# FACTORS INFLUENCING THE GROWTH OF MICROORGANISMS IN FOODS

28102021
NM

# LET'S RECAP OUR LAST LECTURE

**Kahoot time!!**

# MICROBIAL GROWTH

Foodborne disease

Food spoilage

Fermented food

# WHAT ARE THE DIFFERENCES BETWEEN FOOD SPOILAGE ORGANISMS AND FOODBORNE PATHOGENS?

## Food spoilage organisms

- Caused by bacteria, yeasts, & molds
- These organisms are often smelled, seen, or tasted
  - E.g. the smell of spoiled milk
  - Moldy bread
- Generally, food spoilage organisms do not cause life-threatening infections (except for fungal/ bacterial spoilage that might produce toxins)

## Foodborne pathogens

- Caused by bacteria, viruses, parasites
- Generally they do not affect the taste, smell, or appearance of food.
- Pathogenic bacteria cause illness.

# FACTORS INFLUENCING THE GROWTH OF MICROORGANISMS IN FOODS

# FACTORS DETERMINING THE FOOD SPOILAGE

Food environment / characteristic of food

(Intrinsic factor)

The storage environment

(Extrinsic factor)

**Microbial growth**

Determine which microbes grow & it's growth rate

# FACTORS DETERMINING THE FOOD SPOILAGE

- Nutrient
- pH (Acidity / alkalinity)
- Water activity / moisture content
- Antimicrobial chemical
- Oxidation-reduction potential
- Biological barriers (e.g. shells)

## Intrinsic factors

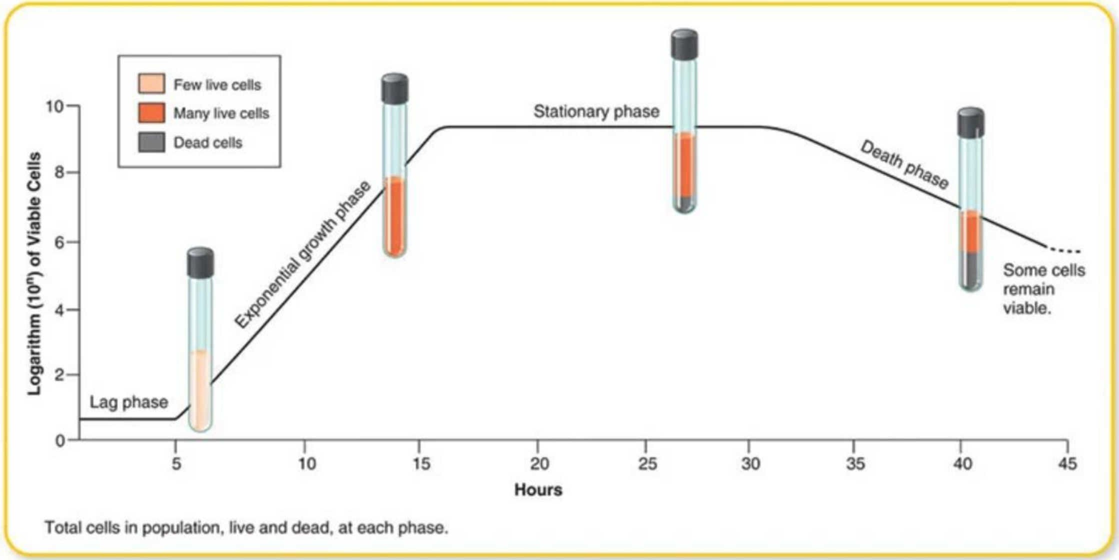
- Temperature / Time
- Relative humidity
- Presence and concentration of gases
- Presence and activities of other microorganism

## Extrinsic factors

# BACTERIAL GROWTH

- Binary fission – increase the number of cell
- Under optimum condition, bacteria can double every 20-30 minutes
- Food is generally considered spoiled when the bacterial counts exceed $10^6$ or $10^7$
- Most spoilage is a surface phenomenon occurring only on the surface



