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Microbiology of Food
Microbial Growth and Food Spoilage

• Results from growth of microbes in food
  – alters food visibly and in other ways, rendering it unsuitable for consumption (this is not the same as foodborne pathogens)

• Involves predictable succession of microbes

• Different foods undergo different types of spoilage processes

• Toxins are sometimes produced

• Food spoilage bacteria are not specifically pathogenic bacteria
Microbial Growth and Food Spoilage

- Microbial growth is controlled by
  - intrinsic factors
    - factors related to the food itself
  - extrinsic factors
    - environment where food stored
Intrinsic Factors

- Food composition - carbohydrates
  - mold predominates
    - degrades food by hydrolysis
    - little odor
    - ergotism
      - hallucinogenic alkaloids released by *Claviceps purpurea*
      - may cause death

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**Table 41.1 Differences in Spoilage Processes in Relation to Food Characteristics**

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Food Example</th>
<th>Chemical Reactions or Processes</th>
<th>Typical Products (and Effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectin</td>
<td>Fruits</td>
<td>Pectinolysis</td>
<td>Methanol, uronic acids (loss of fruit structure, soft rots)</td>
</tr>
<tr>
<td>Proteins</td>
<td>Meat</td>
<td>Proteolysis, deamination</td>
<td>Amino acids, peptides, amines, H₂S, ammonia, indole (bitterness, souring, bad odor, sliminess)</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>Starchy foods</td>
<td>Hydrolysis, fermentations</td>
<td>Organic acids, CO₂, mixed alcohols (souring, acidification)</td>
</tr>
<tr>
<td>Lipids</td>
<td>Butter</td>
<td>Hydrolysis, fatty acid degradation</td>
<td>Glycerol and mixed fatty acids (rancidity, bitterness)</td>
</tr>
</tbody>
</table>

1 Other reactions also occur during the spoilage of these substrates.

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Intrinsic Factors

- Food composition – proteins or fats
  - bacterial growth predominates
- Putrefaction
  - proteolysis and anaerobic breakdown of proteins; foul smelling amine compounds
- Unpasteurized milk spoilage
  - acid production followed by putrification
- Butter
  - short-chained fatty acid production; rancid butter
Intrinsic Factors continued

• pH
  – impacts the make up of microbial community and therefore types of chemical reactions that occur when microbes grow in food
  – e.g., low pH favors yeast and mold

• Presence and availability of water
  – in general, lower water activity inhibits microbial growth
Intrinsic Factors continued

- Physical structure
  - grinding and mixing distribute microbes; increases the surface area and promotes microbial growth
  - outer skin of vegetables and fruits slows microbial growth
- Oxidation-reduction potential
  - higher is preferred by aerobes and fungi
  - altered by cooking
  - lower redox – more bacteria and anaerobes
Antimicrobial Substances

- Coumarins – fruits and vegetables
- Lysozyme – cow’s milk and eggs
- Aldehydic and phenolic compounds – herbs and spices such as rosemary, sage, cinnamon, mustard, basil
- Allicin – garlic
- Eugenol – cloves
- Polyphenols – green and black teas
Extrinsic Factors

• Temperature
  – lower temperatures slow microbial growth

• Relative humidity
  – higher levels promote microbial growth

• Atmosphere
  – oxygen promotes growth (high oxygen reduces growth in MAP)
  – modified atmosphere packaging (MAP)
    • use of shrink wrap and vacuum technologies to package food in controlled atmospheres (high CO2 frequently used and others)
Controlling Food Spoilage

Methods of preservation

- goal is to eliminate or reduce the populations of spoilage and disease causing microbes while maintaining food quality

• Filtration
  - Water, wine, beer, juices, soft drinks, and other liquids usually by filtration
  - May better preserve flavor and aroma

• Low Temperatures
  - Refrigeration at 5°C retards but does not stop microbial growth
    - microorganisms can still cause spoilage with extended storage
    - growth at temperatures below 10°C has been observed
      - fruit juice concentrates, ice cream, some fruits
Controlling Food Spoilage cont.

