Microorganisms and Foodborne Illness

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Microorganisms are tiny living creatures, much too small to see with the naked eye. In recent years, a number of widely reported outbreaks of foodborne illness caused by microbial contamination have increased public awareness and concern about the safety of food.

Microorganisms are everywhere in nature and in human environments. There are many beneficial bacteria that give many food products their characteristic flavor and quality. Ripened cheeses, pickles, sauerkraut, and fermented sausages benefit from certain lactic acid bacteria that ferments the food and produces an acidic flavor. A good example of adding a beneficial bacteria is adding lactic acid to milk to form curds for cheese. Microorganisms need food, just as humans do, so they compete with us for our food supply. Food can supply nutrients that support their growth. Under the right conditions, some of those microorganisms can cause human illness; others can cause the food to spoil. Spoilage bacteria, such as mold, can cause food to deteriorate and spoil. These bacteria typically cause flavor changes, unpleasant odors, and texture changes. An example is moldy fruit. Spoilage bacteria typically don't cause illness but are unpleasant to eat. In contrast, pathogenic bacteria may not cause visible changes to food; therefore, the consumer will not know if the bacteria is present. These bacteria will be discussed in more detail.

The Problem of Foodborne Illnesses

Foodborne illnesses generally cause temporary disorders of the digestive tract; however, they can also lead to more serious consequences. According to the Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, there are an estimated 250 foodborne pathogens. Contamination can occur at any point in the food chain, from farm to table.

According to U.S. Department of Agriculture estimates, the cost of medical treatment, lost productivity, and costs of premature deaths for diseases from selected bacteria may have been as much as $6.9 billion during 2000. Because of ineffective and under-resourced monitoring procedures, data on actual cases and outbreaks of foodborne illness are inaccurate and greatly underrepresent the actual incidence of illness.

The Foodborne Diseases Active Surveillance Network (FoodNet) was created in 1996 as the primary foodborne disease portion of CDC's Emerging Infections Program (EIP). Ten states are currently part of the FoodNet program including California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, and Tennessee. The purpose of the program is to better determine the enormity of foodborne disease across the United States. Trends are tracked to monitor the growth or decline in foodborne illness. Specific foods and locations are identified to determine the proportion of foodborne disease to those foods. Pathogens that are monitored include *Campylobacter jejuni*, *Cyclospora*, *Crytosporidium*, *E. coli* O157:H7, *Listeria monocytogenes*, *Salmonella*, *Shigella*, *Vibrio vulnificus*, and *Yersinia enterocolitica*.

The majority of cases of foodborne illnesses are not reported because the initial symptoms of most foodborne illnesses are not severe enough to require medical attention, the medical facility or state does not report such cases, or the illness is not recognized as foodborne. It is estimated, however, that millions of people become sick each year from contaminated food and several thousand die. In 1996, it was estimated that between 6.5 million and 81 million cases of foodborne illness and as many as 9,100 related deaths occur each year.

In 2004, it was reported there were significant declines in foodborne illness due to common bacterial pathogens. From 1996-2004, the incidence of *E.coli* O157:H7 decreased 42 percent. *Campylobacter* infections decreased 31 percent, *Cryptosporidium* dropped 40 percent and *Yersinia* dropped 45 percent. Overall, *Salmonella* infections dropped 8 percent, but only one strain showed a significant decline.

Bacterial pathogens are the most commonly identified cause of foodborne illness. They are easily transmitted and can multiply rapidly in food, making them difficult to control.

In 2003, CDC has targeted the following foodborne diseases as reportable: *E. coli* O157:H7, Salmonellosis, Listeriosis, and Trichinellosis.

The CDC also is concerned about other bacterial pathogens, such as *Vibrio vulnificus* and *Yersinia enterocolitica* that can cause serious illnesses, and *Clostridium perfringens* and *Staphylococcus aureus* that cause less serious illnesses but are very common.

Viral pathogens are often transmitted by infected food handlers or through contact with sewage. Hepatitis A and Norwalk viruses are proven to cause foodborne illnesses.

Public health officials believe that the risk of foodborne illnesses is increasing. Because of our large-scale food production and distribution system, products that may be contaminated can reach a greater number of people.

In addition, new and more virulent strains of previously identified harmful bacteria have appeared in the past several decades. Some of these organisms are resistant to usual controls such as refrigeration.

Furthermore, the populations of "at risk" persons – the old, the very young especially in day-care settings, those who have chronic illnesses, those with immune disorders such as HIV/AIDS—are increasing. Also, employee turnover and the need for constant training and supervision and other factors in the foodservice industry, and mishandling or improper preparation at any step in the food system, including the home, can further increase the risk.

In general, animal foods – beef, pork, poultry, seafood, milk, and eggs – are more frequently identified as the source of outbreaks in the United States than nonanimal foods. Increasingly, however, produce such as apples, lettuce, potatoes, onions, garlic, sprouts, berries, melons, and tomatoes have been associated with foodborne illnesses.

