“Extrinsic Factors Affecting The Growth of Microbes”

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Factors that Impact Microbial Growth

- Food
- Acid/pH
- Temperature
- Time
- Oxygen
- Moisture
- Salinity
- Pressure
- Radiation
Factors that influence microbial activity

Six major factors:
1. Moisture
2. Oxygen
3. Temperature
4. Acidity, pH
5. Nutrients
6. Growth inhibitors
Factors Influencing Growth of Microorganisms in Food

• Understanding factors that influence microbial growth essential to maintaining food quality
  – In production and preservation
• Conditions naturally present in food termed intrinsic factors
• Environmental conditions are termed extrinsic factors
Factors that Impact Microbial Growth

Intrinsic Factors:
1. Nutrient
2. Moisture & Aw
3. pH
4. Antimicrobial substances

Extrinsic Factors:
1. Temperature
2. Oxygen
3. RH
4. Other microbes
Factors Influencing Growth of Microorganisms in Food

• **Intrinsic factors**
  
  – Multiplication of food greatly influenced by inherent characteristics of food
    
    • Microbes multiply most rapidly in moist, nutritionally rich, pH neutral foods
  
  – **Intrinsic factors include**:
    
    • Nutrients
    • Water availability
    • pH
    • Biological barriers
    • Antimicrobial chemicals
Factors Influencing Growth of Microorganisms in Food

- **Extrinsic** or environmental factors fundamentally affect the function of metabolic enzymes.

- **Extrinsic Factors include**:
  - Temperature
  - Gas composition: oxygen requirements
  - Electromagnetic radiation
  - Pressure: barometric and osmotic pressure
  - Relative Humidity (RH)
  - Radiation
  - Other microbial activities
Factors Influencing Growth of Microorganisms in Food

- **Extrinsic factors**
  -Extent of microbial growth largely dependent on storage of food
  -Microbes multiply rapidly in warm, oxygen-rich environments
Factors Influencing Growth of Microorganisms in Food

• **Extrinsic factors**
  
  – **Storage temperature**
  
    • Storage temperature affects rate of microbial growth
      
      – Below freezing water availability is significantly decreased
        
        » Water crystallizes and is unavailable halting microbial growth
      
      – At low temperature (above freezing) enzymatic action is very slow or non-existent
        
        » Results in inability of microbe to grow
Temperature has a profound effect on microorganism **viability**, primarily because enzyme-catalyzed reactions are sensitive to temperature.
Cardinal Temperatures

- **Minimum temperature** – lowest temperature that permits a microbe’s growth and metabolism
- **Optimum temperature** – promotes the fastest rate of growth and metabolism
- **Maximum temperature** – highest temperature that permits a microbe’s growth and metabolism
Cardinal temperatures for growth

- **Minimum**
  - Membrane "gels" and does not function properly

- **Optimum**
  - Fastest growth rate

- **Maximum**
  - Proteins denature; membranes break down
• **Minimum growth temperature**
  - Many bacteria will survive below this temperature, despite the fact the cell membrane is less fluid and transport processes are too slow

• **Maximum growth temperature**
  - Above this value proteins denature and the cell dies
Temperatures in this range destroy most microbes, although lower temperatures take more time.

Very slow bacterial growth.

Rapid growth of bacteria; some may produce toxins.

Many bacteria survive; some may grow.

Refrigerator temperatures; may allow slow growth of spoilage bacteria, very few pathogens.

No significant growth below freezing.
Psychrophiles grow best at temperatures below 15°C and can grow at temperatures below 0°C. They generally die above 20°C. Include algae, fungi and bacteria that live in snowfields, ice and cold water. Most of them can’t cause disease in humans. Can cause some food spoilage. Hard to manage in laboratory.
Terms related to temperature

- **Psychrotrophs**: bacteria that grow at “normal/room” temperature ranges but can also grow in the refrigerator; responsible for food spoilage.

- **Thermoduric**: more to do with survival than growth; bacteria that can withstand brief heat treatments.
• **Mesophiles** are organisms that grow best at temperatures ranging from 30°C to about 40°C, but can survive at higher and lower temperatures.
• Because human body temperature is 37°C, most pathogens are mesophiles.
• **Thermoduric mesophiles** are mesophiles that can survive brief periods at higher temperatures.
• Inadequate heating during pasteurization and canning can result in food spoilage by thermoduric mesophiles.
• **Thermophiles** grow at temperatures above 45°C in habitats such as hot springs and compost piles. Optimum growth 55-75°C
• **Hyperthermophiles** are archaea that can live in water above 80°C. Others live above 100°C
• Thermophiles and hyperthermophiles do not cause disease because they “freeze” at body temperature
Classes of microbes based on optimal temperature