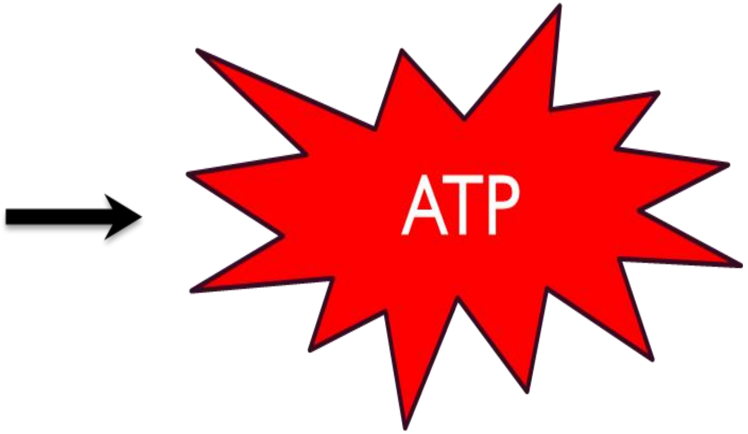


# INTRINSIC FACTORS

# NUTRIENT

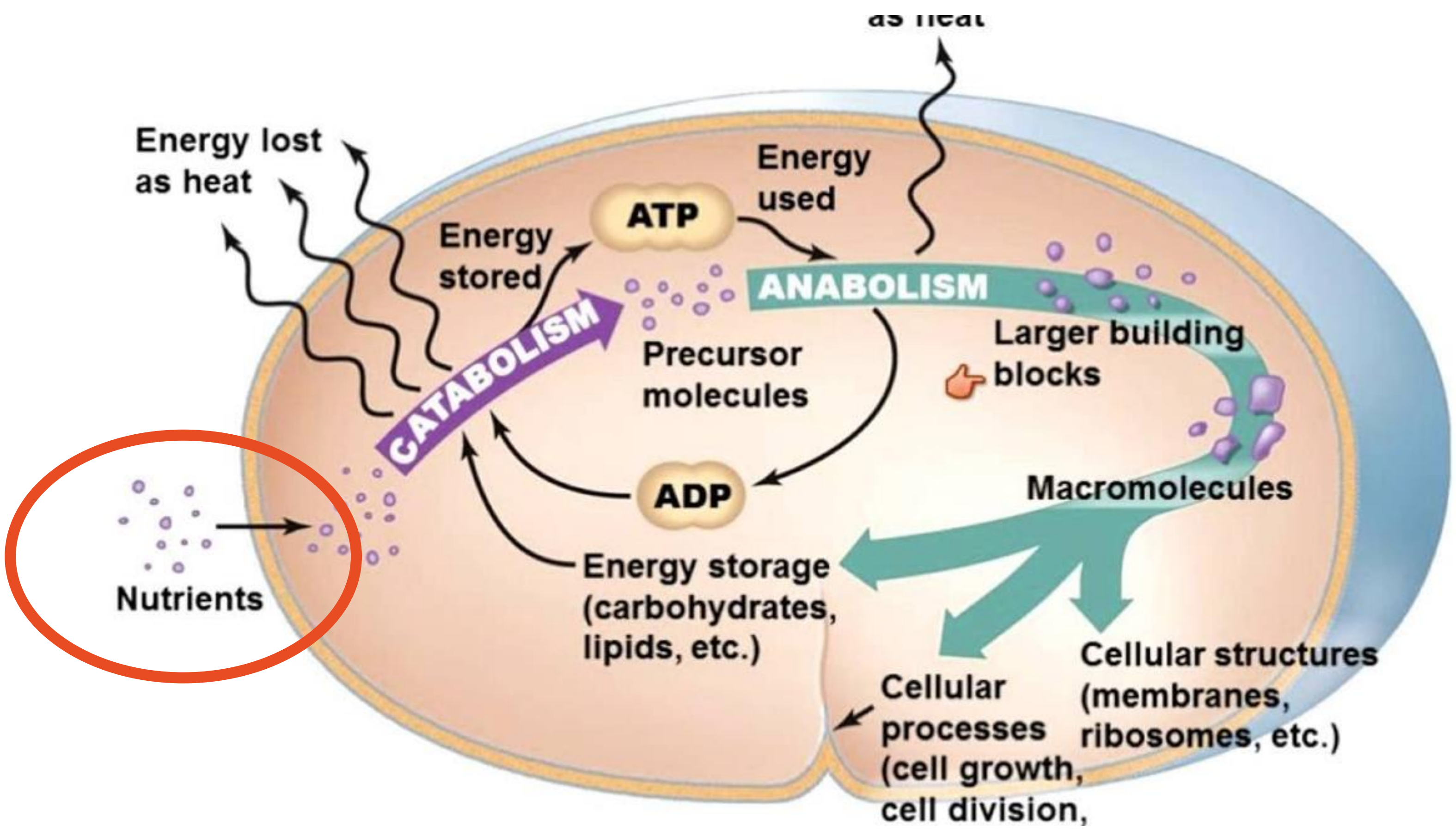
- Nutrients: as the sources of energy for microbes (carbohydrate, protein, lipid)
  - Meat & poultry – proteins, lipids
  - Plant based food – high carbohydrate

- Breakdown of nutrient by enzymes:
  - Carbohydrate to sugar monomer
  - Proteins to amino acids
  - Lipid to fatty acid



# Bacterial Metabolism

The series of biochemical reactions by which the cells breaks down various biomolecules such as **nutrients (carbohydrates, fat, protein)** for **energy** generation and the use of energy to synthesize cell material (lipids, polysaccharides, proteins) from small molecules.



# pH

- Many  microorganisms are inhibited by acid conditions
  - Except lactic acid bacteria
- Lactic acid bacteria (LAB) used in fermentation process of food production
- LAB also cause spoilage of unpasteurized milk and other foods
- Fungi are able to survive at relatively low pH
  - Most acid foods spoil from fungal contamination as opposed to bacteria
- pH can determine bacteria's ability to produce toxin
  - Toxin production of many organisms is inhibited by acid pH

**Pathogens do not grow,** or grow very slowly, at **pH below 4.6,** except:

- ***Clostridium botulinum*** (produce toxin at pH 4.2)
- ***Salmonella* spp.** < pH 4.2

| Table 3-3. pH ranges of some common foods. | | |
|---|---|---|
| Food | | pH Range |
| **Dairy Products** | Butter | 6.1 - 6.4 |
| | Buttermilk | 4.5 |
| | Milk | 6.3 - 6.5 |
| | Cream | 6.5 |
| | Cheese (American mild and cheddar) | 4.9; 5.9 |
| | Yogurt | 3.8 - 4.2 |
| **Meat and Poultry** | Beef (ground) | 5.1 - 6.2 |
| | Ham | 5.9 - 6.1 |
| | Veal | 6.0 |
| | Chicken | 6.2 - 6.4 |

| | | |
|---|---|---|
| **Fruits and Vegetables** | Apples | 2.9 - 3.3 |
| | Apple Cider | 3.6 - 3.8 |
| | Bananas | 4.5 - 4.7 |
| | Figs | 4.6 |
| | Grapefruit (juice) | 3.0 |
| | Limes | 1.8 - 2.0 |
| | Honeydew melons | 6.3 - 6.7 |
| | Oranges (juice) | 3.6 - 4.3 |
| | Plums | 2.8 - 4.6 |
| | Watermelons | 5.2 - 5.6 |
| | Grapes | 3.4 - 4.5 |
| | Asparagus (buds and stalks) | 5.7 - 6.1 |
| | Beans (string and lima) | 4.6 - 6.5 |
| | Beets (sugar) | 4.2 - 4.4 |

Intrinsic Factor

# Microbial Growth Ability in Different pH

| M/O | pH Range |
| --- | --- |
| Molds | 0.2-11 |
| Yeasts | 1.5-8.5 |
| *Salmonella* | 3.6-9.5 |
| *Listeria monocytogenes* | 4.2-9.6 |
| *Yersinia enterocolitica* | 4.2-9.0 |
| *Escherichia coli* | 4.3-9.0 |
| *Clostridium botulinum* | 4.3-8.5 |
| *Bacillus cereus* | 5.0-9.5 |
| *Campylobacter* | 5.0-9.0 |
| *Shigella* | 5.0-9.2 |
| *Vibrio parahaemolyticus* | 5.0-11 |
| *V. Cholerae* | 5.0-9.5 |
| *Cl. perfringens* | 5.0-8.5 |

