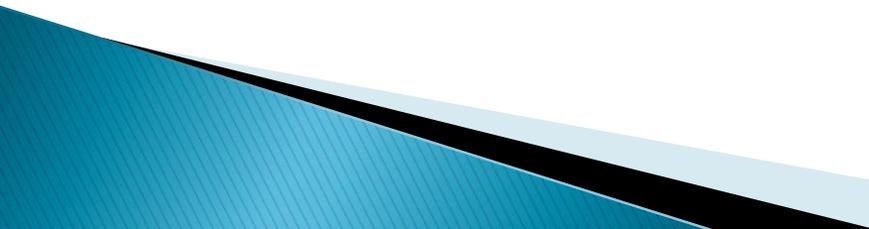


Heat penetration

Determination of thermal process

- ▶ **Fo value** is the integral heating effect received by all points inside the can
- ▶ 1. Margin of Safety – TDT curves
- ▶ 2. Receipt of heat treatment at all points
 - Heat penetration studies

Slowest Heating Point or Cold Point

- ▶ The point of greatest temperature lag or the point in the can which is last to reach the final heating temperature
 - ▶ **Process evaluation** – based on temp. at the cold point and integrating the lethal effects
 - ▶ Assumption – If cold point received a heat process sufficient to attain commercial sterility, then all points have received an equal or greater thermal process
- 

Come up time (CUT)

- ▶ Time required to vent the retort and bring it to the processing temperature
- ▶ Different for different sizes and types of retort and can loads
- ▶ Temp. $> 60^{\circ}\text{C}$ have killing effect on bacteria – so heating and cooling phases data required for total lethality of the process
- ▶ Measure heat penetration into the product during thermal processing

Determination of cold point

- ▶ Determine heat penetration by thermocouples
- ▶ **Principle** – Two dissimilar metal wires are joined at both ends to form a closed circuit. The junctions are held at two different temp. A current is set up. The magnitude depends on the difference in temp. between the two junctions. One junction introduced into the can at the coldest temp. while other is held at a constant temp. (0°C). Temp. measured by potentiometer. Copper and constantan or chromel and alumel are the common metal pairs

Mechanism of heat transfer

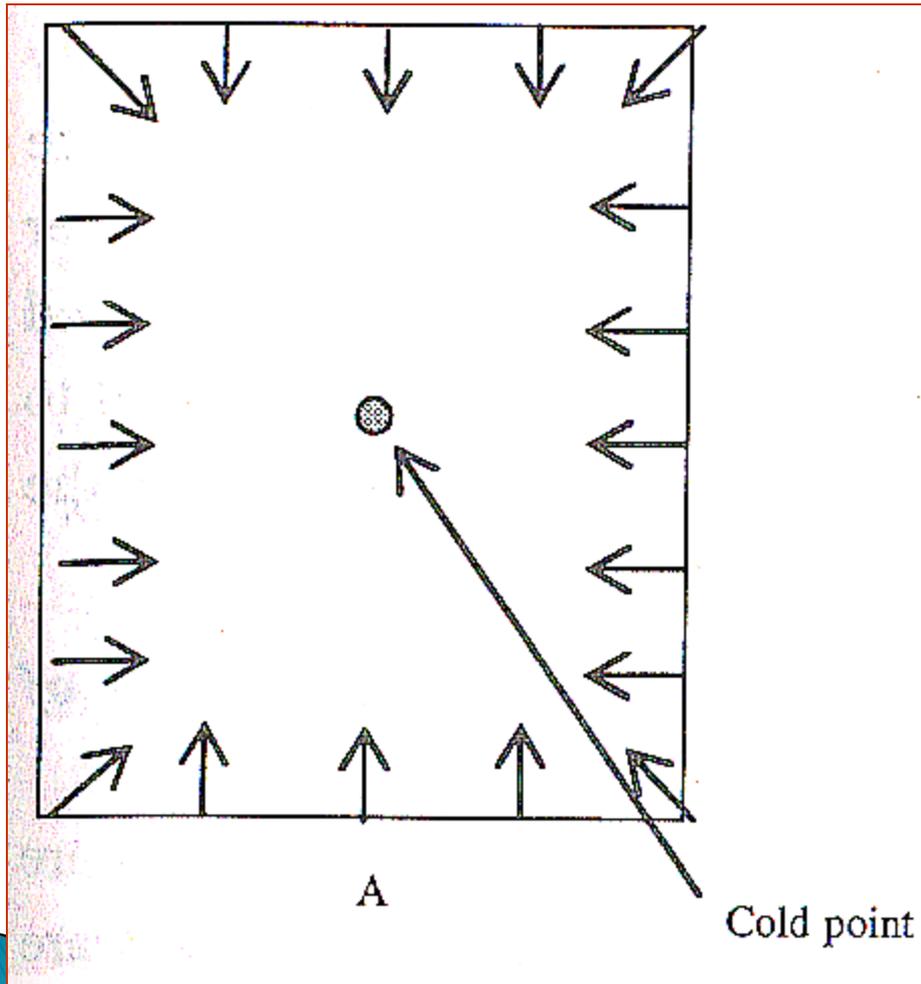
- ▶ Depends on nature of foods – fluid, solid etc.
- ▶ Conduction
 - Solid foods heat by conduction
 - Heat transfer by molecular activity from one substance to another
 - Initially, temp. at can center remains constant but near can walls increases
 - After a lag period, temp rises from can center showing symmetrical conduction of heat from the can outside towards the center
 - Cold point at the geometric center of the can
 - If head space, it is just above the geometric center

