

TYPHOIDAL SALMONELLAE

THE ORGANISM/TOXIN

- Salmonellae are mostly motile, non-spore-forming, Gram negative rods (1).
- The genus *Salmonella* is highly diverse and can be classified into two species, six subspecies and more than 2600 serovars (2).
- Typhoidal and non-typhoidal serovars belong to the same subspecies. They share similar bacterial characteristics but have very different disease manifestations (3, 4).
- Typhoidal serovars are restricted to the human host and result in life-threatening systemic disease (3, 4, 5, 6).
- Salmonella* Typhi (*S. Typhi*) is the causal agent of typhoid fever (also referred to as enteric fever). A related, but evolutionary distinct serovar, *S. Paratyphi* A, B (except B Java) and C can cause an enteric fever disease virtually indistinguishable from typhoid. These *Salmonella* serovars are collectively referred to as typhoidal salmonellae (4, 7).
- The organism does not produce toxins in food (1).

GROWTH AND ITS CONTROL

The characteristics of typhoidal salmonellae are essentially those given in full in the datasheet “non-typhoidal salmonellae”. An abridged version appears here, with *S. Typhi*/*Paratyphi* specific data given where available. Unless otherwise stated, the information below was derived from the following references (1, 8).

Growth:

	Minimum	Optimum	Maximum
Temperature*	7°C	35-37°C	45-47°C
Water activity	0.94	0.99	>0.99
pH**	3.8	6.5 - 7.5	9.5
Atmosphere	<ul style="list-style-type: none"> Can grow in the presence or absence of oxygen. Growth under nitrogen is only slightly less than that under air. <i>S. Typhi</i> grows at 8-11°C in the presence of 20-50% CO₂. 		

*Growth greatly reduced at <15°C.

**Minimum pH is influenced by other factors including temperature of incubation, acidulant used and the presence of salt and nitrate.

Survival:

Temperature	<ul style="list-style-type: none"> Survives well in the environment. <i>S. Typhi</i> can survive for 4 days in shellfish stored at 10-13°C, and in ice for in excess of 90 days. A slow decrease in bacteria occurs during frozen storage. Numbers of <i>S. Typhi</i> on fish fillets, at 4°C and -20°C, were reduced after one week compared to those of a non-typhoidal serovar (9).
Water activity	<ul style="list-style-type: none"> <i>S. Typhi</i> can survive for a year or more in

	foods with low <i>a_w</i> such as chocolate, peanut butter and black pepper (10).
pH	<ul style="list-style-type: none"> Tolerance of acidic conditions advantageous for environmental survival and virulence.
Biofilm production	<ul style="list-style-type: none"> Typhoidal salmonellae can produce disinfectant and antibiotic-resistant biofilms that contribute to the carrier state (in the host) and persistence (in non-host environments) (11, 12, 13, 14).
VBNC	<ul style="list-style-type: none"> Viable but Non-Culturable (VBNC) <i>S. Typhi</i> can exist in diverse food products leading to underestimation of prevalence. VBNC <i>S. Typhi</i> can be resuscitated following a temperature shift and the addition of Tween 20 or catalase (15, 16).

Inactivation:

Temperature	<ul style="list-style-type: none"> Typhoidal salmonellae are sensitive to heat and are killed by normal cooking conditions (core temperature of 75°C instantaneously or an equivalent time-temperature combination, e.g. 70°C for 2 minutes). High fat and low moisture foods require severe heat treatments to kill the bacteria.
D values	<ul style="list-style-type: none"> A literature review suggests the following time/temperature (°C/minutes) in “all meats”: <i>D</i>₆₀ 12.2; <i>D</i>₆₅ 2.1; <i>D</i>₇₀ 0.4 (17).
Sanitisers /disinfectants	<ul style="list-style-type: none"> Most disinfectants, commonly used in the food industry, are effective against <i>Salmonella</i> at recommended user concentrations. Some disinfectants have reduced effect, at recommended user concentrations, against <i>Salmonella</i>-forming biofilms on surfaces (12). Ozone, ultraviolet and chlorine can be used to reduce and inhibit the growth of <i>S. Typhi</i> in drinking water (18). Chlorine treatment of water infected with <i>S. Typhi</i> requires a concentration of 0.05 mg/L for 20 minutes, pH 7, 20-25°C to achieve 99.2% inactivation (19).
Preservatives and other non-thermal processing technologies	<ul style="list-style-type: none"> Sensitive to preservatives commonly used in foods. Inhibition enhanced by the use of several preservative factors in combination. For example, Nisin and <i>p</i>-Cymene have a synergistic antimicrobial effect on <i>S. Typhi</i> when added simultaneously to ready-to-eat Thai-style pork sausages (20). Water-extracted samples of turmeric stored at room temperature have been shown to inhibit the growth of <i>S. Typhi</i> (21).

THE ILLNESS

Incubation: Range 7-28 days (average 14) (1).

