

Bad Bug Book

Foodborne Pathogenic Microorganisms and Natural Toxins

Staphylococcus aureus

1. Organism

Staphylococcal species are Gram-positive, non-motile, catalase-positive, small, spherical bacteria (cocci), which, on microscopic examination, appear in pairs, short chains, or bunched in grape-like clusters. Staphylococci are ubiquitous and impossible to eradicate from the environment. Many of the 32 species and subspecies in the genus *Staphylococcus* are potentially found in foods due to environmental, human, and animal contamination.

Several staphylococcal species, including both coagulase-negative and coagulase-positive strains, have the ability to produce highly heat-stable enterotoxins that cause gastroenteritis in humans. *S. aureus* is the etiologic agent predominantly associated with staphylococcal food poisoning.

S. aureus is a versatile human pathogen capable of causing staphylococcal food poisoning, toxic shock syndrome, pneumonia, postoperative wound infection, and nosocomial bacteremia. *S. aureus* produces a variety of extracellular products, many of which act as virulence factors. Staphylococcal enterotoxins can act as superantigens capable of stimulating an elevated percentage of T-cells.

S. aureus is one of the most resistant non-spore-forming human pathogens and can survive for extended periods in a dry state. Staphylococci are mesophilic. *S. aureus* growth, in general, ranges from 7°C to 47.8°C, with 35°C being the optimum temperature for growth. The growth pH range is between 4.5 and 9.3, with an optimum between 7.0 and 7.5. Staphylococci are atypical, in that they are able to grow at low levels of water activity, with growth demonstrated at a_w as low as 0.83, under ideal conditions. Optimum growth of *S. aureus* occurs at a_w of >0.99. For the most part, strains of *S. aureus* are highly tolerant to salts and sugars.

For Consumers: A Snapshot

This bacterium, often called “Staph” for short, can cause food poisoning. It’s very common in the environment and can be found in soil, water, and air, and on everyday objects and surfaces. It can live in humans and animals. *Staphylococcus aureus* is found in foods and can make toxins (enterotoxins) that might not be destroyed by cooking, although the bacterium itself can be destroyed by heat. These toxins can cause nausea, stomach cramps, vomiting, and diarrhea. In more severe cases, the toxins may cause loss of body fluid (dehydration), headache, muscle cramps, and temporary changes in blood pressure and heart rate. The illness usually is intense, but normally lasts from just a few hours to a day. The toxins are fast-acting; they cause symptoms within 1 to 7 hours after contaminated food is eaten. Follow basic [food-safety tips](#) to help protect yourself from this illness. Outbreaks often have been linked to foods that require a lot of handling when they’re being processed or prepared and/or weren’t kept at proper refrigerator temperature (40°F or below). To help protect yourself, it’s especially important to [wash your hands well](#) when handling food, properly clean your cooking equipment and surfaces, keep your cooked foods from touching raw foods or unclean equipment or surfaces, and keep foods refrigerated at 40°F or below. Examples of foods that have been linked to this type of food poisoning include meat and meat products; poultry and egg products; salads, such as egg, tuna, chicken, potato, and macaroni; bakery products, such as cream-filled pastries, cream pies, and chocolate éclairs; sandwich fillings; and milk and dairy products.

Staphylococcal Enterotoxins (SE)

Staphylococcal enterotoxins are single-chain proteins with molecular weights of 26,000 to 29,000. They are resistant to proteolytic enzymes, such as trypsin and pepsin, which allows them to transit intact through the digestive tract. There are five classical enterotoxin serotypes: SEA, SEB, SEC1,2,3, SED, and SEE and the more recently described SEG, SEH, and SEI; all exhibit emetic activity. There are also SE-like enterotoxin serotypes, SEIJ-SEIU; these SE-like designations have not been confirmed to exhibit emetic activity. The different SE serotypes are similar in composition and biological activity, but are different in antigenicity and are identified serologically as separate proteins.

2. Illness

Staphylococcal food poisoning (staphyloenterotoxiosis; staphyloenterotoxemia) is the name of the condition caused by the enterotoxins. Treatment typically involves managing the complications.

