill at 100 C	min
Bacillus anthracis	*1.7*
Bacillus subtilis	*15–20*
Clostridium botulinum	*100–330*
Clostridium calidotolerans	*520*
Flat sour bacteria	Over 1.030

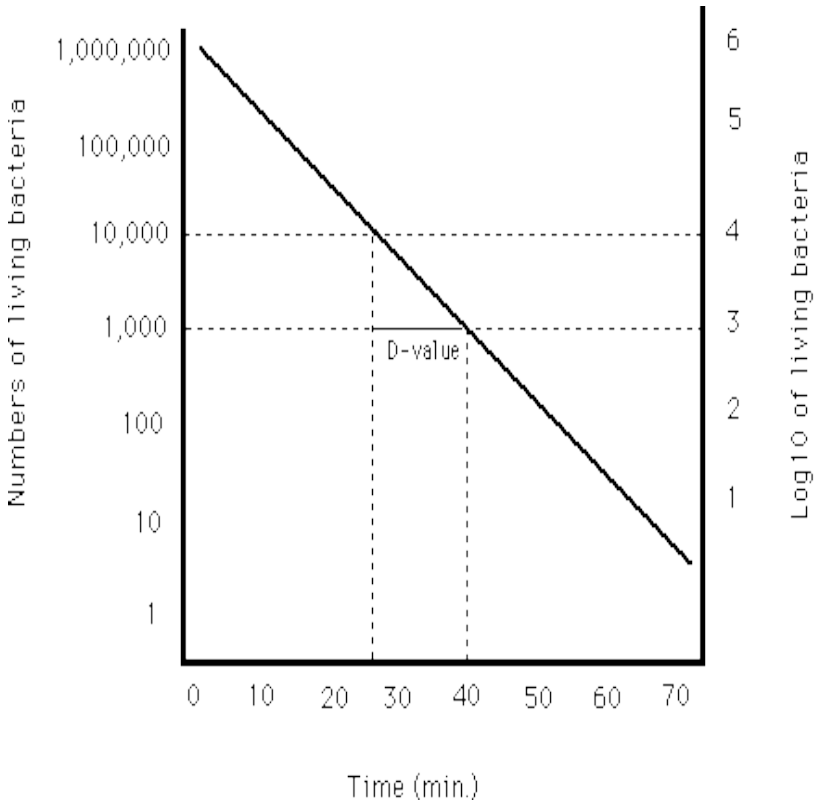
D-Value, Z-Value, F-Value & 12D Concept

Survival of Bacterial Spores during heat processing (Decimal Reduction)

