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Understanding Salmonella; Its Presence and Control in Live Poultry

From the hatchery to table, it is important to maintain biosecurity and sanitation practices to reduce *Salmonella* transmission in poultry.

Salmonella is a common foodborne pathogen that can contaminate a variety of foods, including meat and vegetables. It is a significant cause of foodborne illness and death on a global scale (Knodler and Elfenbein, 2020). In the United States, there are an estimated 1.35 million infections and 420 deaths per year from *Salmonella* (CDC, 2020a).

In 2011, *Salmonella* caused one of the largest meat recalls in the U.S., totaling 36 million pounds of ground turkey (Bearson et al., 2017). Many foodborne illnesses and meat recalls are linked to *Salmonella*-contaminated eggs or chicken meat (Humphrey, 2006). *Salmonella* infections can also come from direct contact with live poultry. In fact, backyard poultry flocks are an increasingly important cause of *Salmonella* infections in people in the United States (CDC, 2018). Figure 1 shows the general trend that *Salmonella* outbreaks have been increasing since 2011.

As commensal, or non-harmful, resident bacteria in the gastrointestinal tract of poultry, *Salmonella* is difficult to eliminate among poultry flocks (White et al., 1997). Poultry growers can take many types of precautionary measures to prevent *Salmonella* spread and improve food safety. All the measures revolve around maintaining strong biosecurity practices and sanitation routines. *Salmonella* may cause intestinal infection which can lead to decreased bird welfare and performance. Bird management is important because stressors, such as heat, overcrowding, and lack of feed can increase flock susceptibility to *Salmonella.* As a result, poultry growers have a responsibility to manage the presence of

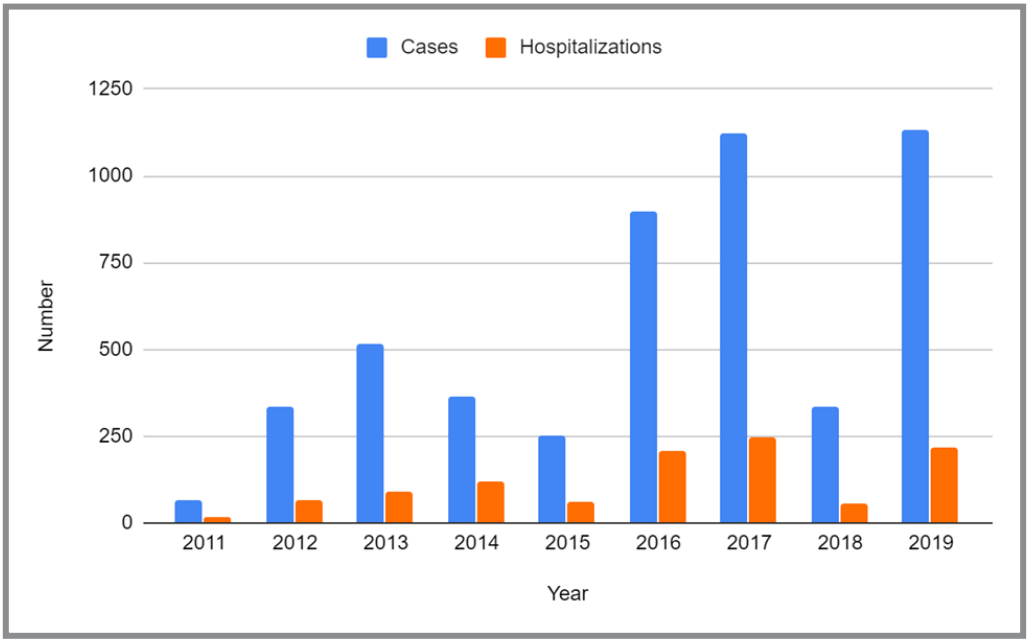

Figure 1. *Reported human cases and hospitalizations of selected Salmonella outbreak investigations from 2011-2019 due to infection via live poultry*

Source: Adapted from CDC, 2020b

Salmonella in their flocks and to prevent its spread from the farm to the table.

This Extension bulletin provides an understanding of what *Salmonella* is, how it is carried and transmitted by poultry, and what control strategies you can implement to reduce its survival and transmission in poultry flocks.

Salmonella is Zoonotic

Salmonella species are zoonotic, causing infections in both humans and animals. The species belong to the *Enterobacteriaceae* family (White et al., 1997) and thrive in the intestinal tract of the host. Over 2,300 *Salmonella* serotypes are known to exist, and nearly 100 can survive on food or in humans and animals (White et al., 1997). Of these, the serotypes *Salmonella enteritidis* and *Salmonella typhimurium* are the most prevalent in the United States, responsible for about half of all human food-related infections (USDA-FSIS, 2013).

Salmonella remains a common foodborne pathogen because it can spread via the oral-fecal route. An infected animal will spread the bacteria in its droppings, which contaminate the surrounding environment. In humans, consumption of foods contaminated with *Salmonella* will cause Salmonellosis (*Salmonella* infection) (CDC, 2020a). Contact with live, infected animals can also cause Salmonellosis (CDC, 2020a). Human infection typically results in gastroenteritis, with symptoms such as diarrhea, cramping, and fever. Infection can lead to more serious complications among individuals with weakened immune systems (CDC, 2020a).

Since *Salmonella* can survive in various environmental conditions and has a wide host range, it is difficult to control once it spreads (White et al., 1997). In addition, some serotypes of *Salmonella* are resistant to antimicrobials or antibiotics (Bearson et al., 2017), making treatment challenging.