Not Just the Flu

Many foodborne illnesses are brief and cause flu-like symptoms—nausea, vomiting, and minor aches and pains. In a small percentage of cases, more serious illness and death can result. Foodborne infections can spread through the bloodstream to other organs. Complications also can result when diarrhetic infections act as trigger mechanisms in certain individuals, causing an illness such as reactive arthritis to flare up. In other cases, no immediate symptoms appear, but serious consequences eventually develop. About 2 to 3 percent of all cases of foodborne illness lead to serious consequences.

E. coli O157:H7 can cause kidney failure in young children and infants. It is most commonly transmitted to humans through eating undercooked ground beef.

The largest reported outbreak in North America occurred in 1993 and affected more than 700 people. Fifty-five patients, including four children who died, developed hemolytic uremic syndrome, which is characterized by kidney failure.

Salmonella can lead to reactive arthritis, serious infections, and deaths. In recent years, outbreaks have been caused by the consumption of many different foods of animal origin, including beef, poultry, eggs, milk, and dairy products, and pork.

The largest outbreak occurred in the Chicago area in 1985 and involved more than 16,000 laboratory-confirmed

Figure 1. Some Foodborne Pathogens that Can Cause Serious Illnesses.

Bacteria	***Potential illnesses***	***Food sources of the bacteria***
Campylobacter	Arthritis, blood poisoning, Guillain-Barre syndrome (paralysis); chronic diarrhea; meningitis; and inflammation of the heart, gallbladder, colon, and pancreas.	Poultry, raw milk, meat, mushrooms, shellfish, clams, eggs, water
E. coli O157:H7	Hemolytic uremic syndrome (HUS) which is associated with kidney failure, neurologic disorders, other illnesses	Meat (especially ground beef), raw milk, alfalfa sprouts, apple cider, poultry, hot dogs, lettuce, dry cured salami
Listeria	Meningitis, blood poisoning, stillbirths, and other disorders.	Soft cheese, other dairy products, meat, poultry, seafood, fruits, vegetables, hot dogs
Salmonella	Reactive arthritis, blood poisoning, Reiter's disease (inflammation of joints, eye membranes, and urinary tract), and inflammation of the pancreas, spleen, colon, gallbladder, thyroid, and heart.	Poultry, meat, eggs, dairy products, seafood, fruits, vegetables, chocolate, peanuts, sauces, salad dressings,
Shigella	Reiter's disease, HUS, pneumonia, blood poisoning, neurologic disorders, and inflammation of the spleen.	Salads (potato, tuna, shrimp, macaroni, chicken), milk and dairy products, and produce, poultry, water
Vibrio vulnificus	Blood poisoning	Seafood (oysters, clams, crabs)
Yersinia enterocolitica	Reiter's disease, pneumonia, and inflammation of the vertebrae, lymphatic glands, liver, and spleen	Meat, raw milk, oysters, fish

cases and an estimated 200,000 total cases. Some of these cases resulted in reactive arthritis. One institution that treated 565 patients from this outbreak confirmed that 13 patients developed reactive arthritis after consuming contaminated milk. In addition, 14 deaths may have been associated with the outbreak.

Listeria can cause meningitis and stillbirths and has a fatality rate of 20 deaths per 100 illnesses. The CDC reports that the rate of listeriosis dropped 35 percent from 1996 to 2002. All foods may contain these organisms, particularly raw poultry and unpasteurized dairy products. It is also found in ready-to-cut meats.

The largest outbreak occurred in 1985 in Los Angeles, largely in pregnant women and their fetuses. More than 140 cases of illness were reported, including at least 13 cases of meningitis. At least 48 deaths, including 20 stillbirths or miscarriages, were attributed to the outbreak. Soft cheese produced in a contaminated factory environment was confirmed as the source.

Campylobacter may be the most common factor for Guillain-Barre (G-B) syndrome, which is now one of the leading causes of paralysis from disease in the United States. *Campylobacter* infections occur in all age groups, with the greatest incidence in children under one year of age. Most cases occur individually, primarily from poultry, not during large outbreaks.

The CDC estimates 1 in every 1,000 reported cases of *Campylobacter* leads to G-B syndrome. That means about 40 percent of G-B cases are a result of *Campylobacter* infection.

Figure 2. How Microorganisms Grow

Starting with one organism. . .

Generation	Number of Bacteria
1	1
2	2
3	4
4	8
5	16
6	32
7	64
8	128
9	256
10	512
11	1,024
12	2,048
13	4,096
14	8,192
15	16,384
16	32,768
17	65,536
18	131,072
19	262,144
20	524,288
21	1,048,576
22	2,097,152
23	4,194,304
24	8,388,608
25	16,777,216
26	33,554,432
27	67,108,864
28	134,217,728
29	268,435,456
30	536,870,912

Preventing Growth of Microorganisms

Microorganisms are everywhere. When fruits, vegetables, and other crops are harvested and when livestock are slaughtered or milk is taken from cows, microorganisms are present. Further contamination occurs as food commodities move through the food system.

