

Chapter 4: Normal microbiological quality of foods

4.1. Introduction

Although many types (genera, species, strains) of microorganisms are present in nature, under normal conditions a food generally harbors only a few types. These types include those that are naturally present in raw foods (which provide the ecological niche) and those that enter from outside sources to which the foods are exposed from the time of production until consumption. The relative numbers (population level) of a specific type of microorganism initially present (without growth) in a food depend on the intrinsic and extrinsic conditions to which the food is exposed. If growth occurs, the predominant types will be the ones for which the optimum growth condition is present in the food.

4.2. Raw and ready-to-eat meat products

4.2.1. Raw meat

- Following slaughter, carcasses contain many microorganisms from:
 - Skin, hair, feathers, gastrointestinal tract
 - Feedlot/pasture environment (feed, water, soil)
 - Slaughtering facilities (equipment, air, water, humans)
- **Average:** 10^{1-3} bacterial cells/in².
- **Enteric pathogens** (low levels normally):
 - *Salmonella* serovars
 - *Yersinia enterocolitica*
 - *Campylobacter jejuni*
 - *Escherichia coli*
 - *Clostridium perfringens*
 - *Staphylococcus aureus*
- **Poultry** has higher incidence of *Salmonella* than red meat.
- After boning, chilling, and grinding, microorganisms come from: carcasses, equipment, personnel, air, water
- **Chilled meat** contains:
 - Mesophiles: *Micrococcus*, *Enterococcus*, *Staphylococcus*, *Bacillus*, *Clostridium*, *Lactobacillus*, coliforms, other *Enterobacteriaceae*, enteric pathogens
 - Psychrotrophs (major problem at -1 to 5°C):
 - *Lactobacillus*, *Leuconostoc*
 - *Brochothrix thermosphacta*
 - *Clostridium laramie*

- Some coliforms, *Serratia*, *Pseudomonas*, *Alteromonas*, *Achromobacter*, *Alcaligenes*, *Acinetobacter*, *Moraxella*, *Aeromonas*, *Proteus*
 - Psychrotrophic pathogens: *Listeria monocytogenes*, *Yersinia enterocolitica*
 - **Microbial load:**
 - Fresh meat: varies greatly, bacteria predominate
 - Ground meat: 10^4 – 10^5 microorganisms/g
 - *Salmonella*: ~1 cell/25 g
 - **Storage atmosphere:**
 - **Aerobic:** psychrotrophic aerobes grow rapidly (Gram-negative rods: *Pseudomonas*, *Alteromonas*, *Proteus*, *Alcaligenes*; yeasts)
 - **Anaerobic packaging:** psychrotrophic facultative anaerobes and anaerobes predominate (*Lactobacillus*, *Leuconostoc*, *Brochothrix*, *Serratia*, some coliforms, *Clostridium*)
 - **pH effect:**
 - Beef: ~5.6 (low)
 - Poultry: ~6.0 (high)
 - High protein, low carbohydrate → determines predominant types during storage

4.2.2. Low-heat-processed red meat and poultry products

- Includes perishable cured/uncured products heated to ~ 70°C
- Packaged aerobically or anaerobically; stored refrigerated.
- Expected storage life: 50 days or more (especially anaerobically packaged and cured).
- **Microbial sources before heat treatment:**
 - Raw meat, ingredients, equipment, air, personnel
- **Heat treatment:**
 - Kills most microorganisms
 - Surviving thermotolerant: *Micrococcus*, some *Enterococcus*, some *Lactobacillus*, spores of *Bacillus* and *Clostridium*
 - Microbial level: 10^1 – 10^2 /g
- **Post-heating contamination** (during casing removal, slicing, packaging):
 - Bacteria, yeasts, molds, pathogens from equipment, personnel, air, water
 - Initial level normally $\leq 10^2$ /g
 - Psychrotrophic facultative anaerobes and anaerobes: *Lactobacillus*, *Leuconostoc*, some coliforms, *Serratia*, *Listeria*, *Clostridium* spp.
- **Extended storage** (vacuum/modified-air packages):
 - Even from low initial levels, bacterial population can rise
 - Adversely affects safety and shelf life
 - Aggravated by: storage temperature fluctuations, low fat, high pH, high A_w products

