Thermal Processing of Food

Introduction

In a many cases the microscopic flora create serious problems in our food.

The problems associated may fit into two categories:

- Food spoilage - occurs when the food becomes unpalatable due to microbial growth and develop undesirable flavors, odors, appearances or textures
- Food poisoning- which occurs when the organisms present in food cause human illness or death through a toxin resulted into intestinal infection

Therefore, to avoid both of these problems we need to understand the techniques which prevent their growth

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:

- **What time-temperature combination is required to inactivate the most heat resistant pathogens and spoilage organisms ? The higher the temperature, the less time needed and vice versa**
- **What are the heat penetration characteristics in one particular food and 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**
- **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**
- **What is the effect of various environmental factors? such as pH and salts or solutes Food acidity / pH value**

There are two main temperature categories employed in thermal processing:

- **Pasteurization**
- **Sterilization**

The basic purpose for the thermal processing of foods is:

- **To reduce or destroy microbial activity**
- **To reduce or destroy enzyme activity**
- **To produce physical or chemical changes to make the food meet a certain quality standard**

Methods of Thermal Treatment

- **Mild processes (Blanching, Pasteurization) –Heating a liquid, particularly milk, to a temperature between 55 and 70 degrees C (131 and 158 degrees F), to destroy harmful bacteria**
- **More severe processes – Canning, Baking, Roasting, Frying**
- **Sterilization – Complete destruction of micro-organisms, heat resistant spores by treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent**

Blanching

- The primary purpose of blanching is to destroy enzyme activity in fruit and vegetables
- It is not intended as a sole method of preservation, but as a pretreatment prior to freezing, drying and canning
- Other functions of blanching include: • Reducing surface microbial contamination • Softening vegetable tissues to facilitate filling into containers • Removing air from intercellular spaces prior to canning
- Enzymes are proteins which are denatured at high temperatures and lose their activity
- Enzymes which cause loss of quality include Lipoxygenase, Polyphenoloxidase, Polygaacturonase and Chlorophyllase. Heat resistant enzymes include Catalase and Peroxidase

Methods of Blanching –

- Blanching is carried out at up to 100°C using hot water or steam at or near atmospheric pressure
- Fluidized bed blanchers- utilizing a mixture of air and steam, has been reported
- Microwaves blanching - include rapid heating and less loss of water soluble components
- Steam Blanchers -the preferred method for foods with large cut surface areas as lower leaching losses
- Individual Quick Blanching (IQB) - involves a single layer of the food is heated to sufficient temperature to inactivate enzymes and a second stage in which a deep bed of the product is held for sufficient time to allow the temperature at the centre of each piece
- Hot Water Blanchers - Includes various designs which hold the food in hot water (70 to 100°C) for a specified time, then moves it to a dewatering/cooling section

Advantages and Disadvantages of Blanching

- Advantages include faster, more uniform heating, good mixing of the product, reduction in effluent, shorter processing time and hence reduced loss of soluble and heat sensitive components
- Disadvantages include high capital costs and potential difficulties in uniformity of heating

Pasteurization

- Pasteurization is a relatively mild heat treatment in which food is heated to <100°C
- It is widely used throughout the food industry
- As a unit operation in food processing it can be used to destroy enzymes and relatively heat sensitive micro-organisms (e.g. non spore forming bacteria, yeast and moulds)
- It used to extend shelf life by several days e.g. milk or months e.g. bottled fruit
- The severity of treatment and resulting extension of shelf life is determined mostly by pH of the food, the destruction of spoilage microorganisms or enzyme deactivation
- The extent of heat treatment required is determined by the D value (Decimal reduction time or time to reduce numbers by a factor of 10 or 90% of the initial load) of most heat resistant enzyme or micro-organism which may be present
- In terms of checking the effectiveness of the process, alkaline phosphatase is a naturally occurring enzyme in raw milk with a similar D value to heat-resistant pathogens and so is routinely used as an indicator of adequate pasteurisation

