STAPHYLOCOCCUS AUREUS

What is Staphylococcus aureus?

Staphylococcus aureus is a Gram-positive, spherical or ovoid shaped bacterium that is able to grow both with, and without oxygen (a facultative anaerobe). Some strains have the ability to produce toxins (enterotoxins) in food, which can cause the symptoms of food poisoning if ingested.

Although *Staph aureus* is the principle *Staphylococcus* species causing food poisoning, other species have also been shown to produce enterotoxins, although *Staph intermedius* is the only non-*Staph aureus* species to be clearly implicated in foodborne outbreaks.

To date, 21 different staphylococcal enterotoxins have been described (known by letters of the alphabet, A - V, although a few letters are missing from the sequence). All are heat stable, water-soluble proteins and retain their activity in the digestive tract after ingestion. Staphylococcal enterotoxin A (SEA), either alone, or in combination with other staphylococcal enterotoxins, is the one most frequently found in foods and the most common cause of staphylococcal food poisoning outbreaks.

In recent years there have been concerns that some strains of meticillin-resistant (or methicillin-resistant) *Staph aureus* (MRSA) may occasionally be foodborne.

What foods can be contaminated?

Foods that have caused outbreaks of staphylococcal food poisoning have usually been stored or processed at incorrect temperatures. Foods at particular risk are those that are handled and where the

competing microorganisms have either been destroyed, or inhibited, by cooking or salting.

Foods involved in outbreaks have included milk and milk-based products, such as chocolate milk, cream, custard or cream-filled pastries, butter, ham and other cured meats such as corned beef and bacon. Cooked meats and poultry products are also commonly implicated, as are cheeses – especially where there has been a slow start in the fermentation process leading to a delay in acid production. Other foods linked to outbreaks have included sausages, canned meat, salads, cooked meals (particularly pasta-based products), rice balls, ice cream, crepes and sandwich fillings.

Low numbers of MRSA have been found in raw meats, including pork, lamb, beef, rabbit, turkey and chicken, and in dairy products.

How does it affect human health?

Staphylococcal food poisoning is an intoxication, rather than an infection, and a mild form of foodborne disease, although all individuals are thought to be susceptible. The toxin is pre-formed in the food, so the onset of symptoms is rapid, 30 minutes – 7 hours (average 2-4 hours). The severity of symptoms is related to the amount of enterotoxin ingested and the susceptibility of the individual. No live *Staph aureus* cells need to be ingested for staphylococcal food poisoning to occur. But to produce sufficient quantities of enterotoxin to cause illness, the bacteria need to reach levels of 100,000 - 1,000,000/g in food. It is thought that the amount of enterotoxin needed to cause illness is between 0.1-1 micrograms.

Symptoms are usually nausea and vomiting with abdominal cramps, sometimes followed by diarrhoea. In more severe cases, headache, muscle cramping, dehydration and low blood pressure occur, but patients usually recover within two days. Although deaths have occurred amongst children and the elderly, these are rare.

Many MRSA strains have the potential to produce enterotoxins and cause 'classic' staphylococcal food poisoning. However, of more concern is the possibility of the pathogen being spread as a contaminant in food, especially among patients in a healthcare setting. Wound and systemic infections in susceptible individuals are persistent and difficult to treat.

How common is illness?

The European Food Safety Authority reported that in 2008, staphylococcal enterotoxins were involved in 5.5 % of all notified food poisoning outbreaks in the EU. In England and Wales *Staph aureus* was linked to 1.5% of all outbreaks from 1992 to 2009 and during this period was ranked as the sixth most common bacterial cause of food poisoning. In the United States during the 5-year period between 1993 and 1997, 42 food poisoning outbreaks involving 1,413 cases (including one death) were caused by staphylococcal enterotoxins. However, the usually mild nature of staphylococcal food poisoning means that it is probably a very under-reported illness and its true incidence is uncertain.

Outbreaks

In 1986 a large outbreak linked to chocolate milk in the US affected schoolchildren and was apparently caused by low levels of enterotoxin (144 nanograms approx). The toxin was probably produced during a period of temperature abuse before pasteurisation.

A mass outbreak (more than 10,000 cases) of staphylococcal food poisoning occurred in Japan during 2000 and was linked to milk from a single dairy. This outbreak was thought to have involved SEA at a very low level (80 nanograms), but later research suggested that samples of implicated product may have contained other enterotoxins (SEH), which had gone undetected in the original testing (only 'classical' staphylococcal enterotoxins (A-E) are detected by most commercial kits).

In 2004 a very large staphylococcal food poisoning outbreak affected around 4,000 people (with 16 deaths) at an event in Brazil. Food handlers who tested positive for enterotoxigenic S*taph aureus* from nasopharyngeal and fingernail swabs were found to have contaminated food prepared for the occasion.

Two food mediated MRSA outbreaks have been described in the literature. In the first incident, food contaminated by a food handler with no direct patient contact caused an MRSA infection in a patient at a haematology unit in the Netherlands. The infection was subsequently spread to other patients via healthcare workers, resulting in 27 cases and 5 deaths. The second report concerned an outbreak of acute gastroenteritis in the USA linked to enterotoxin C-producing MRSA in coleslaw purchased from a delicatessen. The outbreak MRSA strain was isolated from a food handler, food sample and three affected adults.

Where does it come from?

Humans are a main reservoir for staphylococci. *Staph aureus* is carried in the throats and nasal cavities of around 40% of healthy humans and also in infected cuts and sores. Food handlers can potentially contaminate almost any foodstuff with *Staph aureus*. It can be transmitted to foods via manual handling as well as by coughing and sneezing.