4.3. Raw and pasteurized milk

4.3.1. Raw milk

- Sources: cows, buffalo, sheep, goats
- Composition: high in proteins and carbohydrates (lactose) → supports microbial growth
- **Microbial sources:**
 - o Inside udder: *Micrococcus*, *Streptococcus*, *Corynebacterium*
 - o Animal body surfaces, feed, air, water, equipment
- **Normal level:** $<10^3$ microorganisms/ml
- **Refrigerated storage** (before pasteurization):
 - o Only psychrotrophs grow: *Pseudomonas*, *Flavobacterium*, *Alcaligenes*, some coliforms, *Bacillus* spp.
 - o Can affect acceptance quality (flavor, texture)
 - o Some produce heat-stable enzymes (proteinases, lipases) → affect quality even after pasteurization
 - o Psychrotrophic pathogens: *Listeria monocytogenes*, *Yersinia enterocolitica*

4.3.2. Pasteurized milk

- Includes whole, skim, low fat, flavored milks, cream
- **Microorganisms present:**
 - o **Thermotolerants** surviving pasteurization: *Micrococcus*, some *Enterococcus* (*Ent. faecalis*), *Streptococcus*, some *Lactobacillus* (*Lab. viridescens*), spores of *Bacillus* and *Clostridium*
 - o **Post-pasteurization contaminants:** coliforms, *Pseudomonas*, *Alcaligenes*, *Flavobacterium*
 - o Heat-sensitive pathogens can enter after heating
 - o Psychrotrophs can grow during refrigerated storage

4.4. Shell egg and liquid egg

4.4.1. Shell eggs

- Contaminated on outer surface from:
 - o Fecal matter, nesting materials, feeds, air, equipment
- Each shell: up to 10^7 bacteria (depending on contamination level)
- Washing reduces bacterial level considerably
- Bacteria on eggshells:
 - o *Pseudomonas*, *Alcaligenes*, *Proteus*, *Citrobacter*, *Escherichia coli*, *Enterobacter*, *Enterococcus*, *Micrococcus*, *Bacillus*
 - o *Salmonella* from fecal contamination
- Infected ovaries of laying hens → *Salmonella* Enteritidis in yolk

4.4.2. Liquid egg contamination:

- Shell of washed eggs, breaking equipment, water, air
- Pasteurization reduces numbers to $10^3/\text{ml}$
- Bacterial entry through shell pores (especially if wet)
- Antimicrobial factors in egg albumin: lysozyme, conalbumin (binds iron), avidin (binds biotin), alkaline pH (8.0–9.0)
- If storage temperature favorable → bacteria can grow in yolk (rich in nutrients, pH 7.0)
- Pasteurization of liquid egg: designed to destroy pathogens (especially *Salmonella*) and other Gram-negative rods
- Thermotolerant bacteria surviving pasteurization: *Micrococcus*, *Enterococcus*, *Bacillus*

4.5. Fish and shellfish

- Includes finfish, crustaceans (shrimp, lobster, crabs), mollusks (oysters, clams, scallops)
- Harvested from marine and freshwater environments (natural sources and aquacultures)
- Composition: rich in protein and nonprotein nitrogenous compounds; fat varies with type and season
- Carbohydrates: very low (except mollusks: ~3% glycogen)