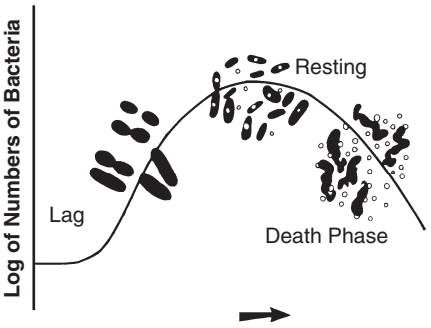
Some of these bacteria may spoil food as they produce acids (souring), long chains of carbohydrates (slimes), odoriferous compounds from protein (foul odor), and pigments (discolorations); sometimes they liquefy food. Other bacteria may cause illness if people eat food that has not been handled properly.

Growth of Microorganisms

Microorganisms grow rapidly. Figure 2 shows how microorganisms grow by starting with a single microorganism: 1 becomes 2, 2 become 4, 4 become 8, 8 become 16, and so on. This is called logarithmic growth.

The time it takes a bacterial cell to reproduce is called the generation time. The figure also shows how important initial numbers of bacteria are.

Figure 3. Typical Growth Curve



If we start with the 20th generation containing 524,288 bacteria, it takes only one generation to reach 1,000,000 bacteria, which is a large enough population to cause spoilage to begin in food products. If the equipment, personnel, and product are clean, the initial numbers of bacteria will be lower, and we may begin with the 15th generation of 16,384. In this case, shelf life will increase, and it will take five times longer to reach 1,000,000 bacteria.

Figure 3 shows a typical growth curve. Four distinct phases occur in the growth curve: lag; log or growth phase; stationary or resting phase; and death phase.

Bacteria need about four hours to adapt to a new environment before they begin rapid growth. In handling food, this means we have less than four hours to make a decision to either cool the food, heat it, or eat it.

For example, when chickens arrive at the dock of a fast food outlet, at a restaurant, or at your home, you must decide whether to heat and eat them, to refrigerate them at a low temperature (chickens freeze at 28°F) for a short period of time, or to wrap and freeze the chicken for longer storage. If you don't decide, the bacteria will enter the log phase of growth, multiplying rapidly and causing food to spoil or causing an opportunity for foodborne illnesses.

Spoilage bacteria produce the slime, toxins, off-colors, and odors associated with food spoilage in the log phase of growth. Pathogenic bacteria can grow

and produce large numbers or toxic compounds and these are usually not detected by off odors, flavors, etc. Remember, the four hours bacteria remain in the log phase is approximate and cumulative.

As microorganisms grow, they tend to form colonies of millions of individual cells. Once a colony forms, the food available to each cell is limited and excretions from these millions of cells become toxic to a microbe. This is the stationary phase. Some of the cells now begin to die.

If we can control bacterial growth, we can control the major cause of food spoilage and foodborne illness.

Keeping initial bacteria levels low is important. A food product that starts with 100 microorganisms per gram may have a shelf life of 12 days before it develops off odors, slime, and spoilage. When the initial number is 5,000 per gram, the shelf life of that same foodstuff may be shortened to seven days. Because so much depends on the initial number of bacteria, temperatures, and handling practices, a specific shelf life for a category of food products is difficult to determine.

A good "rule of thumb" is:

To double the shelf life of a food that needs refrigeration, lower the temperature 18° F.

That is, for every 18° F decrease in storage temperature, food will last twice as long.

Good personal hygiene, sanitizing equipment, controlling temperature, and using chlorinated water where possible are all practices that help keep initial numbers low.

Requirements for Growth—FATTOM

Microorganisms need

- food to meet growth requirements,
- the right acid/base conditions,
- time at conditions that allow growth,
- temperatures that support growth,
- specific oxygen (or no oxygen) requirements, and
- moisture.

Different microorganisms require different combinations of these factors.

Food. Like all living things, bacteria require food to live, but they need only very small quantities. Some protein or fat left on the wall of a processing plant, grease on the blade of a knife, or food residues on the wheel of a can opener or on a cutting board are a feast for microorganisms as well as for larger pests.

Acid/base. Every microorganism has an optimal pH (acid) concentration for growth. Yeasts and molds favor more acidic conditions than bacteria.

Time. Some organisms grow faster than others. Under ideal conditions, certain bacterial populations can double in as short as nine minutes; others require hours. Bacteria that reproduce most quickly will dominate.

Temperature. Temperature is probably the single most important factor in preventing microbial food spoilage. Generally speaking, the cooler the food is kept, the longer shelf life it will have.

A thermometer in the refrigerator is a necessity. Maintain the temperature at 35° to 40°F. Remember, however, that some foods, such as tomatoes and lettuce, will freeze or be damaged at 32° to 33°F.

