AMERICAN MEAT ASSOCIATION • FACT SHEET

Salmonella Overview

The *Salmonella* Problem

Salmonella is the **most frequently reported bacterial cause of foodborne illness** in the U.S. Each year, more than 1 million U.S. cases of Salmonellosis occur, causing ~400 deaths and ~20,000 hospitalizations (Scallan *et al.*, 2011). The total cost to the U.S. economy for these illnesses, including medical costs and loss of productivity, has been estimated at $3.7 to $11.4 billion per year (Hoffmann *et al.*, 2012, Scharff, 2012).

Eggs and poultry are well known for their role in transmitting *Salmonella* infections; however, all foods can harbor the organism, including beef, pork, lamb, fish, dairy products, vegetables, fruits, nuts, etc. **About one-third of the *Salmonella*-related disease reported in the US is attributed to poultry, beef, pork, or lamb** (Hsi *et al.*, 2015). The average American has a 1 in 40 lifetime risk of acquiring *Salmonella*-related illness from consuming poultry, and a 1 in 100 lifetime risk from eating beef and from eating pork (Hsi *et al.*, 2015).

Overview of the Bacteria

Salmonella is a gram-negative, rod-shaped bacteria with a talent for adapting to its environment. **This ability to grow or persist in many different conditions makes it particularly problematic as a foodborne pathogen.** *Salmonella*'s preferred habitat is the gastrointestinal tract of animals, where it often establishes a relationship that results in little or no clinical disease to its host. From there, however, the bacteria can shed in feces and easily contaminate soils, waters, and surfaces, potentially infecting other animals. Importantly, fecal shedding also leads to hide and wastewater contamination during slaughtering.

Salmonella can grow aerobically or anaerobically depending upon conditions. Although a temperature of 37°C (98.6°F) and a pH of 6.5 to 7.5 are optimal, different strains grow under many conditions, ranging from temperatures between 2°C (36°F) to 54°C (129°F) and pH values between 4.0 and 9.5 (Li *et al.*, 2013). *Salmonella* can survive under harsh conditions, including persisting in frozen meat for a year or more (Muller *et al.*, 2012).

For growth, *Salmonella* requires a water activity of at least 0.93. However, it can survive and persist for months at much lower water activities, as low as a_w=0.18 in one report (Kotzekidou, 1998). When *Salmonella* adapts to low-moisture environments, it becomes more resistant to heat, making it a serious problem in dried foods such as beef jerky and spices (Buege *et al.*, 2006). **Exposure of *Salmonella* to environmental stresses can result in the organism becoming more hardy and resistant to other adverse conditions**. For example, sub-lethal heat exposure increases heat resistance, while growth at a low pH makes the microbe more resistant to both heat and high salt concentrations (Li *et al.*, 2013).

The genus *Salmonella* is part of the family Enterobacteriaceae, which includes other well-known human pathogens such as members of the genera *Shigella, Yersinia,* and *Escherichia* (Baylis *et al.*, 2011). Only two species of *Salmonella* are recognized currently (Barrow *et al.*, 2012). **Nearly all human disease attributed to *Salmonella* is caused by the species *Salmonella enterica*,** although rare (and likely not foodborne) human infections with *Salmonella bongori* have been reported (Marti *et al.*, 2013, Pignato *et al.*, 1998). Six subspecies exist within *Salmonella enterica* (Figure 1). Most human *Salmonella* isolates (99% of those in the U.S.) belong to subspecies I, which is also somewhat confusingly called *enterica;* these strains are thus formally known as *Salmonella enterica* subspecies *enterica* (Centers for Disease Control and Prevention, 2011).

Salmonella subspecies are further categorized into serotypes (or serovars) based on two surface antigens. More than 2600 *Salmonella* serotypes have been identified. Figure 1 summarizes the subdivisions within the *Salmonella* genus.

In recent years, the most common *Salmonella* serotypes associated with foodborne disease in the U.S. have been Enteritidis, Typhimurium, Heidelberg, and Newport, although many other serotypes have triggered outbreaks (Gould *et al.*, 2013). Some serotypes are associated with specific animals and thus

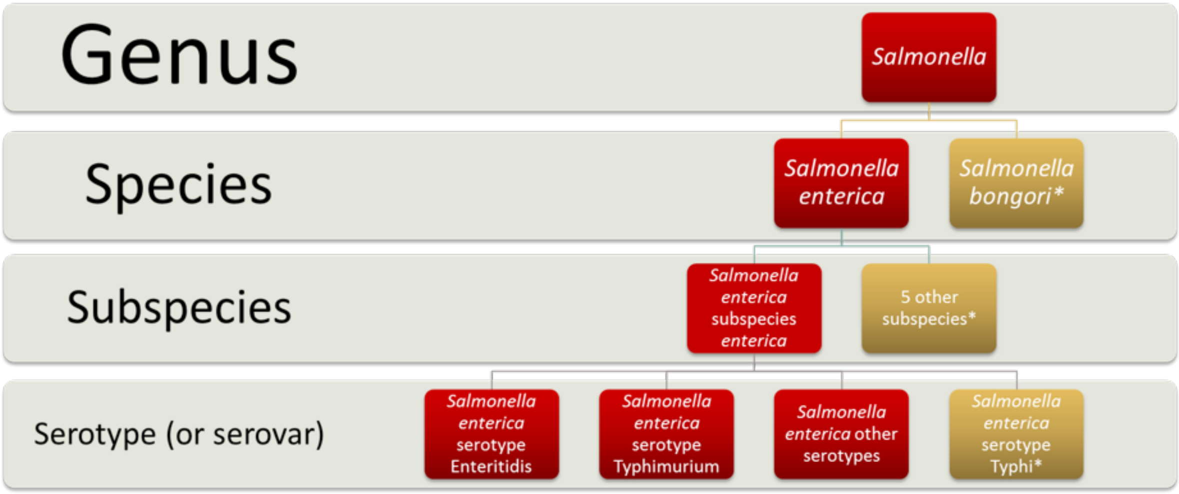

Figure 1. Nomenclature within the *Salmonella* Genus
**Salmonella* categories not typically associated with foodborne disease are denoted with asterisks.

with specific foods. For example, the serotype Enteritidis is often associated with eggs and poultry, while serotype Dublin infects cattle and has caused outbreaks associated with raw milk (Mateus *et al.*, 2008). In contrast, serotype Typhimurium infects many types of animals and has been associated with a wide range of foods (Thorns, 2000). *Salmonella* serotypes that are adapted to their host tend to cause more severe, systemic disease in their hosts and may cause very mild or no illness in animals to which they are not adapted (Baumler *et al.*, 1998). Conversely, *Salmonella* serotypes that lack host specificity tend to be less virulent (Langridge *et al.*, 2015) and may be more likely to cause illness in young animals that lack a fully developed immune system (Baumler *et al.*, 1998). Table 1 presents some of the host animals for common *Salmonella enterica* serotypes.