Mechanism of heat transfer...

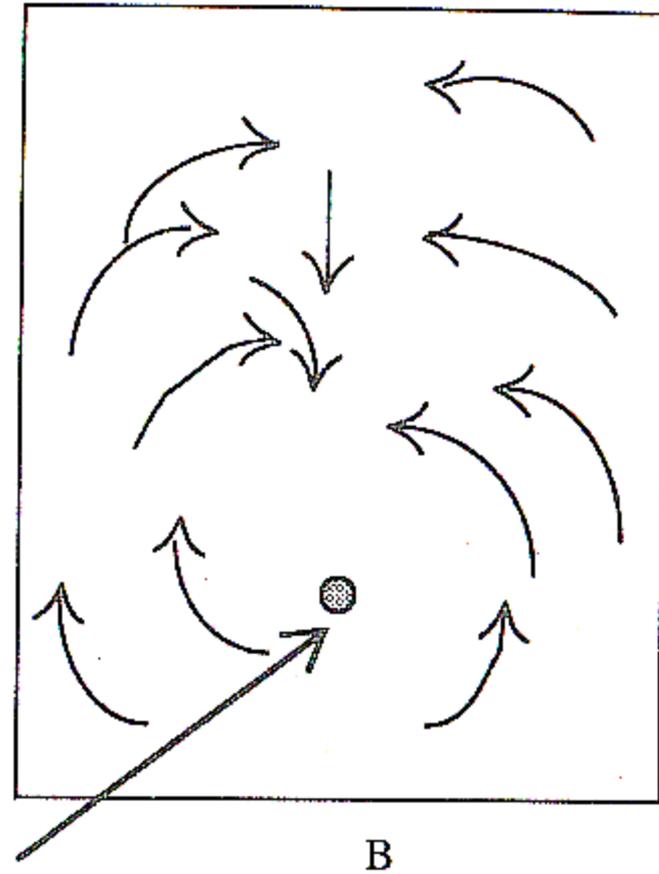
▶ Convection

- Heat changes the density of fluids and set a convection current
- Rapid convection in thin liquids
- If solids dissolved, it increases viscosity and decrease heat transfer
- Heated portion becomes lighter in density and rises. This sets up a circulation.
- Cold point below the dead center of the can or below the geometric center of the can

Conduction



Convection



Mechanism of heat transfer...