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 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 by 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

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.**

3. Ultra High Temperature (UHT) Processing Treatments : UTH involve exposure of a brief, intense heating, normally to temperatures in the range 135-140 °C but for a very short time, a second or less

The process depends upon a fairly complicated sterilizer/aseptic filling desig

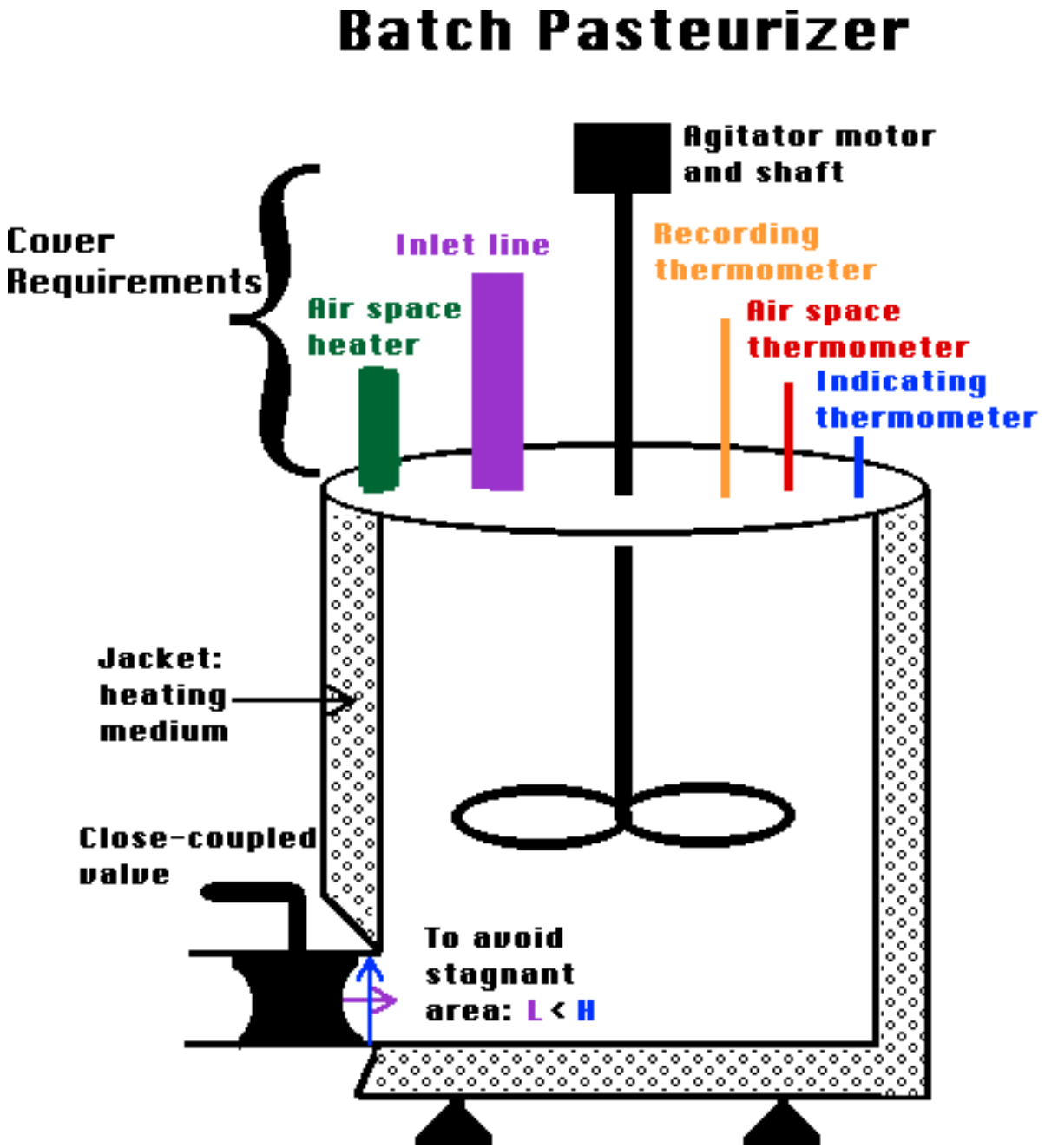
The two stages of effective heat sterilization followed by aseptic filling represent an integral system. Frequently the packaging material for UHT milk is cardboard which must be chemically sterilized prior to the filling operation