Human Risks and Epidemiology

Although food is its primary vehicle, a small percentage (~6%) of *Salmonella* infections in the U.S. are acquired in others ways, such as **handling food animals, turtles, other reptiles or amphibians, chicks, and on occasion, from contact with pet foods and treats** (Hoelzer *et al.*, 2011, Scallan *et al.*, 2011). Person-to-person transmission is also possible (Steere *et al.*, 1975).

Salmonellosis, the gastrointestinal illness associated with non-typhoid *Salmonella* strains, typically occurs within 12 to 72 hours of eating a contaminated food. **The number of *Salmonella* cells needed to cause disease may be very low** in some cases (<10 cells), depending on the serotype and the type of food, with high-fat foods sometimes resulting in lower infectious doses (Li *et al.*, 2013). Food contaminated with *Salmonella* generally does not smell, taste, or look any different from uncontaminated food. Once ingested, bacterial cells that survive digestion may invade intestinal cells, leading to the classic Salmonellosis symptoms of fever, nausea, abdominal cramps, vomiting, and diarrhea. While most patients recover within a week without treatment, long-term complications such as reactive arthritis may occur in susceptible populations. People taking drugs that reduce gastric acidity may be more prone to Salmonellosis, as are the very young, the elderly, and the immunocompromised, who may experience more severe illness leading to a systemic infection (Lund *et al.*, 2011, Chen *et al.*, 2013). There is no human vaccine for non-typhoid *Salmonella*.

Despite significant efforts to control *Salmonella* infections, rates of foodborne disease attributed to *Salmonella* are not declining in the U.S. (Gilliss *et al.*, 2011). The organism continues to cause significant non-typhoidal disease throughout the world (Majowicz *et al.*, 2010), contributing to an estimated 94 million enteric and 3.4 million invasive infections and >800,000 deaths annually (Majowicz *et al.*, 2010, Ao *et al.*, 2015).

Table 1. Host Animals for Common *Salmonella enterica* Serotypes

***Salmonella enterica* Serotype**	**Host Animals**	**Disease in Humans?**
Enteritidis	Humans, poultry, wild rodents	Gastrointestinal
Typhimurium	Humans, cattle, swine, horses, sheep, poultry, wild rodents	Gastrointestinal
Newport	Cattle, humans	Gastrointestinal
Gallinarum	Poultry	None or rare
Pullorum	Poultry	None or rare
Dublin	Cattle, swine, sheep	Gastrointestinal
Typhi	Humans only	Typhoid fever
Paratyphi	Humans only	Typhoid fever

Sources: Baumler *et al.*, 1998, Chen *et al.*, 2013, Toth *et al.*, 2011

Outbreaks occur when more than one person becomes ill from a common source. Approximately 130 outbreaks of foodborne Salmonellosis occur in the U.S. each year (Gould *et al.*, 2013) with more outbreaks typically during the summer. The U.S. Center for Disease Control (CDC) tracks outbreaks related to foodborne pathogens. Table 2 lists the multistate foodborne disease outbreaks caused by *Salmonella* spp. in the U.S. during 2013.

As illustrated in Table 2, a wide variety of foods may be associated with *Salmonella* outbreaks. While poultry and red meats are responsible for some outbreaks, the contribution of fruit/nuts and vegetables to *Salmonella*-related illnesses is especially evident when examined over a longer period of time (10 years; see Figure 2).

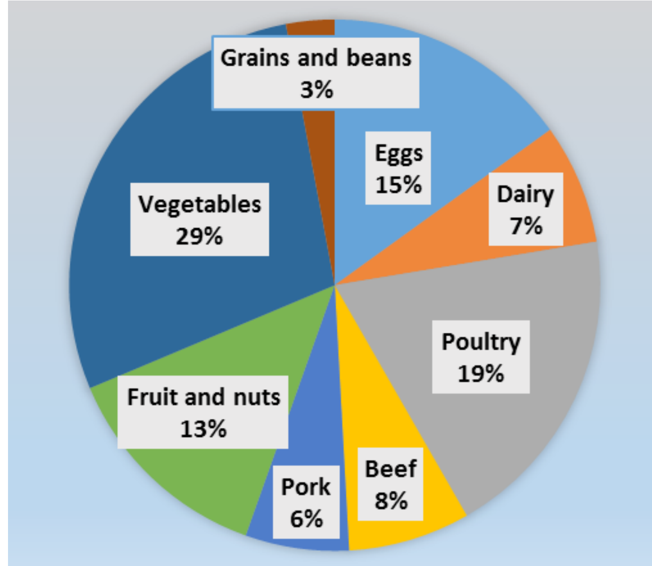

Figure 2. Food Sources of U.S. *Salmonella* Infections, 1998–2009
Source: (Pires *et al.*, 2014)

Salmonella in Food Animals

The variety of foods contributing to the burden of *Salmonella*-related illness presents a global food safety challenge. Significant efforts at reducing *Salmonella* spp. contamination have been made across the entire food industry. However, given that many food animals are natural hosts for *Salmonella* spp., focused efforts to control *Salmonella* in food-producing animals are necessary.

Food animals can acquire *Salmonella* in many ways, including contact with another infected animal or its feces, contaminated housing, wild birds, rodents, insects such as biting flies, improperly rendered animal by-products used in feed, and contaminated water. Vertical transmission is a major concern in the poultry industry, as *Salmonella* can be transmitted to progeny (or eggs for human consumption) via internal or external contamination of eggs (European Food Safety Authority, 2009).