# FERMENTATION vs PICKLING PROCESS

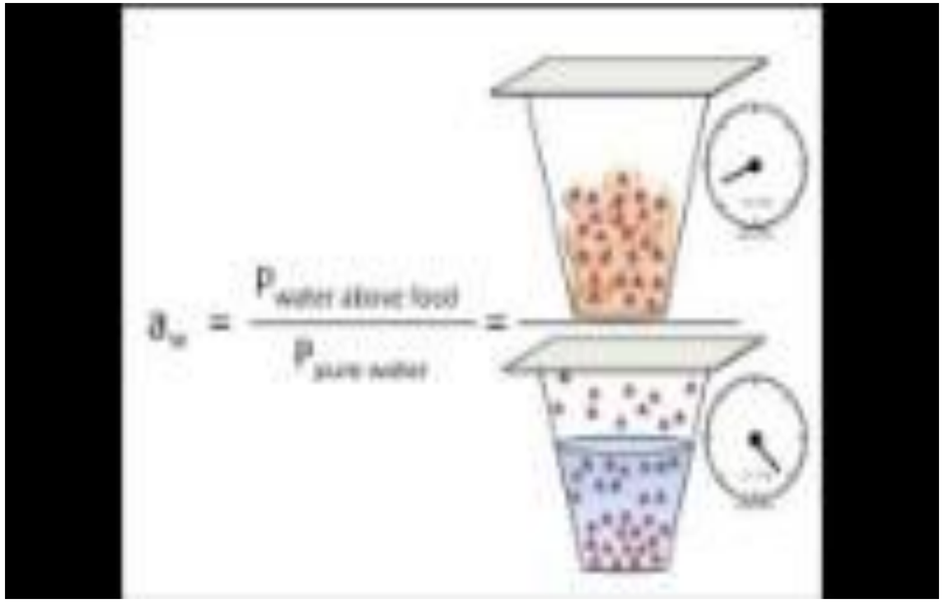
Pickling involves soaking foods in an acidic liquid (e.g. vinegar) to achieve a sour flavor

When foods are fermented, the sour flavor is a result of a chemical reaction between a food’s sugars and naturally present bacteria/yeast — no added acid required.

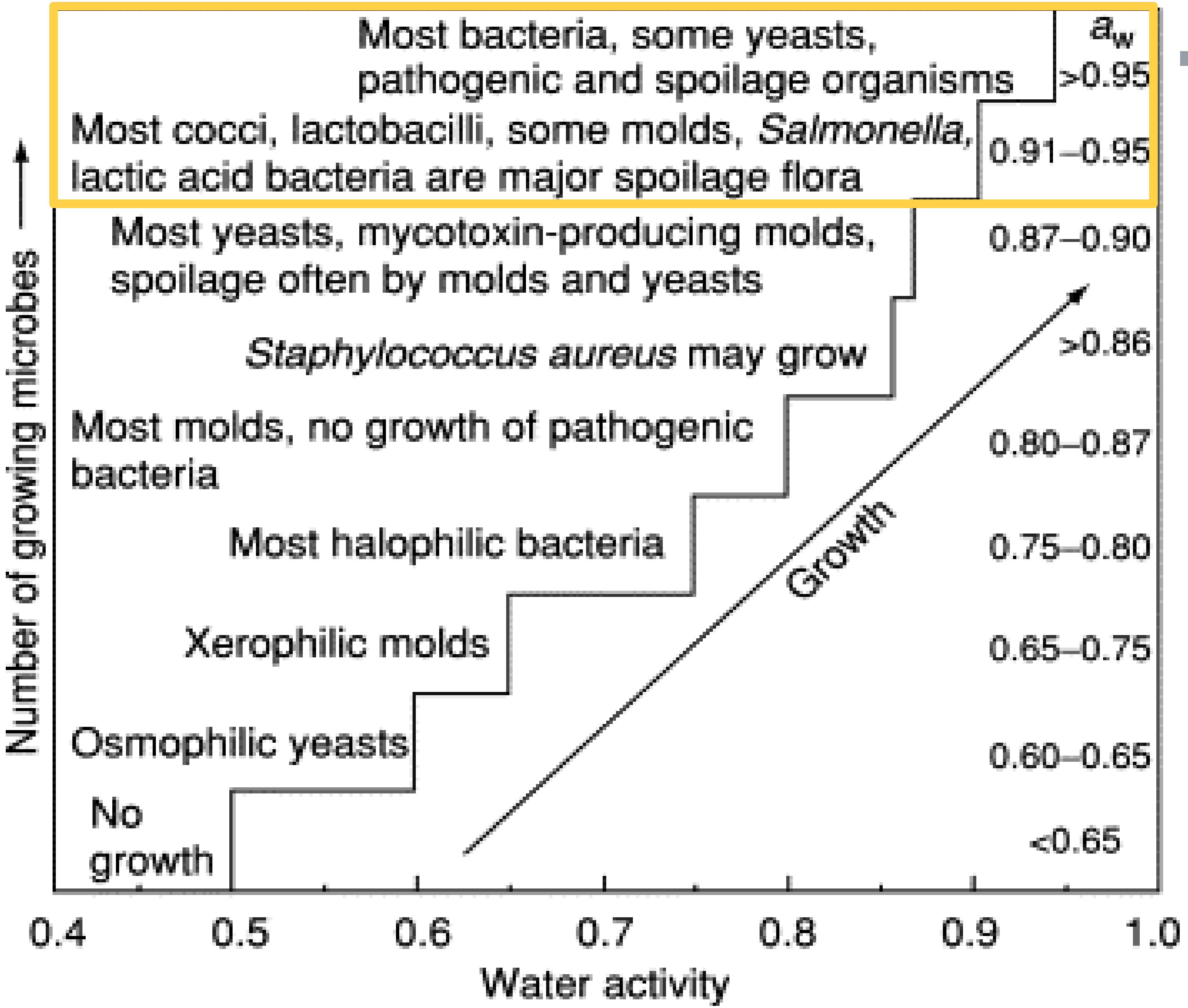
# WATER ACTIVITY ($a_w$)

