Module 2. Microbiology of Thermally Processed Foods

Thermal Processing for Meat and Poultry Products Training

USDA

Introduction

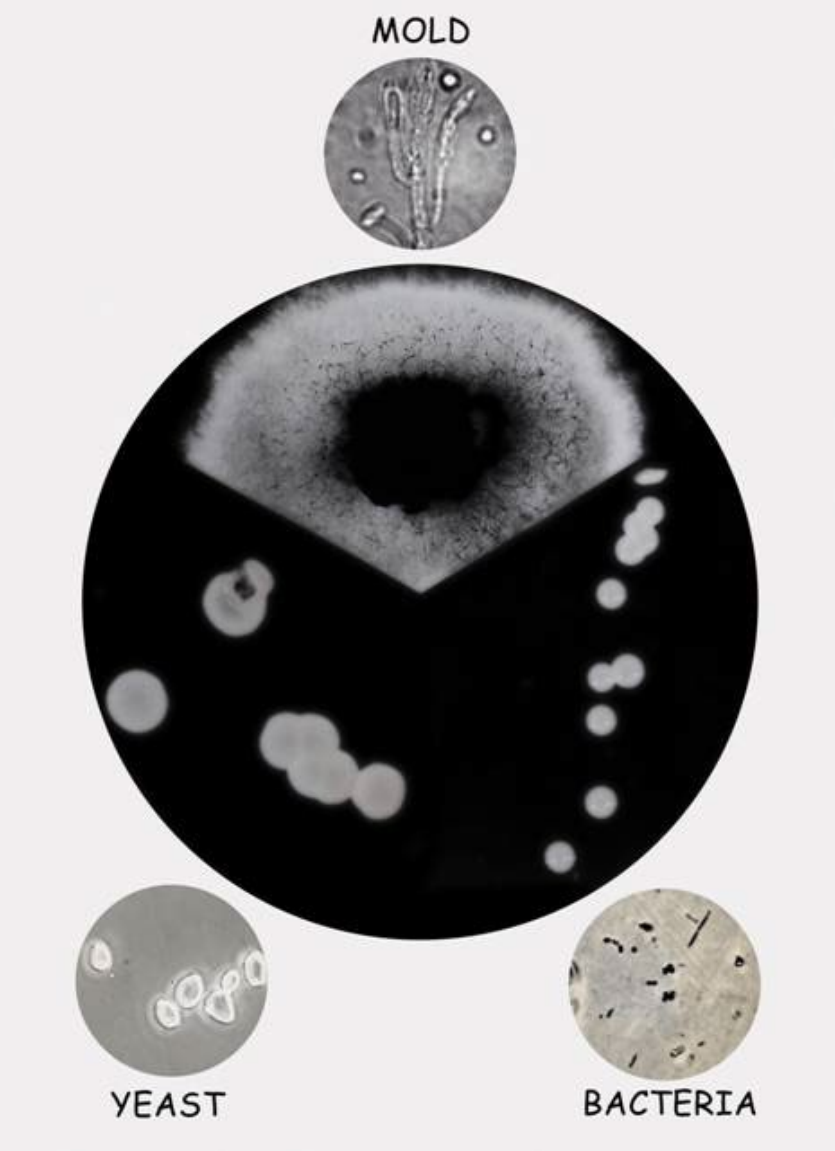
Microbiology is the study of small living organisms seen only by using a microscope.

The Microbiology of Food Processing

- Nicolas Appert – began heat processing for food preservation
- Louis Pasteur – found microorganisms caused food spoilage
- Food microbiology research that began in 1895 linked the two

Characteristics and Behavior of Microorganisms

- Raw foods contain microorganisms
- Microorganisms of concern are molds, yeasts, and bacteria



Classification of Microorganisms

- Visual appearance in colonies
- Materials used as nutrients
- Food spoilage by-products
- Tolerance to environment

Useful Functions of Microorganisms

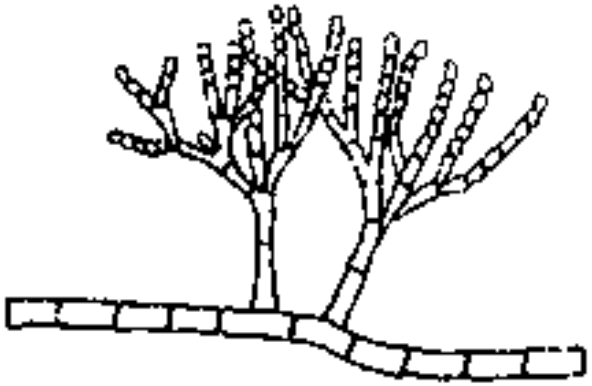
- Fermented foods
- Produce useful chemicals
- Break down organic matter