Many types of animals can harbor *Salmonella*, including cattle, horses, pigs, cats, dogs, rodents, domestic and wild birds, reptiles, amphibians, and fish (Hoelzer *et al.*, 2011), often asymptomatically, and sometimes transmitting the organism to humans or food intended for humans. For example, the serotypes Enterica and Typhimurium can cause a systemic disease with diarrhea and dehydration in newborn poultry chicks. The persistence and asymptomatic colonization of these serotypes in older birds can result in lateral transmission to other birds in the flock or to eggs. This carriage and persistence of *Salmonella* within a poultry flock presents a potential route of transmission to humans via contaminated eggs or poultry meat.

Antibiotic Resistance in *Salmonella*

Although antibiotics are not generally used to treat human *Salmonella* infections, they may be life-saving in invasive infections or in immunocompromised patients. For this reason, maintaining the susceptibility of *Salmonella* to clinically-important antibiotics is imperative. Recently, strains of *Salmonella* that are resistant to antibiotics such as ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole, ceftriaxone, ciprofloxacin, and carbapenems have emerged (Chen *et al.*, 2013). **A significant proportion (15–37%) of *Salmonella* spp. isolates from food animals (chickens, turkeys, swine, cattle) now show resistance to multiple antibiotics** and are considered serious public health threats (Doyle, 2015).

Concern about antibiotic-resistant bacteria, and subsequently resistant infections, has been recognized globally and is currently

Table 2. U.S. Multi-state Salmonella Outbreaks in 2013

Food	Serotype	Number of Illnesses	Number of Hospitalizations	Number of Deaths	States Involved
Cucumber	Saintpaul	84	17	0	18
Pistachio	Senftenberg	8	1	0	6
Tahini	Mbandaka and Montevideo	17	1	1	10
Tomatoes	Saintpaul	131	23	0	23
Chicken	Heidelberg	634	200	0	30
Ground beef	Newport	39	9	0	8
Papaya	Thompson	13	6	1	4
Sugarcane	Virchow	7	1	0	3
Pork	Adelaide	14	2	0	5
Raw cashew cheese	Stanley	18	4	0	3
Tilapia fish	Javiana	33	6	0	6

Source: Centers for Disease Control and Prevention, 2015 being addressed by several global and domestic health organizations. Though not the sole cause of antibiotic resistance, the utilization of sub-therapeutic doses of antibiotics during food-animal production has likely contributed to the rise of antibiotic-resistant bacteria. Within the U.S., significant efforts to combat antibiotic resistance has manifested in multiple policies to eliminate the sub-therapeutic use of clinically important antibiotics in food animal production (U.S. Food and Drug Administration, 2015; U.S. Food and Drug Administration, 2012; U.S. Food and Drug Administration, 2013). Further, any utilization of antibiotics in food-animal production must occur under the supervision and direction of a veterinarian. These policies, combined with increased diligence of medical physicians when selecting and prescribing antibiotics, will help alleviate the growing threat of antibiotic-resistant bacteria.

Salmonella in Meat

Salmonella bacteria generally colonize the gastrointestinal (GI) tract of animals. Though numerous practices and preventative measures are enforced, the meat of animals can become contaminated during slaughter when hides and/or materials from the GI tract come into contact with the carcass surface. Industry policies to prevent this mode of contamination have resulted in significant reductions in carcass *Salmonella* levels. Alternative routes of contamination may include the lymph nodes (particularly in cattle) or the bones of chickens, both of which may sometimes be included in ground meat and poultry products (Arthur *et al.*, 2008, Vieira-Pinto *et al.*, 2005, Garrido *et al.*, 2014, Wu *et al.*, 2014).

Salmonella Testing in Raw Meat in the U.S.

The USDA Food Safety and Inspection Service (FSIS) plays a regulatory role in preventing the contamination of meat, poultry and processed egg products with foodborne pathogens. Following widespread changes to regulatory policy in response to the 1993 *Escherichia coli* O157:H7 outbreak, FSIS implemented mandatory performance testing for *Salmonella* in certain meat products with the 1996 Pathogen Reduction/HACCP Systems Final Rule (USDA Food Safety and Inspection Service, 1996). This Final Rule required that establishments that slaughtered or prepared certain ground meats meet *Salmonella* performance standards based on nationwide baseline rates of *Salmonella* contamination in that type of meat. The implementation of performance standards by FSIS has resulted in the adoption of various internal testing programs by many meat and poultry producers.

Although the performance standards were originally set to be equal to average rates of *Salmonella* contamination within the industry, they have been modified to reflect improved average contamination rates and to help achieve national goals related to reductions in *Salmonella*-related illnesses. The evolution of *Salmonella* performance standards since their inception in 1996 is shown in Table 3.

In 2011, FSIS discontinued *Salmonella* testing on market hogs, cows/bulls, and steers/heifers but began testing ground chicken and turkey. Soon after, FSIS proposed decreasing the acceptable performance standard for ground turkey and chicken and also will be implementing a new standard for chicken parts. In addition, FSIS announced plans to begin exploratory testing in raw pork in 2015 (USDA Food Safety and Inspection Service, 2014), suggesting that *Salmonella* performance standards for pork may be forthcoming.

There is some concern, especially among consumer groups, that the current program of FSIS testing to performance standards does not provide USDA with appropriate mechanisms or sufficient power to control *Salmonella* outbreaks that arise from meat and poultry. While the potential for this policy to change exists, the USDA does not currently consider *Salmonella* an adulterant when present in raw meat. This means that *Salmonella* can be present in raw poultry or meat and sold legally.

Salmonella Requirements for RTE Meats

In contrast to raw meats and poultry, ready-to-eat (RTE) meats contaminated with *Salmonella* spp. are considered adulterated (USDA Food Safety and Inspection Service, 2012a). As such, FSIS conducts testing for *Salmonella* in RTE products. Further, FSIS has developed regulatory requirements for *Salmonella* reduction in certain RTE meat products such as roast, cooked, or corned beef and cooked poultry products (9 CFR Parts 301, 317, 318, 320, and 381), with guidelines for their processing provided in Appendix A as well as additional guidance documents for RTE processors.