Microbial population

- Varies greatly with pollution level and temperature of water
- Bacteria, viruses, parasites, protozoa can be present in raw materials
- Muscles of fish/shellfish are sterile
- Scales, gills, intestines harbor microorganisms
- Finfish and crustaceans: $10^3\text{--}8$ bacterial cells/g
- Mollusks: filter large volumes of water → concentrate bacteria and viruses
- **Marine products:**
 - Halophilic vibrios
 - *Pseudomonas*, *Alteromonas*, *Flavobacterium*, *Enterococcus*, *Micrococcus*, coliforms
 - Pathogens: *Vibrio parahaemolyticus*, *Vib. vulnificus*, *Clostridium botulinum* type E
- **Freshwater fish:** *Pseudomonas*, *Flavobacterium*, *Enterococcus*, *Micrococcus*, *Bacillus*, coliforms
- **Water polluted with human/animal waste:**
 - *Salmonella*, *Shigella*, *Clostridium perfringens*, *Vibrio cholerae*
 - Hepatitis A, Norwalk-like viruses
 - Opportunistic pathogens: *Aeromonas hydrophila*, *Plesiomonas shigelloides*

4.6. Vegetables, fruits, and nuts

4.6.1. Vegetables

- Edible plant components: leaves, stalks, roots, tubers, bulbs, flowers
- Composition: relatively high in carbohydrates; pH 5.0–7.0
- Different bacteria, yeasts, molds can grow if conditions favorable
- Microbial sources: soil, water, air, animals, insects, birds, equipment
- Microbial levels: 10^3 – $5/\text{cm}^2$ or 10^4 – $7/\text{g}$
- Predominant bacteria:
 - o Lactic acid bacteria
 - o *Corynebacterium*, *Enterobacter*, *Proteus*, *Pseudomonas*, *Micrococcus*, *Enterococcus*, sporeformers
- Molds: *Alternaria*, *Fusarium*, *Aspergillus*
- **Enteric pathogens** (if animal/human wastes and polluted water used):
 - o *Listeria monocytogenes*, *Salmonella*, *Shigella*, *Campylobacter*, *Clostridium botulinum*, *Clostridium perfringens*
 - o Pathogenic protozoa and parasites
- Damaged vegetables: plant pathogens (*Erwinia*) can predominate
- Spoilage: different types of rot
- Pathogens can grow and cause foodborne diseases (listeriosis, botulism)
- Lactic acid bacteria: important in natural fermentation (sauerkraut)
- Processing greatly reduces microbial population

4.6.2. Fruits

- High carbohydrates, pH ≤ 4.5 (organic acids), some have antimicrobial essential oils
- Microorganisms: molds, yeasts, lactic acid bacteria
- Sources: air, soil, insects, harvesting equipment
- Microbial levels: 10^3 – $6/\text{g}$
- Improperly harvested/processed fruits: pathogens can survive, grow, cause foodborne disease
- Spoilage: molds, yeasts, bacteria
- Natural flora (especially yeasts): important in alcohol fermentation

4.6.3. Nuts

- From ground (peanuts) or trees (pecans)
- Protective shells, low A_w (0.7)
- Microbial sources: soil (peanuts), air (tree nuts), processing (air, equipment, water)
- Raw nuts and nutmeats: 10^3 – 4 microorganisms/g
 - o *Bacillus* and *Clostridium* spores, *Leuconostoc*, *Pseudomonas*, *Micrococcus*
- Low A_w → bacteria do not grow
- As ingredients → can cause microbiological problems
- Molds can grow and produce mycotoxins (aflatoxins by *Aspergillus flavus*)