Some Microorganisms Cause Disease

- Very few are harmful to humans
- Only a few can be transmit disease through food

Significant Microorganisms in Food Processing: Molds

Molds

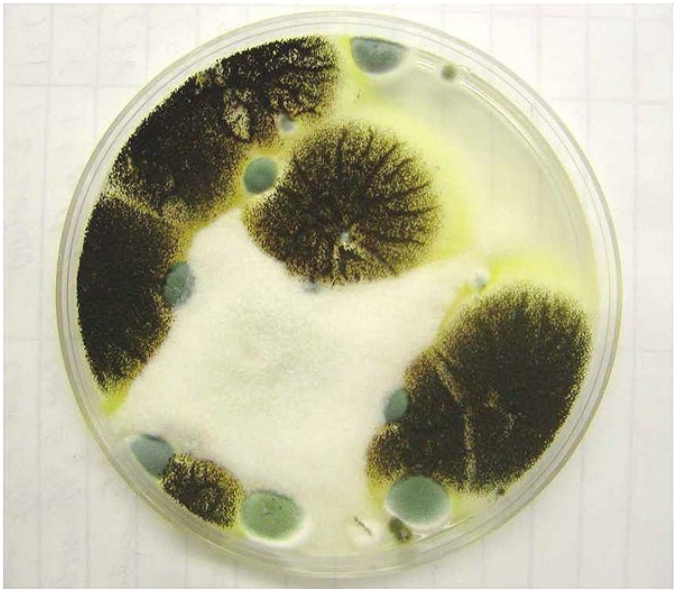


Yeasts

Bacteria

Molds

- Multicellular, tubular filaments
- Reproduce by fruiting bodies
- Larger than bacteria, longer than yeasts
- Widely distributed in nature

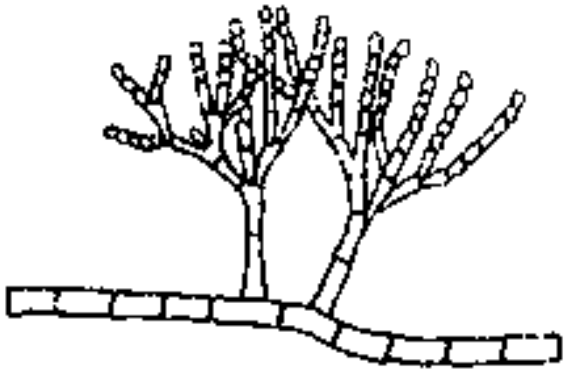


Molds

- Survive on many substances
- More tolerant to cold than heat
- Some may raise pH of acid or acidified low acid foods so that *C. botulinum* can grow and produce toxin
- Most have low heat resistance
- Aerobic

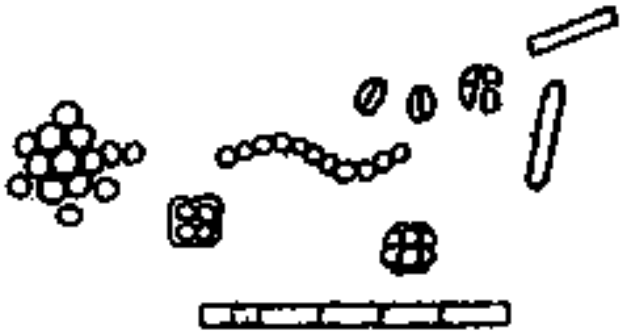
Significant Microorganisms in Food Processing: Yeasts

