Objectives for this Chapter

A student reading this chapter will be able to:

1. Recognize, list, and explain the major reasons for food protection programs.
2. List and describe the major categories and subcategories of agents causing foodborne illness.
3. Describe the major foodborne pathogens including parasitic, viral, and bacterial diseases.

Objectives for this Chapter

A student reading this chapter will be able to:

4. Explain the mechanisms by which these pathogens cause foodborne illness, and describe how the life cycles of these organisms are important in this transmission of disease.
5. List and describe the major disease symptoms in humans for these foodborne pathogens.

Objectives for this Chapter

A student reading this chapter will be able to:

6. Describe and explain the HACCP system in protecting against foodborne disease.
7. Discuss recent regulatory efforts in the area of food protection.

FOODBORNE ILLNESS

Worldwide Distribution of Foodborne Pathogens

1.5 billion children under the age of five suffer from diarrhea, and tragically, over 3 million die as a consequence.
FOODBORNE ILLNESS

- Reasons for varying prevalence among geographic regions
  - Climate
  - Population demographics
  - Nutritional status
  - Cultural aspects

Reason for Food Protection Programs

- The implementation of programs to minimize foodborne diseases is important because of the problems associated with morbidity, mortality, and economic loss.

Morbidity and Mortality Due to Foodborne Disease

- In the United States there are as many as 33 million cases of foodborne illness which are responsible for an estimated 9 thousand deaths annually.

Morbidity and Mortality Due to Foodborne Disease

- The causative agents and modes of transmission (means through which an causative agent is spread) are known in less than 1% of the severe gastroenteritis cases.

Economic Consequences of Foodborne Illness

- Medical Costs
- Loss of Wages
- Recall
- Investigation
- Litigation (Fig. 8-1)
CAUSATIVE AGENTS OF FOODBORNE DISEASE

• Foodborne illness is defined as any illness incurred from the consumption of contaminated food.

CAUSATIVE AGENTS OF FOODBORNE DISEASE

• Radionuclides
• Chemicals
• Food Additives
• Poisonous Plants and Animals
• Pathogens (Table 8-1)

Table 1a

Table 1b

Radionuclides

• Radiation is introduced into the food chain naturally from mineral deposits beneath the earth’s surface or from the atmosphere in the form of ultraviolet and cosmic rays.

Radionuclides

• Radionuclides, which are deposited in the environment accidentally, or intentionally, as a direct result of human activity are of much greater concern.
• Chernobyl
• India vs. Pakistan
Chemicals

- Ironically, man is responsible for many chemical contaminants presently found in food.
- Between 80%-90% of our exposure to potentially harmful chemicals is from food consumption.

Packaging Materials

- Acidic conditions will leach these chemicals from damaged packaging containers
  - Antimony
  - Cadmium
  - Lead

Symptoms

- Antimony
  - Complications of the gastrointestinal, cardiovascular, and hepatic systems
- Cadmium
  - Kidney damage
- Lead
  - Neurological, kidney failure, bone integrity

Industrial Processes

- Mercury
  - Methyl mercury is an acute toxin which causes tremors, neurological complications, kidney failure, and birth defects.
  - Fungicides and animal feed
  - Minamata Bay, Japan
Industrial Processes

- Polychlorinated biphenyls (PCBs)
  - Widely used in industry, they are extremely stable compounds that do not degrade easily, they are resistant to heat, and they are also highly toxic.

Polychlorinated biphenyls (PCBs)

- Rice oil-Japan, 1968
  - 1000 with Symptoms
    - Swelling of the eyes, rash, and gastrointestinal illness, five deaths.

Pesticides

- Organochlorine compounds such as DDT and chlordane, organophosphates such as parathion and malathion, and inorganic compounds such as arsenics, have been have all been applied to food in the form of a pesticide.

Pesticides

- Many of the chemicals banned from use in the United States are sold to developing nations who use them extensively in producing crops for export to the American market.

Pesticides

- The EPA has banned DDT, aldrin, dieldrin, hepaclor, and kepone, yet traces of these compounds and their metabolites continue to be found in our food.
- DDT and other chemicals of its class accumulate in the environment.

Food Additives

- Food additives are intentionally added to food to alter taste, color, texture, nutritive value, appearance, and resistance to deterioration.
Food Additives

• Food additives are considered to be the least hazardous source of foodborne illness, ranking behind pesticides, environmental contaminants, natural toxins, and microbial toxins.

