

SALMONELLA PATHOGENICITY

Salmonella is a genus of bacteria belonging to the Enterobacteriaceae family. It is widespread throughout the environment and found across a large variety of food products including poultry, produce, red meat, eggs, and other products. *Salmonella enterica* is the species that causes salmonellosis, which is one of the most significant foodborne illnesses worldwide, causing substantial medical and economic burdens annually.¹ Approximately 2600 serotypes of *Salmonella* exist and can vary in their pathogenicity or ability to cause illness.² (Serotypes are groups within a single species of microorganisms, such as bacteria or viruses, which share distinctive surface structure). The presence of *Salmonella* does not automatically imply an illness will occur.³ In the past, regulatory agencies have considered all *Salmonella* to be equal regarding regulations impacting public health. The quantity (total cell number) of *Salmonella* in a product as well as the serotype must be considered in regulations in order to implement practical, effective control measures that ultimately impact public health outcomes.

Human Illness from *Salmonella*

There are an estimated 1.35 million cases of salmonellosis in the United States annually.¹ Many foods can be a source of illness in people but chicken, fruits, pork, seeded vegetables, other produce (such as herbs and root vegetables), beef, turkey and eggs account for over 75% of total *Salmonella* infections annually (Figure 1).⁴ Estimates from multiple data sources are currently used for attributing illnesses or outbreaks to a specific food because no single reporting system exists among the contributing public health agencies. Additionally, illness from food sources vs. animal sources are not separated in current reporting which may cause attribution data to be erroneously inflated in some food categories (i.e., illness from food containing chicken breast vs. human contact with live backyard chickens).

Accurate reports of food-related illnesses help industry and researchers identify bacterial sources because many variables impact the likelihood of illness. The quantities of viable cells, the presence of pathogenic genes, the susceptibility of the host (person) and the preparation and handling of food all impact the potential for illness. Understanding all the factors that make humans more or less susceptible can help inform types and placement of interventions throughout the food chain.

Salmonella Sources, Reservoirs, and Transmission

Salmonella is widely distributed in the environment being harbored in animals, water, soil, and other reservoirs.¹ The organism is naturally found in the gut environment and is also found in bone marrow, connective tissue, lymph nodes and synovial fluids of some poultry and livestock but does not usually pose a threat to the animal. The carcasses of livestock and poultry can become contaminated with *Salmonella* from these reservoirs and harborages during the slaughter process which is known as cross-contamination.

Because of the potential presence in lymph nodes of beef and pork⁵, and in various tissues of poultry, *Salmonella* can be within ground meat and poultry.⁶ Interventions, pre- and post-harvest, have been implemented to prevent, control, or reduce contamination, such as prebiotics in the feed, vaccines, or organic acid sprays on carcasses or parts.⁷ Multiple and sequential interventions prove most effective in a farm to fork approach.

Besides the transmission within poultry and livestock, other modes of transfer can occur. *Salmonella* may be spread by wildlife, direct contact with infected animals such as pets or backyard flocks of chicken, or by fecal contamination through irrigation of produce. Humans can spread the organism through the fecal-oral route to one another and improper handwashing and cleanliness by food handlers can lead to rapid spread. One measure consumers can take to avoid Salmonellosis from food is through proper handling and adequate cooking temperatures.⁸ For industry and researchers, understanding sources, transmission modes and bacterial cell numbers at each step in processing can aid in controlling this bacterium.

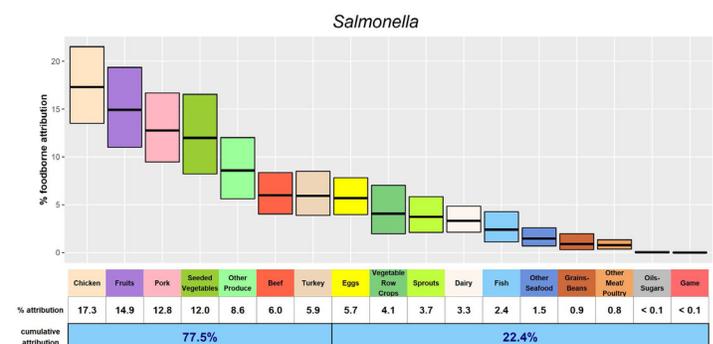


Figure 1. Estimated percentage of foodborne *Salmonella* illnesses (with 90% credibility intervals) for 2019, in descending order of percentage attribution. (CDC, 2022) (Note that this data does not account for consumption patterns, only reports of illness. Higher consumption rates may increase the likelihood of illness occurring and being reported. Conversely, a food with lower consumption may have higher attribution of illness because of a few reported events, not necessarily correlated to consumption rate.)

