Microbial Ecology of Foods

Dean O. Cliver

A food is an ecosystem for microbes

- They don't "know" they are in food!
- Bacteria & molds may multiply, survive, or die.

A food is an ecosystem for microbes

- Viruses & parasites can only persist or be inactivated (die, lose infectivity).
- Most attention devoted to fates of bacterial pathogens.

Pathogenic bacteria in food: potential "outcomes"

- Persistence: viable, numbers unchanged (lag or stationary phase or sporulation)
- Growth (multiplication): rate parameter (variable) based on doubling time

Pathogenic bacteria in food: potential "outcomes"

- Death: another rate parameter (cf. viable-nonculturable)
- Sporulation: another defense (species)
- Toxigenesis: growth is necessary, but possibly not sufficient

Growth curve biology

- Spores & lag phase cells quiescent; adaptation to environmental conditions = selecting needed enzymes (activating appropriate genes) from broad bacterial repertoire.

Growth curve biology

- Multiplying (doubling) cells are metabolically active, often adapting; not all metabolically active cells are multiplying.
- Stress causes adaptation or injury.

Growth curve biology

- Stationary phase may represent quiescence or (more often) growth rate = death rate.
- Some injured cells appear dead ("viable nonculturable").
- Some dead cells autolyze.

Bacteria in broth vs food

- Broth: "planktonic cells"
- Bacteria tend to aggregate, attach to surfaces, form colonies or biofilms
- Foods = solid matrix, microenvironments
- Pathogens outnumbered

Research vs real food

- Food contaminants (water, air, soil, raw material, feces) have mixed microflora.
- Food ecosystem may select one organism

Research vs real food

- At high levels, bacteria signal each other chemically ("consensus")
- Different species interact competitively, but sometimes beneficially

Research vs real food

- "Programmed" successions
- Genetic exchanges among strains or species
- Toxigenic agents (including molds) *grow* under conditions that do not permit toxigenesis.

Major factors (interact)

- Temperature
- E_h
- a_w
- pH (specific cations & anions)
- Nutrients available
- Physical structure
- Microflora
- Antimicrobial agents

Temperatures for Thermophiles

- Minimum: 40–45°C
- Optimum: 55–75°C
- Maximum: 60–90°C

Temperatures for Mesophiles

- Minimum: 5–15°C
- Optimum: 30–45°C
- Maximum: 35–47°C

Temperatures for Psychrophiles

- Minimum: -5–+5°C
- Optimum: 12–15°C
- Maximum: 15–20°C

Temperatures for Psychrotrophs

- Minimum: -5–+5°C
- Optimum: 25–30°C
- Maximum: 30–35?°C (cf. handout)

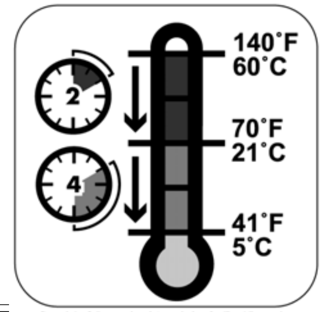
Cold: liquid or solid water?

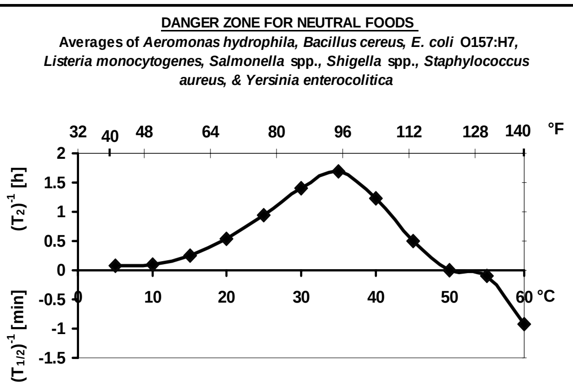
- Freezing kills some cells, frozen storage preserves
- Psychrotrophs grow slowly in refrigerated food

Warm = near optimum?

