SCIENCE OF SAFE FOOD

Special Processes for Food Service

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Lincoln Lancaster County Health Department
University of Nebraska–Lincoln
Microorganisms and Foods

Raw foods normally contain microorganisms!!!
Microorganisms and Foods

Microorganisms of concern include:

• Molds
• Yeast
• Bacteria
• Viruses

Source: mpg.de
Molds

- Multicellular, tubular filaments
- Reproduce by fruiting bodies (spores)
- Larger than bacteria and yeasts
- Widely distributed in nature (soil, air)
- Survive on many substances
- Given right conditions will grow on almost any food
- More tolerant to cold than heat
Yeasts

- Unicellular, usually egg-shaped
- Smaller than molds, larger than bacteria
- Reproduction by budding
- Widely found in nature
- Associated with liquid foods with sugar and acid
Bacteria

• Most important and troublesome
• May produce and release enzymes or toxins into the foods
• Single cell, microscopic
• Several shapes and forms
Viruses

- Small infectious agent that replicates only inside of living cells
- While not inside a cell, it exists as a viral particle (virions):
  - Genetic material
  - Protein coat
  - Envelope of lipids, in some cases
- A virion is 1/100 the size of a bacterium
Reproduction of Bacterial Cells

• Reproduction by division (fission)
• Referred as “growth”
• Under optimum conditions a cell divides every 20-30 minutes

http://www.leavingcertbiology.net
Reproduction of Bacterial Cells

G. stearothermophilus has a shorter doubling time ($t_d$) than E. coli and N. meningitidis.
Sporeforming Bacteria

- Bacterial spores are resistant to heat, cold and chemical agents
- Vegetative cells are less heat resistant
Sporeforming Bacteria

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Don Albrecht, AlbrechtGFX
Kathryn Cross, Institute of Food Research
Factors Affecting Bacterial Growth and Survival

- Nutritional Requirements
- Water Activity
- pH
- Oxygen Requirements
- Moisture
- Temperature
Nutritional Requirements

- Carbon source
- Nitrogen sources
- Sulfur and phosphorus
- Trace elements (i.e. copper, zinc, cobalt)
- Vitamins (i.e. folic acid, vitamin B-12)
Moisture

Passive transport

Active transport

Diffusion
Facilitated diffusion

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http://kmbiology.weebly.com
Oxygen Requirements

- Aerobes
- Anaerobes
- Facultative anaerobes

Oxygen concentration

High

Low

(a) Obligate aerobes
(b) Obligate anaerobes
(c) Facultative anaerobes
(d) Aerotolerant anaerobes
Temperature

[Graph showing growth rate of bacteria at different temperatures for psychrophiles, mesophiles, thermophiles, and hyperthermophiles.]

https://courses.lumenlearning.com/microbiology/
Temperature

Thermal death curve of microorganisms at a certain temperature:

- Temperature: 60 °C
- D value: 132 s

Number of Surviving Organisms vs. Time (min)
Temperature

Thermal death curve of microorganisms at different temperatures:

- **55 °C**: D value = 1110 s
- **60 °C**: D value = 132 s
- **67 °C**: D value = 60 s
- **75 °C**: D value = 9 s
pH

- It refers to the degree of acidity or alkalinity
- Organisms have a most favorable pH range for growth
  - Yeast and mold: lower pH
  - Bacteria: neutral pH
Water Activity ($a_w$)

- Water availability is important for bacterial growth
- Influenced by water-binding capacity of ingredients
- Most foods:
  - $A_w > 0.95$ which support bacterial growth

https://muse.union.edu
## Water Activity ($a_w$)

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Minimal $a_w$ for Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molds</td>
<td>0.75</td>
</tr>
<tr>
<td>Yeasts</td>
<td>0.88</td>
</tr>
<tr>
<td><em>Clostridium botulinum</em></td>
<td>0.93</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>0.93</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>0.85</td>
</tr>
</tbody>
</table>
Sources of Foodborne Organisms

Modern Farmer Media, 2017

Soil

Water

http://www.crystalclearwater.co
Characteristics and behavior:

• The Good,
• The Bad, and
• The Ugly
The Good

• We add them to foods
• Ferment foods to make flavors and textures we like
  – Examples: yogurt, cheese, sour cream, pickles and bread
The Good

• Properties of fermented foods:
  - Enhanced preservation
  - Enhanced nutritional value
  - Enhanced functionality
  - Enhanced organoleptic properties
  - Increased economic value
The Bad

• Change food and cause them to “go bad” or spoil
The Ugly

- Can make us sick - pathogens
- Illness can range from mild to life-threatening
- Bacterial foodborne illnesses:
  - *Salmonella* spp.
  - *Campylobacter* spp.
  - *Bacillus cereus*
  - *Staphylococcus aureus*
  - *Clostridium botulinum*
  - *Clostridium perfringens*
  - *Escherichia coli*
  - *Listeria monocytogenes*
## The Ugly

<table>
<thead>
<tr>
<th></th>
<th>% from the total cases</th>
<th>% of cases hospitalized</th>
<th>% of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norovirus (viral)</td>
<td>58%</td>
<td>26%</td>
<td>11%</td>
</tr>
<tr>
<td><em>Salmonella</em> non-typhoidal</td>
<td>11 %</td>
<td>35%</td>
<td>28%</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>10 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Campylobacter</em> spp.</td>
<td>9 %</td>
<td>15%</td>
<td>6%</td>
</tr>
<tr>
<td><em>Staphylococcus</em> aureus</td>
<td>3 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. coli</em> O157</td>
<td></td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td></td>
<td></td>
<td>19%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>91 %</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: CDC, 2011
**Listeria monocytogenes**

