Pasteurization and Heat Sterilization

Please refer to Chapter 5 in Paul Singh & Heldman (2009) book

ERT 426 FOOD ENGINEERING
One of the Methods of Food Preservation
(In previous topic)

For each 10 °C rise in temperature, the activity of micro-organisms and enzymes increases by at least 2x, in the range 0-60 °C. Above this, heat quickly destroys enzymes and stops living cells from working.
Heat Treatment Processing

This is a method that uses heat to kill microorganisms or suppress their growth and to inactivate enzymes.

Objectives of Heat Treatment Processing

- Eliminate microorganisms
- Minimize foodborne diseases
- Increase storage life
Pasteurization – a thermal process used to eliminate specific pathogenic microorganisms from food.

Is a process of heating a food, usually liquid, to a specific temperature (below boiling point) for a definite length of time, and then cooling it immediately. This process **slows microbial growth** in food.

Unlike *sterilization*, pasteurization is not intended to kill all micro-organisms in the food. Instead pasteurization aims to **reduce the number of viable pathogens** so they are unlikely to cause disease (assuming the pasteurized product is stored as indicated and consumed before its expiration date).

The process of pasteurization was named after **Louis Pasteur** who discovered that spoilage organisms could be inactivated in wine by applying heat at temperatures below its boiling point. The process was later applied to milk and remains the most important operation in the processing of milk.
Destroys pathogenic microorganisms in vegetative state
- Juices, milk, liquid eggs

Extend product shelf life by reducing microbial and enzymatic spoilage
- Beer, wine and other alcoholic drinks
- Fruit juices
- Pickles
There are basically two methods of pasteurization in use today:

**Batch**

In the batch process (batch pasteurizer, right), a large quantity of milk is held in a heated vat at 65°C for 30 minutes, followed by quick cooling to about 4°C.

**Continuous flow**

In the continuous flow process (continuous flow pasteurizer, below, right)—also known as HTST, for high temperature, short time, milk is forced between metal plates or through pipes heated on the outside by hot water. While flowing under pressure, the milk is held at 72°C for at least 16 seconds. Before being chilled back to 4°C or cooler, it flows through a heat exchanger to pre-warm cold milk just entering the system.
A continuous high-temperature-short-time (HTST) pasteurization system.
The continuous high temperature- short-time (HTST) pasteurization system has several basic components, including the following:

- **Heat exchangers for product heating/cooling.** Most often, plate heat exchangers are used to heat the product to the desired temperature. The heating medium may be hot water or steam, and a regeneration section is used to increase efficiency of the process. In this section, hot product becomes the heating medium. Cold water is the cooling medium in a separate section of the heat exchanger.

- **Holding tube.** The holding tube is an important component of the pasteurization system. Although lethality accumulates in the heating, holding, and cooling sections, the Food and Drug Administration (FDA) will consider only the lethality accumulating in the holding section (Dignan et al., 1989). It follows that the design of the holding tube is crucial to achieve a uniform and sufficient thermal process.

- **Pumps and flow control.** A metering pump, located upstream from the holding tube, is used to maintain the required product flow rate. Usually a positive displacement pump is used for this application. Centrifugal pumps are more sensitive to pressure drop and should be used only for clean-in-place (CIP) applications.

- **Flow diversion valve.** An important control point in any pasteurization system is the flow diversion valve (FDV). This remotely activated valve is located downstream from the holding tube. A temperature sensor located at the exit to the holding tube
A blanching system achieves a process similar to pasteurization but with application to a **solid** food and to **inactivate an enzymes system**.