Food Additives

• Food and Drug Act of 1906
  • In 1958, the Food Additive Amendment to the Food Drug and Cosmetic Act required FDA approval before use.
  • Color Additive Amendment of 1950

Food Additives

• Saccharin
  – Causes bladder cancer in lab animals
  – Not covered under the Delaney clause

Food Additives

• Monosodium Glutamate
  – Chinese Restaurant Syndrome (headaches and possible nausea), and lesions of the retina.
  – An allowable daily intake (ADI) of 120mg/kg has been established for individuals over one year of age.

Food Additives

• Nitrates and Nitrites
  – Prevent the growth of Clostridium spores.
  – In the body, nitrates can be reduced to nitrites which in turn oxidize hemoglobin and cause anoxia.
  – In food, nitrites react with amines, to form nitrosamines.
    • Have caused cancer of the liver, kidney, bladder, stomach, and pancreas of laboratory animals.

Food Additives

• GRAS (Generally Recognized as Safe)
  – GRAS substances are chemicals that had a history of safe use before the 1958 Food Additive Amendment passed.
  – There are approximately 700 GRAS substances.
  – Currently, the FDA is reviewing their safety and reclassifying if necessary.
Poisonous Plants and Animals

• By the process of trial and error, humans have identified plants that were either harmful to man, or possessed little nutritional value, and excluded them from our diet.
• Some plants and animals known to be harmful to man have a significant nutritional value and are still part of our diet.

Plant Sources

• Lectins
  – Lectins are plant proteins (the Leguminosae family) that agglutinate red blood cells.
• Saponins
  – Saponins are glycosides that hemolyze red blood cells.
  – As we are experiencing dietary shift to healthier foods such as alfalfa and soy based products, we can also expect an increase of saponin intoxications.

Animal Sources

• Paralytic Shellfish Poisoning
  – Shellfish become toxic to humans when they feed on dinoflagellates such as Gonyaulax catenella in numbers greater than 200/ml of water.
  – Symptoms include a tingling or burning sensation of the lips and gums, ataxia, and paralysis of the diaphragm.

FOODBORNE PATHOGENS

• More than 40 potential foodborne pathogens have been listed by CAST (Table 8-3).

Table 8-3
FOODBORNE PATHOGENS

- Listed below are reasons for the surfacing of new and old pathogens.
  - Decrease in lactic acid bacteria
  - Contaminated water applied to food
  - Abuse of Antibiotics
  - Dietary shift
  - Longer shelf-life, ready-to-eat

Parasitic Infections
  - The Nematodes
    - Trichinella spiralis (Fig. 8-2)
    - Taenia solium (Fig. 8-3)
    - Taenia saginata (Fig. 8-4)

Fig. 8-2
Trichinosis life cycle

Fig. 8-3a
Taenia solium life cycle

Fig. 8-3b
Taenia solium life cycle

Fig. 8-4a
Taenia saginata life cycle
The Protozoans

- Entamoeba histolytica (Fig. 8-5 a-b)
  - Affects about 10% of the world's population.
  - Outbreaks occur where sanitation is poor, risky sexual habits are practiced, and in institutional facilities.
  - Symptoms range from mild diarrhea to amoebic dysentery.

- Giardia lamblia
  - Giardia lamblia is a protozoan flagellate found in areas with poor sanitation, and in unfiltered surface water supplies (Fig. 8-6).
  - Giardiasis is most common among those who travel to endemic areas, in homosexuals, and in child day care settings.
**Giardia lamblia**
- Cysts reach the surface water supplies through the fecal deposits of beaver and muskrats
- Symptoms consist of nausea, explosive diarrhea (up to ten movements per day), and fatigue.

**The Protozoans**
- **Cryptosporidium**
  - Primarily a waterborne pathogen, *Cryptosporidium* is transmitted via water contaminated with feces from human and agricultural origins.
  - Milwaukee, 1993

**Cryptosporidium**
- Foodborne transmission of *Cryptosporidium* occurs via the fecal-oral route, usually from careless food handlers shedding the hardy oocysts (see life cycle, Fig. 8-7) of the organism.

**FOODBORNE PATHOGENS**
- **Viruses**
  - Microscopic particles that usually contain a single strand of RNA
  - Require a host cell for replication to occur.
  - The two most prominent foodborne viruses of present day are Hepatitis A and Norwalk-like virus.
Viruses

• Hepatitis A
  – Transmitted via the fecal-oral route, and causes liver infection occasionally accompanied by jaundice.
  – Contamination occur by infected food workers handling foodstuffs, or from food products that have come in contact with water polluted with fecal matter.