Table 3. FSIS *Salmonella* Performance Standards in Raw Meat and Carcasses

Product	Performance Standards (% Positive for Salmonella) Since 1996			
	1996	**2006**	**2011**	**2015**
Ground beef	7.5%	7.5%	7.5%	7.5%
Young chicken carcasses	None	20%	7.5%	7.5%
Young turkey carcasses	None	19.6%	1.7%	1.7%
Ground chicken	None	None	44.6%	25% (proposed)
Ground turkey	None	None	49.9%	13.5% (proposed)
Chicken parts	None	None	None	15.4% (proposed)
Market hog	8.7%	8.7%	Discontinued	None
Cow/bull	2.7%	2.7%	Discontinued	None
Steer/heifer	1.0%	1.0%	Discontinued	None

Sources: USDA Food Safety and Inspection Service, 1996, USDA Food Safety and Inspection Service, 2010, USDA Food Safety and Inspection Service, 2006b, USDA Food Safety and Inspection Service, 2015a

While the incidence of *Salmonella* in RTE products is relatively low, contamination may occur when a product is insufficiently processed, is mixed with contaminated ingredients (i.e. spices, sauces, etc.), or acquires contamination through environmental sources (food handlers, insects, etc.).

Of particular concern are products which are mistakenly thought by consumers to be RTE, but are actually raw. Chicken Cordon Bleu and Chicken Kiev products have resulted in Salmonellosis outbreaks (USDA Food Safety and Inspection Service, 2015). Because consumers may believe such products are RTE, FSIS requires they be labeled to emphasize that the products are not precooked (USDA Food Safety and Inspection Service, 2006).

Strategies to Prevent or Minimize *Salmonella* in Meat and Poultry

Although some studies have suggested that the most common *Salmonella* serotypes found in meat products are not the most common causes of human illness (Wilhelm *et al.*, 2011), minimizing *Salmonella* in meat products remains a priority and is expected to impact public health.

Strategies to prevent or minimize *Salmonella* contamination of meat and poultry include steps to reduce carriage and transmission in food animals as well as pre- and post-harvest approaches.

Reducing Carriage and Transmission in Food Animals

Strategies to reduce the carriage and transmission of *Salmonella* among food animals are listed below.

Protect breeding stock from *Salmonella* infection. Microbiological monitoring, removal of infected animals, vaccination, and other strategies are used in an effort to prevent horizontal transmission of *Salmonella* within a herd or flock. Careful surveillance and testing were key to the dramatic reduction in *Salmonella* in pork in Denmark (Wegener *et al.*, 2003).

Prevent *Salmonella* contamination of animal feed and water. Measures to prevent *Salmonella* contamination of water and feed supply systems may include heat treatment of feed, incorporation of organic acids, bacteriocins, or minerals into feed, addition of acidifiers to feed or water, etc. (Awad *et al.*, 2014, Ojha *et al.*, 2007, De Busser *et al.*, 2013).

Implement biosecurity at farms and processing facilities. Controlling access of rodents, insects, wild birds, and personnel to food animals can prevent horizontal disease transmission from these potential disease carriers (Andres *et al.*, 2015).

Prevention of *Salmonella* infection within food animals.

- **Vaccines.** Although vaccination may make it difficult to distinguish vaccinated from infected animals serologically, there is evidence it can reduce *Salmonella* in food animals and products derived from them (Revolledo *et al.*, 2012). Many egg producers already vaccinate against *Salmonella enterica*.
- **Antibiotics.** Though pending regulatory changes regarding antibiotic use in food animals will restrict their use to an extent, antibiotic treatment of *Salmonella*-infected food animals is still a valid and necessary practice.
- **Phage therapy.** Phages are viruses that specifically infect and lyse bacteria of a specific strain. The efficacy of phage therapy to control *Salmonella* in poultry and swine has been demonstrated, and its use in live food animals has been approved by the FDA (Endersen *et al.*, 2014). Phage treatments against *Salmonella* in animal feed have also been approved.
- **Competitive exclusion with other bacteria.** In the absence of other microbes, a new microbe can establish a foothold and thrive. The successful control of *Salmonella enterica* serotypes Pullorum and Gallinarum (which cause significant mortality in poultry but do not infect humans) in the 1950s in the U.S. and Europe may have inadvertently created an opening which allowed colonization by *S. enterica* serotype Enteritidis (Foley *et al.*, 2011), a serotype which can cause human disease. Competitive exclusion can, however, be harnessed towards positive ends. The introduction of a defined mixture of nonpathogenic bacteria (obtained from healthy animals) to very young animals has been demonstrated to prevent subsequent infection with pathogens such as *Salmonella* (Jordan *et al.*, 2014).
- **Probiotics and prebiotics.** Probiotics are a competitive exclusion approach in which live bacteria, often lactic acid bacteria or other microbes not normally found in the host species, are given to animals in an attempt to remodel the gut microbiome (Ojha *et al.*, 2007). Use of probiotics may enhance growth of food animals and prevent the growth of pathogens. Prebiotics are diet ingredients that are not digested by the host, but instead "feed" beneficial microbes residing in the gut. Fermented liquid feed can be considered a probiotic and has been shown to protect animals from *Salmonella* infection (Missotten *et al.*, 2015).

Improved hygiene for animals. Although increasing cleaning and sanitation frequency and maintaining animals at lower density might be expected to reduce *Salmonella* infection in food animals (and likely be beneficial), demonstrating that specific hygiene and sanitation practices reduce *Salmonella* infection rates in animals has not been straightforward. The difficulty in documenting benefit from such practices may be related to the large numbers of *Salmonella* that can be present and persist in the environment (Andres *et al.*, 2015).

Pre-Harvest

Animal transport and slaughterhouse practices can greatly impact *Salmonella* contamination rates for animal carcasses and the eventual meat or poultry products.

Timing of feed withdrawal. A typical practice is to remove feed from animals well before slaughter to minimize fecal contamination of the carcass. However, removal of food too early can stress the animal, which can impact *Salmonella* shedding in addition to affecting meat quality. Timing of feed withdrawal may influence where pathogens are found within the animal carcass. For example, early feed withdrawal in broiler chickens may increase amounts of *Salmonella* present in the crop (esophagus) or the ceca (large intestine), as chickens are more likely to peck at and consume contaminated litter after feed withdrawal (Corrier *et al.*, 1999).