• High Temperatures
  – Food heated in special containers to 115°C for 25 to 100 minutes
  – Kills spoilage microbes, but not necessarily all microbes in food
  – Spoilage of canned foods - spoilage prior to canning, underprocessing, leakage of contaminated, water into cans during cooling process

• Pasteurization
  – Kills pathogens and substantially reduces number of spoilage organisms
  – Different pasteurization procedures heat for different lengths of time
    • shorter heating times result in improved flavor
  – Milk:
    • LTH (low temp holding/batch) 62.8 C for 30 mins
    • HTST (high temp short time) 72 C for 15 secs
    • UHT (ultra high temp) 138 C for 2 secs
Controlling Food Spoilage cont.

• Water Availability
  – Dehydration
    • e.g., lyophilization to produce freeze-dried foods is commonly used to eliminate bacterial growth
    • food preservation occurs as a result of free-water loss and an increase in solute concentration

• Radiation
  – Radappertization
    • use of ionizing radiation (gamma radiation) to extend shelf life or sterilize meat, seafoods, fruits, and vegetables
    • excellent penetrating power – food \textit{not} rendered radioactive
    • kills microbes in moist foods by producing peroxides from water
      – peroxides oxidize cellular constituents
Controlling Food Spoilage cont.

• Chemical Based Methods
  – GRAS
    • chemical agents “generally recognized as safe”
    • agents include organic acids, sulfite, ethylene oxide gas, ethyl formate
    • sodium nitrite – inhibits spore formation in meats, forms nitrosamines
  – pH of food impacts effectiveness of chemical preservative

• High Hydrostatic Pressure (HHP)
  – Applies pressures from 100-800 milliPascals (MPs) without significant changes in temperature
    • highly detrimental to cell membranes
    • effective at eliminating eukaryotic microbes
    • not as effective at elimination of Gram-positive microbes
  – No industry standards for HHP conditions (yet)
<table>
<thead>
<tr>
<th>Preservatives</th>
<th>Approximate Maximum Use</th>
<th>Organisms Affected</th>
<th>Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propionic acid/propionates</td>
<td>0.32%</td>
<td>Molds</td>
<td>Bread, cakes, some cheeses; inhibitor of ropy bread dough</td>
</tr>
<tr>
<td>Sorbic acid/sorbates</td>
<td>0.2%</td>
<td>Molds</td>
<td>Hard cheeses, figs, syrups, salad dressings, jellies, cakes</td>
</tr>
<tr>
<td>Benzoic acid/benzoates</td>
<td>0.1%</td>
<td>Yeasts and molds</td>
<td>Margarine, pickle relishes, apple cider, soft drinks, tomato ketchup, salad dressings</td>
</tr>
<tr>
<td>Parabens¹</td>
<td>0.1%</td>
<td>Yeasts and molds</td>
<td>Bakery products, soft drinks, pickles, salad dressings</td>
</tr>
<tr>
<td>SO₂/sulfites</td>
<td>200–300 ppm</td>
<td>Insects and microorganisms</td>
<td>Molasses, dried fruits, wine, lemon juice (not used in meats or other foods recognized as sources of thiamine)</td>
</tr>
<tr>
<td>Ethylene/propylene oxides</td>
<td>700 ppm</td>
<td>Yeasts, molds, vermin</td>
<td>Fumigant for spices, nuts</td>
</tr>
<tr>
<td>Sodium diacetate</td>
<td>0.32%</td>
<td>Molds</td>
<td>Bread</td>
</tr>
<tr>
<td>Dehydroacetic acid</td>
<td>65 ppm</td>
<td>Insects</td>
<td>Pesticide on strawberries, squash</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>120 ppm</td>
<td>Clostridia</td>
<td>Cold cuts, hot dogs, sausages</td>
</tr>
<tr>
<td>Ethyl formate</td>
<td>15–200 ppm</td>
<td>Yeasts and molds</td>
<td>Dried fruits, nuts</td>
</tr>
</tbody>
</table>


¹ Methyl, propyl, and heptyl esters of p-hydroxybenzoic acid.
• Microbial product based inhibition
  – Bacteriocins
    • bactericidal proteins active against related species
    • some dissipate proton motive force of susceptible bacteria
    • some form pores in plasma membranes
    • some inhibit protein or RNA synthesis
  – e.g., nisin from *Lactococcus lactis*
    • used in low-acid foods to inactivate *Clostridium botulinum* during canning process
  – e.g., bacteriophages that kill *Listeria monocytogenes*
    • sprayed onto ready-to-eat meats prior to packaging
Controlling Food Spoilage cont.