- Psychrophiles
- Psychrotrophs
- Mesophiles
- Thermophiles
- Hyperthermophiles

Temperature (°C)

Rate of growth

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Classes of microbes based on optimal temperature

- **Psychrophile**: $< 15^\circ C$
- **Mesophile**: $20 - 50^\circ C$
- **Thermophile**: $50 - 80^\circ C$
- **Hyperthermophile**: $80 - 113^\circ C$

Temperature ($^\circ C$)

Examples:

- **Psychrophile**
- **Mesophile**
- **Thermophile**
- **Hyperthermophile**

Growth rate

Temperature ($^\circ C$)
Classes of microbes based on optimal temperature
<table>
<thead>
<tr>
<th>Groups</th>
<th>$T_{\text{min}}$ (°C)</th>
<th>$T_{\text{opt}}$ (°C)</th>
<th>$T_{\text{max}}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psycrofilic</td>
<td>-15</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Psycotroph</td>
<td>-5</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Mesofilic</td>
<td>5-10</td>
<td>30-37</td>
<td>45</td>
</tr>
<tr>
<td>Thermoduric/Thermotroph</td>
<td>15</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Thermofilic</td>
<td>40</td>
<td>45-55</td>
<td>60-80</td>
</tr>
<tr>
<td>Hyperthermofilic</td>
<td>60</td>
<td>65-80</td>
<td>90</td>
</tr>
</tbody>
</table>
Effect of Temperature

• Denature proteins (enzyme) at higher temperatures
• Effect of temperature on lipid-containing membranes of cells and organelles
  – If too low, membranes become rigid and fragile
  – If too high, membranes become too fluid and cannot contain the cell or organelle
• Affect on the growth and survival of microbes
Three different effects of temperature contribute to the death of microbial cells:

1. Denaturation of proteins (enzymes) by heat
2. Intoxication due to accelerated metabolic reactions
3. Changes in essential lipids. Melting points of the fats found in the organisms and temperature ranges of death are related.
Effect of Temperature

• **Low temperature**
  – Enzymatic reactions too slow; enzymes too stiff
  – Lipid membranes no longer fluid

• **High temperature**
  – Enzymes denature, lose shape and stop functioning
  – Lipid membranes get too fluid, leak
  – DNA denatures
Factors Influencing Growth of Microorganisms in Food

• **Extrinsic factors**
  
  – Atmosphere
    
    • **Presence or absence of oxygen** affects type of microbial population
      
      – Obligate aerobes cannot grow under anaerobic conditions
      – Obligate anaerobes will grow in anaerobic conditions
        
        » Including certain foodborne pathogens
Pressure

- **Atmospheric pressure** reflects the weight of the air column.
- **Hydrostatic pressure** reflects the weight of a column of water.
- Microorganisms have adaptations that allow them to survive (thrive) in high pressure environments.
### Chemical Requirements for Growth: Oxygen

**O₂ requirements vary greatly**

<table>
<thead>
<tr>
<th>Obligate Aerobes</th>
<th>b. Facultative Anaerobes</th>
<th>c. Obligate Anaerobes</th>
<th>d. Aerotolerant Anaerobes</th>
<th>e. Microaerophiles</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Obligate Aerobes" /></td>
<td><img src="image2" alt="b. Facultative Anaerobes" /></td>
<td><img src="image3" alt="c. Obligate Anaerobes" /></td>
<td><img src="image4" alt="d. Aerotolerant Anaerobes" /></td>
<td><img src="image5" alt="e. Microaerophiles" /></td>
</tr>
</tbody>
</table>