• Norwalk-like Virus
  – In 1982, Norwalk-like viruses were the leading cause of reported foodborne illness in the United States, responsible for 5000 cases from two different outbreaks.

• Norwalk-like Virus
  – Food products such as creams, cream fillings, and salads, are efficient vehicles for viruses because they do not undergo any extensive heating before being served.
  – Symptoms include diarrhea and nausea

FOODBORNE PATHOGENS

• Fungi
  – Fungi, such as molds and yeasts are single and multi-celled plant-like organisms that grow on cereals, breads, fruits, vegetables, and cheeses (Fig. 8-8).

FOODBORNE PATHOGENS

• Fungi
  – The majority of molds are aerobes.
  – Yeasts are facultative anaerobes.
  – Mycotoxins are mold metabolites produced on food, which cause illness or death when ingested by man or animals.
Fungi

• Aspergillus flavus (Fig. 8-9)
  • Turkey X Disease
  • Four primary aflatoxins, B1, B2, G1, and G2, which are found in peanuts, corn, and cotton seed.
  • Causes hemorrhaging, anemia, ataxia, hemoptosis, cirrhosis of the liver, and is a very potent carcinogen.

*Penicillium* spp. (Fig. 8-9)

• Rubratoxin, patulin, and yellow rice toxins are produced by members of the genus *Penicillium*.
• Symptoms include vomiting, difficulty breathing, low blood pressure and respiratory arrest.

*Mucor and Rhizopus* spp. (Fig. 8-9)

• Mucormycosis is the disease caused by fungi in the order Mucorales.
• Common spoilage organisms of bread and fruit.
• Symptoms include the invasion of blood vessels, causing embolisms and tissue necrosis.

FOODBORNE PATHOGENS

• Bacteria
  • Bacteria are the single-celled organisms which are responsible for more than 80% of foodborne illness.
  • Two broad groups of bacteria classification are:
    • gram-positive
    • gram-negative.
Another characteristic useful in identifying bacteria is the ability to grow in the presence or the absence of oxygen (Fig. 8-11).

- Aerobic bacteria
- Anaerobic
- Facultative anaerobe
- Microaerophilic

If the anaerobe *Clostridium botulinum* is suspected, the investigator might search for endospores, which are structures produced during the life cycle of certain bacteria (Fig. 8-12).

*Salmonella spp.*
- Gram-negative, facultative anaerobes.
- Estimated 2-4 million cases a year in the U.S.
- Three syndromes are caused by *Salmonella* species, typhoid fever, enteric fever, and gastroenteritis.
### Bacteria

- **Salmonella spp.**
  - The disease is transmitted via food, water, and the fecal-oral route.
  - These organisms colonize in the small intestine, causing intestinal inflammation, resulting in diarrhea, abdominal cramps, chills, fever, and vomiting, which last 1-4 days.

### Bacteria

- **Staphylococcus spp**
  - Staphylococcus food poisoning, caused by the gram-positive cocci, *Staphylococcus aureus*.
  - Sickness is due to the consumption of the heat stable enterotoxin, and includes nausea, vomiting, and diarrhea.

### Staphylococcus aureus

- Contamination occurs through the preparation of foods by infected food handlers. Foods such as creams, cream pies, potato salad, and ham have all been implicated in outbreaks of Staphylococci food poisoning.

### Bacteria

- **Clostridium spp.**
  - *Clostridium perfringens* and *Clostridium botulinum* are spore-forming anaerobic bacteria found in soils throughout the world.

### Clostridium botulinum

- Botulism is the illness that results when *C. botulinum* spores germinate and produce a toxin in the food to be ingested.
- By destroying the spores in foods before canning or storing products, risk of botulism can be eliminated.

### Bacteria

- **Clostridium botulinum**
  - There are seven types of *C. botulinum*, A-G, which are identified by the toxin they produce.
  - The A toxin is the most common in the United States, and has been isolated in fruits, vegetables, fish, condiments, beef, pork, and poultry.
**Clostridium botulinum**

- **Symptoms**
  - At the onset, symptoms such as nausea, vomiting and diarrhea, are present, then as the condition develops, fatigue, blurred vision, difficulty speaking and swallowing are experienced.

**Bacteria**

- **Campylobacter**
  - *Campylobacter* species are part of the normal flora of the gastrointestinal tract of warm blooded animals.
  - During food processing, the intestinal tract is lacerated, allowing feces to contaminate the food.

