



Salmonella spp.

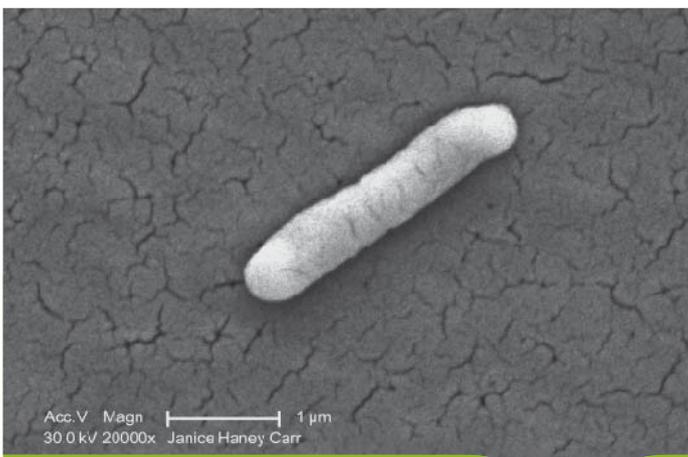
Family: *Enterobacteriaceae*
Genus: *Salmonella*
Bacterium

Characteristics and sources of *Salmonella* spp.

Main microbiological characteristics

Under certain conditions, serotypes (or serovars) of non-typhoid *Salmonella* cause salmonellosis, one of the principal gastroenteric syndromes of bacterial origin in industrialised countries. Other serovars cause typhoid fevers (*S. Typhi* and *S. Paratyphi* A, B and C).

Salmonella is a genus of Gram-negative bacilli composed of two species (*S. enterica* and *S. bongori*), with *S. enterica* itself being divided into six subspecies (*enterica*, *salamae*, *arizonae*, *diarizonae*, *houtenae* and *indica*) on the basis of phenotype criteria. Serology is used to classify the subspecies into serovars, based on the characterisation of somatic (O) and flagellar (H) antigens; those belonging to the *enterica* subspecies are frequently given a name corresponding to a geographical location, while the others are identified by their antigenic formula. All known serovars (more than 2,600) are catalogued under the Kauffmann-White-Le Minor scheme⁽¹⁾. *S. Enteritidis* and *S. Typhimurium* predominate in food, but their relative importance varies over time and geographically (by country). All serotypes must therefore be considered as potential pathogens.



S. Typhimurium (SEM) © CDC/Janice Haney Carr

Table 1. Survival and growth characteristics of *Salmonella*

Parameters	Survival (extreme values)	Growth	
		Optimum	Extremes
Temperature (°C)	-23 (butter)	35 - 37	5 - 50
pH	/	7 - 7.5	3.8 - 9.5
a_w	0.3 - 0.5 (chocolate)	0.99	0.94 - > 0.99

Hazard sources

The gastro-intestinal tract of mammals (pigs and cattle) and birds (domestic poultry) is the principal reservoir of *Salmonella* spp. Some strains can also be found in other sources, such as cold-blooded animals (reptiles, turtles) and aquatic animals (molluscs, fish). The animal reservoir is the main source of the hazard. *Salmonella* in faecal matter from animals can contaminate pastures, soil and water, and can survive for several months; the environment can thus become a source of hazard.

Humans form the only reservoir for *S. Typhi*.

Transmission routes

Non-typhoid human salmonellosis are considered to be zoonotic diseases. Transmission to humans mostly occurs through the consumption of raw or undercooked contaminated foods. It has been estimated that 95% of non-typhoid *Salmonella* and 80% of typhoid *Salmonella* are transmitted by ingestion.

Non-typhoid *Salmonella* can also be transmitted to humans directly, either between humans or by contact with infected animals.

Transmission of *Salmonella* Typhi and Paratyphi occurs from person to person or *via* ingestion of water or food contaminated by the faeces of infected subjects.