- ▶ Broken heating curves
 - Certain foods – change or break in rate of heat penetration
 - Initial period – rapid heat transfer – cease more or less abruptly – slower rate of heat penetration
 - Shift in heating pattern from convection to conduction
 - Change due to sol-gel transformation eg. Starch foods

Mechanism of heat transfer...

- ▶ Mixed conduction-convection heating packs
 - Products with high solids to liquid ratio heat simultaneously by conduction and convection
 - This may also occur accidentally when solid clumps together forming large pieces
 - Heat transfer slow down due to change from convection to mixed conduction-convection heating
 - Lead to under processing and consequent spoilage

Positioning of thermocouple

- ▶ Mount thermocouple on the side of the test cans
- ▶ Position thermocouple at every $\frac{1}{4}$ inch starting at $\frac{1}{2}$ inch from the bottom
- ▶ Fill cans with food, seal, retort and record temperature at every minute
- ▶ Heat by convection – cold point is geometric center
- ▶ Heat by convection – cold point between geometric center and bottom

Factors affecting heat penetration

▶ Filling

- Temperature gradient between can and retort
 - rate slow as temp. diff. decreases
- Increase in retort temp.
 - more rapid heat penetration
- Hot cans attain lethal temp. more rapidly than cold filled cans
- Ratio of solid to liquid
- Arrangements of solids in the liquid
 - Channels facilitate convection heating
 - Loose packing quick heat transfer
 - Overfilling retard heat penetration

Factors affecting heat penetration..

- ▶ Ingredient related factors
 - Fatty tissues are poor conductor of heat
 - Substance which undergoes change of state (sol-gel)
 - Solids absorbing water change solid/liquid ratio
- ▶ Preparation related factors
 - Use of partially thawed frozen fish causes temperature lag in heat penetration
 - Differences in handling practices over those standardized and tested in laboratory or pilot scale production

Factors affecting heat penetration..

- ▶ Processing related factors
 - Come up time – 42% of CUT should be added to the processing time at the retort temp
 - Agitation of cans during heating – end-over-end agitation
 - Shape and size of the container – ratio of the surface area of the container to its volume
 - Smaller cans heat more rapidly because of the large surface area in relation to the volume of the can

Process evaluation

Process evaluation

- ▶ Temp > growth max. lethal
 - ▶ Bacterial spores lethal effect 93°C
 - ▶ Calculate time requirement from
 - Knowledge of lethal rate at that temp.
 - TDT curve
 - Heating and cooling curve
- 

Lethality

- ▶ **Lethal rate** - Rate of destruction of an organism per min at any given lethal temp. is the reciprocal of the time in min required to completely destroy it at that temp.

$$LR = \text{Antilog} [(T-121.1)/z]$$

If z value is 10°C, the LR for 111.1°C is 0.1

- ▶ Determination of thermal process, F_0 involves
 - Measurement of temp. at SHP
 - Integration of lethal effect at this point
 - Graphical method
 - Mathematical method
 - Modification method