Animals are also a source of *Staph aureus*. The pathogen can cause mastitis in cows, resulting in the contamination of raw milk and raw milk products, such as cheese. Raw meat, particularly pork, can be contaminated, as can raw poultry and seafood.

The organism is also able to persist in the food-processing environment. It is quite resistant to desiccation and can survive on dry surfaces such as glass, metal and porcelain. It is often found in the dust in ventilation systems.

Humans and animals, including pets and livestock, may also carry MRSA without symptoms. A relatively new MRSA strain of unknown origin (MRSA CC398) has been found in livestock in Europe and North America and is thought to be widespread in intensively reared pigs, cattle and possibly poultry. However, there is no evidence of foodborne transmission of MRSA CC398 to date.

How is it affected by environmental factors?

Temperature

Staph aureus can grow over the growth range 7 – 48ºC and the optimum temperature for growth is 37ºC. Enterotoxin can be produced over the temperature range 10 – 45ºC, with an optimum temperature for production of around 40ºC. The cells survive frozen storage well.

Under normal circumstances *Staph aureus* is not particularly heat resistant and is inactivated by normal pasteurisation temperatures. D_{60}-values of around 2 min are typical in high water activity substrates. However, at reduced water activities, as in salty foods (cheese, ham and bacon), pasta, or high fat foods, heat resistance is enhanced and D_{60}-values of up to 50 min have been recorded.

Staphylococcal enterotoxins are very heat resistant. Although heating at 100ºC for a minimum of 30 minutes will generally inactivate enterotoxin, that time will be extended at lower water activities. If enough enterotoxin is present, it is possible for some to survive heat processes used in the sterilization of low-acid products. Correctly processed canned mushrooms were implicated in an outbreak of staphylococcal food poisoning in the USA.

pH

The pH range for the growth of *Staph aureus* is 4.2 - 9.3, and the optimum is around 7.0. Enterotoxin can be produced between pH 4.8 - 9.0, though production is usually inhibited below pH 5.0. The optimum pH for enterotoxin production depends on strain and type of toxin and is between 6.5 and 7.3.

Water activity

Staph aureus is notable amongst food poisoning bacteria for being unusually tolerant of low water activities. It is also more tolerant of salt (sodium chloride) than many other bacteria and is generally able to grow in 7 – 10% salt, although some strains can grow at levels as high as 20%. Enterotoxin production has also been shown at around 10% salt. The minimum water activity for growth is generally considered to be 0.86. The ability to grow at such low water activity values gives *Staph aureus* a competitive advantage in low moisture foods. Enterotoxin can be produced at water activities as low as 0.87, but the optimum is 0.90 or above. *Staph aureus* is very resistant to drying and can survive for extended periods in dried foods.

Atmosphere

Staph aureus is best able to grow and produce enterotoxin in the presence of oxygen, but it can also grow and produce small quantities of enterotoxin under anaerobic conditions. High concentrations of carbon dioxide (80%) effectively inhibit growth.

How can it be controlled?

For food processors

The presence of low levels of *Staph aureus* in raw products is not necessarily a cause for concern – it is the prevention of staphylococcal enterotoxin production that should be the focus of risk

assessments. However, measures to reduce the risk of *Staph aureus* food poisoning during processing should focus on avoiding contamination. This can be achieved by minimising physical handling of food, keeping preparation areas clean and by good temperature control. Using utensils and disposable gloves can help reduce direct human contact with food products. Individuals suffering from infected cuts and sores and from colds should be temporarily excluded from dealing with ready-to-eat products.

Systems where rework is fed back into the process (e.g. pasta/batter production), and where temperatures may permit the growth of *Staph aureus*, are at risk from enterotoxin production, which subsequent cooking may not remove. In these circumstances, short run times, discarding any remaining unused product and good cleaning regimes are important factors for minimizing the risk.

For retailers, caterers and consumers

After processing, the physical handling of 'at risk' processed foods or cured/salted products should be kept to a minimum to reduce the risk of contamination with *Staph aureus*.

'At risk' products should either be kept well refrigerated (less than 5ºC) or kept hot (above 63ºC): under these conditions *Staph aureus* cells will be unable to grow.

Are there rules and regulations?

EU legislation has requirements governing sampling plans and limits for 'coagulase-positive' staphylococci in various cheeses, milk powder and whey powder. For these foods levels of coagulase-positive staphylococci below 10 – 10,000/g (depending on product) at the time of removal from the premises are generally satisfactory. However, tests for staphylococcal enterotoxin are required where levels of coagulase-positive staphylococci are detected at more than 100,000/g, and these toxins should be absent in 25 g. If coagulase-

positive staphylococci are found at levels above 1,000/g in shelled and shucked cooked crustaceans and shellfish, EU regulations require improvements in production hygiene.

The US Food & Drug Administration's (FDA) food compliance program suggests that any cheese, fish or seafood product could be removed from the market place if it is found positive for staphylococcal enterotoxin or if levels of *Staph aureus* are 10,000/g or more.

Where can I learn more?

US FDA Bad Bug Book - Staphylococcus aureus

Opinion of the Scientific Committee on Veterinary Measures relating to Public Health on staphylococcal enterotoxins in milk products, particularly cheeses. European Commission. (2003).

EFSA Assessment of the public health significance of meticillin resistant *Staphylococcus aureus* (MRSA) in animals and foods (2009).