4.7. Cereal, starches, and gums

- Includes grains, flour, meals, breakfast cereals, pasta, baked products, dry mixes, frozen/refrigerated cereal products (also beans, lentils)
- Starches: flours of cereals (corn, rice), tapioca, potatoes, other tubers
- Gums: stabilizers, gelling agents, film formers
 - o From plants, seaweeds, microorganisms (tragacanth, pectin, xanthan, agar, carrageenan)
 - o Modified compounds (carboxymethyl cellulose)
- Rich in amylose and amylopectin; can have simple sugars and protein
- Microbial sources: soil, air, insects, birds, equipment
- **Microbial levels:**
 - **Unprocessed grains:**
 - o Aerobic plate count: $\sim 10^4/\text{g}$
 - o Coliform: $\sim 10^2/\text{g}$
 - o Yeasts and molds: $\sim 10^3/\text{g}$
 - o May contain mycotoxins from toxicogenic molds
 - **Processed products:**
 - o Wide variety of yeasts, molds, bacteria
 - o Flours and starches: higher counts (similar to grains)
 - o Breakfast cereals and pasta: aerobic plate count $10^2\text{--}3/\text{g}$; coliform $<10^{1-2}/\text{g}$; yeasts and molds $<10^{1-2}/\text{g}$
 - o Can contain bacterial spores and psychrotrophs
 - o Pathogens isolated: *Salmonella*, *Staphylococcus aureus*, *Clostridium perfringens*
- Gums: source of yeasts, molds (mycotoxins), bacterial spores, lactic acid bacteria

4.8. Canned foods

- Packed in hermetically sealed containers; given high heat treatment
- **pH ≥ 4.6 :** heat treatment to obtain commercial sterility
- **pH < 4.6 :** heat treatment $\sim 100^\circ\text{C}$

Commercially sterile canned foods

- Can have spores of **thermophilic spoilage bacteria:**
 - o *Bacillus stearothermophilus*
 - o *Clostridium thermosaccharolyticum*
 - o *Desulfotomaculum nigrificans*
- Sources: soil, blanching water, sugar, starches
- Storage at $\leq 30^\circ\text{C}$: thermophilic spores do not germinate
- Temperature abuse to $\geq 40^\circ\text{C}$: spores germinate, cells multiply, spoil product

Lower heat treatment (~100°C)

- Spores of **mesophilic bacteria** survive:
 - Spoilage: *Bacillus coagulans*, *Bac. licheniformis*, *Clostridium sporogenes*, *Clo. butyricum*
 - Pathogenic: *Bac. cereus*, *Clo. perfringens*, *Clo. botulinum*
 - Also thermophilic spores
- **Low-pH products** (tomato products): *Bac. coagulans* spores germinate, cells multiply, cause spoilage
- **High-pH products**: other sporeformers germinate and grow
- ***Staphylococcus aureus* toxins**: if present in raw products, not destroyed by heat treatment → food poisoning

4.9. Sugars and confectioneries

4.9.1. Refined sugar

- From sugar cane and beets
- Can have:
 - Thermophilic spores: *Bac. stearothermophilus*, *Bac. coagulans*, *Clo. thermosaccharolyticum*, *Des. nigrificans*
 - Mesophilic bacteria: *Lactobacillus*, *Leuconostoc*
 - Yeasts, molds
- As ingredients: spores can survive and cause spoilage
- Pathogens: not present unless contaminated
- Liquid sugar: mesophiles can grow
- Strict microbiological standards for spores (canned products, liquid sugar)

4.9.2. Confectioneries

- Large variety of sweet-tasting products
- Low A_w (≤ 0.84), some low pH
- May contain bacteria, yeasts, molds
- Microbiological standards well regulated
- May harbor:
 - *Lactobacillus*, *Leuconostoc*
 - Spores of *Bacillus* and *Clostridium*
 - Yeasts, molds
- Only few osmotolerant yeasts and molds can grow
- As additives: can be source of microbes
- Ready-to-consume products: if contaminated with pathogens (raw materials, environment, personnel) → foodborne diseases

4.10. Soft drinks, fruit and vegetable drinks, juices, and bottled water

✓ **Soft drinks**

- Nonalcoholic beverages: water, sweeteners, acids, flavoring, coloring, emulsifying agents, preservatives
- Some contain fruit juices; carbonated or noncarbonated
- pH: 2.5–4.0
- Fruit juices (100%): $\text{pH} \leq 4.0$
- Vegetable juices (tomato): $\text{pH} \geq 4.5$
- Bottled water: natural springs or drilled wells; handled to prevent contamination