- **Mortality:** Death from staphylococcal food poisoning is uncommon, although it has occurred among the elderly, infants, and severely debilitated people.
- **Infective dose:** The intoxication dose of SE is less than 1.0 microgram. This toxin level is reached when *S. aureus* populations exceed 100,000 organisms/g in food. This level is indicative of unsanitary conditions in which the product can be rendered injurious to health. In highly sensitive people, ingestion of 100 to 200 ng of enterotoxin can cause symptoms. The population of *S. aureus* at the time of analysis may be significantly different, and not representative of, the highest population that occurred in the product. This should be taken into consideration when examining foods.
- **Onset:** The onset of symptoms usually is rapid (1 to 7 hours) and in many cases acute, depending on individual susceptibility to the toxin, amount of toxin ingested, and general health.
- **Illness / complications:** Staphylococcal food poisoning generally causes self-limiting, acutely intense illness in most people. Not all people demonstrate all symptoms associated with the illness. The most common complication is dehydration caused by diarrhea and vomiting.
- **Symptoms:** When ingested, the enterotoxin may rapidly produce symptoms, which commonly include nausea, abdominal cramping, vomiting, and diarrhea. In more severe cases, dehydration, headache, muscle cramping, and transient changes in blood pressure and pulse rate may occur.
- **Duration:** The illness is relatively mild and usually lasts from only a few hours to one day; however, in some instances, the illness is severe enough to require hospitalization.
- **Route of entry:** Consumption of food contaminated with enterotoxigenic *S. aureus* or ingestion of the preformed enterotoxin.
- **Pathway:** Staphylococcal enterotoxins are stable in the gastrointestinal tract and indirectly stimulate the emetic reflex center by way of undetermined molecular events. It

is thought that the vagus nerve is involved in the sequence of events that produce the emetic response.

3. Frequency

S. aureus is the cause of sporadic food poisoning episodes around the world. The Centers for Disease Control and Prevention (CDC) estimates that, in the United States, staphylococcal food poisoning causes approximately 241,188 illnesses, 1,064 hospitalizations, and 6 deaths each year. The true incidence is unknown for a number of reasons, including poor responses from victims during interviews with health officials; misdiagnosis of the illness, which may be symptomatically similar to other types of food poisoning (such as vomiting caused by *Bacillus cereus* emetic toxin); inadequate collection of samples for laboratory analyses; improper laboratory examination; and, most important, many victims do not seek medical attention because of the short duration of the illness. Although it is under-reported, staphylococcal food poisoning remains a common cause of foodborne illness as indicated by the recent Centers for Disease Control and Prevention (CDC) report (see Resources section, Scallan *et al.*).

4. Sources

Staphylococci are widely distributed in the environment. They can be found in the air, dust, sewage, water, milk, and food, or on food equipment, environmental surfaces, humans, and animals.

Foods frequently implicated in staphylococcal food poisoning include meat and meat products; poultry and egg products; salads, such as egg, tuna, chicken, potato, and macaroni; bakery products, such as cream-filled pastries, cream pies, and chocolate éclairs; sandwich fillings; and milk and dairy products. Foods that require considerable handling during preparation and are kept slightly above proper refrigeration temperatures for an extended period after preparation are frequently involved in staphylococcal food poisoning.

Unless heat processes are applied, staphylococci are expected to exist in any and all foods that are handled directly by humans or are of animal origin. Destruction of viable cells by heat does not destroy the biological activity of preformed staphylococcal enterotoxins. These toxins are highly heat stable and can remain biologically active.

Staphylococci are present in the nasal passages and throats and on the hair and skin of 50% or more of healthy individuals. The incidence is even higher among those who associate with sick people and hospital environments. Contamination may be introduced into foods by direct contact with workers with hand or arm lesions caused by *S. aureus*, or by coughing and sneezing, which is common during respiratory infections. Food handlers are frequently the source of food contamination in staphylococcal outbreaks; however, equipment and environmental surfaces also can be sources.

Avoiding time and temperature abuse of food products that are at high risk of containing *S. aureus* is essential in preventing the proliferation of the bacterium and subsequent production of enterotoxin. In cases of human intoxication, the implicated food usually has not been kept at a refrigerated temperature of <10°C or has not been kept hot enough (>45°C).

5. Diagnosis

Staphylococcal food poisoning is diagnosed based on isolation of the pre-formed enterotoxin or the isolation of enterotoxigenic staphylococci from the suspect food consumed and/or the vomitus or feces of the patient. The food history and rapid onset of symptoms often are sufficient to diagnose this type of food poisoning. Suspect foods are collected and examined for presence of viable staphylococci and preformed enterotoxin. The most conclusive test is the linking of an illness with a specific food, or in cases in which multiple vehicles exist, detection of pre-formed enterotoxin in food sample(s).

6. Target populations

All people are believed to be susceptible to this type of bacterial intoxication; however, intensity of symptoms may vary.