Temperature	Time
63°C	For 30 min (low temperature long time LTLT)
72°C	For 15 sec (primary high temperature short time, HTST method)
89°C	For 1.0 sec
90°C	For 0.5 sec
94°C	For 0.1 sec
100°C	For 0.01 sec

These temperatures are equivalent and are suffcient to destroy the most heat sensitive of the non-spore-forming pathogenic organisms. Milk pasteurization temperatures are also suffcient to destroy all yeasts, moulds, gram negative bacteria and many gram positive

Typical Equipment employed for HTST method includes:

- Plate Heat Exchanger (PHE)
- Holding tube – sized to ensure the correct treatment time is achieved
- Holding tanks – for storage of the raw and pasteurised milk
- Balance tank – to assist in maintaining full flow, and to take returned milk if temperature not achieved
- Control and monitoring system – to record temperature and to divert flow back to the balance tank if correct temperature is not achieved



Canning

- Canning is a method of preserving food in which the food contents are processed and sealed in an airtight container (jars like Mason jars, and steel and tin cans)
- Canning provides a shelf life typically ranging from one to five years, although under specific circumstances it can be much longer
- They should be ‘commercially sterile’ that means if any microbes survive the processing, they should not be capable of growing (and therefore spoiling the contents) under the normal storage conditions of the can
- Most canned foods are sterile (i.e. there are no living organisms present) but some may contain viable organisms which cannot grow because of unsuitable conditions

e.g. Water, Temperature, pH, water activity, preservatives

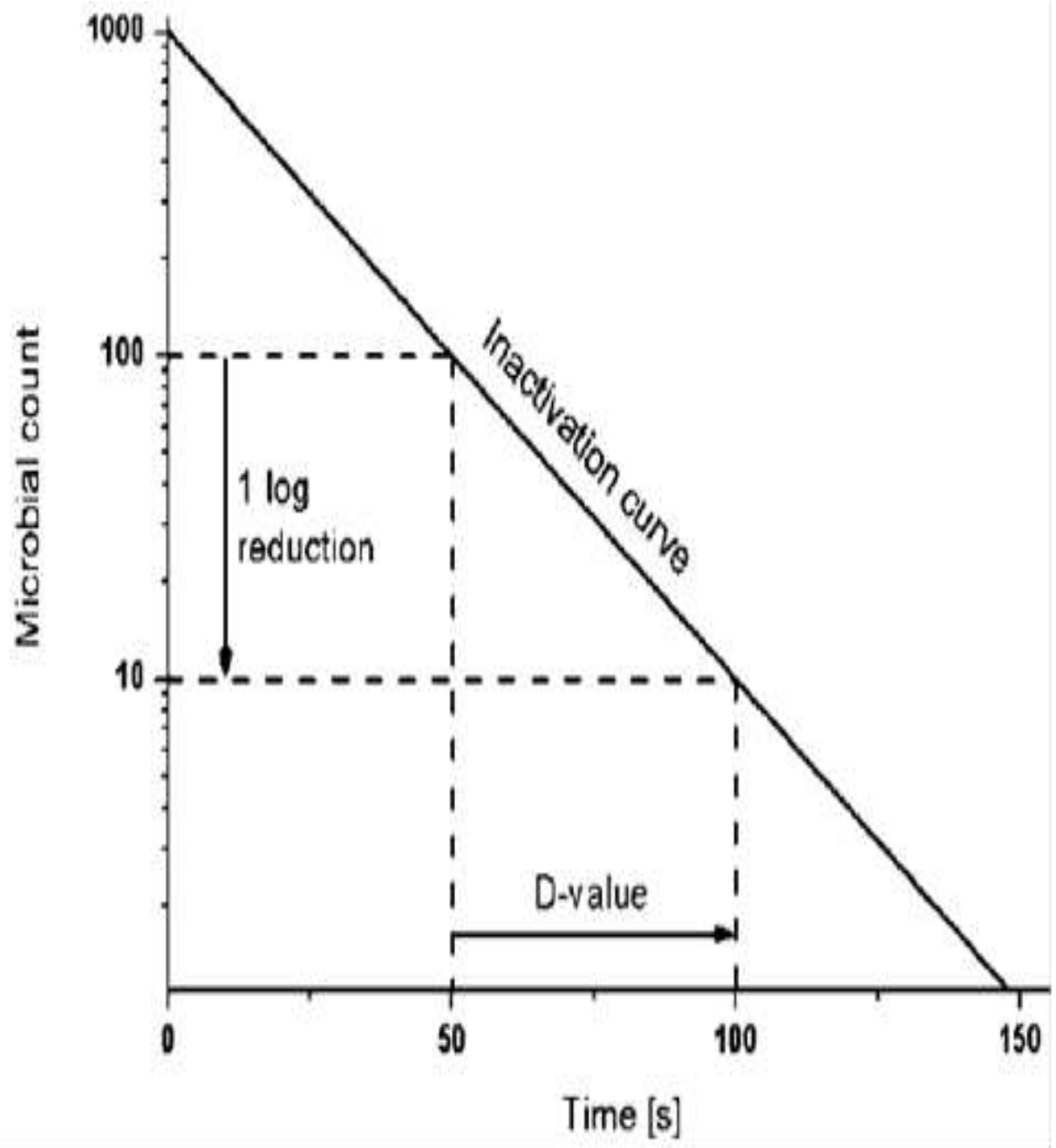
the effectiveness of a canning process is determined from a combination of experimentation and calculation. Processing parameters are expressed in terms of a series of symbols of which D, Z, and F keys