Minimization of animal stress. Stress during transport and prior to slaughter increases shedding of *Salmonella* in animals (Arguello *et al.*, 2013, Beach *et al.*, 2002), increasing the risk of infection of other animals. Animal density and acclimation time prior to slaughter are important factors impacting animal stress.

Transport, lairage, and slaughterhouse practices. Segregation of herds with high vs. low *Salmonella* infection rates during transport, the methods used to clean and sanitize containers and trucks used to transport animals, the time and distance of travel, and other factors can affect *Salmonella* infection rates in animals after transport (Berends *et al.*, 1996). Similarly, the time and conditions (including segregation of infected animals) during lairage and at the slaughterhouse have a significant impact on *Salmonella* cross-contamination. Animals can become infected after very short exposures to *Salmonella*; turkeys can become infected from 2 hours of exposure to *Salmonella*-contaminated airborne dust (Harbaugh *et al.*, 2006), and pigs become infected within 2 hours of being placed in a contaminated environment (Hurd *et al.*, 2002).

Post-Harvest

Slaughter and carcass processing. Slaughter and carcass processing involve many variables that can introduce *Salmonella* contamination onto meat and poultry products. Most HACCP plans include procedures designed to reduce contamination rates during this part of meat production; however, their impact on *Salmonella* reduction can vary (Wilhelm *et al.*, 2011). Overall, the incorporation of practices which best address an individual processor's *Salmonella* contamination concerns is an important component of reducing *Salmonella* on meat and poultry products.

Meat processing. Processed meats that are considered raw (meat patties, fresh pork sausage, uncooked bratwurst, bacon, etc.) may not receive additional interventions with respect to *Salmonella* since they must be cooked by consumers prior to eating, although some manufacturers do implement interventions to target Salmonella that might arise during processing (i.e., contamination from lymph nodes). Conversely, however, significant attention is paid to reducing the risk of *Salmonella* contamination in RTE (cooked, fermented, or dried) meat products:

- Raw and RTE product should be effectively separated to prevent post-process contamination.
- Cooking requirements for RTE products (prior to marketing) ensure destruction of any *Salmonella* present in the raw meat. *Salmonella* is generally less resistant to heat than *Listeria monocytogenes.* Additionally, *Salmonella* does not persist in a refrigerated RTE environment.
- Dried meats such as jerky are required to have a high humidity thermal step during production before drying to eliminate *Salmonella* before they can develop heat resistance due to drying (Buege *et al.*, 2006).

Consumer-level Strategies

Though the industry employs significant efforts to reduce *Salmonella* contamination in meat and poultry products, consumers can follow a number of recommendations to reduce the risk of *Salmonella* infection:

Separate foods. Keep raw meat, fish, eggs, and poultry separate from other foods during storage and food preparation. Be careful not to cross-contaminate. Use separate utensils or cutting boards for raw and cooked foods, or wash well between uses.

Wash hands and surfaces. Wash hands, and food contact surfaces often and after being in contact with raw meat, fish, or poultry.

Consider who will have contact with what you are cooking as you are cooking. Be aware that infants, the elderly, and the immunocompromised may be more susceptible to infection. When cooking with raw meat, fish, or poultry, make sure you wash properly before feeding an infant, for example.

Cook foods to a proper temperature. Measure temperature with a clean digital thermometer. FSIS recommends that foods be cooked to the temperatures shown in Table 4 to ensure safety.

Take-home Messages

Salmonella is the most frequently reported cause of bacterial foodborne illness in the U.S.

About one-third of the *Salmonella*-related disease reported in the US is attributed to poultry and meat, with almost another third of infections associated with vegetables. Eggs and fruit/nuts each contribute to about 15% of *Salmonella* cases.

Salmonella can grow at pH values as low as 4 and temperatures as low as 2°C (36°F), and can survive for years in low-water-activity foods such as peanut butter or in frozen meats. Its ability to grow, adapt to, or persist in so many conditions (in combination with a low infectious dose) make it a particularly problematic foodborne pathogen.

More than 2600 serotypes of *Salmonella* exist. Some are adapted to a particular host, and tend to cause severe systemic disease in those animals but little effect in other species. Other serotypes are generalists, infecting many species and typically causing a milder gastrointestinal illness.

A significant proportion of *Salmonella* isolates from food animals show resistance to multiple antibiotics and is considered serious public health threat.

Since 1996, USDA's Food Safety Inspection Service has required establishments that slaughter or prepare certain raw meat products meet minimal performance standards of *Salmonella* contamination. *Salmonella* is not currently considered an adulterant in raw meat.

The industry recognizes the risk of *Salmonella* associated with meat and poultry and has employed significant and broad-based strategies to minimize the threat of contamination.

Consumers can work with the meat industry to ensure the safety of food by following a few simple and easily implementable practices (i.e. separation of raw/cooked foods, cooking foods to the proper temperature, etc.).

Acknowledgements

The authors would like to thank Lindsey Jahn and Drs. Mark Cook, Keith Poulsen, Kathy Glass, and Chuck Czuprynski from the University of Wisconsin – Madison and Dr. Melvin Hunt of Kansas State University for helpful comments.

Table 4. FSIS Recommended Safe Cooking Temperatures

Food Type	Safe Temperature	Comments
Raw beef, pork, lamb steaks, chops, roasts	62.8°C (145°F)	Measure the temperature before removing meat from source, and let rest for at least 3 minutes before serving
Ground beef, pork, lamb	71.1°C (160°F)	
Poultry	73.9°C (165°F)	
Ham (fresh or smoked; uncooked)	62.8°C (145°F)	Allow to rest at least 3 minutes
Ham (cooked)	60°C (140°F)	If packaged in USDA-inspected plants
Stuffing for poultry	NA	Not recommended to be cooked inside poultry; cook separately to 73.9°C (165°F)
Fish	62.8°C (145°F)	
Egg dishes	71.1°C (160°F)	
Sauces	Reheat to a boil	
Leftovers or casseroles	73.9°C (165°F)	

Source: USDA Food Safety and Inspection Service, 2013, USDA Food Safety and Inspection Service, 2012b

References

ANDRES, V. M.; DAVIES, R. H. 2015. Biosecurity measures to control *Salmonella* and other infectious agents in pig farms: A review. *Comprehensive Reviews in Food Science and Food Safety,* 14**,** 317-335.

