NON-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).
- Most non-typhoidal serovars result in mild enteritis in many hosts however some serovars can result in severe systemic disease in a limited number of host species. By contrast, typhoidal serovars (*Salmonella* Typhi and Paratyphi) are restricted to the human host and result in severe systemic infection (2, 3, 4, 5).
- Worldwide, the two most common serovars associated with foodborne disease in humans are *Salmonella* Typhimurium (*S.* Typhimurium) and *S.* Enteritidis (6).
- The organism does not produce toxins in food (1).

GROWTH AND ITS CONTROL

Unless otherwise stated, the information below was derived from the following references (1, 7).

Growth:

	Minimum	Optimum	Maximum
Temperature*	5.2°C (8, 9)	35-37°C	49.5°C
Water activity	0.94	0.99	>0.99
pH**	3.8	6.5 - 7.5	9.5
Atmosphere	Can grow in the presence or absence of oxygen.		
	• On beef muscle stored at 20ºC, growth under nitrogen is only slightly less than that under air (4). • Salmonellae grow in inoculated raw minced beef and cooked crab meat (stored at 8-11ºC) in the presence of 20-50% CO_2 (4).		

*Most serovars fail to grow at <7°C.
**Minimum pH is influenced by other factors including temperature of incubation, acidulant used and the presence of salt and nitrate.

Survival:

Temperature	• Survives well in the environment, on foods, human skin and other substrates, resulting in wide dissemination. • Survival is longer at chilled, compared with ambient, temperatures but is dependent on other factors such as pH and a_w. • Can survive for long periods in frozen foods with a slow decrease in bacterial numbers due to cellular damage. More rapid bacterial reduction in the range 0 to 10ºC than in the range -17 to -20ºC. • Some foods (e.g. raw meat, fish and liquid egg) provide protection of bacteria during freezing and frozen storage (8, 9).
Water activity	• Survives well in dry environments. • Some serovars can survive for months or years in foods with a low a_w such as black pepper, chocolate, peanut butter and gelatine (10).
pH	• Tolerance of acidic conditions advantageous for environmental survival and virulence.
Biofilm production	• Can form disinfectant and antibiotic-resistant biofilms which contribute to persistence in host, non-host and food-processing environments (11).
VBNC	• Transition to the Viable but Non-Culturable (VBNC) state after exposure to low temperatures (5ºC) in nutrient-limiting microcosms for up to 300 days (12).

Inactivation:

Temperature	• Most serovars are killed by normal cooking conditions (core temperature of 75ºC instantaneously or an equivalent time-temperature combination, e.g. 70ºC for 2 minutes). • Particular strains of *S.* Senftenberg have been reported as heat-resistant when tested in culture, influenced by a_w, solutes and pH of the suspending medium (1). • High fat and low moisture foods require severe heat treatments to kill *Salmonella* e.g. in milk chocolate with <10% moisture, $D_{80ºC}$ for *S.* Typhimurium is 222 minutes.
***D* values**	• **A literature review suggests the following time/temperature (ºC/minutes) in "all meats": D_{60} 12.2; D_{65} 2.1; D_{70} 0.4** (13).
Drying	• Salmonellae die slowly at water activities below 0.94.
pH	• Salmonellae die outside the ranges of pH permitting growth. • Inactivation depends on factors including the type of acid present and the temperature with the rate of death decreasing as the temperature is reduced e.g. inactivation is more rapid in commercial mayonnaise at 20ºC than it is at 4ºC.
Sanitisers /disinfectants	• Most disinfectants, commonly used in the food industry, are effective against *Salmonella* at recommended user concentrations. • Some disinfectants have reduced effect, at recommended user concentrations, against *Salmonella* on surfaces and in biofilms (14). • Novel disinfectant strategies such as electrolysed water, antimicrobial materials and anti-biofilm –specific compounds have been shown to reduce or eliminate *Salmonella* under certain conditions (15).
Radiation	• *D*-values in foods between 0.5 kGy and 0.8 kGy with values higher in dried foods. • Sensitivity influenced by the substrate, temperature and the presence or absence of oxygen. • UV and heat treatment applied together provide a synergistic, simultaneous lethal

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	effect for *S.* Typhimurium and *S.* Enteritidis in broth culture (15).
Preservatives and other non-thermal processing technologies	• Sensitive to preservatives commonly used in foods. • Growth inhibited by benzoic, sorbic and propionic acid. • Inhibition enhanced by using a combination of factors e.g. the use of a preservative together with reduction in pH and temperature (16, 17) • High pressure processing (300 MPa, 35ºC, 1 minute) reduced *Salmonella* load on uncooked chicken breasts by 2 $\log_{10}$ (18).

THE ILLNESS

Incubation: 6 to 72 hours (usually 12-36 hours) (1).

Symptoms:
- Self-limiting watery diarrhoea, abdominal cramping, vomiting, nausea, fever and headache (1, 3).
- Symptoms typically last between 2-7 days (1).

Condition: Salmonellosis.

At Risk Groups:
- Young, elderly, immunocompromised and those with underlying disease (3).
- Highest incidence reported for infants < 1 year and children aged 1-4 years (19).
- Risk factors include consumption of food at retail premises, travelling abroad and contact with farm animals (19).

Long-term effects:
- Bacteraemia and focal systemic infections can result in up to 5% of cases (3).
- Major risk factors for invasive disease are co-infection with HIV, malaria and malnutrition (3).
- Reactive arthritis and Reiter's syndrome may develop in a small percentage of patients 3-4 weeks after enteritis (3, 20).
- Excretion of *Salmonella* for up to seven weeks after infection can occur (3, 4).