Decimal reduction time (D-value):

- The D-value, which denotes the decimal reduction time, is the time required at a specific temperature and under specified conditions to reduce a microbial population by one decimal
- The decimal reduction time is dependent on the temperature, the type of microorganism and the composition of the medium containing the microorganism
- At slightly elevated temperatures most microbes will grow and multiply quickly
- There is a lot of variation within any one population of microbes of the same species – most will be killed relatively quickly, others can survive much longer

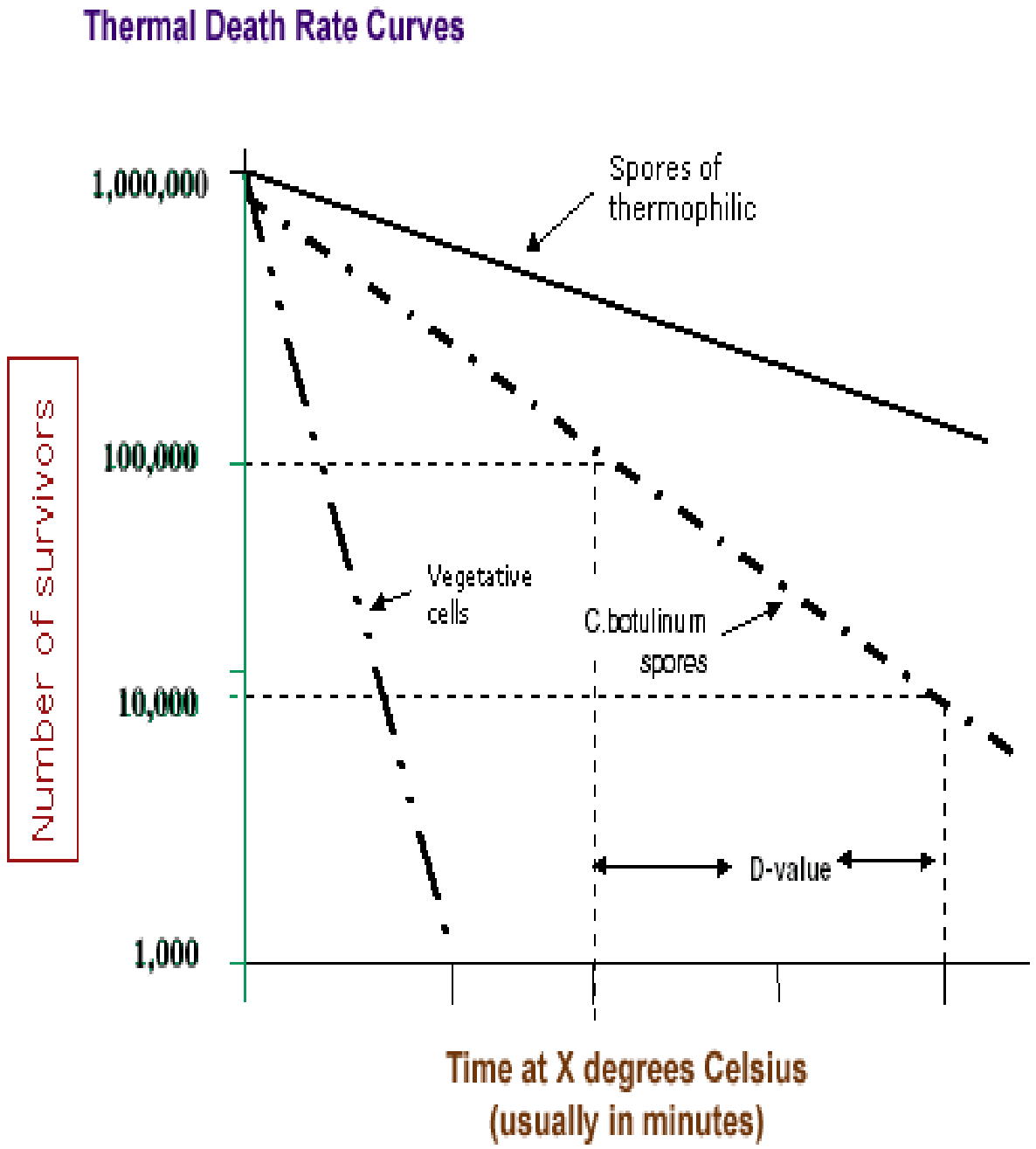
Death Rate Curve (D value)

- If a population of microbes is held at a constant high temperature, the number of surviving spores or cells plotted against time (on a logarithmic scale) will look like the following graph – which is referred to as the 'death rate curve
- The time period for each "log reduction" is referred to as the decimal reduction time or D value



For example the D-value of *Bacillus stearothermophillus* a common spoilage microorganism at 121°C is about 4 minutes This means if you had cans of food product each containing 1000 of these spore and you held the product at a constant temperature of 121°C

- **After 4 minutes (1 D-value) there would be 100 spores surviving in each can (1 log reduction)**
- **After 8 minutes (twice D-value) there would be 10 spores surviving in each can (2 log reductions)**
- **After 12 minutes (3 times D-value) there would be 1 spore surviving in each can (3 log reductions)**