AO, T. T.; FEASEY, N. A.; GORDON, M. A.; KEDDY, K. H.; ANGULO, F. J.; CRUMP, J. A. 2015. Global burden of invasive nontyphoidal *Salmonella* disease, 2010. *Emerging Infectious Diseases,* 21**,** 941-949.

ARGUELLO, H.; ALVAREZ-ORDONEZ, A.; CARVAJAL, A.; RUBIO, P.; PRIETO, M. 2013. Role of slaughtering in *Salmonella* spreading and control in pork production. *Journal of Food Protection,* 76**,** 899-911.

ARTHUR, T. M.; BRICHTA-HARHAY, D. M.; BOSILEVAC, J. M.; GUERINI, M. N.; KALCHAYANAND, N.; WELLS, J. E.; SHACKELFORD, S. D.; WHEELER, T. L.; KOOHMARAIE, M. 2008. Prevalence and characterization of *Salmonella* in bovine lymph nodes potentially destined for use in ground beef. *Journal of Food Protection,* 71**,** 1685-1688.

AWAD, W. A.; GHAREEB, K. 2014. Some aspects of control of *Salmonella* infection in poultry for minimising contamination in the food chain. *World Poultry Science Journal,* 70**,** 519-530.

BARROW, P. A.; JONES, M. A.; SMITH, A. L.; WIGLEY, P. 2012. The long view: *Salmonella* - the last forty years. *Avian Pathology,* 41**,** 413-420.

BAUMLER, A. J.; TSOLIS, R. M.; FICHT, T. A.; ADAMS, L. G. 1998. Evolution of host adaptation in *Salmonella enterica*. *Infection and Immunity,* 66**,** 4579-4587.

BAYLIS, C.; UYTTENDAELE, M.; JOOSTEN, H. M.; DAVIES, A. 2011. The Enterobacteriaceae and their significance to the food industry. Brussels, Belgium: ILSI Europe.

BEACH, J. C.; MURANO, E. A.; ACUFF, G. R. 2002. Prevalence of *Salmonella* and *Campylobacter* in beef cattle from transport to slaughter. *Journal of Food Protection,* 65**,** 1687-1693.

BERENDS, B. R.; URLINGS, H. A. P.; SNIJDERS, J. M. A.; VANKNAPEN, F. 1996. Identification and quantification of risk factors in animal management and transport regarding *Salmonella spp* in pigs. *International Journal of Food Microbiology,* 30**,** 37-53.

BUEGE, D. R.; SEARLS, G.; INGHAM, S. C. 2006. Lethality of commercial whole-muscle beef jerky manufacturing processes against *Salmonella* serovars and *Escherichia coli* O157 : H7. *Journal of Food Protection,* 69**,** 2091-2099.

CENTERS FOR DISEASE CONTROL AND PREVENTION 2011. National *Salmonella* surveillance overview. Atlanta, Georgia: U.S. Department of Health and Human Services, CDC.

CENTERS FOR DISEASE CONTROL AND PREVENTION 2015. Surveillance for foodborne disease outbreaks, United States, 2013, annual report. Atlanta, Georgia: U.S. Department of Health and Human Services, CDC.

CHEN, H. M.; WANG, Y.; SU, L. H.; CHIU, C. H. 2013. Nontyphoid *Salmonella* infection: microbiology, clinical features, and antimicrobial therapy. *Pediatrics and Neonatology,* 54**,** 147-152.

CORRIER, D. E.; BYRD, J. A.; HARGIS, B. M.; HUME, M. E.; BAILEY, R. H.; STANKER, L. H. 1999. Presence of *Salmonella* in the crop and ceca of broiler chickens before and after preslaughter feed withdrawal. *Poultry Science,* 78**,** 45-49.

DE BUSSER, E. V.; DE ZUTTER, L.; DEWULF, J.; HOUF, K.; MAES, D. 2013. *Salmonella* control in live pigs and at slaughter. *Veterinary Journal,* 196**,** 20-27.

DOYLE, M. E. 2015. Multidrug-resistant pathogens in the food supply. *Foodborne Pathogens and Disease,* 12**,** 261-279.

ENDERSEN, L.; O'MAHONY, J.; HILL, C.; ROSS, R. P.; MCAULIFFE, O.; COFFEY, A. 2014. Phage therapy in the food industry. *In:* DOYLE, M. P. & KLAENHAMMER, T. R. (eds.) *Annual Review of Food Science and Technology, Vol 5.* Palo Alto: Annual Reviews.

EUROPEAN FOOD SAFETY AUTHORITY. 2009. Scientific opinion of the panel on biological hazards on a request from European Commission on quantitative estimation of the impact of setting a new target for the reduction of *Salmonella* in breeding hens of *Gallus gallus*. *The EFSA Journal,* 1036**,** 1-68.

FOLEY, S. L.; NAYAK, R.; HANNING, I. B.; JOHNSON, T. J.; HAN, J.; RICKE, S. C. 2011. Population dynamics of *Salmonella enterica* serotypes in commercial egg and poultry production. *Applied and Environmental Microbiology,* 77**,** 4273-9.

GARRIDO, V.; SANCHEZ, S.; SAN ROMAN, B.; ZABALZA-BARANGUA, A.; DIAZ-TENDERO, Y.; DE FRUTOS, C.; MAINAR-JAIME, R. C.; GRILLO, M. J. 2014. Simultaneous infections by different *Salmonella* strains in mesenteric lymph nodes of finishing pigs. *BMC Veterinary Research,* 10**,** 6.

GILLISS, D.; CRONQUIST, A.; CARTTER, M.; TOBIN-D'ANGELO, M.; BLYTHE, D.; SMITH, K.; LATHROP, S.; BIRKHEAD, G.; CIESLAK, P.; DUNN, J.; HOLT, K. G.; GUZEWICH, J. J.; HENAO, O. L.; MAHON, B.; GRIFFIN, P.; TAUXE, R. V.; CRIM, S. M. 2011. Vital signs: Incidence and trends of infection with pathogens transmitted commonly through food - foodborne diseases active surveillance network, 10 US sites, 1996-2010. *Morbidity and Mortality Weekly Report,* 60**,** 749-755.