Symptoms:

- Gradual onset of sustained fever (39-40°C), malaise, chills, abdominal pain, headache, constipation or diarrhoea, dry cough, rapid pulse, anorexia, presence of rose-coloured spots on the chest, enlarged spleen and liver (1, 3).

- Slow recovery of 1 to 8 weeks.

Condition: Typhoid fever, paratyphoid fever or enteric fever.

At Risk Groups:

- Enteric fevers are endemic in developing parts of the world, including Africa, Asia and South America, where poor sanitation and inadequate clean water are common (3).
- Regarded as a disease of children (aged >2 years), adolescents and elderly people in endemic areas (22).
- Infections in very young children (< 2 years of age) are relatively rare (22).
- Travellers returning from countries where Enteric fevers are endemic are at greater risk of developing the disease (1, 3).

Long-term effects:

- Intestinal perforation, septicaemia and meningitis (23).
- Neurological complications including upper motor neuron signs, ataxia and parkinsonism (22, 24).
- Asymptomatic, chronic carriers: 1-4% of infected individuals continue to intermittently excrete *S. Typhi* in faeces and urine for more than 12 months after infection representing a threat to public health (3, 25).
- Chronic life-long infections in the gall bladder of convalescent individuals leading to the carrier state (4, 23) and indicated as a pre-disposing factor for the development of gallbladder cancer (25).

Dose: Determined in human challenge studies to be approximately 10^4 colony forming units or slightly lower (22, 26).

Incidence:

Globally:

- Typhoidal salmonellae cause approximately 22 million cases of typhoid fever, 5.4 million cases of paratyphoid fever and over 216,000 deaths annually in endemic areas (22, 25).

New Zealand:

- New Zealand incidence rate between 0.7 and 1.1/100,000 for 2006-2016. Notifications for typhoid fever have seen an increasing trend from 1997 to 2015. From 2008 to 2015, the numbers of notified cases per year have ranged from 29 to 50 (27).
- A high percentage of cases (>65%) are travel-related.
- New Zealand incidence rates are slightly higher than the EU (0.31/100,000 (2014)) and Australia (0.5/100,000 (2015)). Most cases in the developed world are either travel-related or in patients with unknown travel history (28) (29).
- Rates are a little lower for *S. Paratyphi* (between 0.3 and 0.7/100,000 for 2006-2016 (27)).

Treatment:

- Supportive therapy (maintenance of hydration and electrolyte balance) (3, 5).
- Fluoroquinolones are the antibiotic of choice but resistance has emerged (3, 30).
- Azithromycin is a relatively new antibiotic used for multi-drug-resistant isolates (3, 5).
- Third generation cephalosporins used in cases when other antibiotics fail or when the illness is severe (31).

- Three licensed typhoid vaccines available and others in various stages of development. No licensed vaccine available against *S. Paratyphi A* (3, 22).
- Vaccines recommended for travellers to areas where there is a risk of exposure to *S. Typhi*, people with intimate exposure to a *S. Typhi* chronic carrier or those in high-risk populations and laboratory workers routinely exposed to cultures of *S. Typhi* (32, 33).

SOURCES

Human:

- Humans are the sole reservoir for *S. Typhi* and *S. Paratyphi* (3, 4).

Animal:

- *S. Typhi* and *S. Paratyphi* do not infect animals.

Food:

- Raw vegetables and shellfish, fertilised by contaminated soil or water.
- Any food or beverage that comes into contact with body fluids, from infected individuals, may be contaminated with typhoidal salmonellae (34).

Environment/Water:

- Typhoidal salmonellae, shed in faeces, can survive in the environment, soil, sewage and water.
- Contaminated environment can be a source of infection for humans (1, 5, 34).

Transmission Routes:

- Spread mainly from person-to-person via the faecal-oral route with no animal reservoirs.
- Consumption of contaminated food and water and environmental exposure (3, 34).

OUTBREAKS AND INCIDENTS

Outbreaks:

New Zealand

- Between 2010-2015, there have been 1-5 outbreaks per year involving 2-17 cases. Person-to-person transmission is the primary mode of infection, followed by cases associated with overseas travel to *S. Typhi*-infected areas (35).

Worldwide

Notable foodborne outbreaks of typhoid fever in recent years are included below.

Year	Cases (deaths)	Suspected foods	Country	Control measure failure
2014	7 (0)	Fresh salad	Tokyo, Japan	Poor kitchen hygiene. Chef who was an asymptomatic <i>S. Typhi</i> carrier was implicated as the source of the outbreak ⁽³⁶⁾ .
2010	12 (0)	Imported frozen mamey pulp	USA	Imported fruit from a typhoid-endemic region in Guatemala. Poor food manufacturing practices and food-handler hygiene implicated ⁽³⁷⁾ .
1997	13 (0)	Pork	Utelle (France)	Poor kitchen hygiene and food contamination by a chronic <i>S. Typhi</i> carrier ⁽³⁸⁾ .

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