- Water activity ($a_w$) used to designate amount of water available in foods
  - ➢ Pure water has $a_w$ of 1.0
  - ➢ Most bacteria require $a_w$ of above 0.90
  - ➢ Most fungi require $a_w$ of above 0.80

- Foods vary dramatically in terms of water availability
  - ➢ Fresh meats and milk have high $a_w$ (Supports microbial growth)
  - ➢ Cookies, nuts and dried foods have low $a_w$



https://www.youtube.com/watch?v=-LiSankbfSk


Most bacteria, some yeasts, pathogenic and spoilage organisms
>0.95
Most cocci, lactobacilli, some molds, Salmonella, lactic acid bacteria are major spoilage flora
0.91–0.95
Most yeasts, mycotoxin-producing molds, spoilage often by molds and yeasts
0.87–0.90
Staphylococcus aureus may grow
>0.86
Most molds, no growth of pathogenic bacteria
0.80–0.87
Most halophilic bacteria
0.75–0.80
Xerophilic molds
0.65–0.75
Osmophilic yeasts
0.60–0.65
No growth
<0.65
$a_w$
Growth
Number of growing microbes
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Water activity

| Table 3-1. Approximate $a_w$ values of selected food categories. | |
|---|---|
| **Animal Products** | $a_w$ |
| fresh meat, poultry, fish | 0.99 - 1.00 |
| natural cheeses | 0.95 - 1.00 |
| pudding | 0.97 - 0.99 |
| eggs | 0.97 |
| cured meat | 0.87 - 0.95 |
| sweetened condensed milk | 0.83 |
| Parmesan cheese | 0.68 - 0.76 |
| honey | 0.75 |
| dried whole egg | 0.40 |
| dried whole milk | 0.20 |

| Plant Products | $a_w$ |
|---|---|
| fresh fruits, vegetables | 0.97 - 1.00 |
| bread | ~0.96 |
| bread, white | 0.94 - 0.97 |
| bread, crust | 0.30 |
| baked cake | 0.90 - 0.94 |
| maple syrup | 0.85 |
| jam | 0.75 - 0.80 |
| jellies | 0.82 - 0.94 |
| uncooked rice | 0.80 - 0.87 |
| fruit juice concentrates | 0.79 - 0.84 |
| fruit cake | 0.73 - 0.83 |
| cake icing | 0.76 - 0.84 |
| flour | 0.67 - 0.87 |
| dried fruit | 0.55 - 0.80 |
| cereal | 0.10 - 0.20 |

## Modified the $a_w$ for food preservation

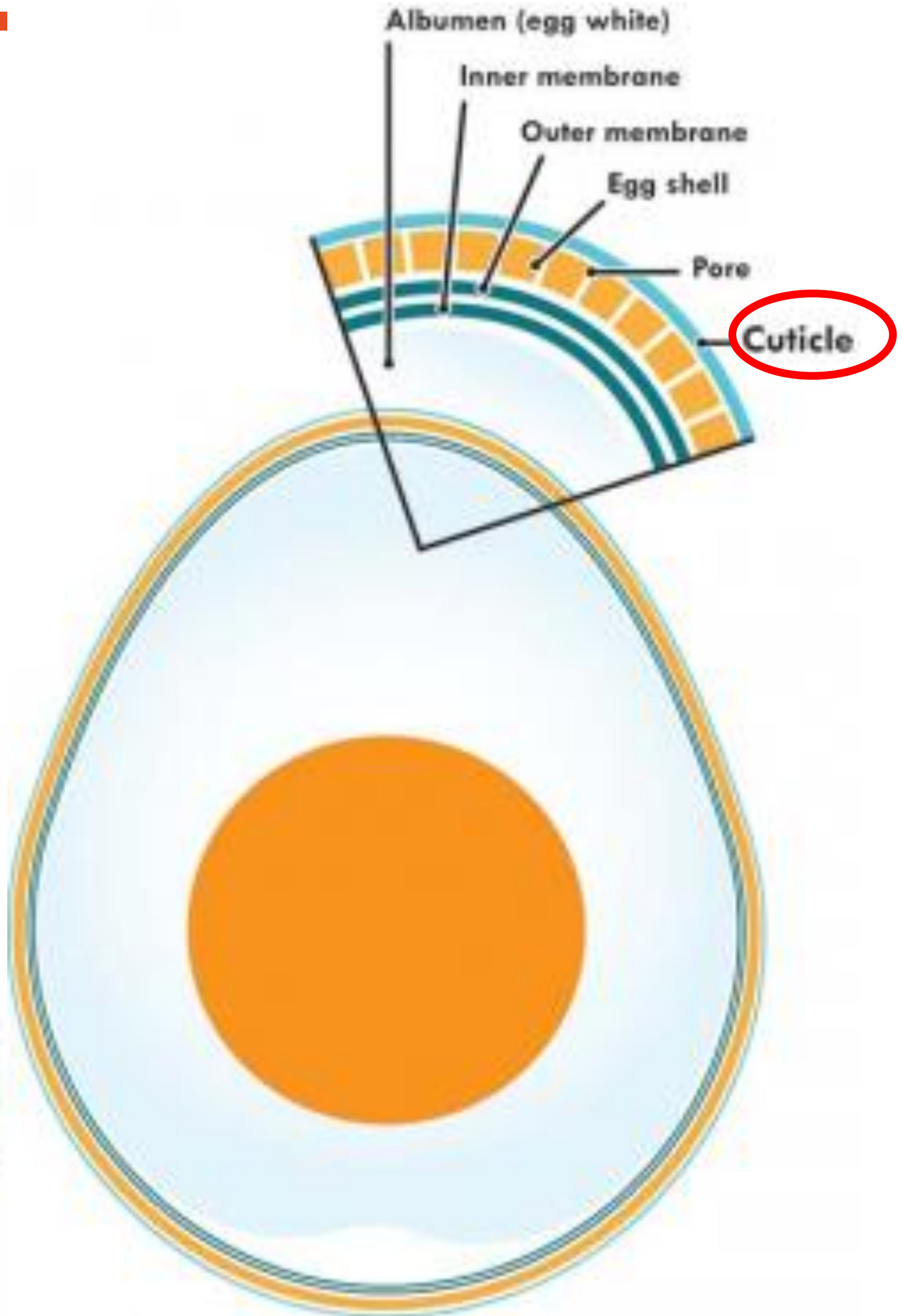
- Physical removal of water (drying, baking)