GOULD, L. H.; WALSH, K. A.; VIEIRA, A. R.; HERMAN, K.; WILLIAMS, I. T.; HALL, A. J.; COLE, D. 2013. Surveillance for foodborne disease outbreaks - United States, 1998-2008. *MMWR Surveillance Summaries,* 62**,** 1-34.

HARBAUGH, E.; TRAMPEL, D.; WESLEY, I.; HOFF, S.; GRIFFITH, R.; HURD, H. S. 2006. Rapid aerosol transmission of *Salmonella* among turkeys in a simulated holding-shed environment. *Poultry Science,* 85**,** 1693-1699.

HOELZER, K.; SWITT, A. I. M.; WIEDMANN, M. 2011. Animal contact as a source of human non-typhoidal salmonellosis. *Veterinary Research,* 42**,** 28.

HOFFMANN, S.; BATZ, M. B.; MORRIS, J. G. 2012. Annual cost of illness and quality-adjusted life year losses in the United States due to 14 foodborne pathogens. *Journal of Food Protection,* 75**,** 1292-1302.

HSI, D. J.; EBEL, E. D.; WILLIAMS, M. S.; GOLDEN, N. J.; SCHLOSSER, W. D. 2015. Comparing foodborne illness risks among meat commodities in the United States. *Food Control,* 54**,** 353-359.

HURD, H. S.; MCKEAN, J. D.; GRIFFITH, R. W.; WESLEY, I. V.; ROSTAGNO, M. H. 2002. *Salmonella enterica* infections in market swine with and without transport and holding. *Applied and Environmental Microbiology,* 68**,** 2376-2381.

JORDAN, K.; DALMASSO, M.; ZENTEK, J.; MADER, A.; BRUGGEMAN, G.; WALLACE, J.; DE MEDICI, D.; FIORE, A.; PRUKNER-RADOVCIC, E.; LUKAC, M.; AXELSSON, L.; HOLCK, A.; INGMER, H.; MALAKAUSKAS, M. 2014. Microbes versus microbes: control of pathogens in the food chain. *Journal of the Science of Food and Agriculture,* 94**,** 3079-3089.

KOTZEKIDOU, P. 1998. Microbial stability and fate of *Salmonella* Enteritidis in halva, a low-moisture confection. *Journal of Food Protection,* 61**,** 181-185.

LANGRIDGE, G. C.; FOOKES, M.; CONNOR, T. R.; FELTWELL, T.; FEASEY, N.; PARSONS, B. N.; SETH-SMITH, H. M. B.; BARQUIST, L.; STEDMAN, A.; HUMPHREY, T.; WIGLEY, P.; PETERS, S. E.; MASKELL, D. J.; CORANDER, J.; CHABALGOITY, J. A.; BARROW, P.; PARKHILL, J.; DOUGAN, G.; THOMSON, N. R. 2015. Patterns of genome evolution that have accompanied host adaptation in *Salmonella*. *Proceedings of the National Academy of Sciences of the United States of America,* 112**,** 863-868.

LI, H. P.; WANG, H.; D'AOUST, J. Y.; MAURER, J. 2013. *Salmonella* species. *Food microbiology: fundamentals and frontiers***,** 225-261.

LUND, B. M.; O'BRIEN, S. J. 2011. The occurrence and prevention of foodborne disease in vulnerable people. *Foodborne Pathogens and Disease,* 8**,** 961-73.

MAJOWICZ, S. E.; MUSTO, J.; SCALLAN, E.; ANGULO, F. J.; KIRK, M.; O'BRIEN, S. J.; JONES, T. F.; FAZIL, A.; HOEKSTRA, R. M.; INTERNATIONAL COLLABORATION ON ENTERIC DISEASE 'BURDEN OF ILLNESS' STUDIES. 2010. The global burden of nontyphoidal *Salmonella* gastroenteritis. *Clinical Infectious Diseases,* 50**,** 882-889.

MARTI, R.; HAGENS, S.; LOESSNER, M. J.; KLUMPP, J. 2013. Genome sequence of *Salmonella bongori* strain N268-08, a rare clinical isolate. *Genome Announcements,* 1**,** e00580-13.

MATEUS, A.; TAYLOR, D. J.; BROWN, D.; MELLOR, D. J.; BEXIGA, R.; ELLIS, K. 2008. Looking for the unusual suspects: a *Salmonella* Dublin outbreak investigation. *Public Health,* 122**,** 1321-1323.

MISSOTTEN, J. A.; MICHIELS, J.; DEGROOTE, J.; DE SMET, S. 2015. Fermented liquid feed for pigs: an ancient technique for the future. *Journal of Animal Science and Biotechnology,* 6**,** 4.

MULLER, K.; AABO, S.; BIRK, T.; MORDHORST, H.; BJARNADOTTIR, B.; AGERSO, Y. 2012. Survival and growth of epidemically successful and nonsuccessful *Salmonella enterica* clones after freezing and dehydration. *Journal of Food Protection,* 75**,** 456-464.

OJHA, S.; KOSTRZYNSKA, M. 2007. Approaches for reducing *Salmonella* in pork production. *Journal of Food Protection,* 70**,** 2676-2694.

PIGNATO, S.; GIAMMANCO, G.; SANTANGELO, C.; GIAMMANCO, G. M. 1998. Endemic presence of *Salmonella bongori* 48 : z(35):-causing enteritis in children in Sicily. *Research in Microbiology,* 149**,** 429-431.

PIRES, S. M.; VIEIRA, A. R.; HALD, T.; COLE, D. 2014. Source attribution of human salmonellosis: An overview of methods and estimates. *Foodborne Pathogens and Disease,* 11**,** 667-676.

REVOLLEDO, L.; FERREIRA, A. J. P. 2012. Current perspectives in avian salmonellosis: Vaccines and immune mechanisms of protection. *Journal of Applied Poultry Research,* 21**,** 418-431.

SCALLAN, E.; HOEKSTRA, R. M.; ANGULO, F. J.; TAUXE, R. V.; WIDDOWSON, M. A.; ROY, S. L.; JONES, J. L.; GRIFFIN, P. M. 2011. Foodborne illness acquired in the United States-major pathogens. *Emerging Infectious Diseases,* 17**,** 7-15.

SCHARFF, R. L. 2012. Economic burden from health losses due to foodborne illness in the United States. *Journal of Food Protection,* 75**,** 123-131.