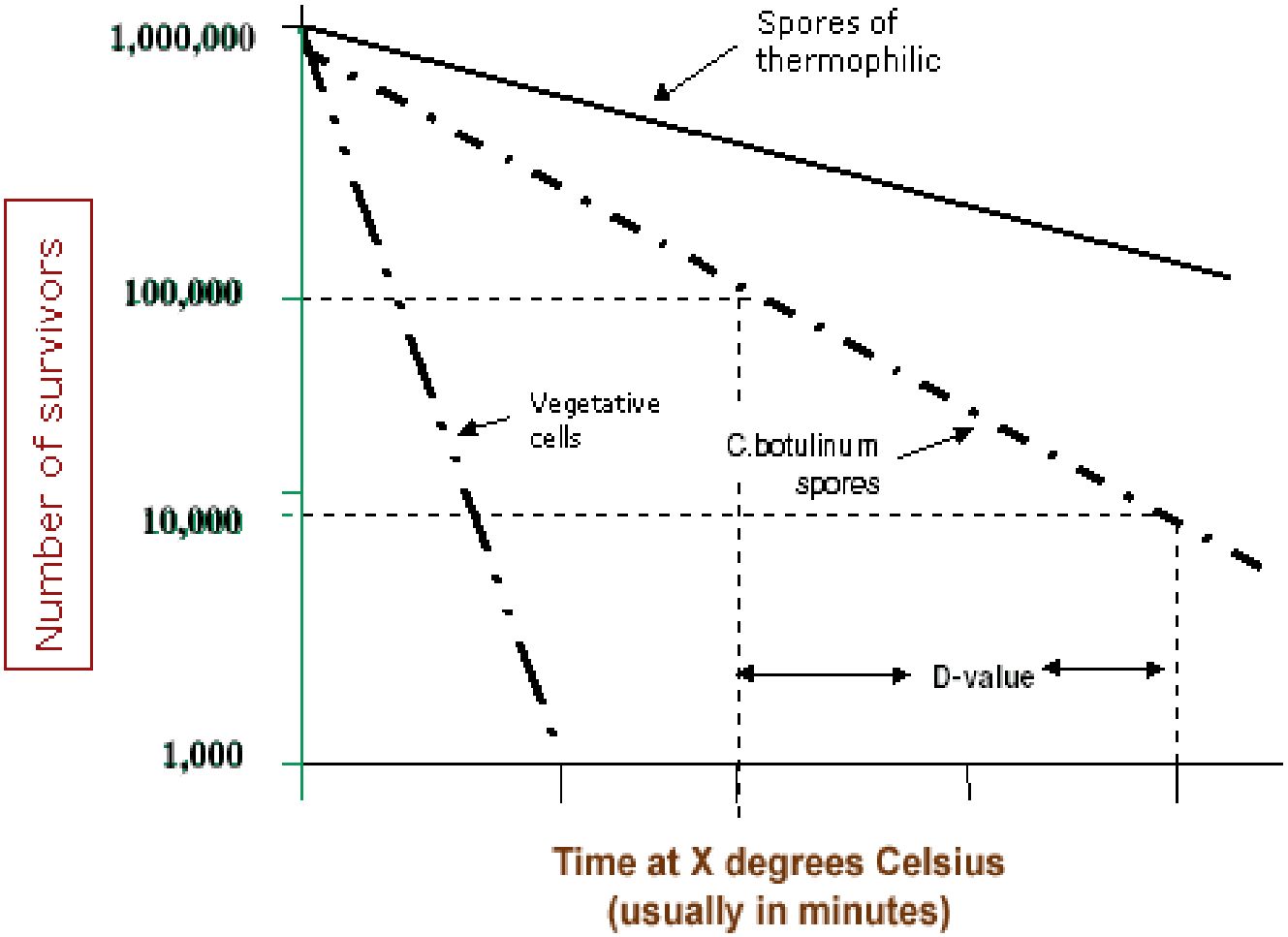
- Thermal destruction of bacteria or spores takes place in definite pattern.
- Suspension of bacterial spores exposed to constant lethal temp.
- **Logarithms of the number of the surviving spores are plotted against time on linear scale** (or the number of survivors in a log scale against time in linear scale) a straight line graph will be obtained.

Thermal Death Rate Curve or Decimal Reduction Time Curve or Survival Curve

- The slope of the curve Decimal Reduction Time (D) or Death Rate.
- D is equal to time in minutes required to reduce the number of survivors to one tenth of the original at a specified temperature.
- Time required for the curve to traverse one log cycle.
- D_{121}˚C
- Higher the load longer the time.