✓ **Microorganisms**

- **Soft drinks:** only aciduric microorganisms multiply
 - Molds, yeasts, lactic acid bacteria, acetic acid bacteria
 - Carbonated beverages: some microaerophilic yeasts grow
 - With fruit juices: *Lactobacillus*, *Leuconostoc* grow
 - Noncarbonated: molds (*Geotrichum*), *Acetobacter*, *Gluconobacter*
 - Most from processing environment and equipment
- **Fruit juices:**
 - Molds, yeasts
 - *Lactobacillus* (*Lab. fermentum*, *Lab. plantarum*)
 - *Leuconostoc* (*Leu. mesenteroides*)
 - Acetic acid bacteria
 - Acid-resistant sporeformer *Alicyclobacillus* → spoilage
 - Pathogens: acid-tolerant *Salmonella* spp., *E. coli* O157:H7 in orange juice and apple cider → viable >30 days
- **Vegetable juices:**
 - Molds, yeasts, lactic acid bacteria
 - *Bac. coagulans*, *Clo. butyricum*, *Clo. pasteurianum*
- **Bottled water:**
 - Should not contain >10–100 bacteria and >10 coliforms/100 ml
 - Indigenous flora: *Flavobacterium*, *Alcaligenes*, *Micrococcus*
 - Some *Pseudomonas* as contaminants
 - Should not have pathogens unless poor sanitation

4.11. Mayonnaise and salad dressings

- Water-in-oil emulsion products
- Formulated with: oil, water, vinegar (~0.25% acetic acid) or lemon juice, sugar, salt, starch, gum, egg, spices, vegetable pieces
- pH: 3.5–4.0
- Low-calorie/less sour products: less acid, less oil, more water → $\text{pH} \geq 4.5$

✓ **Microorganisms**

- Introduced through ingredients, equipment, air
- Except aciduric microorganisms, most die (especially during long storage at room temperature)
- Aciduric microorganisms isolated:
 - Molds: *Geotrichum*, *Aspergillus* spp.
 - Yeasts: *Saccharomyces* spp.
 - *Lactobacillus*: *Lab. fructivorans*, *Lab. brevis*
 - *Bacillus*: *Bac. subtilis*, *Bac. mesentericus*
- Normal numbers: $\leq 10^6$ /g
- Pathogens (e.g., *Salmonella* through eggs):
 - Expected to be killed rapidly
 - May survive longer in low-calorie, high-pH products kept at refrigerated temperatures

4.12. Spices and condiments

- Spices: plant products (seed, flower, leaf, bark, roots, bulb) used whole or ground, singly or mixed
- Condiments: spices blended with other components; saucelike consistency (catsup, mustard)
- Used in small amounts for aroma and color

✓ **Microorganisms**

- Without antimicrobial treatments (irradiation; ethylene oxide no longer permitted): can contain up to 10^{6-7} microorganisms/g
- Most important: spores of molds, *Bacillus*, *Clostridium* spp.
- Also: micrococci, enterococci, yeasts
- Pathogens found: *Salmonella* spp., *Staphylococcus aureus*, *Bac. cereus*
- Can also have mycotoxins
- Although used in small amounts → can be source of spoilage and pathogenic microorganisms in food
- Some spices have antimicrobial properties: cloves, allspice, garlic

➤ **Conclusion**

- Normal microbiological quality of foods varies widely by food group.
- Key factors determining microbial types and levels:
 - Intrinsic properties (pH, A_w , nutrients, antimicrobials)
 - Extrinsic conditions (temperature, atmosphere, humidity)
 - Initial contamination sources
 - Processing methods

- Storage conditions
- Understanding normal microbiological quality is essential for:
 - Setting microbiological standards and specifications
 - Developing control methods
 - Determining shelf life and safety
 - Detecting deviations from normal quality
- Pathogens of concern vary by food group:
 - Meat: *Salmonella*, *Listeria*, *Yersinia*, *Campylobacter*, *E. coli*, *Clostridium*
 - Milk: *Salmonella*, *Listeria*, *Yersinia*, *Campylobacter*
 - Eggs: *Salmonella*
 - Fish/shellfish: *Vibrio*, *Clostridium botulinum* type E, hepatitis A, Norwalk-like viruses
 - Vegetables/fruits: *Listeria*, *Salmonella*, *Shigella*, *Campylobacter*, *Clostridium*
 - Juices: acid-tolerant *Salmonella*, *E. coli* O157:H7
- Spoilage microorganisms also vary by food group and storage conditions.