Molds



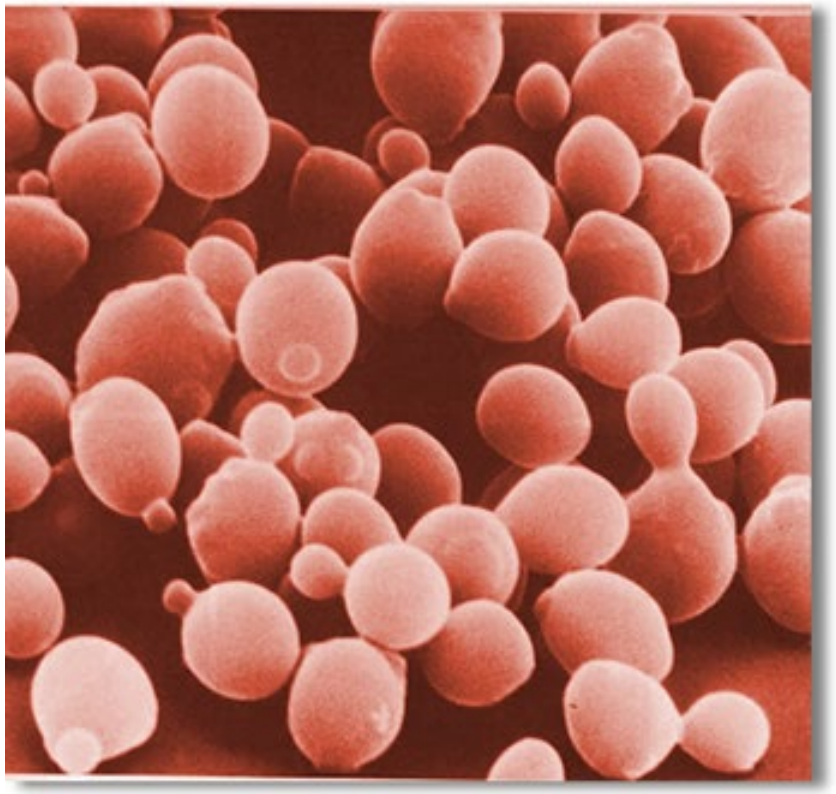
Yeasts

Bacteria



Yeasts

- Unicellular, usually egg-shaped
- Smaller than molds, larger than bacteria
- Reproduce by budding
- Widely found in nature

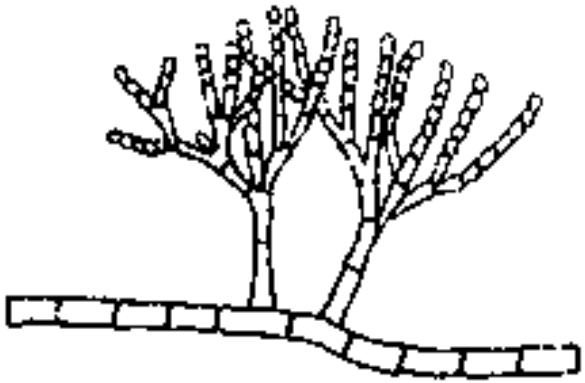


Yeasts

- More tolerant to cold than heat
- Liquid foods with sugar and acid
- Little resistance to heat
- Alcohol and carbon dioxide are by-products of growth
- No public health problem