Different bacteria require different temperatures for maximum growth. Some bacteria will grow at refrigerated temperatures. Others will only grow at moderate temperatures. Warm-loving bacteria grow at temperatures above 140°F. They grow and reproduce at a slower rate at temperatures above and below the optimum. Food spoilage bacteria grow best at environmental temperatures of 70° to 100°F.

Oxygen use. Microorganisms are considered aerobic if they can use oxygen, anaerobic if they grow best without oxygen, and facultative if they can grow well with or without oxygen.

Moisture. All living things require moisture, and bacteria are no exception. Perishable foods requiring refrigeration usually have very high moisture contents. Moist food left over for long periods of time provides adequate moisture for bacterial growth.

Bacteria need water because their only means of obtaining food is by absorption similar to that of a sponge. This process cannot be accomplished without moisture, which explains why foods such as dried milk, dried soups, and cereals do not spoil microbiologically. The organisms are there . . . but they can't eat.

Bacterial Causes of Foodborne Illness

Bacillus cereus

The disease: Two distinct syndromes may occur. In one, the toxin produced results in diarrhea, and in the other, the toxin causes vomiting. Generally, the diarrheal toxin is associated with consumption of puddings, starchy sauces, or vegetables such as mashed potatoes. The emetic syndrome is most frequently associated with cooked rice.

The organism: Bacillus cereus forms heat-resistant spores so it can survive the initial cooking of starch-based products. The spore can then germinate if cooked products are not kept hot (140°F or higher) before serving.

Control: Avoid holding freshly cooked, hot grain foods and vegetables any longer than necessary before serving. Keep cooked foods hot to prevent spore germination or refrigerate and chill rapidly. Reheat previously cooked rice and vegetable dishes to 165°F prior to serving. Avoid slow cooling and reheating.

Campylobacter jejuni

The disease: Campylobacter jejuni has been recognized for years as a cause of abortion in sheep. Campylobacteriosis or Campylobacter enteritis in humans is now more common in the United States than salmonellosis. Common symptoms include profuse and sometimes bloody diarrhea, nausea, cramps, headache, and fever.

Onset is within two to five days after eating contaminated food. The illness may last two or three days, but it can last weeks or months with complications such as meningitis, cholecystitis, urinary tract infection, and reactive

arthritis. The CDC estimates 124 fatalities each year.

The organism: C. jejuni is found in the intestinal tract of animals, with almost 100 percent occurrence in poultry. Raw meats and poultry are important sources along with raw milk and untreated water supplies. The majority of cases have occurred after consuming raw milk, undercooked poultry, or raw meat. Infected cats and puppies are also sources.

Control: The organism requires reduced oxygen levels and can survive several weeks of refrigerator temperatures. It is easily killed by heat and is inhibited by acid, salt, and drying.

To control *C. jejuni*, drink only pasteurized milk; avoid cross-contamination of cooked or ready-to-eat foods by utensils, equipment, or cutting surfaces not properly cleaned and disinfected after contact with fresh, uncooked meats or poultry; and use good personal hygiene; wash hands after handling raw meats to avoid transmitting organisms to other foods and utensils.

Clostridium perfringens

The disease: Ingestion of food containing large numbers of vegetative cells of *Clostridium perfringens* is necessary for illness to occur. In the intestines, the vegetative cells can form spores and release toxins. Diarrhea and severe abdominal pain are the usual symptoms. Nausea is less frequent. Fever and vomiting are unusual. Death is uncommon, but has occurred in older, debilitated people.

The organism: Spores of *C. perfringens* are found in soil. The organism also is part of the normal intestinal content of animals and humans. *C. perfringens* requires protein for growth and will grow with or without oxygen. Spores are common in raw foods, and they are heat-resistant.

Cooking foods will destroy vegetative cells but not necessarily the spore forms of the bacteria. In addition, cooking drives off oxygen, kills competing organisms, and heat shocks the spores. Then, the remaining spores may germinate, resulting in rapid growth of new vegetative cells, especially in foods that have been allowed to cool slowly with inadequate refrigeration. If food is inadequately reheated, ingested organisms could then cause illness.

Control: Illness can be prevented by proper handling of foods, particularly meats, poultry, stews, roasts, meats, pies, casseroles, and gravies. Cook items and then cool them rapidly in shallow pans in the refrigerator. Avoid cooling gravy, stews, or chili in deep cooking pots. If foods are to be held hot, keep the temperature above 140°F. Thoroughly reheat leftovers (to 165°F) before eating. Use good personal hygiene.

Clostridium botulinum

The disease: Foodborne botulism results from eating food in which *Clostridium botulinum* has grown and produced neurotoxin. The toxin is absorbed and binds to nerve endings. It causes vomiting and diarrhea, fatigue, dizziness, and headache. Later there is constipation, double vision, dry mouth, and difficulty speaking and swallowing. Involuntary muscles become paralyzed. Cardiac and respiratory failure, and ultimately, death occurs. Symptoms usually show within 18 to 36 hours after eating, but could be as long as 10 days. Today, because of rapid treatment, botulism is fatal in fewer than 10 percent of cases. Recovery may take years.