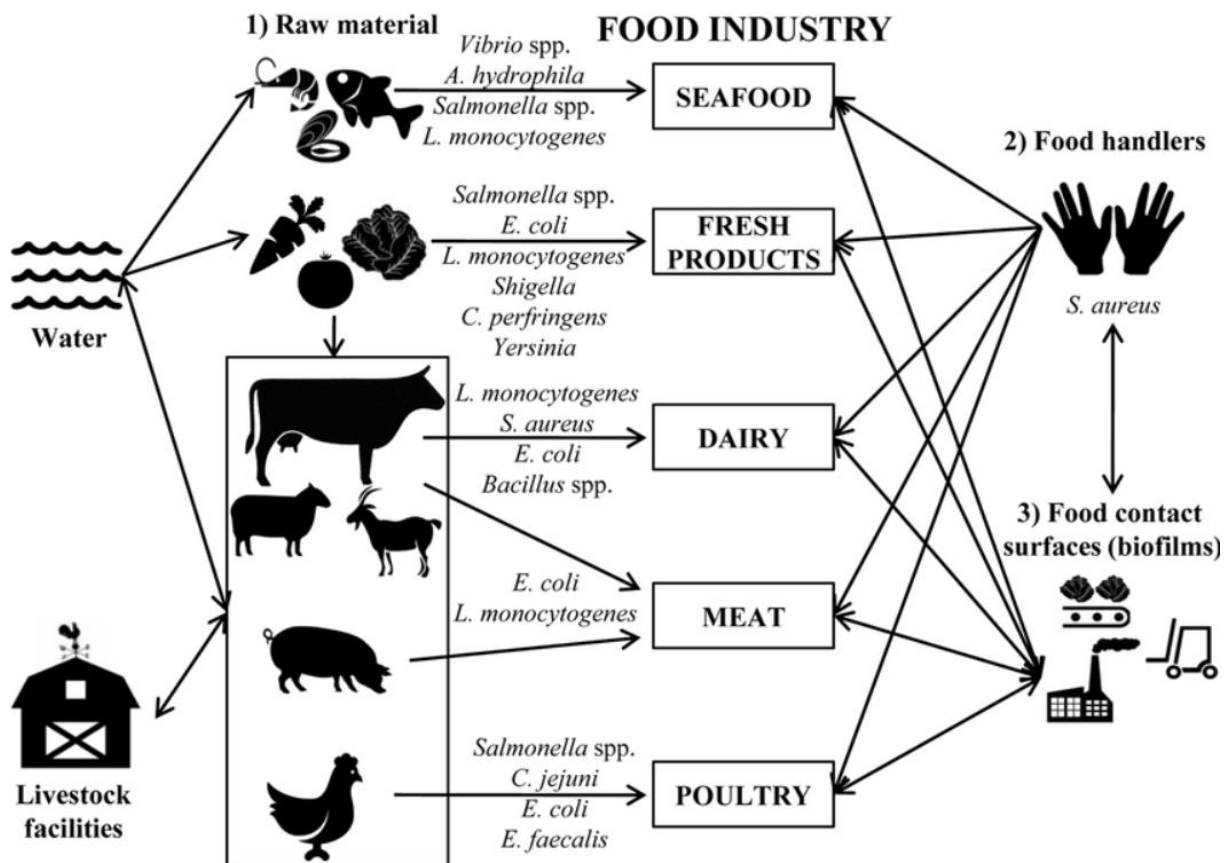


Figure: Schematic representation of the main sources of contamination in food industries.