Significant Microorganisms in Food Processing: Bacteria

Molds



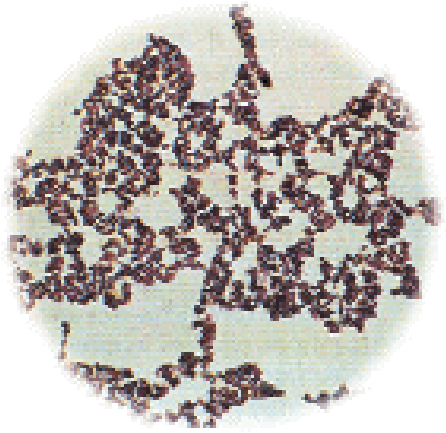
Yeasts

Bacteria

Bacteria

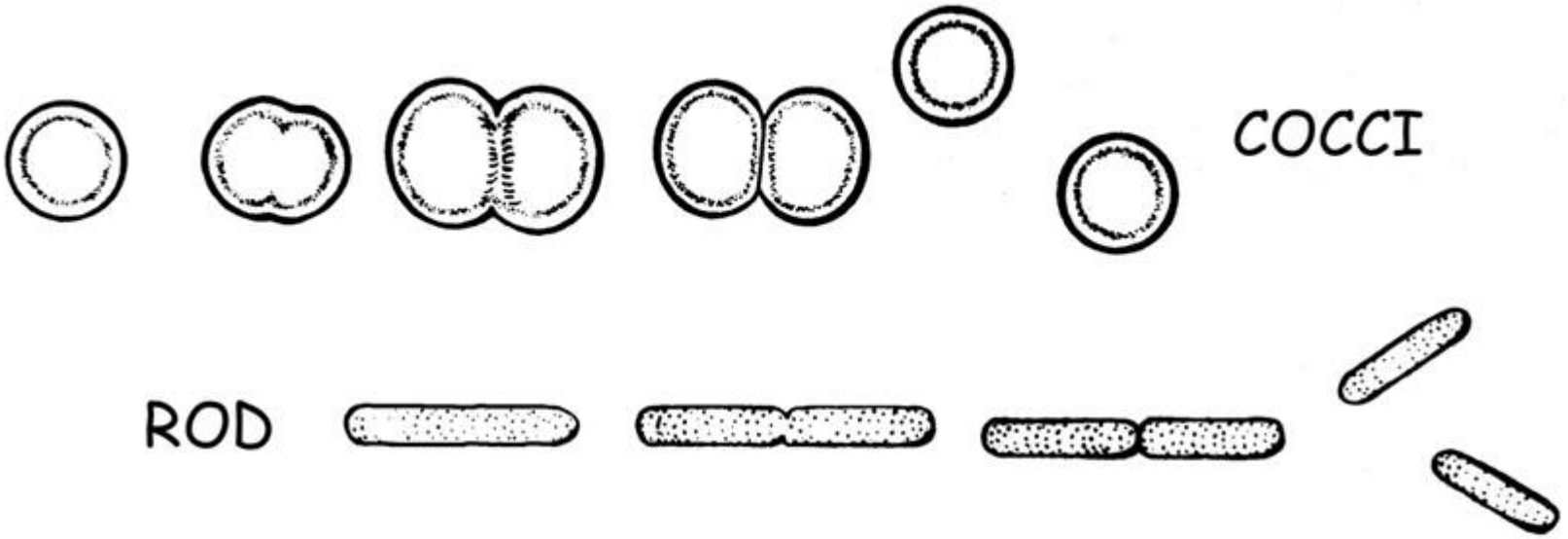
- Most important and troublesome
- May excrete enzymes or toxins
- Single cell, microscopic
- Several shapes (rods, cocci, and spiral) and forms

***E. Coli* O157:H7**



Staph

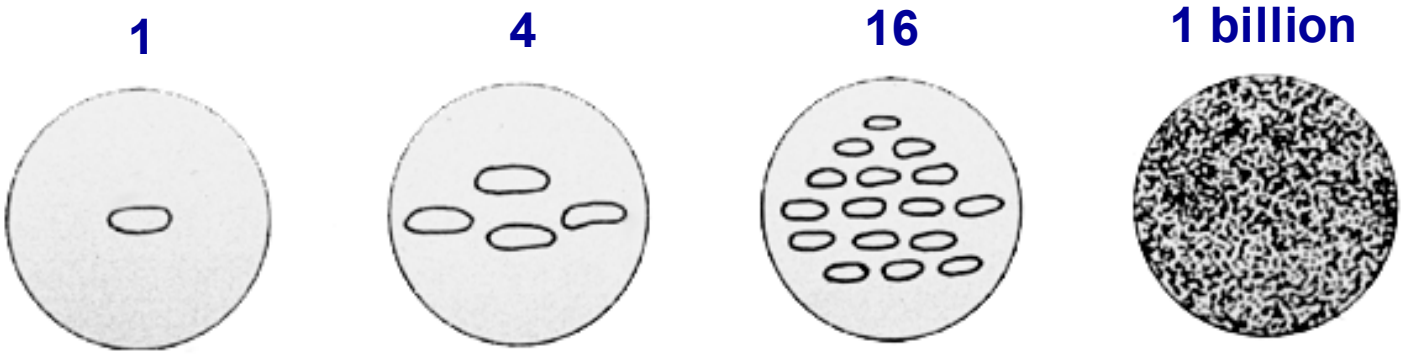
Shapes of Organisms of Significance in Foods