(1) Antigenic formulae of *Salmonella* serovars:
<http://www.pasteur.fr/ip/portal/action/WebdriveActionEvent/oid/01s-000036-08a>

Recommendations for primary production

- The risk of infection and the dissemination of *Salmonella* in production sectors can be controlled by implementing strict measures to prevent biological contamination in production livestock, especially pigs and poultry, including in breeding farms.
- Medical prophylactic measures such as vaccination could be considered specifically to combat certain serotypes (e.g. *S. Enteritidis*, *S. Typhimurium*) in particular production sectors (e.g. laying hens).
- Controlling the microbiological quality of the water used in crop production sectors is an indispensable aspect of controlling contamination.

Human foodborne illness

Nature of the disease

The characteristics of the disease are presented in Table 2.

Salmonella infections cause acute gastro-enteritis. The outcome is generally favourable within a few days, but this infection can proceed to a septicæmic or localised form.

Infections by *Salmonella* Typhi (typhoid fevers) and *S. Paratyphi* A, B and C (paratyphoid fevers) are generalised infections. Paratyphoid fever is generally less severe than typhoid fever. There are two types of *Salmonella* Paratyphi B: Java type (d-tartrate positive), which is considered as a minor salmonella most often responsible for febrile gastro-enteritis, and non-Java type (d-tartrate negative), responsible for paratyphoid fever.

Susceptible population groups⁽²⁾: anyone can become infected by *Salmonella* spp. Susceptibility to infection is greater in subjects suffering from malnutrition, achlorhydria, hypochlorhydria or a neoplastic disease, or following an antiacid treatment, broad spectrum antibiotherapy or immunosuppressor treatment. In immunocompromised subjects and infants, *Salmonella* spp. infections can be severe and even lead to death.

Dose-effect⁽³⁾ and dose-response⁽⁴⁾ relationships

The literature currently contains no accounts of a dose-effect relationship. However, experience shows that the higher the ingested dose, the faster gastro-intestinal disorders appear. Data obtained from surveys following

outbreaks indicate that digestive disorders can appear after ingestion of 10^1 to 10^{11} bacteria. It has also been observed that foods with high fat or protein content protect the bacteria against gastric acidity; lower doses can cause disorders when ingested with such foods.

Concerning the dose-response relationship, the World Health Organization (WHO) has stated that the dose of *S. Enteritidis* causing disorders in 50% of consumers is in the order of 10,000 bacteria, but does not conclude as to whether this relationship can be extrapolated to the other serovars.

However, a recent meta-analysis indicated that the infectious dose causing salmonellosis in 50% of exposed subjects is in the order of a few tens of bacteria for the serovars Typhimurium and Enteritidis, irrespective of the population group exposed.

Epidemiology

In France, between 2006 and 2008, salmonellosis accounted for almost half (46.8%) of confirmed outbreaks of collective foodborne illness reported as a notifiable disease. Since 2001, however, there has been a reduction in the number of outbreaks where *Salmonella* has been isolated. The serovars Typhimurium (40.2%) and Enteritidis (29.4%) remain the most frequently identified; we may also note that in more than 25% of confirmed cases, the serovar is not specified. *Salmonella* was responsible for 30% of patients in foodborne outbreaks whose origin was confirmed. For 2009, the National Centre of Reference for *Salmonella* recorded almost 10,000 cases of *Salmonella* spp. isolated in humans. The Typhimurium serovar is predominant, confirming the results obtained since 2005; the new monophasic variant of *S. Typhimurium* (1,4,[5],12:i:-) is progressing even faster with more than 1,000 isolates identified.

In Europe, *Salmonella* spp. is the second most frequently reported zoonotic infection in humans and remains the commonest cause of foodborne illness outbreaks. The joint annual report by the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC), published in 2011, confirms the steady reduction in cases of human salmonellosis in the European Union (-17% in 2009). *S. Enteritidis* and *S. Typhimurium* are the main serovars found.

(2) Susceptible population group: people with a higher than average probability of developing symptoms of the disease, or severe forms of the disease, after exposure to a foodborne hazard [definition used in ANSES data sheets].

(3) Relationship between the dose (the quantity of microbial cells ingested during a meal) and the effect on an individual.