- **Food spoilage promoted; test of sanitation**
- **“Danger Zone”: 4–60°C (40–140°F) or 5–57°C (41–135°F)**
- **Rapid transition from hot to cold or cold to hot**

“Danger zone” depicted

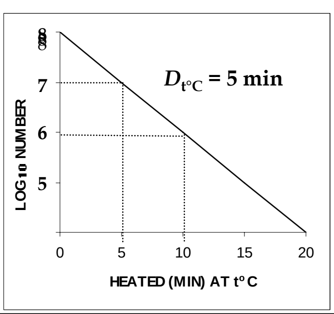




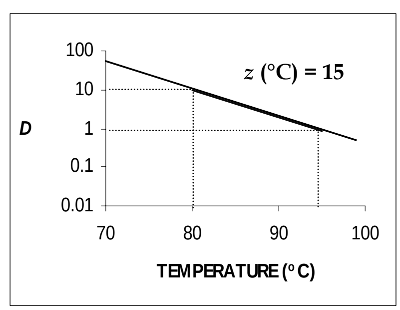
Hot—temps > max for growth cause death

- ***D*** **value: time for decimal reduction at t°C; organisms are in log death phase**
- ***z*** **value: temperature change (°C) to reduce the** ***D*** **value 10-fold**

D *value example*



z *value example*



Heat

- Cooking, blanching, pasteurization not for "commercial sterility"
- Cells in log phase are more heat-sensitive

Heat

- "Heat-shock" proteins aid adaptation; some produced in response to other stresses.
- Mesophiles or psychrotrophs — infectious agents must be able to multiply at body temperature.

Tyndallization: boiling on 3 days

- Day 1: vegetative cells killed, spores heat-shocked
- Day 2: veg cells from spores killed, last spores heat-shocked
- Day 3: vegetative cells from final spores killed; endpoint: sterility

Eh

- Aerobic (>0 mV), microaerophiles, facultative, anaerobic (<0 mV)
- "Strict" aerobes $E_h > 0$ mV, "obligate" anaerobes $E_h < -300$ mV

Eh

- Facultative organisms often use available energy more efficiently under aerobic conditions
- *C. perfringens* may not start growing under aerobic conditions, but is not inhibited by oxygen once growth begins.

Eh

- E_h hard to measure in foods
- Live foods metabolize or bind oxygen
- Packaging, modified atmosphere
- Molds generally strict aerobes

Water activity—"a_w"

Water available for microbial growth, based on water present and on binding by solutes such as salt or sugar; equilibrium relative humidity ÷ 100; range is 0 to 1.00

Approximate a_w of some foods

◆Fresh fruit or vegetables	≥0.97
◆Fresh poultry or fish	≥0.98
◆Fresh meats	≥0.95
◆Juices, fruit & vegetable	0.97
◆Cheese, most types	≥0.91
◆Honey	0.54–0.75
◆Cereals	0.10–0.20

Minimum a_w for some foodborne pathogens

◆***Salmonella***	**0.93**
◆***C. botulinum***	**0.93**
◆***Staphylococcus aureus***	**0.85**
◆**(Most yeasts)**	**0.88**
◆**Most molds**	**0.75**

pH: hydrogen-ion potential

- **Foods range from pH 7 downward.**
- **Acidification inhibits spoilage & growth of many pathogens.**
- **"Low acid" (bot) pH ≥ 4.6**

pH values of some foods

◆**Egg white**	**7.6–9.5**
◆**Milk**	**6.3–6.8**
◆**Chicken**	**5.5–6.4**
◆**Beef**	**5.3–6.2**
◆**Cheeses, most**	**5.0–6.1**
◆**Tomatoes**	**3.7–4.9**
◆**Apples**	**2.9–3.5**

Important minimum pH values for growth of microbes in foods

◆*Clostridium botulinum*	4.8–5.0
◆*Salmonella* (most types)	4.5–5.0
◆*Staphylococcus aureus*	4.0–4.7
◆Yeasts & molds	1.5–3.5

pH

- "Organic" acids (e.g., lactic, acetic, etc.) more effective antimicrobials than mineral acids
- Most effective undissociated; at a given pH, molar quantity of organic acid >> than that of a mineral acid.

Nutrients available

- C & N sources required, sometimes "growth factors"
- Foods generally good C & N sources
- Other factors, then nutrients decide which organism predominates

Physical structure

- Bacteria grow on surfaces when they can.
- Some surfaces (melon rind, eggshell) limit access to nutrients.
- Food matrix: molds often penetrate better than bacteria.