Reproduction of Bacterial Cells

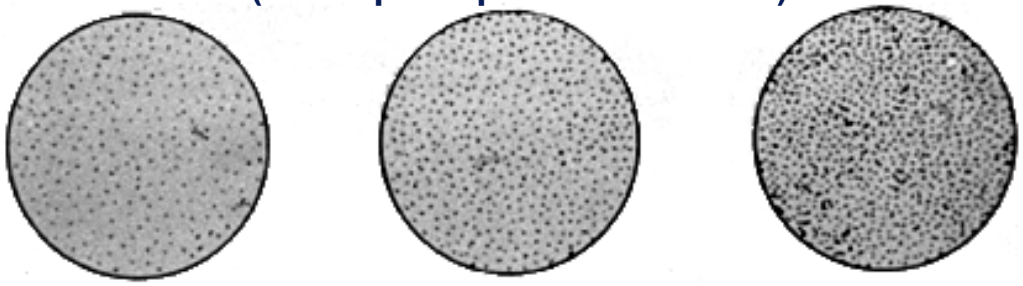
Reproduction of a Single Cell

Reproduced by division – fission



Bacterial Buildup on a Conveyor Belt

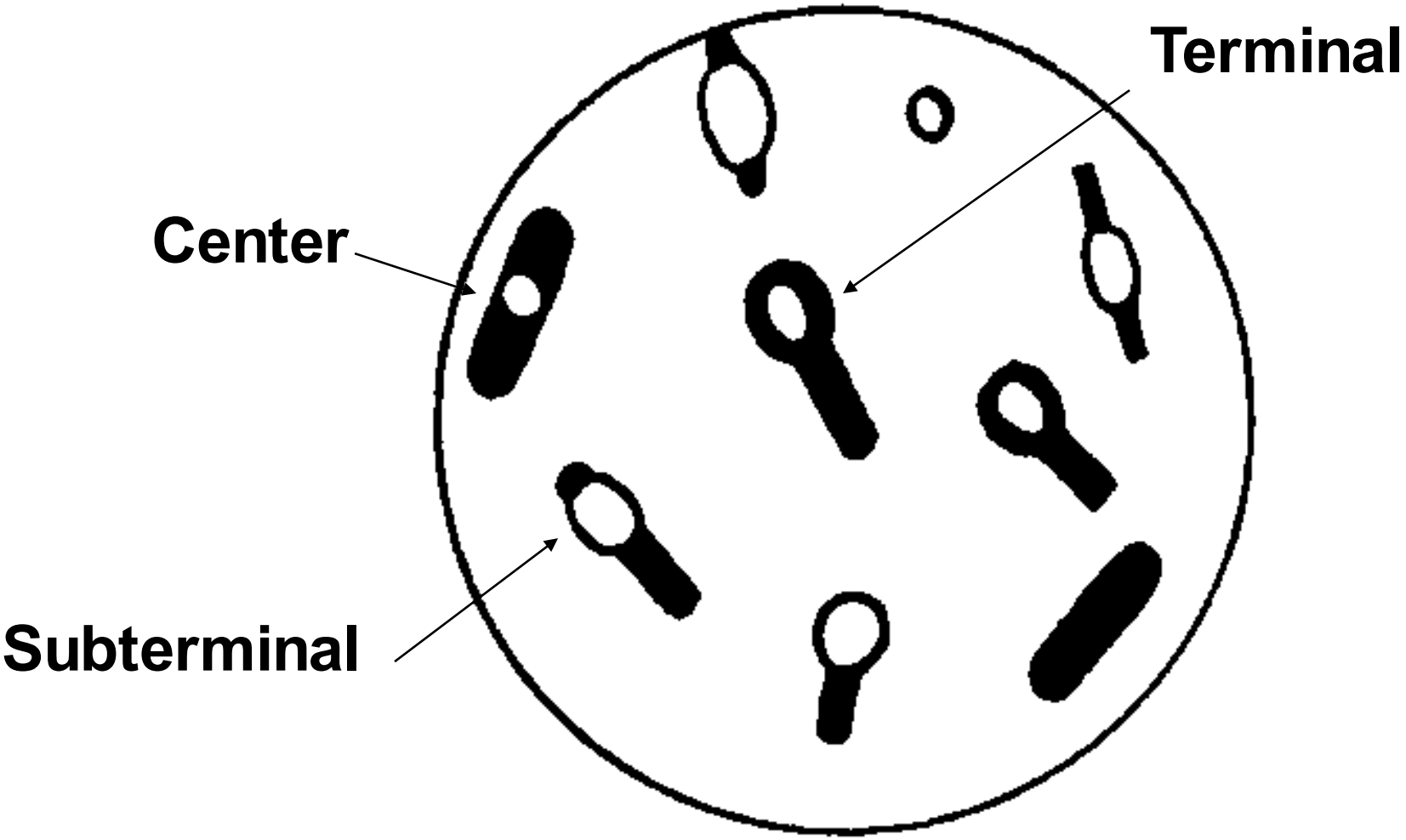
(count per square inch of belt)