(4) For a given effect, the relationship between the dose and the response, i.e., the probability of this effect appearing in the population.

Table 2. Characteristics of the disease: non-typhoid salmonellosis and typhoid fevers

Mean incubation period	Target population	Main symptoms	Duration of symptoms	Duration of the contagious period	Complications	Asymptomatic forms
Non-typhoid salmonellosis						
6-72 hours Most frequently from 12-36 hours	Cosmopolitan, all age groups	Nausea, vomiting Abdominal pains Diarrhoea Headaches Shivering Fever of 39-40°C	5-7 days	Generally from a few days to several weeks. Sometimes several months: 1% of adult patients and 5% of children under 5 years old can continue to shed the bacteria for up to 12 months.	Bacteraemia in 3 to 10% of cases Dehydration Hospitalisation rate (22.1%) Mortality rate (0.8%)	Yes
Typhoid fevers						
3 days-1 month Most often from 8-14 days	Cosmopolitan, all age groups	Prolonged fever Intense headaches Anorexia Most often constipation, or diarrhoea Somnolence, daytime prostration, nocturnal insomnia, petechial rash on flanks or chest	/	Throughout duration of symptoms and for several weeks following. 10% of patients continue to shed the bacteria for 3 months after the start of symptoms. 2 to 5% become chronic carriers	Digestive complications (haemorrhages, perforations) Extradigestive locations: osteitis, cholecystitis, etc. Myocardial complications: heart failure Lethality: 1% (with appropriate antibiotherapy)	Yes + chronic asymptomatic carriage

Role of foods

Main foods to consider

In different surveys relative to declarations of foodborne outbreaks, the most frequently incriminated foods are eggs and products based on raw eggs or eggs having undergone insufficient heat treatment, dairy products (raw or slightly heat-treated milk) and also meat (beef, pork and poultry meat). However, the cases described in the literature mention several other foods (fruit and vegetables, shellfish, etc.).

An important transmission route is *via* eggs for human consumption, contaminated either on the surface of the shell or in the yolk, because of transovarial transmission of the bacteria, more particularly *S. Enteritidis*. During slaughter, carcasses can become contaminated on the surface by the contents of the digestive tract, which can host *Salmonella* spp. Fresh produce, and especially sprouted grains, can harbour salmonella as a result of the use of contaminated fertilisers or water, or of poor practice during harvesting and preparation.

Inactivation treatments in industrial environments

The same result can be obtained at lower temperatures if salt is added to certain egg products (particularly egg white), which can avoid coagulation and the loss of the product's technological qualities.

Salmonella spp. is resistant to nitrites.

Table 3. Inactivation treatments in industrial environments for *Salmonella* spp.

Disinfectants	Effects of temperature
Sensitive to all disinfectants authorised in the food-processing sector, on condition that the recommended procedures for use are followed	Value of D* time: $D_{60^{\circ}\text{C}} = 2\text{-}6$ min; $D_{70^{\circ}\text{C}} \leq 1$ min Thermoresistance depends on the serovar and the food matrix. One particular strain of <i>S. Senftenberg</i> 775 W has been found to have thirty times greater resistance to heat.
Irradiation	High Pressure
D_{10} - value** = 0.5 – 0.8 kGy	600 MPa for 2 min at 35°C → 5- \log_{10} reductions of the initial load. 350 MPa for 5 min at 25°C → 3- \log_{10} reductions of <i>S. Enteritidis</i> in a mixture of egg yolk and egg white. 450 MPa for 5 min at 25°C → 5- \log_{10} reductions of <i>S. Enteritidis</i> in a mixture of egg yolk and egg white. 345 MPa for 5 min at 25°C → 4- \log_{10} reductions of <i>S. Enteritidis</i> in buffered peptone water. Same treatment but at pH 5.5 → 8- \log_{10} reductions of <i>S. Enteritidis</i>

* D is the time needed to divide by 10 the initial population of a microbiological hazard..

** D_{10} - value is the dose of radiation required to reduce the viability of a population by 90% (1 \log_{10} cycle) under the stated conditions..