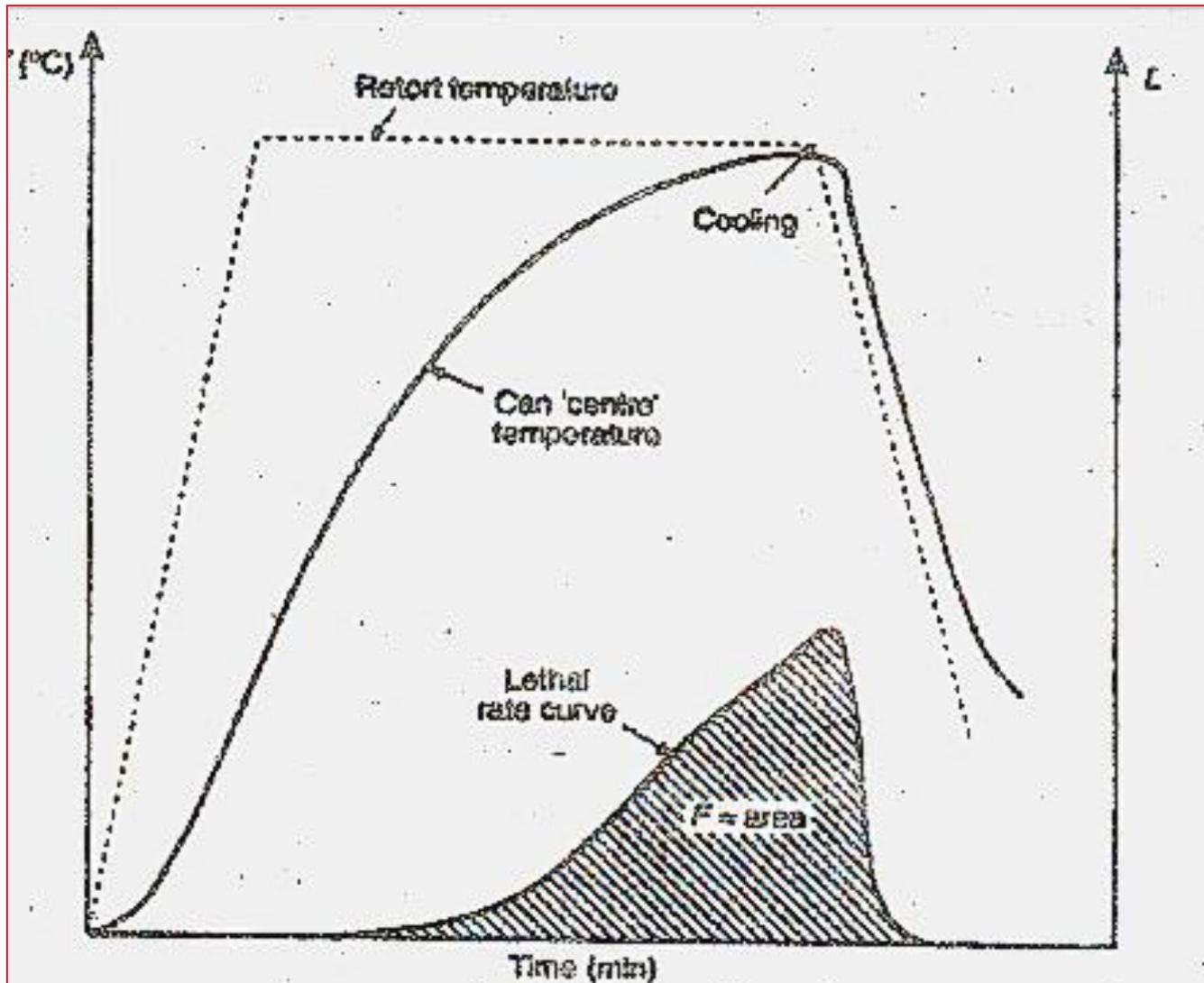


Fig.8.2. Lethal Rate curve

- ▶ *C. botulinum* spores requires F_0 of 2.52 min
- ▶ Theoretically - Heat the food at 121.1°C instantaneously, hold for 2.52 min and cool below lethal temp instantaneously
- ▶ Integrated lethal value equivalent to 2.52 min sufficient
- ▶ Known, F_0 at 121.1°C is unity
- ▶ So, for every temp. change of 10°C, there is 10-fold change in death rate of organisms
- ▶ Work out F_0 equivalent at that time-temp combinations

- ▶ If processing at 111.1°C, needs 10 times more heating to attain sterilization effect
 - ▶ If processing at 131.1°C, needs 1/10th of time
 - ▶ Experimentally, F₀ value of 10 min attained in solid pack tuna by processing at
 - 74 min at 116°C or 50 min at 125.1°C
 - ▶ Methods of estimating process lethality
 - Classical calculation method
 - General method
 - Formula method
 - Integrated lethality method
 - Nomogram method
 - Microbiological method/inoculation pack method
- 