**The Effects of Oxygen on the Growth of Various Types of Bacteria**
<table>
<thead>
<tr>
<th>Organism</th>
<th>Obligate aerobe</th>
<th>Facultative anaerobe</th>
<th>Obligate anaerobe</th>
<th>Aerotolerance anaerobe</th>
<th>Microaerophile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of oxygen on growth</td>
<td>Oxygen required. Only can survive in aerobic conditions. Dies if oxygen is absent.</td>
<td>↑growth in presence of oxygen. Both aerobic and anaerobic</td>
<td>Oxygen not required. Only can survive in anaerobic conditions. Dies if oxygen is present.</td>
<td>Do not care if oxygen is present or absent. Just do not use the oxygen present.</td>
<td>Low oxygen concentration allowed for growth only.</td>
</tr>
<tr>
<td>Enzymes effect on oxygen</td>
<td>CATALASE &amp; superoxide dismutase (SOD) neutralise the toxic forms of oxygen</td>
<td>NO enzymes available to neutralize toxic oxygen</td>
<td>SOD present to partially neutralize oxygen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examples</td>
<td><em>Mycobacterium</em></td>
<td><em>Streptococcus, Staphylococcus, Enterobactericeae</em></td>
<td><em>Clostridium</em></td>
<td><em>Lactobacillus</em></td>
<td><em>Neisseria gonorrhoeae</em></td>
</tr>
<tr>
<td>Aspects</td>
<td>Obligate aerobes</td>
<td>Facultative anaerobes</td>
<td>Obligate anaerobes</td>
<td>Aerotolerant anaerobes</td>
<td>Microaerophiles</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
<td>------------------------</td>
<td>-------------------</td>
<td>------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Energy source</td>
<td>cellular respiration</td>
<td>respiration, fermentation</td>
<td>fermentation, autotrophy</td>
<td>fermentation</td>
<td>cellular respiration</td>
</tr>
<tr>
<td>aerobic</td>
<td>✅</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>✅</td>
</tr>
<tr>
<td>anaerobic</td>
<td>✗</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>SOD enzyme</td>
<td>✅</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>✅</td>
</tr>
<tr>
<td>Peroxidase</td>
<td>✅</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>✅</td>
</tr>
<tr>
<td>Catalase</td>
<td>✅</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>✅</td>
</tr>
<tr>
<td>Example</td>
<td>Bacillus, Pseudomonas</td>
<td>E. coli, Staphylococcus</td>
<td>Clostridium tetani, Bacteroides</td>
<td>Lactobacillus</td>
<td>Campylobacter &amp; Heliobacter pylori</td>
</tr>
</tbody>
</table>
Gas Requirements

**Oxygen**

- As oxygen is utilized it is transformed into several toxic products:
  - singlet oxygen ($O_2$), superoxide ion ($O_2^-$), peroxide ($H_2O_2$), and hydroxyl radicals (OH$^-$)
- Most cells have developed enzymes that neutralize these chemicals:
  - superoxide dismutase, catalase
- If a microbe is not capable of dealing with toxic oxygen, it is forced to live in oxygen free habitats.
Categories of Oxygen Requirement

- **Aerobe** – utilizes oxygen and can detoxify it
- **Obligate aerobe** - cannot grow without oxygen
- **Facultative anaerobe** – utilizes oxygen but can also grow in its absence
- **Microaerophilic** – requires only a small amount of oxygen
Categories of Oxygen Requirement

- **Anaerobe** – does not utilize oxygen
- **Obligate anaerobe** - lacks the enzymes to detoxify oxygen so cannot survive in an oxygen environment
- **Aerotolerant anaerobes** – do no utilize oxygen but can survive and grow in its presence
Carbon Dioxide Requirement

All microbes require some carbon dioxide in their metabolism.

- **Capnophile** – grows best at higher CO$_2$ tensions than normally present in the atmosphere.
Salinity

• All organisms must deal with osmotic pressure, which results from **differences in solute concentrations** on opposite sides of a semi-permeable membrane.

• Microorganisms have evolved **adaptive mechanisms** to permit them to tolerate osmotic pressure within certain ranges.
• Microorganisms that tolerate or require high salt concentrations are called **halotolerant** and **halophilic** respectively.

• These organisms tend to exclude from their cell interiors the high $[\text{Na}^+]$ in their surroundings.
Osmotic Pressure

• Most microbes exist under hypotonic or isotonic conditions

• **Halophiles** – require a high concentration of salt

• **Osmotolerant** – do not require high concentration of solute but can tolerate it when it occurs
• **Barophiles** – can survive under extreme pressure and will rupture if exposed to normal atmospheric pressure.
Radiation

The spectrum of electromagnetic radiation is continuous from extremely energetic, short-wavelength gamma rays to long-wavelength low-energy radio waves.

Visible spectrum plus much much more....
Both gamma rays and x-rays are highly penetrating, and their energy levels are destructive to microorganisms.

- Low-level irradiation may cause mutations
- High-exposure doses destroy both nucleic acids and enzymes and kill microorganisms.
As is true with other environmental extremes, microorganisms tend to be more tolerant of ionizing radiation than macroorganisms.

Bacterial endospores are highly resistant to gamma radiation. It takes 0.3 - 0.4 million rads (Mrads) to cause a 90% kill, whereas 1/10 of this dose kills most vegetative bacteria.
Relative Humidity

- High of RH influence the water content of foods
- High of water content promote microbial growth
- Food deterioration during the increasing of microbial growth
Other Microbes

- Microbial competition in foods
- Some microbes produce antimicrobial substances, ex: organic acids, bacteriocin, alcohol
- Those metabolites inhibit the growth of other microbes
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