Monitoring in foods

The EU reference laboratory for *Salmonella*, set up in application of EU Directive 2003/99, is responsible for collecting all information regarding the presence of *Salmonella* spp. isolated in stock farms and in human foods or animal feed.

In the framework of the French surveillance system, ANSES (the National Reference Laboratory) is responsible for collecting data concerning the strains of *Salmonella* spp. isolated in France in sick animals or healthy carriers, their farm environment, human foods and animal feed, or the environment in slaughterhouses and processing facilities for foods of animal origin, as well as strains found in the natural environment.

There are several possible methods for detecting salmonella in foods or the environments of food-processing facilities. Some of these are governed by procedures validated at French, European or international level. For example, the NF/EN/ISO 6579 standard, amended in October 2007, describes a horizontal reference method for screening for *Salmonella* spp.

both in foods and at the primary production stage; a different international standard (ISO 6785/2008) is recommended for screening for *Salmonella* spp. in milk and milk products; again, in France, a standard (NF V59-104) is proposed for edible gelatine. Lastly, a series of French standards (NF U47-100, 101 and 102) recommend analytical methods for the isolation and identification of any serovar or serovars of concern to animals (in the production environment of animals, poultry and mammals, respectively).

Regulation (EC) no. 2073/2005, on microbiological criteria for foodstuffs, defines safety criteria regarding *Salmonella* for a large number of foods, especially ready-to-eat foods. Microbiological hygiene criteria for processes regarding *Salmonella* spp. have also been established concerning certain categories of products (animal carcasses).

Recommendations to operators

- Operators' attention should be drawn to:
 - the microbiological quality of raw materials, especially eggs, pork, beef and poultry meat, and also milk;
 - the importance of good hygiene practices at every step in the food chain.

Domestic hygiene

Recommendations for consumers

General measures for domestic hygiene

- Hands should be washed thoroughly:
 - after handling risk foods (raw eggs, raw meat, unwashed vegetables);
 - after contact with live animals (especially reptiles, turtles, etc.). Vulnerable subjects (immunocompromised subjects, infants, pregnant women) should avoid all contact with reptile pets.
- Any work surface that has been used for preparing risk foods should be carefully cleaned.
- Foods should be cooked thoroughly, particularly pork and poultry meat, as well as minced meat.

Specific measures concerning eggs

- It is essential to ensure that eggs are stored at a stable temperature to avoid condensation occurring on their surface; if eggs are chilled when sold or at home, they must be kept cool. Eggs should never be washed before being stored as washing modifies the surface of the shell and can facilitate penetration by microorganisms.
- Uncooked egg-based preparations (mayonnaise, creams, chocolate mousse, pastries, etc.) must be prepared as close as possible to the time of consumption, kept cool and consumed within 24 hours.
- The elderly, the sick, young children and pregnant women should not consume raw or undercooked eggs.

References and links

General references

- InVS (2010). *Les toxi-infections alimentaires collectives en France entre 2006 et 2008*. [Food poisoning outbreaks in France between 2006 and 2008] BEH no 31-32.
- Peter F.M. Teunis, Fumiko Kasuga, Aamir Fazil, Iain D. Ogden, Ovidiu Rotariu and Norval J.C. Strachan, (2010). Dose response modeling of *Salmonella* using outbreak data. *International Journal of Food Microbiology* 144 (2),243-249.

Useful links

- European Union Reference Laboratory for the analysis and testing of zoonoses (*Salmonella*): Rijksinstituut voor Volksgezondheid en Milieu (RIVM), 3720 BA Bilthoven, Netherlands.
- French Institute for Public Health Surveillance (InVS): http://www.invs.sante.fr/surveillance/salmonelloses_non_typhiques/default.htm
- National Centre of Reference (NRC) and WHO Collaborating Centre (WHOCC) for *Salmonella*: Laboratory for enteric pathogenic bacteria, Institut Pasteur, Paris.
- National Reference Laboratory (NRL) for *Salmonella* spp.: ANSES Ploufragan - Plouzané Laboratory.