## Modified the $a_w$ for food preservation

- Adding solutes (salt, sugar)

# BIOLOGICAL BARRIER

- Biological barriers in plant and animal derived food (raw) help to **prevent the entry** and **growth** of microorganisms
  - Skin of fruits & vegetables
  - Shell of nuts
  - Egg cuticle

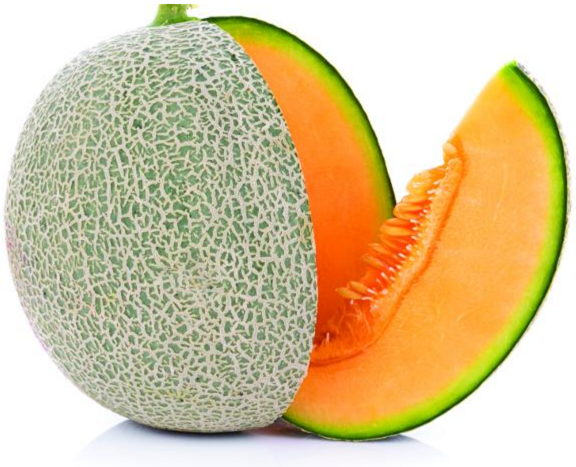


Physical damage

over-ripening of fruits

Invasion of insects

Penetration of microorganism in food



# ANTIMICROBIAL CHEMICALS

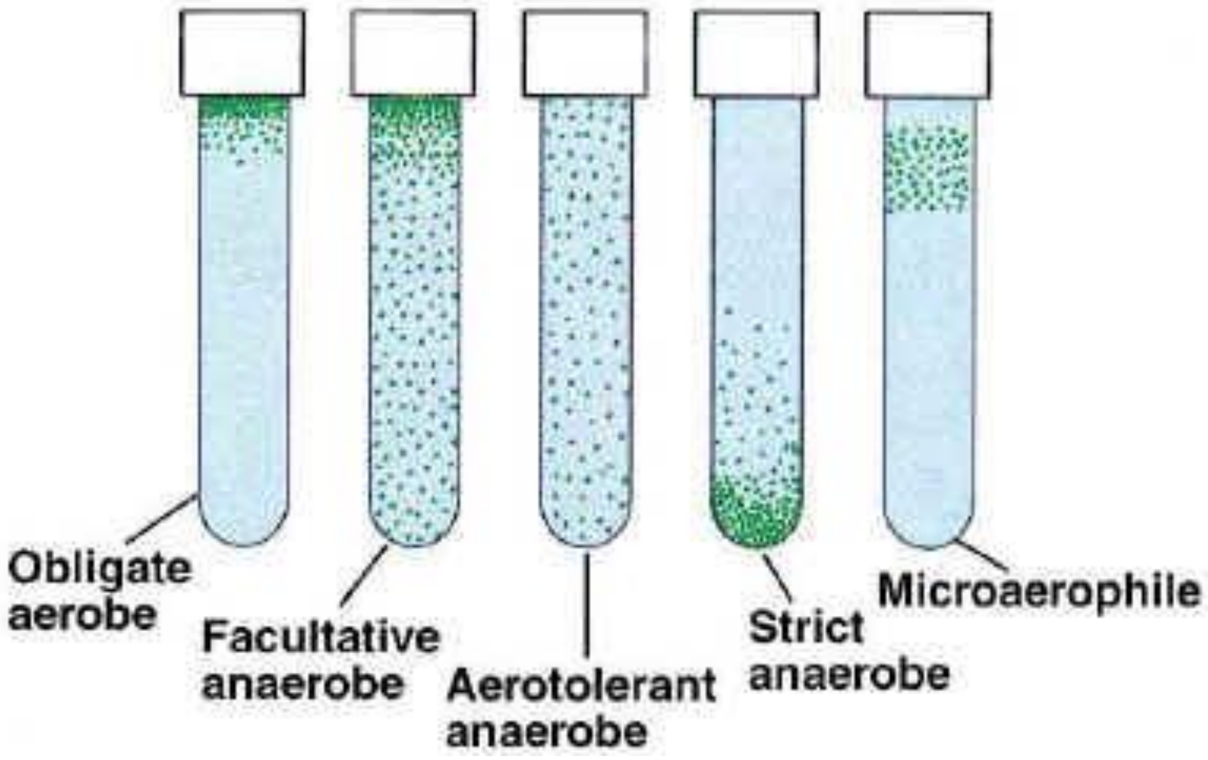
- Some foods contain natural antimicrobial chemicals / chemical preservative & additive that inhibit microbial growth
- Plant-based food: Essential oils, tannin, glycosides, resins
- Animal-based food:
  - Lactoferrin, conglutinin and the lactoperoxidase system (lactoperoxidase, thiocyanate, and hydrogen peroxide) in milk - innate imunity, killing bacteria in milk
  - Lysozyme in eggs and milk (enzyme that can hydrolyze the cell wall of bacteria)
  - Bacteriocin (from LAB), antibiotics (from mold) – inactivate other microorganism

Breast milk inhibits the growth of pathogenic bacteria; *Staphylococcus aureus*, *Bacillus subtilis*, *Clostridium perfringens*, and *Escherichia coli*,

But not inhibit the growth of the beneficial bacteria *Enterococcus faecilis.*

# OXIDATION-REDUCTION / REDOX POTENTIAL

- Redox potential (Eh) is a measurement of the ease for a substance to gain or loses electrons
- Unit in millivolts (mV)
- Major group of microorganism based on their relationship to redox potential:
  - Aerobes +500 to +300 mV
  - Anaerobes +100 to < -250mV
  - Facultative anerobes +300mV to -100mV



- Redox potential in food determine the ability of microbes to grow
  - influenced by chemical composition of food, specific processing treatment give, storage condition
    - e.g. fresh plant and animal origins are in reduced state due to presence of reducing substances such as ascorbic acid, reducing sugars, and the –SH group of protein.
    - processing: heating can alter the redox potential
    - food stored in air have higher Eh (+mV) than when it is stored under MAP.