- Widely spread in nature
- Only this specie, it is associated with pathogenicity in humans
- High mortality rates (around 20-30%)
- Capable of crossing the placenta barrier
Listeria monocytogenes

• Symptoms
  – Flu-like disease (headache, fever and gastroenteritis)
  – Could advance to septicemia or meningitis
• Incubation period
  – 2-5 weeks
• Associated with different foods such as:
  – Meats (hams and sausages)
  – Dairy products (raw milk, pasteurized milk and cheeses)
Staphylococcus aureus

- Commonly found on the skin and in the nose of about 30% of individuals
- Some of them has been reported with antibiotic resistance
- Toxin producer bacteria
  - Usually case of intoxication
- Symptoms
  - Vomiting
  - Diarrhea
**Bacillus cereus**

- It has been found in soil and food production environment
- Sporeformer bacteria
  - Spore survives the heat in some processing and may germinate in the food
  - Ability to produce infection and intoxication
  - Toxin production:
    - pH > 6
    - $a_w > 0.94$
Bacillus cereus

- **Diarrheal syndrome**
  - Abdominal pain, diarrhea, nausea (moderate)
  - Incubation period between 10-14 hours
  - Toxin produced in the intestines
  - Infection Doses: $10^7$ cells/g of food
  - Usually from dairy and meat products

- **Emetic syndrome**
  - Vomiting and nausea
  - Incubation period: 1-5 hours (very similar to an intoxication)
  - Toxin produced in the food (heat stable)
  - Infection Doses: $10^8$ cells/g of food
  - Usually from pasta and starchy food
Clostridium perfringens

- Anaerobic microorganism
- 20 to 30% of the human population are carriers
- Toxin producer (enterotoxin)
- Symptoms
  - Nausea
  - Abdominal pain
  - Diarrhea
  - Less commonly vomiting
- Self limiting in healthy individuals
- Associated with:
  - Meat and poultry dishes
  - Meat products
**Clostridium botulinum**

- Anaerobic microorganism
- Spore is heat resistant
- Do not grow or produce toxin below pH 4.5

- Toxin (neurotoxin):
  - The most powerful toxin known by humans
  - 1 nanogram is enough to kill a human
  - Used for cosmetic purpose
**Clostridium botulinum**

- **Symptoms**
  - Dryness of the mouth and throat
  - Double vision, fixed pupils and difficulty focusing
  - Nausea and vomiting
  - Progressive paralysis that induces cardiac and pulmonary failure
- **Mortality rate:** 30-60% of the cases
- **Associated with:**
  - Domestic canning of meat, fruits and vegetables
Salmonella spp.

- Most of the strains are pathogenic for humans or animal
- Can be classified in two groups:
  - *Salmonella* Typhi: Typhoid fever
  - *Salmonella* non-typhoidal: Gastroenteritis
    - Around 1.4 million of cases per year in USA
Non-typhoidal *Salmonella*:  
- Incubation period: 2 to 28 days  
- Symptoms  
  - Diarrhea  
  - Cramps, chills, abdominal pain  
  - Nausea and vomiting  
- Duration  
  - 2 or 3 days  
- Associated with:  
  - Mainly poultry and eggs products

http://www.cdhd.ne.gov
Escherichia coli

• Subcategories according to their virulence properties:
  – Enterotoxigenic *E. coli* (ETEC)
    o Gastroenteritis (traveler’s diarrhea)
  – Enteropathogenic *E. coli* (EPEC)
    o Infant diarrhea
  – Enterohemorrhagic *E. coli* (EHEC)
    o Hemorrhagic colitis
  – Enteroinvasive *E. coli* (EIEC)
    o Dysentery (similar to *Shigella*)
  – Enteroaggregative *E. coli* (EAEC)
    o Persistent diarrhea, mainly in children
**Escherichia coli**

- *Escherichia coli* (EHEC) O157:H7
  - Incubation time: ranges from 3-8 days
  - Symptoms:
    - Diarrhea and cramps, progressing to a severe bloody diarrhea
    - Fever and vomiting
    - Complication may progress to Hemolytic Uremic Syndrome (HUS)
    - Renal failure in children
  - Mortality rate ranges from 3 to 5% of the cases
  - Associated with:
    - Ground meat
    - Raw milk and juices
    - Produce, fruits and sprouts
**Campylobacter jejuni**

- **Symptoms:**
  - Cramps
  - Fever
  - Vomiting
  - Diarrhea
- **Incubation:** 2-5 days
- **Duration:** 2-10 days
- **Associated with:**
  - Raw and undercooked poultry
  - Unpasteurized milk
  - Water
Norovirus spp.

- Virus: single-stranded RNA, non-enveloped
- Causes gastroenteritis
- Incubation period
  - 24 to 48 hours
- Symptoms
  - Nausea and vomiting
  - Diarrhea and cramping
- Duration
  - 1 or 2 days
- Associated with:
  - Leafy greens
  - Fresh fruits
  - Shellfish
Food Processing and Preservation
Introduction to Food Microbiology
Andreia Bianchini, Ph.D.
Associate Professor