Dose: Wide range: <10 to 10^9 colony forming units with dose dependent on many factors including serovar and food type (foods with a high fat content permit a lower dose to cause infection) (4, 21).

Incidence:
- New Zealand incidence rate of 22.9/100,000 (2015). Notifications for salmonellosis saw a large decrease between 2001 and 2004 and have remained relatively stable since 2005 (19).
- New Zealand incidence rates are comparable with the EU (20.4/100,000 (2013)) (22), slightly higher than the USA (16.3/100,000 (2014)) (23) and lower than Australia (69.7/100,000 (2014)) (24).
- Evidence of geographical variation in the annual case rate for human salmonellosis and in the geographical distribution of specific *Salmonella* serovars (3, 19).
- The most common *Salmonella* serovars identified in New Zealand (2015) were *S.* Typhimurium and *S.* Enteritidis, the phage types of which appear consistent over the last 5 years (19).

Treatment:
- Treatment rarely required, supportive therapy may be given (maintenance of hydration and electrolyte balance) (3, 4).
- When necessary, Fluoroquinolones are the antibiotic of choice (3).
- Azithromycin is a relatively new antibiotic used for multi-drug-resistant isolates (3, 4).

SOURCES

Unless otherwise stated, the information below was derived from the following references (1, 4).

Human:
- Infected persons route (6).
- Non-typhoidal serovars typically have a broad host range and can cause gastroenteritis in humans, and other species. A few serovars, specific to animal hosts, never (*S.* Pullorum and *S.* Gallinarum in poultry) or rarely (*S.* Choleraesuis in pigs and *S.* Dublin in cattle) infect humans (5).

Animal:
- Domesticated or wild animals (including birds, fish and amphibians) are common symptomless carriers acting as reservoirs of infection for humans (1, 3, 4, 25).

Food:
- Many foods of animal and non-animal origin, which may have been subject to faecal contamination, have been identified as vehicles for the transmission of salmonellae to humans. Foods of particular concern include eggs, pork, poultry, milk, chocolate, fruit and vegetables (9, 25).

Environment/Water:
- Salmonellae shed in faeces can contaminate pasture, soil and water (1, 4).
- The environment can be a source of infection for humans and/or other animals (1, 4).

Transmission Routes:
- Consumption of contaminated food and water, environmental exposure, direct contact with animals, person-to-person transmission (3).

OUTBREAKS AND INCIDENTS

Outbreaks:

New Zealand
- The number of foodborne outbreaks have remained stable (11 or less) for the past 10 years (26). The number of cases spiked in 2008 and 2012 due to large outbreaks associated with the consumption of contaminated raw flour (27) and imported tahini sesame paste (28) respectively.
- A large proportion of foodborne outbreaks of *Salmonella* have no identifiable source (26).

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New Zealand

Notable outbreaks in recent years are included below.

Year	Foodborne outbreaks (cases)	Suspected foods
2006	10 (36)	No identifiable source
2007	7 (56)	Poultry, meat, fresh produce, rice/noodles/pasta, kebab, processed meat, eggs
2008	4 (121)	Fish, eggs, raw flour
2009	4 (47)	Fruits/nuts
2010	10 (56)	Poultry, dairy, oils/sugars, eggs, water
2011	8 (42)	Shellfish, fish, pork, beef, leafy vegetables, sprouted vegetables
2012	11 (100)	Grains/beans, oils/sugar, poultry, imported tahini sesame paste, leafy vegetables, root vegetables, beef, pork
2013	9 (45)	Grains/beans, pork, egg
2014	7 (44)	Rice, fish, beef
2015	3 (30)	No identifiable source

Worldwide

Notable outbreaks in recent years are included below.

Year	Cases (deaths)	Suspected foods	Country	Serovar	Control measure failure
2013	16 (1)	Imported tahini	USA (multistate)	*S.* Montevideo, and *S.* Mbandaka	Tahini sesame paste imported from Turkey (29).
2014	287 (6)	Contaminated eggs	UK and Europe	*S.* Enteritidis phage type 14b	Supply of contaminated eggs from a German producer (30).
2014	634	Raw chicken	USA	*S.* Heidelberg	Incorrect handling and/or cooking of contaminated chicken (31).
2015	907 (6)	Imported Mexican cucumbers	USA	*S.* Poona	Produce was prepared, packed and held under unsanitary conditions (32).

LIST OF NZ RISK PROFILES ON SALMONELLAE IN FOODS

Matrix	Date	Link
Poultry (whole and pieces)	2002	*http://www.foodsafety.govt.nz/elibrary/industry/Risk_Profile_Salmonella-Science_Research.pdf*
Poultry (whole and pieces) (update)	2004	Not available
Eggs	2004	*http://www.foodsafety.govt.nz/elibrary/industry/Risk_Profile_Salmonella_Typhoidal_Eggs-Science_Research.pdf*
Pork and pork products	2010	*http://www.foodsafety.govt.nz/elibrary/industry/Salmonella_Typhoidal-Science_Research.pdf*
High lipid foods made from sesame seeds, peanuts or cocoa beans	2010	*http://www.foodsafety.govt.nz/elibrary/industry/salmonella-in-high-lipid-foods.pdf*
Cereal grains	2010	*http://www.foodsafety.govt.nz/elibrary/industry/salmonella-in-cereals.pdf*
Poultry (whole and pieces) (update)	2011	*https://mpi.govt.nz/document-vault/6256*
Eggs (update)	2011	*https://www.mpi.govt.nz/document-vault/9506*
Animal feed	2011	*http://www.foodsafety.govt.nz/elibrary/industry/salmonella-in-feed.pdf*
Eggs (update)	2016	*https://www.mpi.govt.nz/document-vault/14161*

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