Used for fruits & vegetables to inactivate enzymes

Common practice for products to be frozen

Boiling (temp ~ 95 °C ) water sprayed onto fruits & veggies or soaked in boiling water for 1-5 minutes, depending on the product

Blanching is often used as a preliminary step for freezing, canning, or dehydration
Purpose of Blanching

- Inactivate enzymes that can cause
  - Deterioration in flavor, texture, color, and nutrients during storage
  - Reduce number of microorganisms
  - Remove air from tissues
  - Make food more compact
  - Enhance color
Example of Blanching System

- Its process has conveying system, used to carry solid food where its design and speed are to ensure thermal treatment provide desired inactivation of enzyme system
- Slowest heating location of the product will increase in temperature at initial stage
- Second stage – exposed to cold environment
SUMMARY

Pasteurization - Temps < 100oC
- Destroys pathogenic microorganisms
- Extends product shelf life (but not extensively)
- Ex: milk, beer, fruit juices, liquid eggs

Blanching
- Primarily used for fruits & vegetables
- Deactivates enzymes
- Kills some bacteria
Sterilization is a term referring to any process that **eliminates (removes) or kills** all forms of microbial life, including transmissible agents (such as fungi, bacteria, viruses, spore forms, etc.) present on a surface, contained in a fluid, in medication, or in a compound such as biological culture media.

It aims to **destroy or partially/totally inhibit enzymes and microorganisms**, whose presence or proliferation could alter the food or make it unfit for human consumption.

The heat sterilization involves exposing food to a temperature generally **exceeding 100°C** for a period sufficient to inhibit enzymes and all forms of microorganisms including bacteria spore.

One of the first steps toward sterilization was made by Nicolas Appert.

He learned that thorough cooking (applying a suitable amount of heat over a suitable period of time) slowed the decay of foods and various liquids, preserving them for safe consumption for a longer time than was typical. Canning of foods is an extension of the same principle, and has helped to reduce food borne illness ("food poisoning"). Other methods of sterilizing foods include food irradiation and pascalization (the use of high pressure to kill microorganisms).
Complete destruction of microorganisms

- 121°C for 15 minutes or more
- Can be considered to be a very harsh treatment
- Used to sterilize foods in cans or containers
Commercial Sterilization

- Destroys both vegetative and spores of pathogenic organisms.
- Reduces nutritional value.
- Causes loss of organoleptic properties (taste, colour, odour and feel).
Commercial Sterilization System

- **Batch system**
  - Also known as *still retort*
  - Designed to expose product to temperature >100°C
  - Vessel must maintain pressure up to 475 kPa or pressure need to maintain steam temperature of 135-150°C

- **Continuous Retort System**
  - Also known as *crateless retort*
  - Designed to allow for automated filing and discharge of product container
  - Run in semicontinuous where vessel is 1st filled with product container, followed by sealing of the vessel

- **Pouch Processing System**
  - Designed food product placed in metal can
  - Alternative system for product placed in a flexible pouch requires an approach to suspend the pouch in steam environment within retort vessel

- **Aseptic Processing System**
  - Another approach of continuous sterilization where the product is thermally processed prior to being placed in container
  - Require independent sterilization of container, while in aseptic environment and placement of the product into the container

*Please remember this!*
All pathogens and toxin-forming organisms are destroyed as well as other organisms that could cause spoilage under normal conditions.

May contain a small number of heat-resistant bacterial spores, but these will normally not multiply in the food.

Shelf life of two years or more.
Sterilization

Complete destruction of microorganisms

• 121°C (250°F) for 15 minutes

Commercially Sterile

All pathogenic & toxin-forming organisms are destroyed (applies to most preserved foods)
IMPORTANT!
Please read and understand the process of all pasteurization, blanching, and sterilization systems, able to draw the process diagrams as well as comparing those systems.
During preservation processes for foods, Microorganisms are destroyed by **heat** (external agent), but the amount of heating required for the killing of different organisms varies.

Also, many bacteria can exist in two forms, the **vegetative** or growing form and the **spore** or dormant form. The spores are much harder to destroy by heat treatment than are the vegetative forms.

A frequently used indicator organism is **Clostridium botulinum**. This particular organism is a very important food poisoning organism as it produces a deadly toxin and also its spores are amongst the most heat resistant. Processes for the heat treatment of foodstuffs are therefore examined with respect to the effect they would have on the spores of **C. botulinum**. If the heat process would not destroy this organism then it is not adequate. As **C. botulinum** is a very dangerous organism, a selected strain of a non-pathogenic organism of similar heat resistance is often used for testing purposes.