Thermal Death Rate Curves



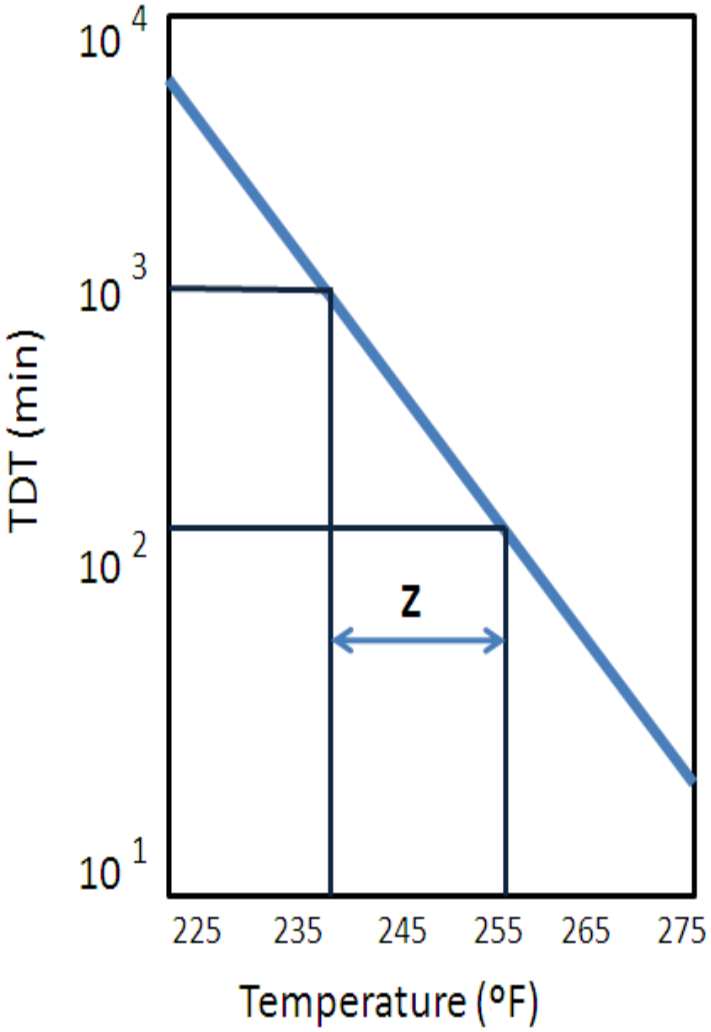
D Value

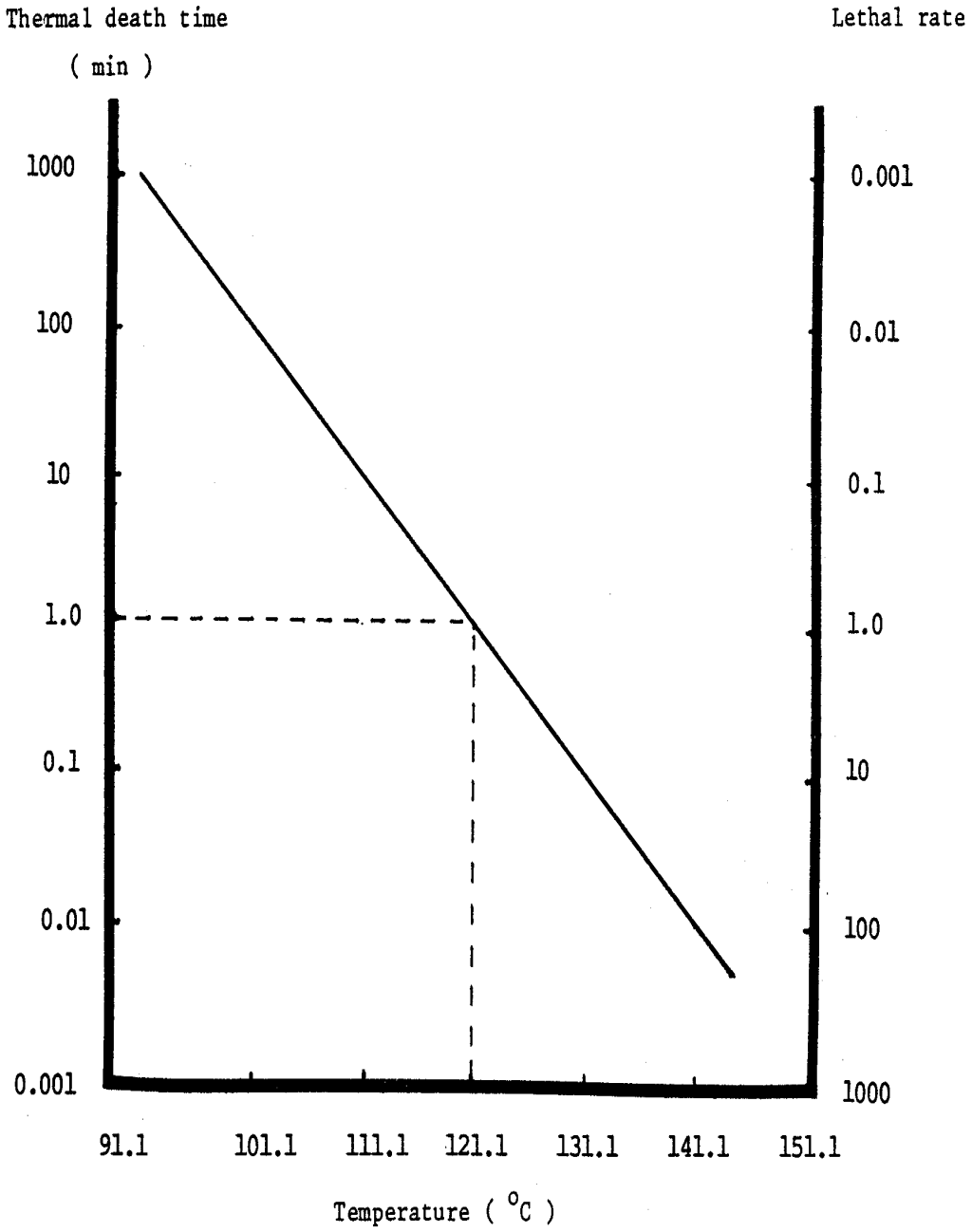
Organism	D value min @ 121.1˚C
Bacillus Stearothermophilus	4-5
C. thermosaccharolyticum	3-4
Desulfotomaculum nigrificancs	2-3
Clostridium botulinum type A & B	0.1-0.25
C. sporogenes (P.A. 3679)	0.1-1.5
B. coagulans	0.01 - 0.07