7. Food Analysis

A number of serological methods have been developed for detection of pre-formed enterotoxin in foods. These same methods are also utilized for determining the enterotoxigenicity of *S. aureus* isolate from a food product.

Enrichment isolation and direct plating are the methods frequently used for detecting and enumerating *S. aureus* in foods. Non-selective enrichment is useful for demonstrating presence of injured cells, whose growth is inhibited by selective enrichment media. Enumeration by enrichment isolation, or selective enrichment isolation, may be achieved by determining either the direct plate count or the most probable number (MPN) of *S. aureus* present. The MPN procedure is recommended for surveillance of products expected to have a small population of *S. aureus* and a large population of competing organisms. Direct plating method is suitable for analysis of foods in which a population of *S. aureus* is expected to be greater than 100 CFU/g.

During outbreak investigations, it is recommended that foods be tested for pre-formed enterotoxin and to determine enterotoxigenicity of isolates. Currently ELISA-based methods are those most widely used to identify staphylococcal enterotoxins. Several commercially available enzyme-linked immunosorbent assays use both monoclonal and polyclonal antibodies. The intensity of the color reaction or fluorescence is proportional to the amount of toxin present in the sample. These extraction and detection methods are described in detail in the BAM online [chapter 13A](#).

Steps during food processing and preservation, including treatment with heat, acidulation, or chemicals, and other treatments stress the staphylococcal enterotoxin protein. A processed product may have serologically inactive and undetectable toxin, while the toxin protein remains biologically active and can cause illness. Procedures have been developed to chemically treat suspect samples that may contain denatured enterotoxins, to restore serological activity, so that the toxin can be detected using classical serological methods.

When food has been treated to eliminate viable microorganisms, as in pasteurization or heating, DNA-based techniques, such as PCR, or direct microscopic observation of the food (if the cells were not lysed), can assist in identification and diagnosis. Pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing (MLST) are the most common molecular subtyping techniques used for staphylococcal species; these are powerful tools that can be used when viable

staphylococci are isolated from the implicated food, victims, and suspected carriers, such as food handlers.

8. Examples of Outbreaks

Example of a typical outbreak:

Among 5,824 children who had eaten lunch served in 16 elementary schools in Texas, 1,364 became ill. The lunches were prepared in a central kitchen and transported to the schools by truck. Epidemiologic studies revealed that 95% of the ill children had eaten chicken salad. The day before, frozen chickens had been boiled for 3 hours, then deboned, cooled to room temperature with a fan, ground into small pieces, placed into 12-inch-deep aluminum pans, and stored overnight in a walk-in refrigerator, at 42°F to 45°F.

The next morning, the remaining ingredients were added and blended in with an electric mixer. The food was placed in thermal containers and transported to the various schools, from 9:30 a.m. to 10:30 a.m., where it was kept at room temperature until served, from 11:30 a.m. to noon. Bacteriologic examination of the chicken salad revealed large numbers of *S. aureus*.

Example of outbreak that is not typical:

In 1989, multiple staphylococcal foodborne diseases were associated with canned mushrooms. Enterotoxin type A (SEA) was identified in several samples of unopened cans from the same lot. (CDC Morbidity and Mortality Weekly Report, June 23, 1989, Vol. 38, #24.)

S. intermedius, typically considered a veterinary pathogen, was isolated from butter blend and margarine implicated in a 1991 food poisoning outbreak. SEA was detected in both clinical and food isolates implicated in this food-related outbreak involving more than 265 cases in the western US. (Khambaty *et al.*, 1994)

Recent outbreaks:

For more information about recent outbreaks, see CDC's [Morbidity and Mortality Weekly Reports](#).

9. Resources

A [Loci index for genome](#) *Staphylococcus aureus* is available from GenBank.

Bennett RW. 2005. Staphylococcal Enterotoxin and Its Rapid Identification in Foods by Enzyme-Linked Immunosorbant Assay-Based Methodology. *J. of Food Protection* 68: 1264-1270.

Khambaty FM, Bennett RW, Shah DB. 1994. Application of pulsed-field gel electrophoresis to the epidemiological characterization of *Staphylococcus intermedius* implicated in food related outbreak. *Epidemiol. Infect.* 113:75-81.

Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson M-A, Roy SL, *et al.* 2011. [Foodborne Illness Acquired in the United States – Major Pathogens](#). *Emerg Infect Dis* 17(1):7-15.

Seo KS, Bohach GA. 2007. *Staphylococcus aureus* in Doyle MP and Beuchat LR, *Food Microbiology*, 3rd ed. ASM Press, Washington D.C. pp. 493-518.