Not All *Salmonella* are Equal

The numerous serotypes of *Salmonella* each have the potential to cause illness in humans, but some are host-specific and can live and grow in only one or a few animal species. Some serotypes are rarely associated with human illness, such as *Kentucky*, which is most frequently isolated from poultry but is low risk to consumers. Two of the highest risk serotypes to consumers tend to be *Enteritidis* and *Typhimurium*.⁹ The number of viable cells in a food product, also referred to as the “dose,” influences likelihood of human illness as shown in Figure 2.¹⁰ With the difference in pathogenicity among serotypes and the impact of dose/response relationship on illness, it is important for the meat and food industry to have detection methods to determine the specific serotype and have accurate quantification methods to make the best decisions for public health.

Regulatory Status in Meat

The United States Department of Agriculture Food Safety and Inspection Services (USDA-FSIS) conducts regular testing of various raw poultry products for the presence of *Salmonella* and has set performance standards for slaughter and processors. A performance standard sets a criterion which establishments must meet when harvesting animals and processing products. These standards are based on the presence of any *Salmonella* in the product. While the agency conducts further testing to determine the serotype, for regulatory purposes, no consideration is given to the pathogenicity in current performance standards.¹¹ This means that products with low cell counts, and low pathogenicity are still considered as failing the standard even though likelihood of causing illness is low to impossible. This regulatory approach can result in unnecessary food waste or costly interventions before the food enters commerce. Performance standards for *Salmonella* in ground beef and pork are still in the proposal stage.

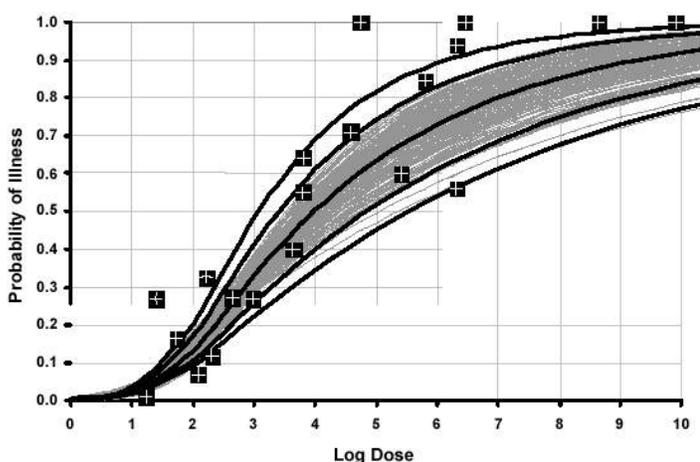


Figure 2. Dose-Response Relationship for *Salmonella* in humans (adapted from FAO, 2002)¹⁰

Research Needs

To improve the safety of meat and poultry, research is needed regarding:

- **Dose-response relationship:** Develop a timely model to include serotyping and pathogenicity gene information
- **Susceptibility profiles:** Develop profiles of individuals affected by salmonellosis
- **Molecular markers:** Utilize a human isolate database to develop molecular markers that identify the bacteria that is most invasive, pathogenic, and highest risk to consumers.
- **Public health reporting:** Improve the reporting process and interagency information sharing to improve attribution data
- **Lymph nodes:** Develop methods for detecting presence of *Salmonella* in lymph nodes

KEY POINTS

- The probability of illness caused by *Salmonella* is highly dependent on:
 - a. Serotype genes which determine pathogenicity
 - b. The dose (quantity) of bacterial cells
 - c. Susceptibility of the host
- Current USDA-FSIS regulations do not factor in serotype differences, pathogenicity variations, or cell quantity when setting performance standards. The limited shelf life of meat products makes it impractical to rely on the time-consuming methods of determining serotype.
- No single reporting system exists among public health agencies for attributing illnesses or outbreaks to specific foods while also considering consumption patterns.
- Estimates from multiple data sources are currently used which creates limitations on data output and on fully understanding the source of human illness.
- Illness from food sources vs. animal sources are not separated in current reporting which may cause attribution data to be erroneously inflated in some food categories

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