Infantile botulism, affecting infants under fourteen months, is another type of botulism, first identified in 1976. This disease can occur after infants ingest bacterial spores which colonize and produce toxin in the intestinal tract.

Spores have been found in honey and syrups and have been implicated in some cases of infantile botulism. Other nonfood items may be sources of spores. Symptoms of infantile botulism include constipation followed by lethargy, poor feeding, weakness, drooling, weak cry, and loss of head control.

The organism: C. botulinum spores are widely distributed in soils, shore, and bottom deposits of lakes and streams, gills and viscera of fish, and seafood. They can be found on fruits and vegetables, as these items are often in contact with the soil. Spores have also been found in honey and corn syrup. Meats and vegetables can provide nutrients for growth and toxin production.

Control: Conditions favoring growth and toxin production by *C. botulinum* include high-moisture, low-salt, low-acid (pH greater than 4.6), low-oxygen foods such as canned or vacuum-packed products, and storage at room temperature. Foods commonly involved include canned vegetables, fish, meats, chili sauce, chili peppers, tomato relish, and salad dressing.

The majority of outbreaks have been caused by home-processed foods. Other foods include foil-wrapped baked potatoes held at warm, not hot temperature (above 140°F); cooked onion also held at warm temperatures; and garlic in oil mixtures stored at room temperature.

C. botulinum spores are heat-resistant. Therefore, canned meat, poultry, fish, and low-acid vegetables (i.e., corn, beans, spinach, beets) require pressure canning to achieve a high enough temperature (240°-250°F) for sufficient time to destroy spores.

It is important for home canners to use research-based, up-to-date processing methods. Oven, microwave, and open-kettle canning are definitely not recommended! Avoid use of home vacuum packaging machines to enhance storage of low-acid, high-moisture refrigerated products. Store leftover foods and commercially vacuum packaged meats in the refrigerator or freezer. Avoid feeding honey and corn syrup to infants.

Escherichia coli O157:H7

The disease: At least four types of *Escherichia coli* can cause gastrointestinal disease in humans. One type causes infantile diarrhea; another can cause traveler's diarrhea, associated with travel in foreign countries.

Another type causes a dysentery-like illness similar to shigellosis, and

a fourth type, O157:H7, produces hemorrhagic colitis, a severe illness characterized by bloody diarrhea and severe abdominal cramps. Hemolytic uremic syndrome (HUS) can be a complication in children and is a leading cause of acute kidney failure.

The organism: This organism is a normal component of the gastrointestinal tract. The major source of the bacteria in the environment is the feces of humans. Feces and contaminated water are the most likely sources for food contamination. For years, *E. coli* was considered harmless to health and was used as an indicator of fecal contamination in food and water.

Control: Foods that have been implicated in *E. coli* O157:H7 outbreaks of foodborne illness include mold-ripened cheeses, inadequately cooked ground beef, lettuce, and unpasteurized apple beverages. Good sanitation practices in the manufacture of products such as cheese, good personal hygiene when working with food, cooking meat thoroughly (155°F is the 2001 Food Code recommendation for foodservice and 160°F is the FSIS recommendation for consumers at home), and avoiding recontamination after cooking or processing will control *E. coli* O157:H7.

Listeria monocytogenes

The disease: Listeria monocytogenes causes the disease listeriosis. Before the 1980s, it was associated with abortions and encephalitis in sheep and cattle. The disease in humans begins with nausea, headache, fever, and vomiting. In severe cases, meningitis, abortion, stillbirth, and perinatal septicemia can occur. The disease is rare in nonpregnant healthy adults; however, adults with the following conditions are more susceptible: neoplasm, AIDS, alcoholism, type 1 diabetes, cardiovascular disease, renal transplant, and corticosteroid therapy. The mortality rate is about 30 percent in the unborn, newborn, or immune compromised. Outbreaks have been associated with consumption of milk, certain soft cheeses, and coleslaw made from contaminated cabbage that had been fertilized with infected sheep manure. Postpasteurization contamination can also be a cause of outbreaks.

The organism: L. monocytogenes is widely distributed in soil, vegetation, water, and animals. The organism can survive for long periods in soil, silage, feces, and milk and other dairy foods. It grows well in sewage. Use of sewage sludge and effluent on edible crops is hazardous, as is the use of manure from infected livestock.

Listeria is capable of growing at refrigerator temperature, but it is sensitive to heat. It also tolerates high concentrations of salt. Because of its wide distribution in nature, its ability to survive for long periods, and its ability to grow under refrigeration, *L. monocytogenes* could be an important cause of foodborne illness in the future, particularly as the popularity of ready-to-eat, refrigerated foods continues to increase.

Control: To control the organism, control its occurrence in raw food materials and follow good sanitation practices in food processing plants. Use pasteurized milk and avoid postpasteurization contamination of milk. Cook foods thoroughly.

