STAPHYLOCOCCUS AUREUS

THE ORGANISM/TOXIN

Growth and toxin production is best in the presence of oxygen but can grow anaerobically. It is not regarded as a good competitor with other bacteria. Infected food handlers are a significant cause of food poisonings.

GROWTH AND ITS CONTROL

Growth:

Temperature: Optimum 37°C, range 6-48°C. Upper limit of growth can be extended above 44°C by addition of NaCl, monosodium glutamate (MSG) and soy sauce.

pH: Optimum pH for growth is 7.0-7.5. Minimum pH for growth is 4.2, maximum 9.3.

Growth was inhibited in the presence of 0.1% acetic acid (pH 5.1).

Atmosphere: Grows best in the presence of oxygen. Capable of growing anaerobically.

Growth is retarded in the presence of 80% CO_2 compared to growth in an air atmosphere.

Water activity: The low a_w at which *S. aureus* grows is particularly significant. The organisms are resistant to drying and may grow and produce enterotoxins in foods with a_w as low as 0.85. Can grow in up to 25% NaCl. Grows well in 7-10% NaCl. Optimum a_w for growth is 0.99.

Its ability to grow at low a_w means that it has a competitive advantage on low a_w foods.

Toxin Production: Combinations of different inhibitory factors (e.g. NaCl content and pH) can be used to control toxin production (and growth), i.e. multiple hurdles can be used. In summary, organisms exposed to an extreme of one inhibitory factor become more susceptible to others.

Temperature: Optimum 35-40°C, range 10-45°C.

pH: Optimum pH for toxin production is 5.3-7.0, minimum 4.8, maximum around 9.0. Toxin production is inhibited more effectively when the pH is reduced by lactic acid rather than hydrochloric acid.

Atmosphere: Greatest toxin production is in the presence of oxygen. Less toxin is produced under anaerobic conditions.

Water activity: Optimum for toxin production is ≥0.90 a_w. Range 0.86 ≥0.99.

Survival:

Temperature: The organisms is usually readily killed at cooking and pasteurisation temperatures. Heat resistance is increased in dry, high-fat and high-salt foods.

Survives frozen storage.

Toxins are extremely resistant to heat. For example the D time of enterotoxin B at 149°C is 100 min at an a_w of 0.99, and 225 min at an a_w of 0.90.

pH:. *S. aureus* can survive in foods down to pH 4.2 but this is dependent on the type of acid present.

Atmosphere: Cells survive longer under anaerobic conditions.

Water Activity: Survive for long periods in dried foods.

Inactivation (CCPs and Hurdles):

Temperature: D_{60} is approx. 2 min. However, the D_{60} for salty foods, e.g. cheese, bacon and ham, is considerably longer (can reach >50 min). Heat resistance is reduced at high and low pH.

pH: Rapid destruction of *S. aureus* has been demonstrated in lemon and lime juices at pH 2.3.

During food fermentations, lactic acid bacteria produce substances that are inhibitory to *S. aureus* including lactic acid, hydrogen peroxide and bacteriocins.

Water activity: Withstands desiccation well.

Preservatives: (NB: Some of the preservatives discussed here may not be permitted in New Zealand). *S. aureus* shows no unusual resistance to common food preservative methods except for its osmotolerance (permits survival and growth in high concentrations of NaCl). Cells grown in high salt foods at high temperatures are less sensitive to some food preservatives.

When reduced pH and a_w are used in combination to control *S. aureus*, less stringent levels of these parameters can be applied.

Sorbate and benzoate are effective inhibitors of *S. aureus* with a minimum inhibitory concentration at pH 6.1 of 1000 mg/kg. The effectiveness of these preservatives increases as pH is reduced.

Methyl and propyl parabens are also effective.

High concentrations of CO_2 substantially reduce growth.

Sanitisers/Disinfectants: (These products must be used as directed by the manufacturer).

Most chemical sanitisers used routinely in the food industry, such as chlorine, other halogens, and quaternary ammonium compounds will destroy *S. aureus* on surfaces when correctly applied.

Some strains found in poultry processing plants have been found to possess resistance to sanitisers.

(N.B. The absence of a sanitiser/disinfectant from this section does not necessarily imply that it is ineffective)

Radiation: Relatively resistant to ionising radiation, but not to UV irradiation, when compared with other

non-sporulating bacteria such as *Salmonella* and *E. coli*. D value of 0.45 kGy.

THE ILLNESS

Incubation: 30 min to 7 hours after eating food containing enterotoxins (mean 2-4 hours).

Symptoms: Symptoms usually include nausea, vomiting and abdominal cramps and may be followed by diarrhoea. In severe cases, headaches, sweating and fever may occur. In mild cases there may be nausea and vomiting without diarrhoea, or cramps and diarrhoea without vomiting. Recovery is rapid, usually within 2 days.

Estimated hospitalisation rate = 18%, case fatality rate = 0.02%.

Condition: Staphyloenterotoxaemia; enterotoxin causes inflammation of the intestinal tract lining. Staphylococcal food poisoning is seldom fatal but fatalities have been reported occasionally in young children and elderly.

Toxins: Illness results from consuming toxins in foods.

At Risk Groups: All people are believed to be susceptible to staphylococcal intoxication, but the intensity of symptoms may vary depending on the amount of food ingested and the susceptibility of the individual to the toxin.

Long Term Effects: None

Dose: Less than 1.0 µg of toxin in contaminated food can produce symptoms. This toxin level is reached when *S. aureus* populations exceed 10^5 per gram. Small numbers of *S. aureus* in food are not a direct hazard to health.

NZ Incidence: In the Annual Summary of Outbreaks in NZ, 16 outbreaks were attributed to staphylococci (43 cases) in 1999 compared with 8 outbreaks in 1998 (41 cases).