**Campylobacter**

- *Campylobacter* can survive for weeks in refrigeration at 4°C
- Symptoms are usually mild including nausea, vomiting, and bloody diarrhea, but in severe infections, Gullian Barre Syndrome develops, which causes neuromuscular paralysis.

**Escherichia coli**

- **Enteroinvasive** *E. coli* invade the epithelial cells of the intestine, resulting in fever, chills, and bloody diarrhea.
- **Enterotoxigenic** *E. coli* are responsible for traveler’s diarrhea, produce a toxin, and exhibit cholera like symptoms.
- **Enteropathogenic** *E. coli* are most commonly found among infant nurseries in developing countries.
- **Enterohemorrhagic** *E. coli*, also known as *E. coli* O157:H7 is the result of consuming improperly cooked ground beef, raw milk, or unpasteurized apple cider.
Escherichia coli

• *E. coli* O157:H7
  – Symptoms generally include abdominal cramps, watery to bloody diarrhea, vomiting, and possibly a fever and;
  – Hemolytic uremic syndrome (HUS), which is the primary cause of renal failure in children.

Vibrio cholerae

– Gram negative vibrio
– Responsible for the disease cholera which is common among LDCs and international travelers.
– In Peru, in 1991, an outbreak of cholera spread to 322,562 Peruvians.

Vibrio cholerae

• *Vibrio cholerae* colonizes on the lining of the intestine and produces the toxin choleragen.
• Symptoms present as abdominal pains, dehydration, and a characteristic diarrhea, which has been termed “rice water stool.”

Factors Frequently Cited in Foodborne Illness

– 1. Improperly refrigerated food.
– 2. Improperly heated or cooked food.
– 4. Lapse of a day or more between preparing and serving food.

Factors Frequently Cited in Foodborne Illness

– 5. Introducing raw or contaminated materials to a food that will not undergo further cooking.
– 6. Improper storage of foods at temperatures ideal for bacterial growth.

Factors Frequently Cited in Foodborne Illness

– 7. Failure to properly heat previously cooked foods to temperatures that will kill bacteria.
– 8. Cross contamination of ready to serve foods with raw foods, contaminated utensils or machinery, or through the mishandling of foods.
Figure 8-13 illustrates some useful procedures for reducing food contamination.

Hazard Analysis Critical Control Points

- In response to this present threat, the federal government has mandated the implementation of hazard analysis critical control points (HACCP) strategies in the seafood, poultry, and meat industries.

Table 8-4

<table>
<thead>
<tr>
<th>HAZARD CRITICAL CONTROL POINT (HACCP SYSTEM)</th>
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<tbody>
<tr>
<td><strong>Assessing Hazards</strong></td>
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<tr>
<td>- Identify generally hazardous foods</td>
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<tr>
<td>- Follow the line of food in process</td>
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<tr>
<td>Hazard: Air movement, storing,</td>
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<td>preparing, cleaning, handling,</td>
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<tr>
<td>cooking, and reheating</td>
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<tr>
<td>- Estimate risk</td>
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<td><strong>Identifying Critical Control Points (CCPs)</strong></td>
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<tr>
<td>- Develop procedure and workflow</td>
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<tr>
<td>showing the flow of food and all the</td>
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<tr>
<td>CCPs</td>
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<tr>
<td><strong>Setting Up Procedures and Standards</strong></td>
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<td>for CCPs</td>
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<tr>
<td>Standards must be at each CCP</td>
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<td>and should be measurable, based on</td>
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<td>fact, correct for trouble, clear</td>
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<td>directions with specific actions.</td>
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<tr>
<td><strong>Managing CCPs</strong></td>
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<tr>
<td>- Observe and identify standards</td>
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<tr>
<td>- Employees should be encouraged to</td>
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<tr>
<td>- Follow up CCPs</td>
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<td>- Monitor CCPs</td>
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<td><strong>Identifying CCPs</strong></td>
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United States Regulatory Efforts with Regard to Food Protection

- On December 18, 1997, the FDA required that all seafood processors, domestic and those importing to the United States, carry out a hazard analysis of their products and processes.
United States Regulatory Efforts with Regard to Food Protection

– On January 27, 1997, the USDA required meat and poultry slaughterers and processing facilities have sanitation SOPs in place, and that they also conduct generic *E. coli* testing.

Surveillance efforts

– The Foodborne Diseases Active Surveillance Network (FoodNet)
– Since January 1, 1996, it has identified outbreaks of *Campylobacter* in California, *Salmonella* in Oregon, and two outbreaks of *E. coli* O157:H7 in Connecticut.