Preservation of Products
The Control of Microbial Growth

Growth

Absolute Factors

- Nutrients
- pH
- Temperature
- Oxygen

Rate-Determining Factors

- Mass transfer rate
- Energy transfer rate

The Microbial Growth Curve

- The microbial growth curve is a record of cell numbers over a time period.
- Absolute and rate-determining factors determine the shape of the microbial growth curve.

The time period to maximal population size is dependent on the initial microbial load or inoculum size.

Opportunity for growth is determined by environmental factors. Unfavorable conditions prolong the lag phase and slow the growth rate.
Microbiological QA & the Microbial Growth Curve

Microbiological QA is centred around obtaining an *appropriate shape* in the *growth curve*.

Microbiological Quality Assurance

Assuring a wholesome product

- **Food safety**
  Requires assuring minimal numbers of specific microorganisms.

- **Spoilage**
  Requires the control of microbial proliferation.

Both aspects are allied and mutually supportive.

Physicochemical Properties of the Product & Microbial Growth

**a. Hydrogen-Ion Concentration**

- pH; optimal enzymatic activity; optimal growth
- Buffering capacity

**b. Oxidation-Reduction Potential (Eh)**

- **Positive Eh (mV):** Aerobic conditions
- **Negative Eh (mV):** Anaerobic conditions

- Influenced by the
  - nature of the product
    - Eh characteristic
  - Poising capacity
  - gaseous environment the product
Oxygen tension and access to the atmosphere

Physicochemical Properties of the Product & Microbial Growth 3

c. Water Activity ($A_w$)

- Without water, no growth can occur.
- A solution's $A_w$ is the ratio of the vapor pressure of the solution to the vapor pressure of water.
- Solute concentration determines the $A_w$ of a solution.
- $A_w$ can also be determined by the amount of water present.

Physicochemical Properties of the Product & Microbial Growth 4
d. Content of Nutrients & Chemical Inhibitors, and Structure

- Type of nutrient
  - Carbohydrates; Proteins; Fats
- Complexity of the nutrient
  - Polymers; monomers
- Naturally occurring inhibitors
  - e.g. Lysozyme; benzoic acid
- Nature of the substrate
  - e.g. Fat layers; fish scales; size

Preservation of Product in Perspective

a. Control of Microbial Growth

- Exclusion of microbial load
- Removal of microbial load
- Inhibition of growth
- Destruction

b. Prevention or delay of self-decomposition

- Destruction or inactivation of food enzymes
- Prevention or delay of chemical reactions

c. Prevention of mechanical, pest and other damage

Methods of Product Preservation 1

<table>
<thead>
<tr>
<th>Mode of action</th>
<th>Preservation factor</th>
<th>Mode of achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactivation of microorganisms</td>
<td>Heat</td>
<td>Pasteurization Sterilization</td>
</tr>
<tr>
<td></td>
<td>Chemical</td>
<td>Gaseous Liquid</td>
</tr>
<tr>
<td></td>
<td>Radiation</td>
<td>Radicidation Radurization Radappertization</td>
</tr>
<tr>
<td>Restriction of access of</td>
<td>Filtration</td>
<td>Membrane filters</td>
</tr>
<tr>
<td>microorganisms to product</td>
<td>Decontamination</td>
<td>Ingredients</td>
</tr>
<tr>
<td></td>
<td>Aseptic or clean handling</td>
<td>Clean processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aseptic processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aseptic or clean packaging</td>
</tr>
</tbody>
</table>
**Methods of Product Preservation 2**

<table>
<thead>
<tr>
<th>Mode of action</th>
<th>Preservation factor</th>
<th>Mode of achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhibition of growth rate</td>
<td>Cool</td>
<td>Chill Freeze</td>
</tr>
<tr>
<td></td>
<td>Restrict water</td>
<td>Freeze</td>
</tr>
<tr>
<td></td>
<td>Restrict oxygen</td>
<td>Nitrogen pack</td>
</tr>
<tr>
<td></td>
<td>Increase carbon dioxide</td>
<td>CO₂ pack</td>
</tr>
<tr>
<td></td>
<td>Acidify</td>
<td>Add acids</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>Fermentation</td>
</tr>
<tr>
<td></td>
<td>Chemicals</td>
<td>Add inorganic or organic preservatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Add antibiotics Use smoke</td>
</tr>
</tbody>
</table>

*After Frazier & Westhoff (1988)*

**Methods of Product Preservation 3**

1. **Inactivation of Microorganisms by Heat**
   a. **Kinetics of Microbial Inactivation**

   **The D-Value**

   \[
   D = \frac{-\log_{10} \log_{it}}{t} = \frac{-\log_{10} \log_{0t}}{t}
   \]

   The exposure time required for the number of survivors to change by a factor of 10 or the population to be reduced by 90%.