Sporeforming and Non-Sporeforming Bacteria

- Some of the rod-shaped bacteria produce spores
- Spore = dormant stage

Position of Spores



Resistance of Spores to Environment

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

Oxygen Requirements

- Aerobes – require oxygen to live
- Anaerobes – oxygen prevents growth
- Facultative anaerobes – tolerate presence or absence of oxygen

Moisture Requirements

- The amount of moisture and its availability in a food are important factors for bacterial growth
- Measured by water activity
- Influenced by the addition of ingredients such as salt and sugar

Minimum a_w Requirements for Microorganism Growth

Most molds (e.g., *Aspergillus*)	0.75
Most yeasts	0.88
C. botulinum	0.93
Staphylococcus aureus	0.85
Salmonella	0.93

pH Requirements

- Microbial growth is generally greater at a neutral pH
- Bacteria, yeast and molds have optimum, minimum and maximum pH for growth

pH

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Acidity **Neutral** **Alkalinity**

Approximate pH Range for Certain Foods

Lemon Juice	2.0 - 2.6	Tuna	5.2 - 6.1
Apples	3.1 - 4.0	Sweet Potatoes	5.3 - 5.6
Blueberries	3.1 - 3.3	Onions	5.3 - 5.8
Sauerkraut	3.3 - 3.6	White Potatoes	5.4 - 5.9
Orange Juice	3.3 - 4.2	Spinach	5.5 - 6.8
Pineapple, canned	3.4 - 4.1	Beans	5.6 - 6.5
Apricots	3.3 - 4.0	Peas, canned	5.7 - 6.0
Tomatoes, canned	3.5 - 4.7	Corn, canned	5.9 - 6.5
Peaches, canned	3.7 - 4.2	Soy Beans	6.0 - 6.6
Pears, canned	4.0 - 4.1	Mushrooms	6.0 - 6.7
Bananas	4.5 - 5.2	Clams	6.0 - 7.1
Beets, canned	4.9 - 5.8	Salmon	6.1 - 6.3
Asparagus, canned	5.0 - 6.0	Coconut milk	6.1 - 7.0
Beef	5.1 - 7.0	Milk	6.4 - 6.8
Carrots	4.9 - 5.2	Garbanzo Beans	6.4 - 6.8
Peppers, green	5.2 - 5.9	Chicken	6.5 - 6.7
Papaya	5.2 - 6.0	Eggs, whole	7.1 - 7.9

pH of Some Canned Meat Products

Food	pH
Beef stew	5.4-5.9
Corned beef hash	5.0-5.7
Ham	6.0-6.5
Spaghetti sauce with beef	4.0 - 4.2
Vienna sausage	6.2-6.5

Temperature Requirements

- Bacterial group names are based on optimum temperatures for growth
  - Psychrotrophs
  - Mesophiles
  - Thermophiles

The Psychrotrophic Group

- Grow best at 58°F to 68°F
- Can grow slowly at 40°F
- Only *C. botulinum* Type E and non-proteolytic strains of types B and F are of concern in canned food

The Mesophilic Group

- Grow best 86°F to 98°F
- Includes all microorganisms that affect food safety
- *C. botulinum*—a sporeformer—is in this group

The Thermophilic Group

- Optimum growth of obligate thermophiles occurs at 122°F to 150°F
- Spores are very heat resistant
- No human pathogens

Interaction of Conditions Affecting the Growth of Bacteria

- Each growth limiting factor (e.g., minimum pH) is determined when all other conditions (moisture level, temperature, absence or presence of oxygen, etc.) are optimal

Interaction of Conditions Affecting the Growth of Bacteria (2)

- A growth condition that is not optimal can affect the optimum for another growth condition
  - Lowering the a_w raises the minimum pH for growth and vice versa
  - Preservatives (e.g., salt or nitrite) can raise the minimum pH at which an organism grows or increase growth time at lower temperatures

Clostridium botulinum

- Pathogen of concern for canned meat and poultry products
- Anaerobic, mesophilic sporeformer
- The organism produces a deadly toxin
- Botulism is the disease in humans

Clostridium botulinum

- The organism is contained in soil and water throughout the world
- Spores found everywhere, but vegetative form produces toxin
- Spores survive unfavorable conditions such as acid environments and heat