- Presence of oxygen in food determine the capability of particular microbe to grow
  - oxygen presence in food in the gaseous state or in dissolved form
- Aerobes need free oxygen as the final electron acceptor – aerobic respiration
- Facultative anaerobes can use free oxygen if available or bound oxygen such as $NO_3$ or $SO_4$ as final electron acceptor (anaerobic respiration)
- Anaerobes use other compound (pyruvate) to accept electron through fermentation

# Redox potential of some foods

**Table 3- 6. Redox potentials on some foods.**

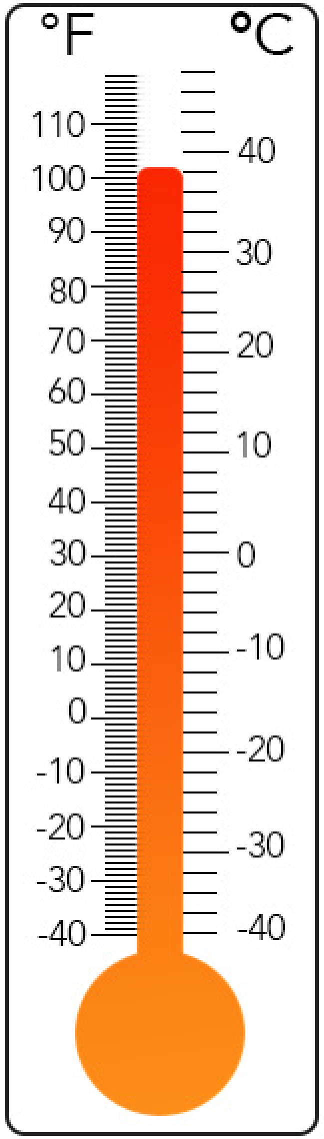
| FOOD | | | Presence of air | Eh (mV) |
|---|---|---|---|---|
| Milk | | | + | +300 to +340 |
| **Cheese** | Cheddar | | + | +300 to -100 |
| | Dutch | | + | -20 to -310 |
| | Emmenthal | | + | -50 to -200 |
| Butter serum | | | - | +290 to +350 |
| **Plant juices** | Grape | | - | +409 |
| | Lemon | | - | +383 |
| | Pear | | - | +436 |
| | Spinach | | - | +74 |
| **Meats** | Liver, raw minced | | - | -200 |
| | **Muscle** | Raw, post-rigor | - | -60 to -150 |
| | | Raw, minced | + | +225 |
| | | Minced, cooked | + | +300 |
| | Cooked sausages and canned meat | | - | -20 to -150 |
| **Cereals** | Wheat (whole grain) | | - | -320 to -360 |
| | Wheat (germ) | | - | -470 |
| | Barley (ground) | | + | +225 |
| **Canned foods** | "Neutral" | | - | -130 to -550 |
| | "Acid" | | - | -410 to -550 |

- Aerobes +500 to +300 mV
- Anaerobes +100 to < -250mV
- Facultative anerobes +300mV to -100mV

# EXTRINSIC FACTORS

# STORAGE TIME & TEMPERATURE

- Storage temperature & time affects rate of microbial growth
- Bacterial proliferation can be controlled by both heat and cold temperature
- Bacteria generally do not grow at freezer temperatures but they can survive
  - 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



# How temperature can affect the bacterial growth??

| LOW TEMPERATURE | HIGH TEMPERATURE |
|---|---|
| • Reaction rate for enzyme become slower<br>• Reduce fluidity of the cytoplasmic membrane – interfere with transport mechanism | • Cell component denatured<br>• Heat-sensitive enzymes are inactivated or denatured |