A combination of **temperature and time** must be used that is sufficient to inactivate the particular species of bacteria or enzyme under consideration.
Microbial survivor curve is used to describe the decreasing pattern on population of vegetative cells such as E.coli or Salmonella. The population of microbial spores will decrease in a similar manner but after an initial lag period. Refer to Figure 5.8.

When survivor curve data are presented on semilog coordinates, a straight line is obtained (Fig. 5.9).

D = Decimal reduction time = The time necessary for a 90% reduction in the microbial population.
Thermal Resistance Constant \((z)\) is used to describe the influence of temperature on decimal reduction time \((D)\) for microbial population \((N)\).

**Remember:** Heat is external agent.

Thermal Resistance Constant \((z)\) is define as the increase in temperature necessary to cause 90% reduction in reduction time \((D)\).

Refer Fig. 5.11

Refer to handout for elaboration...
Thermal death time, \( F \) is the total time required to \textbf{accomplish} a stated reduction in a population of vegetative cells or spores.

It can be expressed as a multiple of \( D \) values.

A typical \( F \) in thermal processing of shelf-stable foods is \( F=12D \), with the \( D \) value for \( C. \) botulinum.

\( F \) usually expressed as \( F^z_T \), where \( F \) is the thermal death time for a temperature \( T \) and a thermal resistance constant \( z \).

For a \textbf{reference} purpose, a commonly used thermal death time is \( F^{10}_{121} \).

This reference thermal death time is simply written as \( F_0 \).

Refer to handout for more elaboration...
Spoilage Probability

Is used to estimate the number of spoiled containers within a total batch of processed product.

Refer to handout for more elaboration...
The processes for sterilization and pasteurization illustrate very well the application of heat transfer as a unit operation in food processing. The temperatures and times required are determined and then the heat transfer equipment is designed using the equations developed for heat-transfer operations.

Heat processing is a harsh method of food preservation, it will give adverse effect on taste, texture and nutritive value of the food products.
TUTORIAL 4
(Please refer to Chapter 5 in Paul Singh & Heldman book and Handout)
EXERCISE 1

- Draw a schematic of a typical steam blanching system.

- Draw a schematic diagram of a hydrostatic sterilization system for canned foods.

- Distinguish between pasteurization, blanching, and sterilization.
PROBLEM 5.1

Calculate the D value for the microorganism when given the following thermal resistance data for a spore suspension:

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Number of survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10^6</td>
</tr>
<tr>
<td>15</td>
<td>2.9 x 10^5</td>
</tr>
<tr>
<td>30</td>
<td>8.4 x 10^4</td>
</tr>
<tr>
<td>45</td>
<td>2.4 x 10^4</td>
</tr>
<tr>
<td>60</td>
<td>6.9 x 10^3</td>
</tr>
</tbody>
</table>

Construct the survivor curve on regular and semilogarithmic coordinates.
The results of a thermal resistance experiment gave a D value of 7.5 minutes at 110°C. If there were 4.9 x 10⁴ survivors at 10 minutes, calculate the $N_0$ and ratio $(N/N_0)$ for 5, 15, and 20 minutes.
PROBLEM 5.3

Calculate the z value for a microorganism that has the following decimal reduction times: $D_{110} = 6$ minutes, $D_{116} = 1.5$ minutes, $D_{121} = 0.35$ minutes, and $D_{127} = 0.09$ minutes.
PROBLEM 5.4

An $F_o$ value of 7 minutes provides an acceptable economic spoilage for a given product. Calculate the process time at 115$^\circ$ C.
If the z value of a microorganism is 16.5°C and \( D_{121} \) is 0.35 minutes, Calculate the \( D_{110} \)?
Estimate the spoilage probability of a 50-minute process at 113°C when $D_{113} = 4$ minutes and the initial microbial population is $10^4$ per container.