Clostridium botulinum

- Proteolytic ("putrefactive") strains
  - Grow best at 86°-98°F; minimum 50°F
  - Metabolize proteins and produce putrid odors
  - High heat resistance
- Non-proteolytic strains
  - Grow best at 64°-77°F; minimum 38°F
  - Metabolize carbohydrates (sugars and starches)
  - Spores do not survive boiling

Clostridium botulinum

- Certain spores survive 5 to 10 hours in boiling water– 212ºF (100ºC)
- Although the spores are heat resistant, the toxin can be inactivated by boiling temperatures

Clostridium botulinum

- Canned foods provide an anaerobic environment favorable for spores to germinate, become vegetative cells, multiply and produce toxin (if the organism has not been destroyed by the heat process)
- Heat processes for canned meat and poultry are designed, at a minimum, to produce a product safe from *C. botulinum*

Control of *C. botulinum* with pH

- Reduced pH designed to prevent growth of *Clostridium botulinum*
- Spores of *C. botulinum* will not germinate and grow in foods below pH 4.8
- pH of 4.6 provides a safety margin
- Acidified low-acid foods – acids or acid foods added to reduce the pH to ≤4.6

Control of *C. botulinum* with Water Activity (a_w)

- It is the free available water, not the % moisture, that is important in controlling *C. botulinum*
- Substances (salt and sugars) dissolved in water bind water molecules, reducing the water available for microbial growth.

Control of *C. botulinum* with Water Activity (a_w)

- Spores of *C. botulinum* will not germinate and grow in foods with an a_w less than 0.93
- If the a_w is 0.85 or less, product is not subject to the canning regulations. This value was chosen because *S. aureus* can grow above an a_w of 0.85

Control of *C. botulinum* with Chemicals

- Acids (lowers pH) and preservatives such as nitrite and sodium chloride (salt)
- Most inhibit growth rather than kill
- When used to produce commercially sterile products, chemicals often combined with other factors such as heat or reduced a_w

Control of *C. botulinum* with Salt

- Salt lowers a_w
- Inhibits germination and growth
- Most resistant *C. botulinum* inhibited by 10 percent salt (a_w = 0.93)
- Less salt is needed when the pH has been reduced

Control of *C. botulinum* with Nitrite

- Inhibits growth and toxin production
- Reduces the heat resistance of the spore
- Still not a complete understanding of how nitrite controls *C. botulinum*
- Nitrite inhibition is due to a combination of factors, not nitrite alone

Control of Microorganisms with Temperature

- Use heat to kill microorganisms
  - Amount depends on target microorganism (e.g., *C. sporogenes* spore, *C. botulinum* spore, vegetative pathogen) number of microorganisms, and the food product
  - pH, a_w, and preservatives such as nitrite can have an impact on death