**Psychrotrophs:** Grow well at 7°C and have optimum growth of 20°C to 30°C

**Mesophiles:** Grow well between 20°C and 45°C with optima between 30°C and 40°C

**Thermophiles:** Grow well at and above 45C with optima between 55°C and 65°C

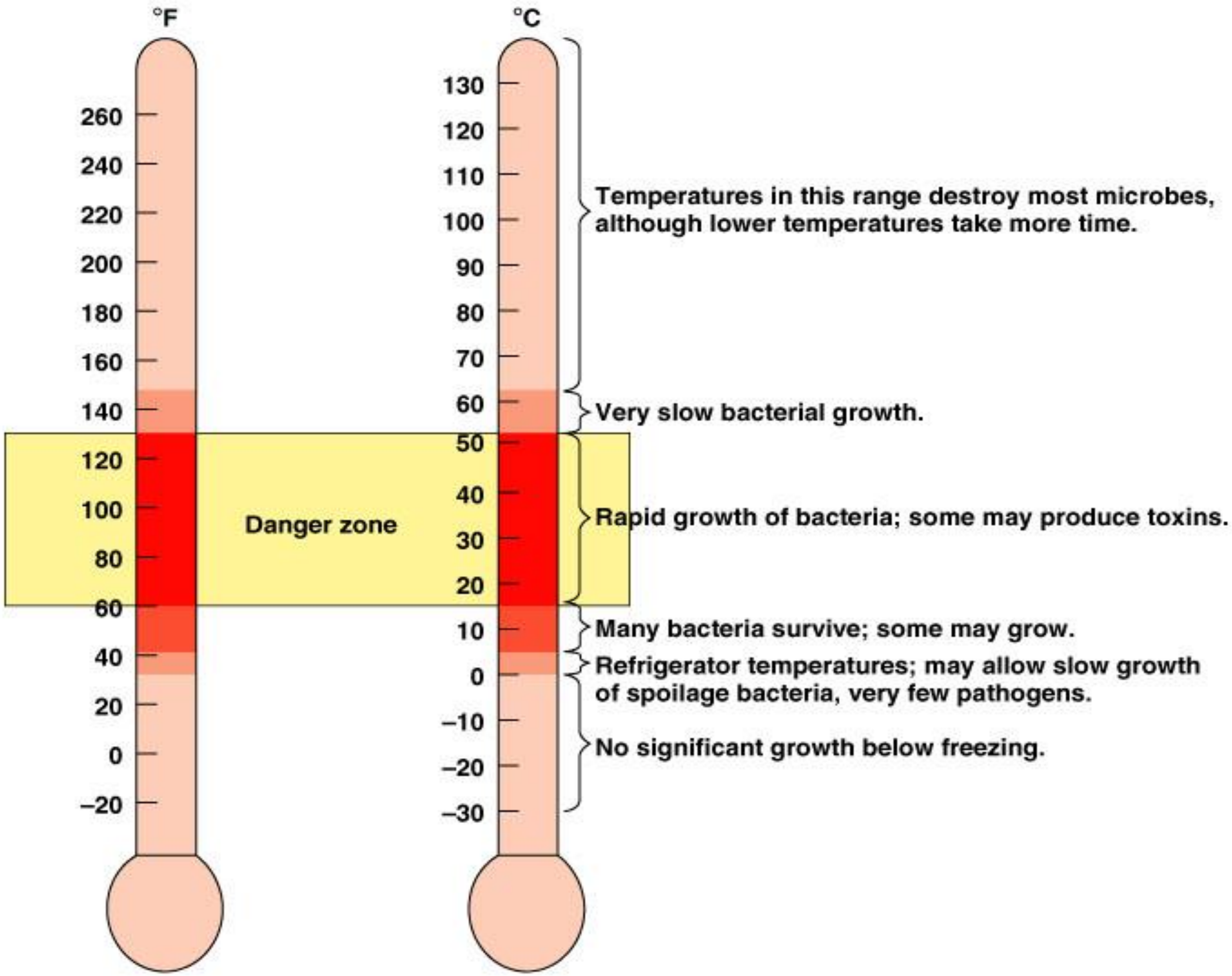
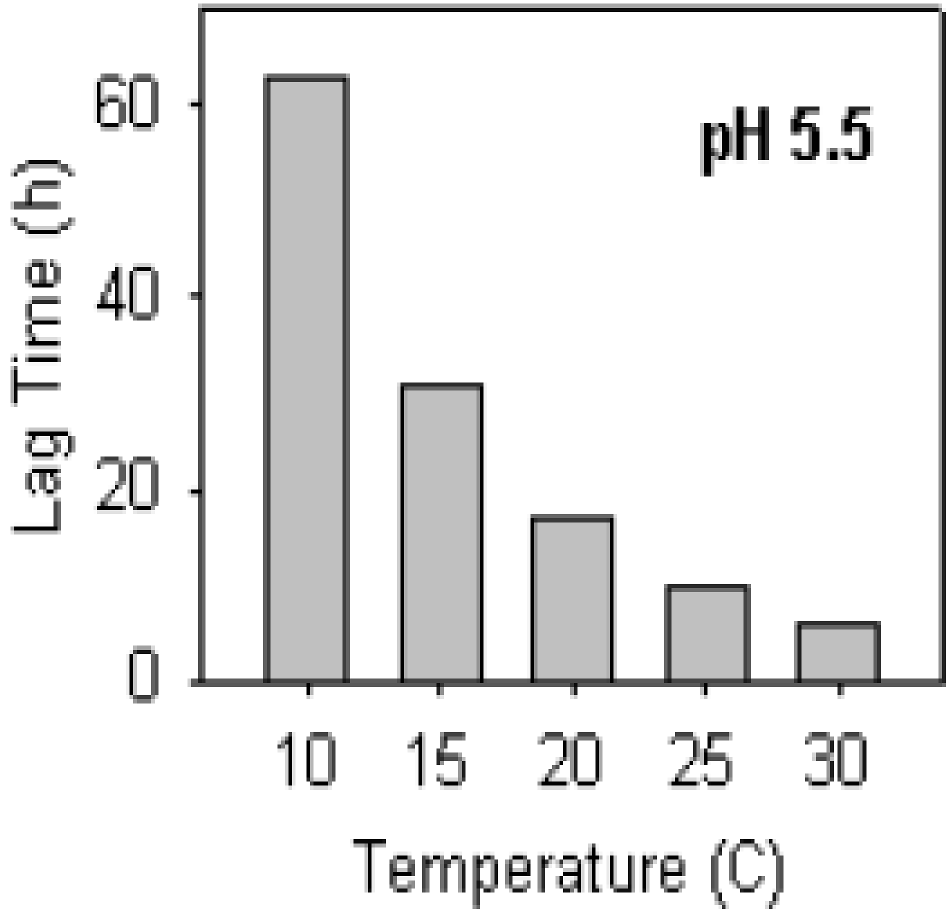