• Packaging
  – Modified atmosphere packaging (MAP)
    • gases in stored food affect microbial growth
    • shrink wrap materials and vacuum technology control atmosphere
      – impermeable to gasses
      – high CO₂ content packaging can be used to prevent fungal growth
      – high O₂ content packaging produces superoxide radicals that inhibit microbial growth
Types of Food-Borne Disease

- About 48 million cases/yr in U.S.
  - approximately 128,000 hospitalizations
  - at least 3,000 deaths/yr in U.S.
  - only 14 million attributed to known pathogens

- Pathogens
  - Noroviruses, *Campylobacter jejuni*, *Salmonella* are major causes
  - *E. coli* and *Listeria* are also important pathogens
  - Other: *S. aureus*, *Clostridium perfringens*, *Bacillus cereus*, *Yersinia enterocolitica*, *Vibrio parahaemalyticus*, *Clostridium botulinum*, *Shigella*
Types of Food-Borne Disease

• Two primary types
  – food-borne infections
  – food intoxications

• Transmission
  – breakdown in hygiene
  – fecal-oral route key
  – fomites also important
  – mishandling
Food-Borne Infection

• Ingestion of pathogen, followed by:
  – growth
  – tissue invasion
  – and/or release of toxins (these toxins are not the same as an intoxication)

• Raw and undercooked foods
  – sprouts, raspberries, cantalope, spinach
  – meat, eggs and seafood
<table>
<thead>
<tr>
<th>Organism</th>
<th>Incubation Period (Hours)</th>
<th>Vomiting</th>
<th>Diarrhea</th>
<th>Fever</th>
<th>Food Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>1–8 (rarely, up to 18)</td>
<td>+++⁺¹</td>
<td>+</td>
<td>-²</td>
<td>Meats, dairy, and bakery products; sprouts, carrots, lettuce, parsley, and radishes</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>2–16</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>Reheated fried rice, sprouts, cucumber</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>8–16</td>
<td>±³</td>
<td>+++</td>
<td>-</td>
<td>Rewarmed meat dishes</td>
</tr>
<tr>
<td><em>Clostridium botulinum</em></td>
<td>18–24</td>
<td>=</td>
<td>Rare</td>
<td>-</td>
<td>Canned goods contaminated during processing or packaging</td>
</tr>
<tr>
<td><em>Escherichia coli</em> (enterohemorrhagic)</td>
<td>3–5 days</td>
<td>=</td>
<td>++</td>
<td>±</td>
<td>Undercooked ground beef, unpasteurized fruit juices and cider, and raw vegetables such as sprouts, lettuce, and celery</td>
</tr>
<tr>
<td><em>Escherichia coli</em> (enterotoxigenic strain)</td>
<td>24–72</td>
<td>±</td>
<td>++</td>
<td>-</td>
<td>Contaminated drinking water; major cause of traveler’s diarrhea.</td>
</tr>
<tr>
<td><em>Vibrio parahaemolyticus</em></td>
<td>6–96</td>
<td>+</td>
<td>++</td>
<td>=</td>
<td>Shellfish, particularly clams and oysters</td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td>24–72</td>
<td>+</td>
<td>+++</td>
<td>-</td>
<td>Contaminated drinking water, as well as cabbage, coconut milk, and lettuce</td>
</tr>
<tr>
<td><em>Shigella</em> spp.</td>
<td>24–72</td>
<td>=</td>
<td>++</td>
<td>+</td>
<td>Celery, melon, lettuce and other greens, parsley, sprouts</td>
</tr>
<tr>
<td><em>Salmonella</em> spp. (gastroenteritis)</td>
<td>8–48</td>
<td>=</td>
<td>++</td>
<td>+</td>
<td>Many fruits and vegetables (including celery, green onions, lettuce and other greens, strawberries, tomatoes, melon), eggs and egg products, poultry</td>
</tr>
<tr>
<td><em>Salmonella enterica</em> serovar Typhi (typhoid fever)</td>
<td>10–14 days</td>
<td>±</td>
<td>±</td>
<td>++</td>
<td>Usually spread from a healthy carrier to food via fecal-oral transmission.</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>2–10 days</td>
<td>-</td>
<td>+++</td>
<td>++</td>
<td>Poultry, shellfish, green onions, lettuce, mushrooms, potatoes, peppers, spinach</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>4–7 days</td>
<td>=</td>
<td>++</td>
<td>+</td>
<td>Fecal-oral transmission from carrier to noncarrier</td>
</tr>
</tbody>
</table>

