

General Overview of the Causative Agents of Foodborne Illness¹

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This is one in a series of facts sheets targeting the retail and processing sector of food safety.

Classification of Foodborne Causative Agents

In general, a foodborne illness event can be caused by contamination of food with biological agents or pathogens (e.g., viruses, bacteria, parasites, prions), chemical agents (e.g., toxins, metals), or physical agents (e.g. glass fragments, bone chips). With more than 200 known diseases being transmitted through food, pathogens are the most significant cause.

With the exception of certain parasites, nearly all foodborne pathogens are microscopic in nature. In increasing order of size, these pathogens include viruses, bacteria, protozoa and other parasites.

Viruses are particulate in nature and multiply only in other living cells. Thus, they are incapable of survival for long periods outside the host. While greater than 100 types of enteric viruses have been shown to cause foodborne illness, the most common foodborne virus pathogens are **Norwalk virus**, **Noroviruses (formerly known as Norwalk-like viruses [NLVs])**, **Rotavirus**, **Astrovirus**, and **Hepatitis A**.

Bacteria are one-celled microorganisms with a cell wall but no nucleus. They exist in a variety of shapes, types and properties. Some pathogenic bacteria are capable of spore formation and thus, highly heat-resistant (e.g., *Clostridium botulinum*, *C. perfringens*, *Bacillus subtilis*, *B. cereus*). Others are capable of producing heat-resistant toxins (e.g., *Staphylococcus aureus*). Most pathogens are mesophilic with optimal growth temperature range from 20°C to 45°C (68°F to 113°F). However, certain foodborne pathogens (termed psychrotrophs) are capable of growth under refrigerated conditions or temperatures less than 10°C (50°F). The most well documented psychrotrophic foodborne pathogens are *Listeria monocytogenes*, and *Yersinia enterocolitica*. *Listeria monocytogenes*, for example, will grow (albeit slowly) at temperatures just of above freezing (approximately 33°F–34°F). Certain strains or serotypes of *Bacillus cereus*, *Clostridium botulinum*, *Salmonella* spp., *E. coli* O157:H7, and *Staphylococcus aureus* may also grow slowly under refrigeration conditions.

Bacteria also vary in their resistance to high salt, sugar, or total solids level as well as the acidity of food products. As shown in Table 1, some pathogens are capable of survival at low pH.

Parasitic Protozoa are one-celled microorganisms without a rigid cell wall, but with an organized nucleus. They are larger than bacteria. Like viruses, they do not multiple in

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foods, only in hosts. The transmissible form of these organisms is termed a **cyst**. Protozoa that have been associated with food and water-borne infections include *Entamoeba histolytica*, *Toxoplasma gondii*, *Giardia lamblia*, *Cryptosporidium parvum* and *Cyclospora cayatenensis*.

Multi-cellular Parasites are animals that live at the expense of the host. They may occur in foods in the form of eggs, larvae, or other immature forms. Trichinosis has been an important reportable pathogen associated with under-cooked pork. Other parasites of concern include flatworms or nematodes (associated with fish), cestodes or tapeworms (usually associated with beef, pork, or fish) and trematodes or flukes (more or a concern outside the US).

Classification of Foodborne Illnesses Caused by Pathogens

Foodborne Illness occurs when a pathogen is ingested with food and establishes itself (and usually multiplies) in the human host, or when a toxigenic pathogen establishes itself in a food product and produces a preformed toxic microbial product is then ingested by the human host. Thus, foodborne illness is generally classified into two main categories, **foodborne infection** and **foodborne intoxication**, as follows:

Foodborne Infections occur as a consequence of growth of the pathogen in the human body. Since an incubation period is usually involved, the time from ingestion until symptoms occur is much longer than that of **foodborne intoxications**. The two basic categories of **foodborne infections** are:

- **Invasive Infections** which are caused by pathogens that invade bodily tissues and organs. Included in this group are the viruses, parasitic protozoa, other parasites, and invasive bacteria (e.g., *Salmonella*, *Aeromonas*, *Campylobacter*, *Shigella*, *Vibrio parahaemolyticus*, *Yersinia* and enteric-type *Escherichia coli*).
- **Toxicoinfections** which are caused by infective bacteria that are not considered invasive in nature, but are capable of multiplication or colonization in human intestinal tract and produce toxins. Included in this group are: *Vibrio cholerae*, *Bacillus cereus* (diarrheal-type), *C. botulinum* (in infants), *C. perfringens* and verotoxigenic *E. coli* (*E. coli* O157:H7 and others).

Foodborne Intoxications are caused by toxins produced by organisms which have grown to sufficient numbers in the food product. In general, intoxication is manifested more rapidly after consumption of contaminated food (shorter

onset time) than are infections. The primary bacteria causing foodborne intoxications include: *C. botulinum*, *B. cereus* (emetic-type) and *Staphylococcus aureus*. Other non-bacterial toxins that cause illness include:

- Paralytic shellfish toxin (caused by the consumption of mussels, clams and scallops which have ingested toxic dinoflagellates),
- Ciguatera toxins (associated with certain tropical fish),
- Scombroid toxins (results from the production of histamine due to bacteria spoilage of fish), and
- Fungal toxins or mycotoxins that can be of long-term carcinogenic concern with consumption of mold contaminated foods (e.g., aflatoxins in contaminated corn, peanuts, or other foods and patulin from contaminated apple or other fruit products).