Salmonella

The disease: Salmonellosis is the classic example of foodborne infection. There are actually three types of diseases caused by *Salmonella:* Enteric fever caused by *S. typhosa*, in which the organism, ingested with food, finds its way into the bloodstream and is excreted in the stools; septicemia caused by *S. choleraesuis* in which the organism causes blood poisoning; and gastroenteritis caused by *S. tyhimurium* and *S. enteritidis*, a true foodborne infection. In this case, large numbers of organisms are ingested with food and cause localized infection of the intestinal tract with no invasion of the blood stream.

Symptoms of salmonellosis include nausea, vomiting, headache, chills, diarrhea, and fever. In most cases the disease is short-lived and the person recovers. It can be fatal, however. Those at greatest risk include the very young, the aged, and those whose health status is poor.

Mortality rate from enteric fever is high. *Salmonella typhi* is the common cause of enteric fever, but any of the more than 2,000 different *Salmonella* organisms are capable of causing enteric fever.

In addition to the acute effects of *Salmonella* infection, it is now known that serious chronic rheumatoid or cardiac problems may occur after recovery from the acute disease.

The organism: Salmonella are widely distributed in both wild and domestic, warm- and cold-blooded animals. It is estimated that some 40 percent of all poultry are contaminated. The disease in humans reflects the close human association with animals.

Meat and poultry are the most important sources of *Salmonella*. Because *Salmonella* are very heat-sensitive, they are destroyed by normal cooking and pasteurization processes. They will, however, survive long periods of time in dried or frozen foods. When frozen foods are thawed, these organisms can grow again.

Control: In homes and foodservice sites, human salmonellosis can be prevented by proper handling of meats, poultry, and other animal foods. Keep raw foods away from cooked foods, avoiding cross-contamination. Cook animal foods thoroughly and hold at either cold temperatures (below 40°F) or hot (above 140°F). Avoid drinking unpasteurized milk. Thaw turkeys, roasts, fish, and other meats in the refrigerator, not on the countertop. Use good personal hygiene practices.

A number of recent outbreaks of salmonellosis have been due to processing errors, particularly in the handling of milk, cheeses, and deli meats. Problems of this nature are controlled by more attention to sanitation and quality control at the processing plant.

Shigella

The disease: Shigellosis, also known as bacillary dysentery, is caused by several bacteria of the genus *Shigella*.

Symptoms include diarrhea (often bloody), abdominal pain, vomiting, and fever. Generally, foodborne shigellosis involves a short incubation time (seven to thirty-six hours), but symptoms persist three to fourteen days. As few as 10 to 100 organisms have been shown to cause illness. Secondary infections occur frequently. Recently, shigellosis has become a problem in day-care centers. Shigella sometimes leads to Reiters syndrome.

The organism: Shigella organisms are generally considered fragile. They are readily killed by heat used in processing or cooking, and they do not survive well in acidic foods (pH below 4.6). They can survive for extended periods, however, in certain foods.

Most outbreaks result from contamination of raw or previously cooked foods during preparation in the home or in foodservice settings. Often, the source of the contamination is traced to a carrier with poor personal hygiene. In fact, the "4 Fs" involved in the transmission of *Shigella* are food, finger, feces, and flies.

Control: Infected food handlers are the most likely source of contamination of food by *Shigella*, so good personal hygiene is necessary to control the organism. Other control measures include use of properly treated water, sanitary disposal of sewage, and control of flies and rodents.

Staphylococcus aureus

The disease: Staphylococcus organisms are capable of producing very heat-resistant enterotoxin. The toxins, rather than the actual bacteria, are responsible for causing foodborne illness. Common symptoms include nausea, vomiting, cramps, sweating, chills, weak pulse, shock, and lowered body temperature. Recovery usually occurs within two days.

The organism: S. aureus is found in the nose and throat and on the hair and skin of more than half of the healthy population. Infected wounds, lesions, boils, and mucous spread by coughs and sneezes of people with respiratory infection are other sources of contamination. Any food that requires handling in its preparation can become contaminated.

The skins and hides of animals can also harbor *Staphylococcus* organisms and may contaminate foods from these animals at slaughter.

Foods that best support growth include protein foods such as meats, poultry, and fish; cream sauces; salads such as ham, turkey, and potato; puddings; custards; and cream-filled pastries. *S. aureus* bacteria are not a problem in raw foods because other harmless bacteria crowd them out.

The harmless bacteria may be destroyed in heated foods, leaving a niche for *S. aureus* should the food become contaminated. In addition, many of these cooked foods are handled and prepared in final form after cooking, which permits the food handler to contaminate foods whose harmless bacteria have already been destroyed.

In mayonnaise-type salads (ham, egg, etc.), the acidity of the mayonnaise inhibits the growth of *Staphylcocci*. But because other low-acid ingredients are mixed with the mayonnaise, the acid level may be diluted sufficiently to support growth of *S. aureus*. Salt and sugar added to certain food systems also inhibit growth of other organisms, but do not inhibit *S. aureus*. The microorganism grows well at body temperature but can grow at both colder and hotter temperatures.