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¹ + indicates condition is present, number of symbols indicates severity.
² − indicates condition is absent.
³ ± indicates condition sometimes occurs.
Food-Borne Intoxications

• Ingestion of toxins in foods in which microbes have grown

• Produce symptoms shortly after the food is consumed because growth of the disease-causing microorganism is not required

• Includes:
  – staphylococcal food poisoning
  – Botulism
  – *Clostridium perfringens* food poisoning
  – *Bacillus cereus* food poisoning
Other Food Disease

- Fungus-derived toxins
  - aflatoxins
    - carcinogens produced in fungus-infected grains and nut products
  - fumonisins
    - carcinogens produced in fungus-infected corn
- Algal toxins
  - contaminate fish and shellfish
Key U.S. Food Safety Legislation

• Driven in part by Upton Sinclair’s 1905 novel *The Jungle*, the Federal Meat Inspection Act was passed

• Other food safety legislation followed

<table>
<thead>
<tr>
<th>Year</th>
<th>Legislation Enacted</th>
<th>Provisions of Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906</td>
<td>Federal Meat Inspection Act</td>
<td>Mandates inspection of live animals, carcasses and processed products; improved sanitary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>conditions for slaughter and processing</td>
</tr>
<tr>
<td>1957</td>
<td>Poultry Products Inspection Act</td>
<td>Mandates inspection of poultry products in major consuming areas, such as metropolitan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>localities</td>
</tr>
<tr>
<td>1946</td>
<td>Agricultural Marketing Act</td>
<td>Enables, but does not mandate, government inspection of fish, shellfish, and fishery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>products</td>
</tr>
<tr>
<td>1967–1968</td>
<td>Wholesome Meat and Wholesome Poultry Products</td>
<td>Extends the federal government’s authority regarding meat and poultry products in</td>
</tr>
<tr>
<td></td>
<td>Acts</td>
<td>intrastate commerce; requires poultry in interstate and foreign commerce to meet federal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inspection standards</td>
</tr>
<tr>
<td>1970</td>
<td>Egg Products Inspection Act</td>
<td>Provides for the mandatory continuous inspection of the processing of liquid, frozen, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dried egg products</td>
</tr>
<tr>
<td>1994</td>
<td>Testing for <em>E. coli</em> O157:H7</td>
<td>Requires testing raw ground beef for <em>E. coli</em> O157:H7</td>
</tr>
<tr>
<td>1995</td>
<td>Federal Food, Drug and Cosmetic Act</td>
<td>Mandates the federal inspection of all fish and fisheries products</td>
</tr>
<tr>
<td>1999</td>
<td>Testing for <em>Listeria monocytogenes</em></td>
<td>Advises manufacturers of ready-to-eat meat and poultry products of the need to ensure</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Listeria</em>-free products. In 2002 federal testing began at plants that produced high- and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>medium-risk ready-to-eat products that did not take action to prevent <em>Listeria</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>contamination.</td>
</tr>
</tbody>
</table>
Food Safety Standards

Milk Testing:

• Phosphatase Test
  – Check for presence of phosphatase, enzyme is destroyed by heat and should not be present after pasteurization

• Aerobic Plate Counts

• Total Coliform Test
  – MPN directly into brilliant green lactose bile
  – Should be less than 10 coliforms/mL

• Cell counts
  – Limited number of WBCs and bacteria

• Antibiotic sensitivity
  – No allowable residual antibiotics
Microbiology of Fermented Foods

Chemical changes in food brought about microbial action

Major fermentations used are lactic, propionic, and alcoholic fermentations

- Majority of fermented milk products rely on lactic acid bacteria (LAB) in the genera *Lactobacillus*, *Lactococcus*, *Leuconostoc*, and *Streptococcus*
  - Mesophilic (app. 20-30° C): Buttermilk/sour cream
    - *Lactobacillus* spp. and *Lactococcus lactis*
  - Thermophilic (app. 45° C): Yogurt
    - *Lactobacillus* spp. and *Streptococcus thermophilus*
  - Yeast lactic: Kefir (ferm. milk with 2% ethanol)
    - yeasts, lactic acid bacteria, and acetic acid bacteria
  - Mold lactic: Viili (Finnish fermented milk)
    - filamentous fungi and lactic acid bacteria
Cheese Production