Thermal Death Time Curve

- Thermal death time (TDT) time in minutes required to inactivate an arbitrary chosen number of spores of a given bacteria at a specified temperature.
- Thermal death time are plotted on log scale against corresponding temperature in linear scale.
- Logarithms of death times can be plotted against corresponding temperature, both on linear scale.
- A straight line graphs_ Thermal Death Time Curve (TDT curve)

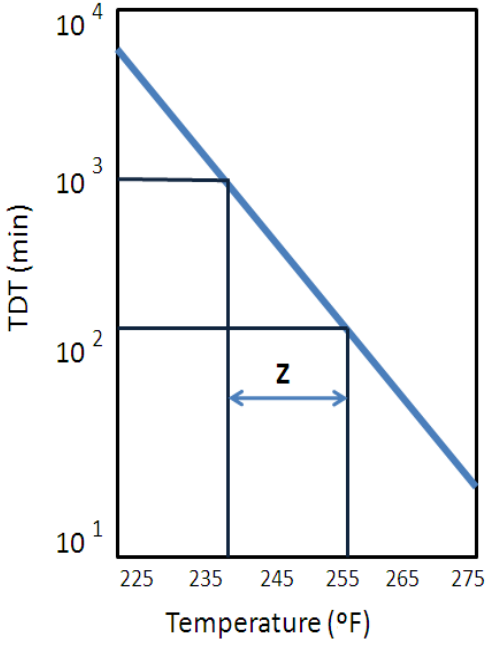
TDT Curve


TDT (min)
10 4
10 3
10 2
10 1
Z
225
235
245
255
265
275
Temperature (°F)


Thermal death time
(min)
Lethal rate
1000
100
10
1.0
0.1
0.01
0.001
0.001
0.01
0.1
1.0
10
100
1000
91.1
101.1
111.1
121.1
131.1
141.1
151.1
Temperature (°C)

Z Value

- The slope of the TDT curve is defined as “Z” which is equal to the number of degrees on the temperature scale when the curve traverse one log cycle.
- Z is the change in temperature necessary to **cause a ten fold change in D-value**.
- The value of Z for C. botulinum is 10˚C
- Every 10˚C change in temperature there is a ten fold change in its death rate.
- *B. subtilis* has Z value of 6.5˚



F Value

- Sterilizing value time in minutes required to kill an organism in a specific medium at 121.1˚C (TDT).
- When the Z value of the process is 10˚C, F is denoted as Fo.
- The unit of sterilization is Fo. Fo can be defined as the integrated heating effect received by all points inside the can.
- Fo value of 1 is equivalent to holding the product at 121.1˚C for one minutes.

F Value

- Do for *B. Stearothermophilus* to be 5 min. & initial number (No) in the container to be 10,000, if it was required to reduce this number to one (Nt) in the heat process, **four decimal reduction** would be needed. The time at 121.1℃ would be 4 x Do = 4 x 5 = 20 min. the number of decimal reductions required is given by

- log No/Nt = logNo-logNt = 4-0 = 4

- This log No/Nt some times refereed as **"order of process" factor of "m"** & the value of the **product of m & Do is called "Process value" or "F value"** i.e. Fo=mDo

$_{12}$D Concept

- **Method of expressing process lethality requirement**.
- Most frequently bacteria found in low acid as well as medium acid food is *C. botulinum* which is having ability to produce a deadly lethal toxin in the food.
- Therefore, **the modern canning practices demands a reduction in *C. botulinum* spores by a factor of 10^{12} in such food**.
- This means that probability of survival spores must be reduce to one can in a billion (i.e., 10^{12}).
- Thus, if there were one spores of *C. botulinum* initially in the container.

12D Concept

- D value of *C. botulinum* = 0.21
- Factor of 10^{12} = 12 x 0.21 = 2.52 min

$$D = \frac{t}{\log N_0 - \log N_t}$$

t = time of heating

$\log N_0$ = initial number of spores

$\log N_t$ =number of survivors