Physical structure

- If water & solutes cannot diffuse freely, local variations in E_h, a_w, and pH are highly possible.
- High viscosity or strongly cellular structure can greatly limit heat transfer (both heating and cooling) in foods.

Microflora

- Bacteria in foods: variety & competition
- Microbial growth may lower E_h & pH; molds use organic acids as carbon sources & raise pH.

Microflora

- Bacteria may produce acetic, lactic, and other acids as fermentation products.
- Some produce bacteriocins—proteins that have a highly-specific lethal effect on closely related organisms.

Competing organisms

- *Staphylococcus aureus*
- *Clostridium botulinum*

"Programmed succession"

- Milk: rapid lactic acid producers (lactococci), then
- Slower acid producers (lactobacilli) that tolerate lower pH's, then
- Acid-stable putrefactive (proteolytic) bacteria and finally,
- Molds (metabolite tolerance).

Antimicrobials: preservatives

- Materials added specifically to inhibit microbial growth
- Nitrite for "curing" meats, vs *C. botulinum*.
- Sorbates, benzoates, & other salts of organic acids bacteriostatic, not bactericidal

Antimicrobials: preservatives

- CO_2 & SO_2 long used in foods; SO_2 is highly toxic to a small segment of the population.
- Spices — especially those with strong flavors — often viewed as preservatives or disinfectants. Probably bacteriostatic, at best.

Antimicrobials: radiation

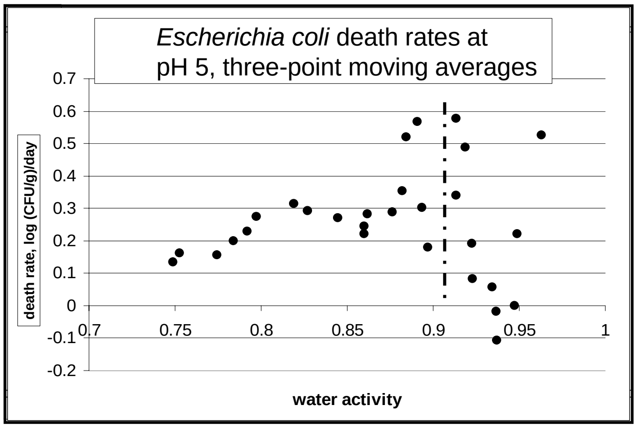
- UV widely applicable to decontamination of food surfaces, food contact surfaces, & water used in food processing; limited penetration.

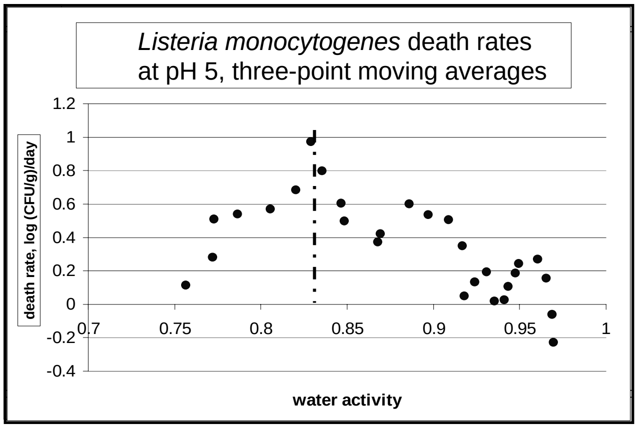
Antimicrobials: radiation

- Surface efficiency enhanced by pulsed laser application (some pulsed laser applications use visible light).
- Ionizing radiation discussed earlier in course.

Interactions

- The pH that permits growth of a bacterium near its optimal temperature may be limiting at a less favorable temperature.





Interactions

- Safe foods "designed" combining slightly unfavorable conditions for several parameters to stop target pathogens and spoilage organisms.

Interactions

- This kind of food design has heavy safety implications; modeling (discussed last time) is used to make choices, then validated by inoculated-pack, product-abuse trials before a new food product is marketed.
- Applied in HACCP.

Pathogen Modeling Program (PMP)

http://www.arserrc.gov/MFS/PATHOGEN.HTM

Summary

- **Food ecosystems govern which microorganisms may grow in them.**
- **Factors, such as temperature, a_w , pH, etc., interact to determine the microbiologic safety of a food.**
- **Food processing takes account of these factors to ensure food safety.**