- Approximately 2,000 distinct varieties representing 20 general types
- Classified based on
  - texture, hardness (soft, semi-soft, hard, very hard)
- All from lactic acid fermentation
  - molds may further enhance flavor
<table>
<thead>
<tr>
<th>Cheese (Country of Origin)</th>
<th>Earlier Stages of Production</th>
<th>Later Stages of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft, unripened Cottage</td>
<td><em>Lactococcus lactis</em></td>
<td><em>Leuconostoc cremoris</em></td>
</tr>
<tr>
<td>Cream</td>
<td><em>Lactococcus cremoris, L. diacetylactis, Streptococcus salivarius subspecies thermophilus, L. delbrueckii subspecies bulgaricus</em></td>
<td></td>
</tr>
<tr>
<td>Mozzarella (Italy)</td>
<td><em>S. thermophilus, L. bulgaricus</em></td>
<td></td>
</tr>
<tr>
<td>Soft, ripened Brie (France)</td>
<td><em>Lactococcus lactis, Lactococcus cremoris</em></td>
<td><em>Penicillium camemberti, P. candidum, Brevibacterium linens</em></td>
</tr>
<tr>
<td>Camembert (France)</td>
<td><em>L. lactis, Lactococcus cremoris</em></td>
<td><em>Penicillium camemberti, B. linens</em></td>
</tr>
<tr>
<td>Semisoft Blue, Roquefort (France)</td>
<td><em>L. lactis, Lactococcus cremoris</em></td>
<td><em>P. roqueforti</em></td>
</tr>
<tr>
<td>Brick, Muenster (United States)</td>
<td><em>L. lactis, Lactococcus cremoris</em></td>
<td><em>B. linens</em></td>
</tr>
<tr>
<td>Limburger (Belgium)</td>
<td><em>L. lactis, Lactococcus cremoris</em></td>
<td><em>B. linens</em></td>
</tr>
<tr>
<td>Hard, ripened Cheddar, Colby (Britain)</td>
<td><em>L. lactis, Lactococcus cremoris</em></td>
<td><em>Lactobacillus casei, L. plantarum</em></td>
</tr>
<tr>
<td>Swiss (Switzerland)</td>
<td><em>L. lactis, L. helveticus, S. salivarius subspecies thermophilus</em></td>
<td><em>Propionibacterium shermanii, P. freudenreichii</em></td>
</tr>
<tr>
<td>Very hard, ripened Parmesan (Italy)</td>
<td><em>L. lactis, Lactococcus cremoris, S. salivarius subspecies thermophilus</em></td>
<td><em>L. delbrueckii subspecies bulgaricus</em></td>
</tr>
</tbody>
</table>

1 *Lactococcus lactis* stands for *L. lactis* subspecies *lactis*. *Lactococcus cremoris* is *L. lactis* subspecies *cremoris*, and *Lactococcus diacetylactis* is *L. lactis* subspecies *diacetylactis*.
Microbiology of Fermented Foods

• Breads
  – Involves growth of *Saccharomyces cerevisiae* (baker’s yeast) under aerobic conditions
    • maximizes CO₂ production, which leavens bread
  – Other microbes used to make special breads (e.g., sourdough bread)
  – Can be spoiled by *Bacillus* species that produce ropiness