Heat processing and normal cooking will kill *S. aureus* organisms, but heating does not destroy the enterotoxins.

Control: Because *S. aureus* bacteria are common and widespread in humans, preventing contamination of food is virtually impossible. Contaminated food must be held at a warm temperature for a sufficient time to permit enough bacteria to grow and produce a level of enterotoxin to make someone sick. Thus, temperature control is one of the most effective ways to control staphylococcal intoxication.

It is important to use good hygiene to help prevent contamination. Cook foods thoroughly. Then, cool foods in shallow containers in refrigerators. Keep meat salads, potato salads, cream pies, puddings, and pastries chilled until served. Avoid leaving foods at room temperature for more than two hours.

Yersinia enterocolitica

The disease: This bacteria causes yersiniosis. The most common form causes various symptoms of gastroenteritis, but more serious forms can lead to polyarthritis, septicemia, and meningitis. Death from gastroenteritis is rare, and recovery, if there are no further complications, occurs within one or two days.

The organism: Y. enterocolitica is commonly found in a wide variety of animals, food, and water sources. Pigs are the most important animal source. Food sources include raw milk, meat, poultry, shellfish, vegetables, and tofu.

Certain strains of the bacteria produce disease, but it appears that many of the strains are nonpathogenic. *Y. enterocolitica* can grow at refrigerator temperatures, but grows best at room temperature. It is sensitive to heat and is destroyed by adequate cooking and by pasteurization of milk.

Control: Postpasteurization contamination is the most frequent cause of foodborne outbreaks. Thus, preventive measures in processing plants need to include strict adherence to procedures for keeping perishable products, such as tofu and milk, clean and cold.

Vibrio

Three *Vibrio* species are considered separately because each is responsible for a different disease syndrome, and their modes of causing foodborne illness also differ. CDC estimates 8,000 cases each year.

Vibrio cholerae

The disease: Cholera causes thousands of deaths each year, primarily in Asian countries. Since 1978, however, there have been numerous reports of human illness in the United States, most of which have been traced to consumption of raw oysters and clams. *Vibrio cholerae* colonizes the small intestine and causes large volumes of

fluid to be secreted. Diarrhea results in loss of body fluids and accompanying minerals.

In severe cases, cardiovascular collapse and death may occur in a day's time. Organisms are excreted in large numbers and can be transmitted through contaminated water supplies and by foods obtained from those waters, particularly seafood.

The organism: Humans are the only natural sources of this organism. The organism is most commonly spread through water. *V. cholerae* does not multiply in water but can survive for up to two weeks. It is salt-tolerant, heat-sensitive, and destroyed by cooking.

Control: V. cholerae is controlled by the use of clean water and by thoroughly cooking seafood.

Vibrio parahaemolyticus

The disease: Vibrio parahaemolyticus causes an illness characterized by severe abdominal pain, nausea, diarrhea, and vomiting. It is the most common foodborne illness in Asia.

The largest outbreak of V. *parahaemolyticus* was in 1997 in raw oysters harvested in California, Oregon, and Washington. As a result, 209 illnesses occurred and one person died.

The organism: V. parahaemolyticus has been found in warm coastal waters of countries throughout the world. Most disease outbreaks occur during warm seasons.

Growth of organisms occurs while seafood are being held for consumption. It does not grow under refrigeration. The organism is salt-tolerant, but it is very sensitive to heat and is destroyed by cooking.

Control: Refrigeration and proper cooking are important means of controlling *V. parahaemolyticus*. Consumption of raw fish and shellfish poses risks. After cooking, it is important to avoid cross-contamination between raw and cooked seafood. In the United States, this has been the most frequent cause of *V. parahaemolyticus* infection. In Japan, however, the illness frequently involves consumption of raw seafood.

Vibrio vulnificus

The disease: This *Vibrio* causes two clinical forms of illness, one affecting the blood (septicemia) and the other causing seawater-associated wound infections (progressive cellulitis). The death rate is 50 percent for those with septicemia and 22 percent for those with wound infections.

The organism: V. vulnificus is common in marine environments and has been found in water, sediment, plankton, oysters, and clams. It is heat-sensitive and grows best in warm temperatures. Cooking destroys it.

Control: Refrigeration and cooking of shellfish are important control measures. In addition, avoid contaminating existing cuts or causing new wounds to hands while cleaning and harvesting shellfish.

Viruses

Viruses are submicroscopic agents that cause a wide range of disease in both plants and animals. Because they are not complete cells, they are not capable of growing and multiplying like bacteria.