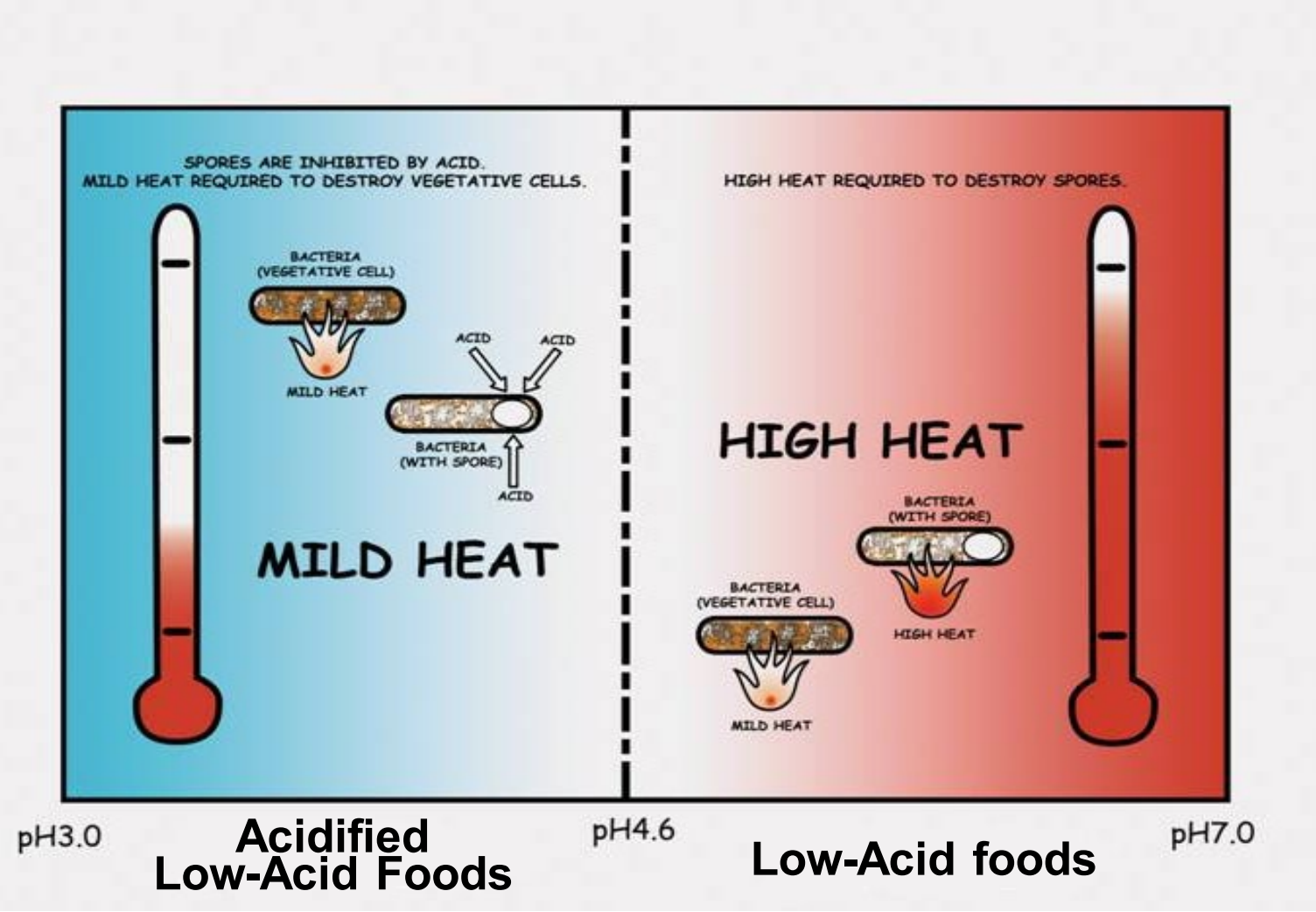
Thermal Destruction (Death) of Microorganisms

- Low-acid canned foods-high temperatures are needed
  - Heat processes designed to destroy *C. sporogenes* and similar anaerobes
  - *C. sporogenes* spores have greater heat resistance than *C. botulinum* spores
  - Targeting *C. sporogenes* spores will also destroy spores of *C. botulinum*

Thermal Destruction (Death) of Microorganisms

- Acidified low-acid canned foods can be processed at lower temperatures
  - Mild heat kills, mold, yeast, *Salmonella, E. coli* O157:H7 and other vegetative cells of pathogens
  - pH of 4.6 or less prevents germination and outgrowth of *C. bot* and *C. sporogenes* spores

Thermal Treatment of Acidified Low-Acid Versus Low-Acid Foods



Thermal Destruction (Death) of Microorganisms

- Canned cured products (hams and luncheon meats) can be processed at lower temperatures
  - Presence of nitrite and salt makes *C. bot* and *C. sporogenes* spores more sensitive to heat
  - Salt and nitrite prevents germination and outgrowth of spores

CS versus Absolute Sterility

- Commercially sterile foods may contain viable microorganisms
- Spores of thermophilic bacteria survive commercial sterility processes
  - Not harmful
  - Do not grow under normal storage conditions
  - May need to be destroyed for hot-vended items

Bacterial Spoilage

- Indications of bacterial spoilage
  - Most bacteria produce gas
  - A few produce acid and no gas

Causes of Bacterial Spoilage

- Incipient spoilage
- Post-process contamination
- Inadequate heat processing
- Thermophilic bacterial growth

Incipient Spoilage Before Processing

- Incipient spoilage is microbial spoilage caused by too long of a delay between container closing and retorting

Contamination After Processing

- Leaker spoilage
- Generally due to inadequately formed seams, container damage, or cooling water contamination

Inadequate Heat Processing

- Heat processes are designed to destroy public health organisms
- Inadequate heat process may lead to public health hazard

Thermophilic Spoilage

- Spores are very heat resistant
- Processes for low-acid foods do not destroy thermophilic spores
- Cool product to below 105°F

Non-Microbial Food Spoilage

- Chemical action causing hydrogen swells or pin-holes
- Overfilling of container gives the appearance of spoilage
- Zero or low vacuum cans may appear to be spoiled

Questions?

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