Treatment: Usually no treatment is given. Fluids may be administered when diarrhoea and vomiting are severe.

SOURCES

Human: Humans are the main reservoir for staphylococci involved in human disease. Human contamination of food can occur by direct contact, indirectly by skin fragments, or through respiratory tract droplets.

Animal: Animals and poultry carry *S. aureus* on parts of their body which can lead to infections. Cows udders and teats, tonsils and skin of pigs, and skin of chickens and turkeys are known sources.

Food: *S. aureus* competes poorly with other bacteria and therefore seldom causes food poisoning in raw products. Unpasteurised milk may cause food poisoning if numbers of organisms are very high, such as when a cow has mastitis. Foods which present the greatest risk are those in which the normal flora has been destroyed (e.g. cooked meats) or inhibited (e.g. cured, salted meats). Staphylococci grow well in cooked foods which are high in protein, sugar or salt, low in acid, or food with moist fillings.

Environment: May colonise food-processing equipment in areas that are difficult to clean. Often found in ventilation system dust.

Transmission Routes: Ingestion of contaminated food.

OUTBREAKS AND INCIDENTS

Outbreaks: Most outbreaks are caused by eating foods in which enterotoxin has been produced because of time and temperature abuse following preparation.

New Zealand:

Yoghurt: 2 outbreaks from yoghurt made in institutional kitchens, 1 resulted in 40 cases, the other, 7 cases. Control measure failures: contamination of food by handlers, slow growth of yoghurt starter culture due to incorrect temperature.

Hot ham sandwiches: 3 cases. Control measure failures: contamination of food by handler, inadequate re-heating and hot holding of cooked ham.

Christmas hams: 19 cases. Control measure failures: inadequate thawing prior to cooking, inadequate cooling of cooked product, prolonged storage at ambient temperature.

Freeze-dried trampers meals: 11 cases. Control measure failure: Presumably ingredients were contaminated prior to freeze-drying.

Overseas:

Baked ham: 196 cases. Control measure failure: contamination of food by handler, cook had infected lesions on hand.

Chicken salad: 1,364 cases. Control measure failures: contamination of chicken during deboning by handler, inadequate cooling, storage at incorrect temperature.

Hot turkey sandwiches: 55 cases. Control measure failures: contamination by handler, storage at incorrect temperature.

Lasagne pasta: 47 cases. Control measure failures: use of unpasteurised egg in pasta manufacture, dried slowly at inadequate drying temperatures.

ADEQUATE PROCESSING GUIDELINES

N.B. These guidelines have been derived from published information. Industry is advised to ensure that processing steps they are using are adequate to meet their particular food safety objectives.

Cook meats to:	**Internal temperature reached**	**Time**
Minced meats (beef, veal, lamb, pork) + pork cuts	71°C	15 sec
Minced poultry	74°C	″
Meat cuts (beef, veal, lamb), fish, seafood	63°C	″
Poultry, breast	77°C	″
Poultry, whole	82°C	″
Cool cooked foods at room temperature until:	≥55°C	
Continuously cool cooked foods under refrigeration to achieve a reduction of:	55ºC to 25ºC	In less than 5 hrs
Followed by:	25ºC to 5ºC	In less than 10 hrs
Cool cooked foods from	54.4°C to 7.2°C	<15 hours
Hold foods at	≤ 5°C or ≥ 60°C	
Reheat cooked foods to	74°C	Instantaneous
Reduce pH of food to ≤ 4.2		
Avoid direct handling of cooked ready-to-eat foods or cured/salted foods		
Reduce a_w to 0.86 or add appropriate level of preservative to store foods safely		

REFERENCES

Ash M. (1997) *Staphylococcus aureus* and Staphylococcal Enterotoxins. In: Foodborne microorganisms of public health importance, 5th Edition, (Eds) Hocking, A.D., Arnold, G., Jenson, I., Newton, K. and Sutherland, P. pp 313-332. AIFST (NSW Branch), Sydney, Australia.

El-Banna AA and Hurst A (1983) Survival in foods of *Staphylococcus aureus* grown under optimal and stressed conditions and the effect of some food preservatives. Canadian Journal of Microbiology 29:297-302.

Hurst A and Hughes A (1983) The protective effect of some food ingredients on *Staphylococcus aureus* MF31. Journal of Applied Bacteriology 55:81-88.

Jablonski LM and Bohach GA. (1997) *Staphylococcus aureus*. In Food Microbiology: fundamentals and frontiers, (Eds) Doyle, M.P., Beuchat, L.R. and Montville, T.D. pp 353-375. ASM Press, Washington, D.C., USA.

The International Commission on Microbiological Specifications for Foods (1996) *Staphylococcus aureus*. In Micro-organisms in Foods 5 Microbiological Specifications of Food Pathogens, pp 299-333. Blackie Academic and Professional, London.

Milling M, Park C, Erdman IE, Todd ECD, Casey J, Fish N, Gale RA, Johnston AJ and Pivnick H (1971) Staphylococcal food poisoning from commercially prepared chicken, from "hot" turkey sandwiches, and from ham. Canadian Journal of Public Health, 62:382-385.

U.S. Food and Drug Administration (30/11/2000) *Staphylococcus aureus*. In Bad Bug Book. Foodborne Pathogenic Microorganisms and Natural Toxins Handbook, chapter 3. Centre for Food Safety and Applied Nutrition. http://vm.cfsan.fda.gov/~mow/chap3.html

Woolaway MC, Bartlett CLR, Wieneke AA, Gilbert RJ, Murrell, HC and Aureli P (1986) International outbreak of staphylococcal food poisoning caused by contaminated lasagne. Journal of Hygiene, Cambridge 96:67-73.