Viruses that infect the gastrointestinal tract are usually transmitted by food or water. Infection results from:

- consumption of food contaminated by a food handler carrying the virus
- consumption of raw seafood taken from waters polluted by human wastes
- drinking polluted water

Hepatitis A virus

The disease: Hepatitis A is usually a mild illness with symptoms of sudden onset of fever, nausea, loss of appetite, and abdominal discomfort, and is followed by jaundice. The incubation time may be 10 to 50 days. During the middle of the incubation period, it can be transmitted to others. Usually, recovery is complete in one to two weeks. The CDC recorded 25,000 cases per year of Hepatitis A from 1980 to 2001. Adjusting for underreporting reveals an estimated 263,000 per year. One of the largest Hepatitis A outbreaks occurred in 2003, which involved green onions imported from Mexico. More than 700 people in four states were infected with Hepatitis A.

Person-to-person transmission, as well as foodborne and waterborne transmission, occur. Adults are more susceptible to this illness. Foods become contaminated by food handlers who do not follow good personal hygiene practices or by contaminated water.

Cold cuts, sandwiches, salads, fruits, shellfish, and iced drinks are commonly implicated in outbreaks. Contamination of foods by infected workers in food processing plants and restaurants is common.

The organism: The Hepatitis A virus is made of a single molecule of RNA surrounded by a small protein capsid.

Control: Wash hands thoroughly after using the restroom or diapering infants. Also, harvest shellfish from unpolluted waters.

Norwalk virus

The disease: Norwalk virus is a more recently discovered foodborne virus. The illness it produces is mild and characterized by nausea, vomiting, diarrhea, and abdominal pain. Headache and low-grade fever may result. Water is the most common source of outbreaks. Shellfish and salad ingredients are the foods most often implicated. This virus is very contagious.

Control: Use good personal hygiene and avoid handling food when ill.

Foodborne parasites

Parasites found in foods or water are divided into three categories: protozoa, flatworms, and roundworms. They grow in living hosts such as animals and are larger in size than bacteria. Parasites can transfer from animals to humans, humans to humans, or humans to animals. The primary source for parasites is feces. Fish are also carriers of parasites. Cooking or freezing fish will kill the parasites.

Cryptosporidium parvum

The disease: Crytosporidiosis is a significant cause of waterborne illness. The disease occurs by consuming contamiated water or from putting any-

thing in your mouth that touched feces containing Crytosporidiosis. Symptoms occur 2 to 10 days after ingestion. Symptoms include diarrhea, cramps, nausea, and fever.

The organism: C. parvum is found in the intestines of herd animals such as cows, sheep, goats, deer, and elk.

Control: Use proper handwashing procedures before handling foods and eating. Drink water only from treated water supplies. Do not swallow swimming pool water. When hiking, camping, or in foreign countries, boil water for one minute or drink bottled beverages. Wash, peel, or cook raw fruits and vegetables.

Cyclospora cayetanensis

The disease: Cyclosporiasis is a waterborne illness. The disease occurs by consuming contaminated water or from putting anything in your mouth that touched feces containing cyclosporiasis. Symptoms appear one week after ingesting. Symptoms include diarrhea, cramps, nausea, vomiting, muscle aches, low-grade fever, and fatigue.

The organism: Cyclosporiasis is a relatively new parasite. The first reported case was in 1979. Since then, more cases have been reported. It is unlikely passed from human to human, and not known if passed from animal to human.

Control: Use proper handwashing procedures before handling foods and eating. Drink water only from treated water supplies. Do not swallow swimming pool water. When hiking, camping, or in foreign countries, boil water for one minute or drink bottled beverages. Wash, peel, or cook raw fruits and vegetables.

Antimicrobial Resistance

This is the ability for some organisms to resist or fight medicines that should inhibit or kill the organisms. This becomes a food-safety issue because some species of *Salmonella* and *Campylobacter* have become resistant to antimicrobial medicines. This has resulted in more cases of foodborne illness.

Bacterial resistance to antibiotics has increased in the last 10 years. Each time a person takes antibiotics, sensitive bacteria are killed, but resistant bacteria can multiply. Misuse of antibiotics compromises the usefulness of essential drugs. To reduce antimicrobial resistance, always follow doctor's prescription instructions. Do not take someone else's medicine. Discard any leftover medicines once you've completed treatment.

For more information

Centers for Disease Control and Prevention
www.cdc.gov

CDC Antibiotic/Antimicrobial Resistance. www.cdc.gov/drugresistance. Accessed December 12, 2005.

FDA Center for Food Safety and Applied Nutrition www.cfsan.fda.gov

FDA Center for Drug Evaluation and Research: Antimicrobial Resistance. www.fda.gov/cder/drug/antimicrobial/default.htm

FightBac!
www.fightbac.org

FoodNet
www.cdc.gov/foodnet/

K-State Research and Extension Antimicrobial Resistance and the Food Supply, MF-2593 at www.oznet.ksu.edu/library/fntr2/mf2593.pdf.

K-State Research and Extension Food Safety
www.oznet.ksu.edu/foodsafety

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Publications from Kansas State University are available on the World Wide Web at: *http://www.oznet.ksu.edu*

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