Mode of Action of Foodborne Pathogens

Pathogens enter the body through the digestive tract. These organisms differ in how they establish themselves (and may or may not cause illness), and in the number of microorganisms (infective dose) or quantity of toxin (toxic dose) required to cause illness. A major factor in the ability of these organisms to cause illness is the characteristics of the host. Humans can be generally characterized as low risk and high risk in terms of susceptibility. Low risk or healthy individuals may be resistant to many (but not all) of the foodborne illnesses. However, high-risk populations (e.g., immunocompromised, immunosuppressed, infirmed, elderly, small children, etc.) have much lowered (and highly varied) resistance.

A person infected with a foodborne pathogen can be a carrier and a source of infection to others. Even infected individuals that do not show signs of illness can be chronic carriers. While this is especially true for persons infected with viruses (e.g. hepatitis A), chronic carrier states occur for many infective foodborne bacteria as well which can be excreted during the illness period (e.g. *Salmonella* spp., *Shigella* spp.). While the carrier state usually ceases after several weeks, it can for longer time periods in certain individuals and for certain pathogens (e.g. *Salmonella typhi*).

While in most cases, the symptoms of foodborne illness cease after a relatively short time, complications (a.k.a. chronic sequelae) can occur in certain infected individuals. While these complications are relatively rare (occurring in less than 5% of cases), they can be severe. Examples of

chronic sequelae include: reactive arthritis, Reiters syndrome, Guillain-Barre syndrome, ankylosing spondylitis, meningitis, rheumatoid arthritis, septic arthritis, septicemia, and cardiac manifestations.

Assessment of Prevalence, Risk and Exposure

Pathogens are found in a variety of sources including the environment, plants, soil, and animals (including humans). Their significance depends on a number of factors including type of food, total population present, treatment/handling of the food, and susceptibility of the consumer. Assessment of the risk of foodborne illness agents can be obtained through evaluation of data from three sources: survey data of prevalence in certain foods, assessment of survival and growth characteristics in certain foods, and epidemiological data.

Pathogen Prevalence Data. Raw foods of animal or soil origin are frequently contaminated with pathogens. A variety of published reports examined the prevalence of certain microorganisms in specific food products. Some of these surveys have shown up in the news media (e.g., alarming reports concerning the levels of *Salmonella* and *Campylobacter* in raw poultry products).

Survival and Growth Data. Growth and survival are affected by the amount and type of nutrients available, water activity, pH, oxygen availability, temperature, and time, etc. Numerous published reports are available, in which these factors are examined using single-culture inoculation of broth culture or specific food products. More limited information is available as to how these organisms are affected by the other flora (spoilage organisms, etc.) in a real-world situations.

Surveillance and Epidemiology. Current estimates suggest that contaminated food causes approximately 76 million illnesses, 325,000 hospitalizations, and 5000 deaths (Mead *et al.*, 1999). However, the majority of the food-related illnesses, hospitalizations, and deaths are from unidentified causes. It is estimated that known pathogens account for 14 million illnesses; 60,000 hospitalizations; and only 1800 deaths. Greater than 75% of the food-related deaths are attributed to three pathogens: *Salmonella*, *Listeria*, and *Toxoplasma*.

Formation of surveillance networks between state and federal agencies such as the Foodborne Diseases Active Surveillance Network (FoodNet) and others, plus improvements in pathogen detection and traceback methodology

have resulted in more accurate estimates of the prevalence of foodborne illness. However, epidemiological investigation of foodborne illness is continuously evolving science, the food industry is continuously changing, and new foodborne illnesses are being identified. Surveillance and risk-assessment models are based upon reported foodborne illness outbreaks through evaluation of the numbers of cases involved, death and severity, microbial type and microbial numbers or exposure level (when available). Data include overall estimates for specific known pathogens as well as for all other causes of foodborne illness. Some risk assessment models may be oversimplified and may also tend to associate certain microorganisms with certain food products. This may lead to a false sense of security for other segments of the industry. For example, because of its initial association with a significant, highly publicized outbreak in Latin-style cheeses manufactured from raw milk and under poor sanitation conditions, *Listeria monocytogenes* was considered by some to be exclusively a dairy industry problem. Yet, marketplace surveys have shown this organism is present in certain food processing and handling environments as well as in a variety of raw food products. In recent years, this organism has been the cause of serious outbreaks in hot dogs and deli meats. *Salmonella*, traditionally associated with poultry and eggs, has been associated with foodborne illness outbreaks in fresh produce and juices, chocolate and cocoa, and cereal products. *E. coli* O157:H7 first associated with ground meat has been referred to as the “hamburger disease”. Yet, there have had been serious outbreaks associated with unpasteurized apple juice. Upon close examination of most foodborne outbreaks, the evidence strongly suggests that the majority of problems are associated improper food handling practices such as inadequate temperature control and poor personal hygiene.

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Table 1. Foodborne pathogens capable of survival at low pH.

Organism	pH (Jay 2000)	pH (Robinson et al. 2000)
<i>Bacillus cereus</i>	4.9	4.3
<i>Campylobacter jejuni</i>	--	4.9
<i>Listeria monocytogenes</i>	4.1	4.0–4.5
<i>Salmonella</i> spp.	4.05	4.0
<i>Staphylococcus aureus</i>	4.0	4.0
<i>Yersinia enterocolitica</i>	4.18	4.5
<i>E. coli</i> O157:H7	4.5	2.5