Classical calculation method

- ▶ Simplest
- ▶ Record SHP temp/ min
- ▶ Obtain LR rate for temp. from LR table or calculate LR
- ▶ Integrate lethal values of heat for all time-temp combinations at this point
- ▶ Find out sterilising value of the process
- ▶ Add LR of temp after steam cut off to arrive cumulative F_0 value

General method

- ▶ Graphical method
- ▶ Construct TDT, H&C curves and lethality curve with LR against time (min)
- ▶ If area under lethality curve is unity (1) – process adequate
- ▶ Measure area by counting squares and estimating fractions of whole squares
- ▶ Convert value into lethality (F_0) by multiplying scale dimensions for each square
- ▶ A planimeter is used to count the squares and fractions
- ▶ Cannot predict F_0 of
 - Shorter or longer process
 - Change in retort temp. or can size

Mathematical method

- ▶ Applicable to convection and conduction packs of any can size and retort temp
 - ▶ Construct HP curve by plotting values representing differences between retort temp. and product temp. on a log scale and time on linear scale
 - ▶ Zero time taken when the steam is turned on
 - ▶ After an initial lag, the graph becomes a straight line
- 

Mathematical method

- ▶ Slope is fh
- ▶ CUT sterilizing effect is 42% of CUT
- ▶ Corrected zero time is 52% of CUT
- ▶ Extend straight line of graph to meet 'y' axis
- ▶ The corresponding temp is theoretical initial temp (I)
- ▶ Ratio of jI/I is referred to as 'j'
 - jI = diff. between retort temp. and theoretical initial temp
 - I = diff. between retort temp and actual initial temp
 - j = lag factor or time before which there is no increase in temperature at SHP

Mathematical method

- ▶ The basic equation is

$$B = fh \log (jI-g)$$

B = process time (min)

g = diff. in oF bet. retort temp and max. temp at SHP

- ▶ From above, g is calculated

- ▶ Value of g is related to the ratio of fh/U

$$U = F_o F_i$$

F_i = Time in min at the retort temp equivalent to F_o
process at 250oF

$$F_i = \log^{-1} (250-t)/z \quad (t - \text{process temp; } z-18\text{oF})$$

- ▶ From above, F_i is calculated

- ▶ From U and F_i , F_o is calculated

Integrated lethality method

- ▶ In convection pack, heating at SHP (F_c) is equal to the effective mean through out the container (F_s)

$$F_c = F_s = D (\log a - \log b)$$

D = DRT at reference temp

a = initial no of spores

b = no of survivors

- ▶ For conduction pack, integration of lethal values of heat received at SHP is more accurate
 - Determine survival ratios for small volume
 - Integrate over the whole volume

Nomogram method

- ▶ American Can Co – Quick method
- ▶ Not accurate
- ▶ Applicable to straight line and broken curve lines
- ▶ Knowledge on Ball method necessary
- ▶ Calculate process value F_0
- ▶ Predict F_0 values for similar products under changed conditions ie. can size, retort temp or filling temp.

Microbiological methods

- ▶ Confirmation – Inoculated pack method
- ▶ Carry out HP tests with inoculated packs
- ▶ Most reliable
- ▶ Two methods
 - Inoculated pack method – spores are directly added to the food
 - Spore bulb method – Spores suspended in a buffer and contained in a small bulb or capillary tube are placed in the food in the can

Inoculated pack method

- ▶ Place heat resistance spores in SHP
 - ▶ Subject to normal heat treatment
 - ▶ Should be a gas former
 - ▶ Presence of blown can
 - ▶ Estimate survival by culture or incubation tests
- 

Spore bulb method

- ▶ Similar to capillary bulb method
 - ▶ Capillaries containing spores implanted in solid pieces of food at SHP
 - ▶ In convection packs, placed using special device
 - ▶ Compare no. of survivors with the initial no. of spores
 - ▶ Evaluate the lethality of the process
- 