   **Kinetics of Microbial Inactivation 1**

   ii. **The Inactivation Factor**

   The reduction in the number of viable microorganisms brought about by the process.

   **IF = 10^t/D**

   Where \( t \) = Exposure time

   D = D-Value for the microorganism under the exposure conditions.

   A process that achieves 12D has an IF of \( 10^{12} \).

   **Kinetics of Microbial Inactivation 2**

   iii. **The Z-Value**
The increase in temperature required to reduce the D-Value of a microorganism by one log cycle or 90%.

\[ Z = \frac{T_2 - T_1}{\log D_1 - \log D_2} \]

### Kinetics of Microbial Inactivation

#### iv. Sterilization Efficiency: The F-Value

- **Saturated steam** is an efficient heat transfer medium.
- Condensation on cooler surface ⇒ release of latent heat.
- Temperatures above 100°C are used. This is achieved by containing the heat treatment in a pressure vessel.
- The pressure within the vessel must be raised by steam alone. Presence of air will contribute to pressure but not to temperature of the steam.
- "Wet steam" and "dry saturated steam"

### Methods of Preservation

#### b. Sterilization by Moist Heat

- Is a measure of the total lethality of a sterilization process.
- Defined as the capacity to destroy a particular microorganism which is equivalent in minutes of heat at 121°C.

\[ F_0 = D_{121} \times IF \]

Where \( F_0 \) is the value when temperature = 121°C and Z-Value = 10°C.

### Sterilization by Moist Heat 2

**Satisfactory sterilizing conditions (U.K. Dept. of Health, 1981)**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Hold Time (Min)</th>
<th>Pressure</th>
<th>( F_0 ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>134</td>
<td>3</td>
<td>30 p.s.i.; 207 Kpa</td>
<td>59</td>
</tr>
<tr>
<td>126</td>
<td>10</td>
<td>20 p.s.i.; 138 Kpa</td>
<td>31</td>
</tr>
<tr>
<td>121</td>
<td>15</td>
<td>15 p.s.i.; 103 Kpa</td>
<td>15</td>
</tr>
<tr>
<td>115</td>
<td>30</td>
<td>10 p.s.i.; 69 Kpa</td>
<td>8.1</td>
</tr>
</tbody>
</table>

The highest temperature compatible with the product to be sterilized should be used
⇒ Highest assurance of sterility + short cycle time.

### Sterilization by Moist Heat 3

#### Stages of a Steam Sterilization Cycle
Sterilization by Moist Heat 4

**Sterilization of Liquids**

- Steam heats the container
- The use of pressure helps to counteract the pressure rise in a heated, sealed container
- Lethality of the process includes the heating up and cooling down periods. This effect depends on the volume of the liquid

**Temperature**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>60*</td>
</tr>
<tr>
<td>160</td>
<td>60</td>
</tr>
<tr>
<td>170</td>
<td>40</td>
</tr>
<tr>
<td>180</td>
<td>20</td>
</tr>
</tbody>
</table>

DH: U.K. Dept. of Health; BP: British Pharmacopoeia
*only for fixed oil, ethyl oleate, liquid paraffin, glycerol

Methods of Preservation 5

**Porous Load Sterilization**

- Wrapped goods and porous materials *e.g.* dressings; linen
- Trapped air is an insulator
- Air removal is required to ensure contact between product and steam
- Air removal is achieved by cyclic application of vacuum evacuation and steam injection at the start of the sterilization cycle

Methods of Preservation 6

**c. Sterilization by Dry Heat**

- Method of choice for heat stable but moisture-sensitive items
  *e.g.* thermostable powders; non-aqueous liquids; corrosion-sensitive equipment
- Temperatures and times required are significantly greater than moist heat
d. Pasteurization

- Heat treatment which kills part but not all microorganisms present

- Used when
  i. More rigorous heat treatment is incompatible with product quality
  ii. One aim is to kill specific microorganisms
  iii. The main spoilage microorganisms are not very heat resistant
  iv. Other treatments are used in conjunction e.g. refrigeration
  v. Followed by desired fermentation e.g. preparation of yogurt

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Time-Temperature Regimes in Pasteurization

Times and temperatures used depend on the method and the product to be treated

- **Low-Temperature-Long-Time Method (LTLT)**
  Milk: 62.8°C for 30 min

- **High-Temperature-Short-Time Method (HTST)**
  Milk: 71.7°C for 15 s
  88.0°C for 1 s
  90.0°C for 0.5 s
  96.0°C for 0.05 s

- **Ultra-High-Temperature Method (UHT)**
  Milk: 137.8°C for 2 s
  Approaches sterilization