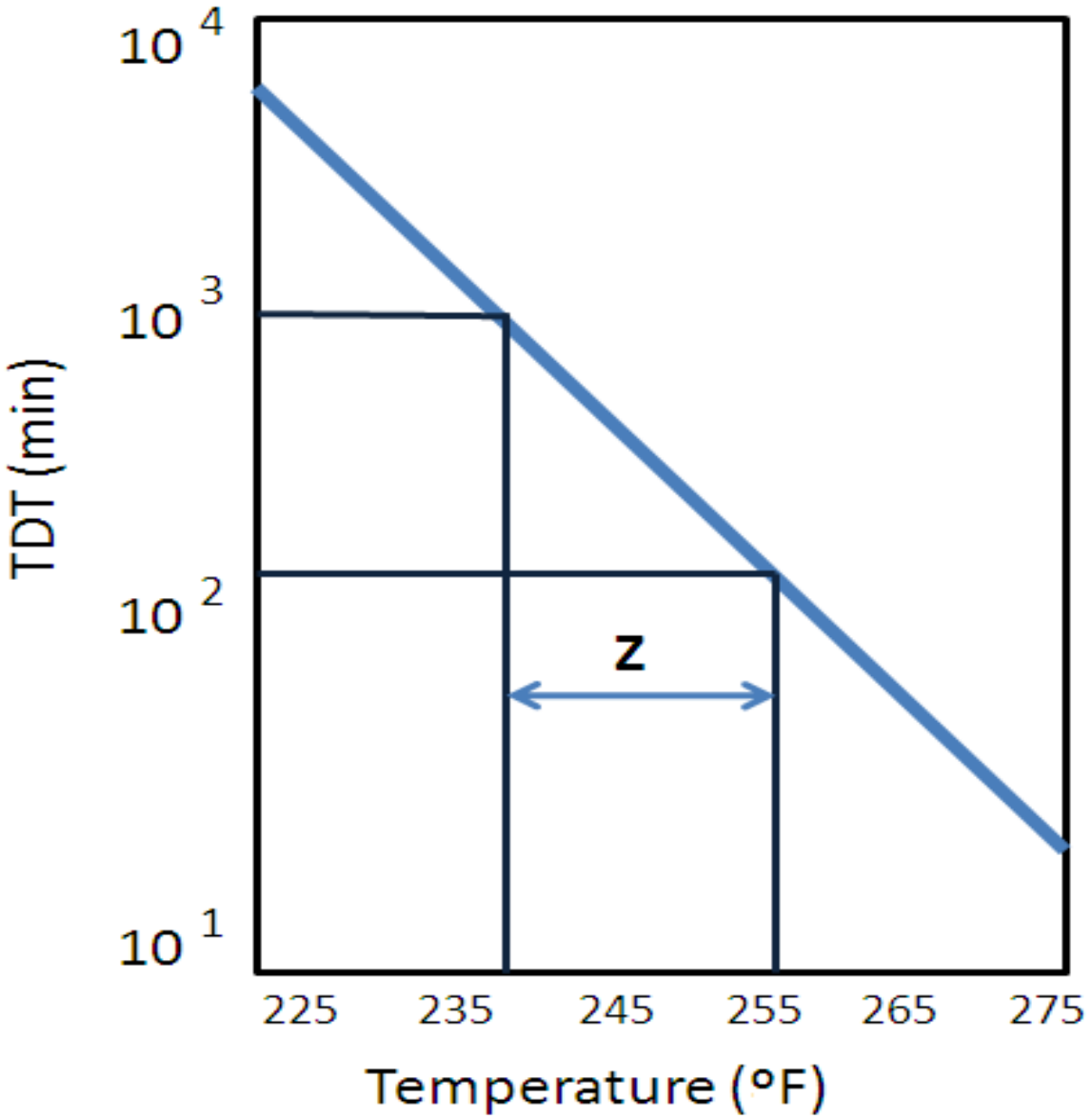


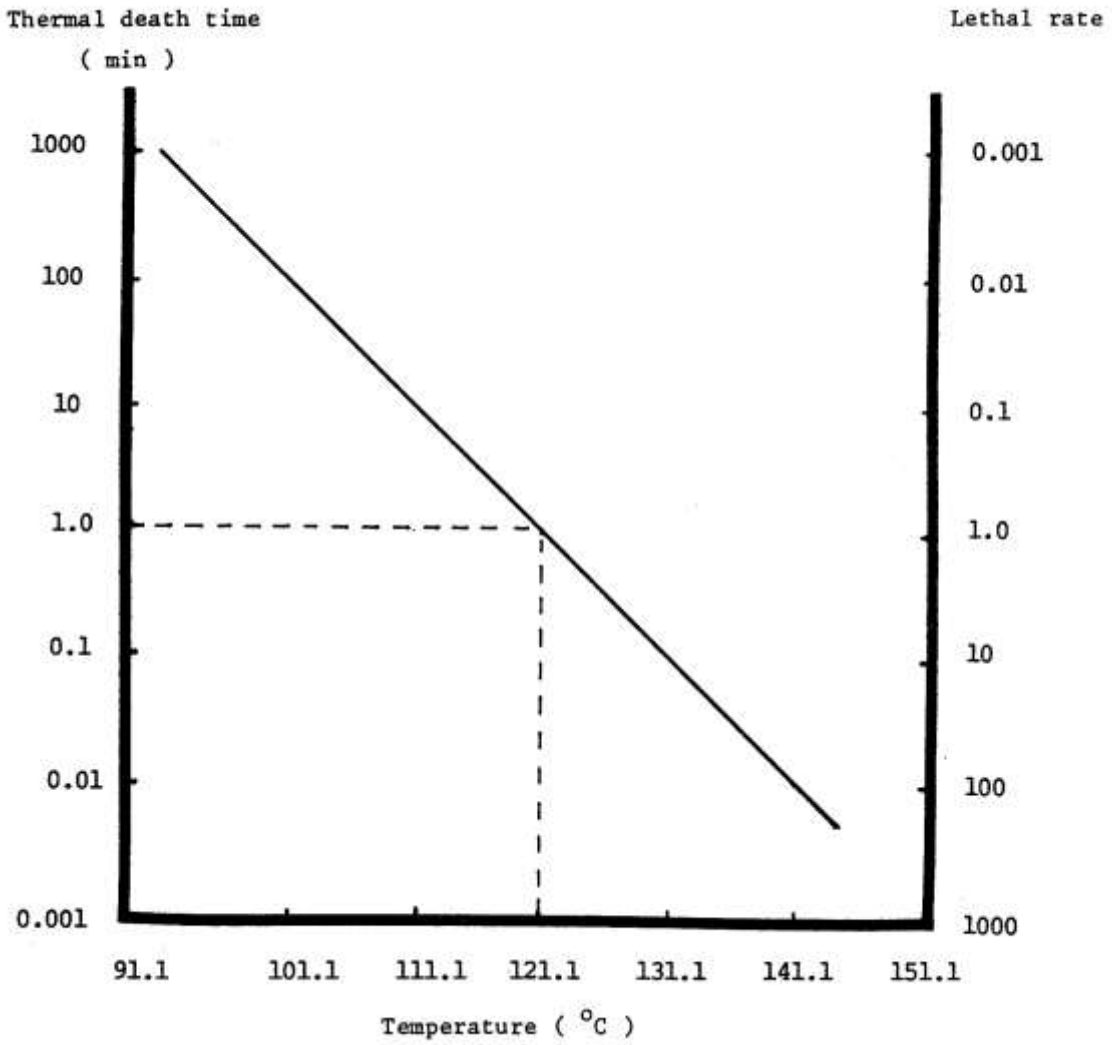
Organism	D value min @ 121.1˚C
• *Bacillus Stearothermophilus*	4-5
• *C. thermosaccharolyticum*	3-4
• *Desulfotomaculum nigrificancs*	2-3
• *Clostridium botulinum* type A & B	0.1-0.25
• *C. sporogenes*	0.1 - 1.5
• *B. coagulans*	0.01 - 0.07

Thermal Death Time Curve

- Thermal death time (TDT) time in minutes required to inactivate an arbitory 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


10 4
10 3
10 2
10 1
TDT (min)
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

- **Z-value is a term used in microbial thermal death time calculations**
- **It is the number of degrees the temperature has to be increased to achieve a tenfold (i.e. 1 $\log_{10}$) reduction in the D-value**
- **The Z-value is the increase or decrease in temperature required to reduce or increase the decimal reduction time by one decimal. It is a measure of the change in death rate with a change in temperature**
- **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