• Other Fermented Foods
  – Sufu – from fermentation of tofu
  – Sauerkraut (sour cabbage) – from wilted, shredded cabbage
  – Pickles – from cucumbers
  – Silage – from grass, chopped corn, and other fresh animal feeds
<table>
<thead>
<tr>
<th>Foods</th>
<th>Raw Ingredients</th>
<th>Fermenting Microorganisms</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>Coffee beans</td>
<td><em>Erwinia dissolvens</em>, <em>Saccharomyces</em> spp.</td>
<td>Brazil, Congo, Hawaii, India</td>
</tr>
<tr>
<td>Gari</td>
<td>Cassava</td>
<td><em>Corynebacterium manihot</em>, <em>Geotrichum</em> spp.</td>
<td>West Africa</td>
</tr>
<tr>
<td>Kenkey</td>
<td>Corn</td>
<td><em>Aspergillus</em> spp., <em>Penicillium</em> spp., lactobacilli, yeasts</td>
<td>Ghana, Nigeria</td>
</tr>
<tr>
<td>Kimchi</td>
<td>Cabbage and other vegetables</td>
<td>Lactic acid bacteria</td>
<td>Korea</td>
</tr>
<tr>
<td>Miso</td>
<td>Soybeans</td>
<td><em>Aspergillus oryzae</em>, <em>Zygosaccharomyces rouxii</em></td>
<td>Japan</td>
</tr>
<tr>
<td>Ogi</td>
<td>Corn</td>
<td><em>Lactobacillus plantarum</em>, <em>Lactococcus lactis</em>, <em>Z. rouxii</em></td>
<td>Nigeria</td>
</tr>
<tr>
<td>Olives</td>
<td>Green olives</td>
<td><em>Leuconostoc mesenteroides</em>, <em>Lactobacillus plantarum</em></td>
<td>Worldwide</td>
</tr>
<tr>
<td>Ontjom</td>
<td>Peanut presscake</td>
<td><em>Neurospora sitophila</em></td>
<td>Indonesia</td>
</tr>
<tr>
<td>Peujeum</td>
<td>Cassava</td>
<td>Molds</td>
<td>Indonesia</td>
</tr>
<tr>
<td>Pickles</td>
<td>Cucumbers</td>
<td><em>Pediococcus cerevisiae</em>, <em>L. plantarum</em>, <em>L. brevis</em></td>
<td>Worldwide</td>
</tr>
<tr>
<td>Poi</td>
<td>Taro roots</td>
<td>Lactic acid bacteria</td>
<td>Hawaii</td>
</tr>
<tr>
<td>Sauerkraut</td>
<td>Cabbage</td>
<td><em>L. mesenteroides</em>, <em>L. plantarum</em>, <em>L. brevis</em></td>
<td>Worldwide</td>
</tr>
<tr>
<td>Soy sauce</td>
<td>Soybeans</td>
<td><em>A. oryzae</em> or <em>A. soyaе</em>, <em>Z. rouxii</em>, <em>Lactobacillus delbrueckii</em></td>
<td>Japan</td>
</tr>
<tr>
<td>Sufu</td>
<td>Soybeans</td>
<td><em>Actinimucor elegans</em>, <em>Mucor</em> spp.</td>
<td>China</td>
</tr>
<tr>
<td>Tao-si</td>
<td>Soybeans</td>
<td><em>A. oryzae</em></td>
<td>Philippines</td>
</tr>
<tr>
<td>Tempeh</td>
<td>Soybeans</td>
<td><em>Rhizopus oligosporus</em>, <em>R. oryzae</em></td>
<td>Indonesia, New Guinea, Surinam</td>
</tr>
</tbody>
</table>

Wines and Champagnes

- **Enology (wine production)**
  - crushed grapes
    - separation and storage of liquid (must) before fermentation
  - fresh must
    - treated with sulfur dioxide fumigant
    - *Saccharomyces cerevisiae* or *S. liposideus* added for consistent results
    - fermented for 3–5 days at 20–28°C

Distilled Spirits

- Similar to beer-making process
  - begins with sour mash
    - mash inoculated with homolactic bacterium
  - following fermentation, is distilled to concentrate alcohol
Beers and Ales

• Cereal grains used for fermentation
  – malt
    • germinated barley grains having activated enzymes
  – mash
    • the malt after being mixed with water in order to hydrolyze starch to usable carbohydrates
  – mash heated with hops
    • hops provide flavor and assist in clarification of wort
    • heating inactivates hydrolytic enzymes

• Similar to beer-making process
  – begins with sour mash
    • mash inoculated with homolactic bacterium
  – following fermentation, is distilled to concentrate alcohol
Probiotics and Standardization

• Probiotics
  – live microorganisms, which when administered in adequate amounts, confer a health benefit to the host
  – specific requirements should be met

• Microorganisms
  – *Lactobacillus*, *Bifidobacterium*
Possible Benefits of Probiotics

• Immunomodulation
• Control of diarrhea
• Possible modulation of Crohn’s Disease
• *Lactobacillus acidophilus* and *Bifidobacterium*
  – help minimize lactose intolerance
  – improve general intestinal health and balance
  – produce bacteriocins that are destructive to pathogens
  – may lower serum cholesterol
  – may have anti-tumor activity
Probiotic Microbes in Farm Animals

• Probiotics
  – *Lactobacillus acidophilus* in beef cattle
    • decrease *E. coli* O157:H7
  – *Bacillus* strain in poultry
    • limit colonization of gut by the process of competitive exclusion
    • reduces *Salmonella* and *Campylobacter*