STEERE, A. C.; HALL, W. J.; WELLS, J. G.; CRAVEN, P. J.; LEOTSAKIS, N.; FARMER, J. J.; GANGAROSA, E. J. 1975. Person-to-person spread of *Salmonella* Typhimurium after a hospital common-source outbreak. *Lancet,* 1**,** 319-322.

THORNS, C. J. 2000. Bacterial food-borne zoonoses. *Revue Scientifique et Technique de l'office International des Epizooties,* 19**,** 226-239.

TOTH, J. D.; ACETO, H. W.; RANKIN, S. C.; DOU, Z. 2011. Survival characteristics of *Salmonella enterica* serovar Newport in the dairy farm environment. *Journal of Dairy Science,* 94**,** 5238-5246.

U.S. FOOD AND DRUG ADMINISTRATION. 2012. Guidance for Industry #209: The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals [Online]. Available: http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM216936.pdf.

U.S. FOOD AND DRUG ADMINISTRATION. 2013. Guidance for industry #213: New animal drugs and new animal drug combination products administered in or on medicated feed or drinking water of food-producing animals: Recommendations for drug sponsors for voluntarily aligning product used conditions with GFI #209 [Online]. Available: http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM299624.pdf.

U.S. FOOD AND DRUG ADMINISTRATION. 2015. FDA's strategy on antimicrobial resistance- questions and answers [Online]. Available: http://www.fda.gov/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/ucm216939.htm#question4 [Accessed 8 July 2015].

USDA FOOD SAFETY AND INSPECTION SERVICE 1996. Pathogen reduction; hazard analysis and critical control point (HACCP) systems; final rule. 61 Federal Register 38806 (25 July 1996).

USDA FOOD SAFETY AND INSPECTION SERVICE. 2006a. Labeling policy guidance: Uncooked, breaded, boneless poultry products [Online]. Available: http://www.fsis.usda.gov/wps/wcm/connect/6d7b7f70-e11b-4861-adc8-6f3269c3eeec/Labeling_Policy_Guidance_Uncooked_Breaded_Boneless_Poultry_Products.pdf?MOD=AJPERES [Accessed 05 November 2015].

USDA FOOD SAFETY AND INSPECTION SERVICE 2006b. Salmonella verification sample result reporting: Agency policy and use in public health protection. 71 Federal Register 9772 (27 February 2006).

USDA FOOD SAFETY AND INSPECTION SERVICE 2010. New performance standards for Salmonella and Campylobacter in young chicken and turkey slaughter establishments; new compliance guidelines. 75 Federal Register 27288 (14 May 2010).

USDA FOOD SAFETY AND INSPECTION SERVICE. 2012a. FSIS Salmonella compliance guidelines for small and very small meat and poultry establishments that produce ready-to-eat (RTE) products [Online]. Available: http://www.fsis.usda.gov/wps/wcm/connect/2ed353b4-7a3a-4f31-80d8-20262c1950c8/Salmonella_Comp_Guide_091912.pdf?MOD=AJPERES [Accessed 05 November 2015.

USDA FOOD SAFETY AND INSPECTION SERVICE. 2012b. Safe minimum internal temperature chart [Online]. Available: http://www.fsis.usda.gov/wps/wcm/connect/625d9435-4f14-46fe-b207-5d6688cb4db5/Safe_Miminum_Internal_Temperature_Chart.pdf?MOD=AJPERES [Accessed 15 July 2015].

USDA FOOD SAFETY AND INSPECTION SERVICE. 2013. Salmonella questions and answers [Online]. Available: http://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/foodborne-illness-and-disease/salmonella-questions-and-answers/ [Accessed 10 July 2015].

USDA FOOD SAFETY AND INSPECTION SERVICE. 2014. Food Safety and Inspection Services's annual sampling program plan: Fiscal year 2015 [Online]. Available: http://www.fsis.usda.gov/wps/wcm/connect/cb091bde-4900-45ec-8bf5-980dc9496bd1/Sampling-Program-Plan-FY2015.pdf?MOD=AJPERES [Accessed 31 July 2015].

USDA FOOD SAFETY AND INSPECTION SERVICE 2015a. Changes to the Salmonella and Campylobacter verification testing program: Proposed performance standards for Salmonella and Campylobacter in not-ready-to-eat comminuted chicken and turkey products and raw chicken parts and related agency verification procedures and other changes to agency sampling. 80 Federal Register 3940 (26 January 2015).

USDA FOOD SAFETY AND INSPECTION SERVICE. 2015b. FSIS issues public health alert for frozen raw stuffed chicken products due to possible salmonella contamination [Online]. Available: http://www.fsis.usda.gov/wps/portal/fsis/newsroom/news-releases-statements-transcripts/news-release-archives-by-year/archive/2015/pha-070115 [Accessed 31 July 2015].

VIEIRA-PINTO, M.; TEMUDO, P.; MARTINS, C. 2005. Occurrence of *Salmonella i*n the ileum, ileocolic lymph nodes, tonsils, mandibular lymph nodes and carcasses of pigs slaughtered for consumption. *Journal of Veterinary Medicine Series B-Infectious Diseases and Veterinary Public Health,* 52**,** 476-481.

WEGENER, H. C.; HALD, T.; WONG, D. L.; MADSEN, M.; KORSGAARD, H.; BAGER, F.; GERNER-SMIDT, P.; MOLBAK, K. 2003. *Salmonella* control programs in Denmark. *Emerging Infectious Diseases,* 9**,** 774-780.

WILHELM, B.; RAJIC, A.; GREIG, J. D.; WADDELL, L.; HARRIS, J. 2011. The effect of hazard analysis critical control point programs on microbial contamination of carcasses in abattoirs: A systematic review of published data. *Foodborne Pathogens and Disease,* 8**,** 949-960.

WU, D. Z.; ALALI, W. Q.; HARRISON, M. A.; HOFACRE, C. L. 2014. Prevalence of *Salmonella* in neck skin and bone of chickens. *Journal of Food Protection,* 77**,** 1193-1197.

This fact sheet was written by Wendy Bedale, PhD, Food Research Institute, University of Wisconsin-Madison; Andrew L. Milkowski, PhD, Department of Animal Sciences and Food Research Institute, University of Wisconsin-Madison and edited by the AMSA Scientific Information Committee