- The F value for a process is the number of minutes required to kill a known population of microorganisms in a given food under specified conditions
- This F value is usually set at 12 D values to give a theoretical 12 log cycle reduction of the most heat-resistant species of mesophilic spores in a can of food
- When the Z value of the process is 10˚C, F is denoted as 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

- **The “Fo value” The amount of heat treatment applied to a food product can be measured using the F-value-concept**
- **This concept is practiced in canning plants, in particular as part of the HACCP-system**
- **The size and format of cans is of utmost importance for the speed of heat penetration. Temperatures to be achieved at the “cold point” of the can where the heat arrives last, are reached faster in small cans due to the shorter distance to the heat source than in large cans.**
- **The Fo value is a measure of the “sterilising value” of a process. It can be thought of as the time required at a temperature of 121°C to reduce microbial numbers by the same amount as the actual process being considered.**
- **When bacterial spores are heated to a lethal temperature as during retorting of canned foods, the death of most species approximates a first order chemical reaction that can be described by a straight line on semi-logarithmic graph paper**

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- **This F value is usually set at 12 D values to give a theoretical 12 log cycle reduction of the most heat-resistant species of mesophilic spores in a can of food**
- **For example, if there were 10,000 spores of a species of spore in a can of food and a 12 D process was given, the initial 10,000 spores (10 4 spores) would be reduced to a theoretical 10 -8 living spores per can, or again in theory, one living spore per 10 8 cans of product (one spore per one hundred million cans)**

Sterilization

- The aim of sterilization is the destruction of all bacteria including their spores
- 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
- Moist heat is a more effective sterilizing 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)
- Temperature over 100 ^{0}C requires heating under elevated pressure, (like in a pressure cooker) 121^{0} C require 100 kpa extra pressure
- Endospores are much more resistant to heat
- Moist heat denatures proteins which destroys essential enzyme activities

- **From the microbial point of view, it would be ideal to employ very intensive heat treatment which would eliminate the risk of any surviving microorganisms**
- **However, most food products cannot be submitted to such intensive heat stress without suffering degradation of their sensory quality or loss of nutritional value (destruction of vitamins and protein components)**
- **In order to comply with above aspects, a compromise has to be reached in order to keep the heat sterilization intensive enough for the microbiological safety of the products and as moderate as possible for product quality reasons**
- **"Commercial sterility" implies less than absolute destruction of all micro-organisms and spores, but any remaining would be incapable of growth in the food under existing conditions**
- **Most heat resistant pathogen is *Clostridium botulinum* and most heat-resistant (non-pathogenic) spoilage microorganisms are *Bacillus stearothermophilis* and *Clostridium thermosaccharolytom***

Two typical forms of sterilized product are:

- **Package sterilized- Product is packed into containers and the container of product is then sterilized**

e.g. canning, some bottled products, retort pouches

- **UHT or Aseptically processed - Product and the package is sterilised separately then the package is filled with the sterile product and sealed under specific conditions**

e.g. long life milk, tetra pack or combi bloc fruit juices and soups etc.

Treatment Parameters

- **Type of container – for example glass is not a good conductor of heat so you would expect product in a glass jar to heat more slowly than an equivalent size/shape metal can.**
- **Size and shape of the container – obviously a large container will take longer to heat than a small container**
- **Retort temperature – a higher retort temperate will result in more rapid heating but also may lead to more over processing of product near the package surface.**

- **Agitation of the containers will increase the heating rate by mixing the contents of the container, especially with viscous or semi-solid foods. End over end agitation is better than axial agitation)**
- **Type of product – obviously different products conduct heat more or less easily and have different heat capacities. Some products are more viscous than others which can have a particularly significant effect in agitating retorts. Therefore different products will heat at a different rate.**
- **Headspace – insufficient headspace can also affect the rate of heating, especially in an agitating retort. Therefore if any of these factors change, the severity of the process needs to be reevaluated**