**Table 3-10. Approximate minimum, maximum and optimum temperature values in °C (°F) permitting growth of selected pathogens relevant to food.**

| Organism | Minimum | Optimum | Maximum |
|---|---|---|---|
| *Bacillus cereus* | 5 (41) | 28 - 40 (82 - 104) | 55 (131) |
| *Campylobacter* spp. | 32 (90) | 42 - 45 (108 - 113) | 45 (113) |
| *Clostridium botulinum* types A & B* | 10 - 12 (50 - 54) | 30 - 40 (86 - 104) | 50 (122) |
| *Clostridium botulinum* type E** | 3 - 3.3 (37 - 38) | 25 - 37 (77 - 99) | 45 (113) |
| *Clostridium perfringens* | 12 (54) | 43 - 47 (109 - 117) | 50 (122) |
| Enterotoxigenic *Escherichia coli* | 7 (45) | 35 - 40 (95 - 104) | 46 (115) |
| *Listeria monocytogenes* | 0 (32) | 30 - 37 (86 - 99) | 45 (113) |
| *Salmonella* spp. | 5 (41) | 35 - 37 (95 - 99) | 45 - 47 (113 - 117) |
| *Staphylococcus aureus* growth | 7 (45) | 35 - 40 (95 - 104) | 48 (118) |
| *Staphylococcus aureus* toxin | 10 (50) | 40 - 45 (104 - 113) | 46 (115) |
| *Shigella* spp. | 7 (45) | 37 (99) | 45 - 47 (113 - 117) |
| *Vibrio cholerae* | 10 (50) | 37 (99) | 43 (109) |
| *Vibrio parahaemolyticus* | 5 (41) | 37 (99) | 43 (109) |

## Effect of temperature or pH on lag times of *Listeria monocytogenes* from USDA PMP ver 5.1 (2% NaCl, $a_w$ 0.989)




Storage of food at ambient temperature – duration should be equal to or less than the lag phase of the pathogens

**Table 3-11. The relationship of pH and temperature to growth rate of *Clostridium perfringens* (welchii) F2985/50.**

| Incubation temperature | Hours to visible turbidity in RCM broth at pH | |
|---|---|---|
| | 5.8 | 7.2 |
| 15 °C (59 °F) | >700 | >700 |
| 20 °C (68 °F) | 74 | 48 |
| 25 °C (77 °F) | 30 | 24 |
| 30 °C (86 °F) | 24 | 8 |
| 37 °C (99 °F) | 5 | 5 |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CONSUMER

# The use of heat

- **Pasteurization:** the cooking / heat treatment of food where only a certain number of bacteria are killed.
- **Sterilization**: total destruction of all living organisms an is only found in canned shelf-stable items
- *Clostridium botulinum* is a bacteria that can form a spore that is very resistant to heat. It produces a toxin that causes paralysis and is often fatal.

## Table 7.2

## Approximate Conditions for Moist Heat Killing

| Organism | Vegetative Cells | Spores |
|---|---|---|
| Yeasts | 5 minutes at 50–60°C | 5 minutes at 70–80°C |
| Molds | 30 minutes at 62°C | 30 minutes at 80°C |
| Bacteria[a] | 10 minutes at 60–70°C | 2 to over 800 minutes at 100°C<br>0.5–12 minutes at 121°C |
| Viruses | 30 minutes at 60°C | |

[a]Conditions for mesophilic bacteria.

# ATMOSPHERE

## MECHANISM OF MICROBIAL INHIBITION BY GASES

### DIRECT INHIBITORY EFFECT

Carbon dioxide ($CO_2$), Ozone ($O_3$), and Oxygen ($O_2$) has a direct toxic effect – inhibit microbial growth & proliferation

Oxidizing radical of $O_2$ and $O_3$ toxic to anaerobic, $CO_2$ gas inhibit aerobes

### INDIRECT INHIBITORY EFFECT

Modifying gas composition will alter the ecology of microbial environment

e.g. nitrogen replacement of $O_2$

Technologies: Modifies atmosphere packaging (MAP) –use $CO_2$ (dissolve in food & lower the pH) and $N_2$ (inert gas)

MAP packaging machine


MAP products

Table 3-8. Examples of gas mixtures used for various MAP products.

| Product | % $CO_2$ | % $O_2$ | % $N_2$ |
|---|---|---|---|
| Fresh meat | 30 | 30 | 40 |
| | 15 - 40 | 60 - 85 | 0 |
| Cured meat | 20 - 50 | 0 | 50 - 80 |
| Sliced cooked roast beef | 75 | 10 | 15 |
| Eggs | 20 | 0 | 80 |
| | 0 | 0 | 100 |
| Poultry | 25 - 30 | 0 | 70 - 75 |
| | 60 - 75 | 5 - 10 | &gte 20 |
| | 100 | 0 | 0 |
| | 20-40 | 60-80 | 0 |
| Pork | 20 | 80 | 0 |
| Processed Meats | 0 | 0 | 100 |
| Fish (White) | 40 | 30 | 30 |
| Fish (Oily) | 40 | 0 | 60 |
| | 60 | 0 | 40 |

| | | | |
|---|---|---|---|
| Hard cheese | 0 - 70 | | 30 - 100 |
| Cheese | 0 | 0 | 100 |
| Cheese; grated/sliced | 30 | 0 | 70 |
| Sandwiches | 20 - 100 | 0 - 10 | 0 - 100 |
| Pasta | 0 | 0 | 100 |
| | 70 - 80 | 0 | 20 - 30 |
| Baked goods | 20 - 70 | 0 | 20 - 80 |
| | 0 | 0 | 100 |
| | 100 | 0 | 0 |

https://www.modifiedatmospherepackaging.com/modified-atmosphere-packaging-resources/vacuum-packaging

# RELATIVE HUMIDITY

- RH of the storage environment is important as moisture from air can increase surface and subsurface $a_w$ of the food where microbial growth can occur
- Food will gain or lose moisture until the ERH is reached.
- When foods with low aw contents are placed in high RH environments, the foods takes up more moisture until equilibrium has been established
- Packaging - protect food from humidity and maintain its $a_w$


munchy's
CRACKERS
Cream Cracker
Perfect Dip
Perfect Dip
EASY packs
Krim Kraker


DANONE
JACOB'S
Low Salt Hi-Fibre
DANONE
JACOB'S
Weetameal
DANONE
All Time
Favourite
ASSORTED BISCUITS

# PRESENCE AND ACTIVITIES OF OTHER MICROORGANISMS

- Microbial competition in food
- The bacterial metabolites inhibit the growth of other microbes
  - Antibiotics
  - Bacteriocins
  - Hydrogen peroxide
  - Organic acids
- Changes in pH may promote the growth of certain microorganism (e.g. in fermentation)

# THANK YOU

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