The bacteria rarely cause clinical illness in birds and can exist undetected, making *Salmonella* a significant challenge in the poultry industry.

Salmonella is Often Commensal in Poultry

Poultry are an easy vector for the transmission of the bacteria into the food supply because birds carry *Salmonella* without symptoms. It is critical to understand how and when poultry transmit *Salmonella* and the factors influencing individual susceptibility or resistance to the bacteria.

There are many opportunities in which poultry can become infected throughout their lifetime (Bearson et al., 2017). If *Salmonella* is present in a hen's reproductive tract, it can be vertically transmitted through deposition into the egg yolk (ovum) released from the ovary during egg development (USDA-FSIS, 2019). *Salmonella* deposition onto the surface of the eggshell also occurs during oviposition (egg laying) by contact with fecal matter or the outside environment. Eggshells are porous and bacteria can enter through these pores into the egg albumen (USDA-FSIS, 2019). In the United States, washing table eggs is a common and effective practice but comes with its share of disadvantages. The chemicals can sterilize and reduce bacteria load but also damage the cuticle (protective layer of the eggshell), increasing *Salmonella's* ability to penetrate the shell (Gole et al., 2014). As a result, it is critical to refrigerate washed table eggs.

Numerous interactions between the bird, the bacteria, and their environment can impact a bird's susceptibility to *Salmonella* colonization. For example, younger birds have immature immune systems and are less resistant to infection (Oakley et al., 2014). Newly hatched chicks have little to no microflora in their gastrointestinal tracts, including commensal microbes. This lack of competition puts the chicks at a higher risk of *Salmonella* colonization (White et al., 1997).

Clean Hatchery and Brooding Environments are Important Control Points to Reduce the Presence and Spread of *Salmonella*

Once infected, bacteria are shed through the bird's feces, contaminating the environment. Horizontal transmission of *Salmonella* can occur when birds consume litter, feed, or water contaminated with the bacteria (White et al., 1997). Colonization can also occur when a bird ingests contaminated feed or water, which can result from improper storage of feed, contact with feces, or contact by vectors (insects, mice, and other pests). **Table 1** provides a summary of bird, host, and environmental factors that can influence *Salmonella* colonization in poultry.

Bird	Agent	Environment
Age	Ability to survive in the digestive system	Environmental hygiene
Diet	Competition in gut	Food/water cleanliness
Physiological status	Ability to colonize	Interaction with other animals, vectors, or feces
Immune/health status		Biosecurity standards
Genetic background		Stressors
Stress		Temperature, humidity
Medication		Stocking density (overcrowding)
Intestinal integrity		

Table 1. Host (bird), agent (bacteria or Salmonella), and environmental factors that can influence the colonization of Salmonella in poultry

Source: Adapted from White et al., 1997; Heyndrickx et al., 2002; Oakley et al., 2014; Alhenaky et al., 2017.

While *Salmonella* is generally not harmful to poultry, in some cases it may negatively impact a bird's production and welfare. Broiler chickens with Salmonellosis can have diarrhea, fever, and reduced feed intake, leading to lower body weight (Xie et al., 2000). *Salmonella* can also indirectly impair a bird's welfare by inducing immune stress. Invasion and colonization of the bacteria can result in an inflammatory response in the intestines (Gomes et al., 2014). Immune stress can negatively affect broiler energy usage and feed consumption (appetite), leading to reduced growth and performance (Liu et al., 2014). As such, a symptomatic bird may also experience lethargy, poor hygiene, and a decreased mobility between food and water or to escape predators.

Environmental stress can also facilitate the transmission of bacteria between birds and increase shedding of the pathogen (Burkholder et al., 2008). Heat and other environmental stressors impair intestinal development and functionality in birds, which can lead to leaky gut (Alhenaky et al., 2017). Leaky gut occurs when the tight junctions of intestinal epithelial cells are loosened, allowing pathogens to pass through and enter the intestines. Fasted birds also showed greater *Salmonella* attachment in the gut (Burkholder et al., 2008) and overcrowding from high stocking density can increase flock susceptibility to *Salmonella* (Gomes et al., 2014). *Salmonella* infection in poultry may also result from existing poor welfare conditions due to insufficient biosecurity and hygiene practices.

Biosecurity is Important to Prevent and Control *Salmonella* Spread

Contamination can occur at many points throughout the process of poultry production. Effective hygiene and biosecurity programs must incorporate multifaceted intervention approaches to control the presence and spread of *Salmonella* (White et al., 1997). Control of *Salmonella* at the hatchery and in the early weeks of life is particularly critical because this is when chicks are most vulnerable to infection (White et al., 1997).

The most significant control strategies are strong biosecurity practices (Heyndrickx et al., 2002). At the most basic level of biosecurity, you should wear a separate pair of shoes and clothes and practice proper handwashing after handling poultry (CDC, 2020c).Vaccines, antibiotics, and other medications are another potential method of control and have proven effective (White et al., 1997). Among chicken species, commercial layers are typically vaccinated for *Salmonella* while broilers are not. Aggressive sanitation standards and biosecurity programs are the most effective methods for controlling *Salmonella* (White et al., 1997).

Another increasingly popular method of reducing the risk of *Salmonella* in poultry is the regulation of gut microbiota through probiotics and prebiotic supplements in poultry feed. These products improve pathogen resistance by either introducing beneficial microflora to the gut (probiotics) or providing the existing microflora with nutrients to support their growth (prebiotics). Probiotics have proven beneficial on numerous accounts and when administered to chickens, have shown improved control over some bacterial infections, including *Salmonella* as reported in experimental settings (Brisbin, 2011).

A field trial involving broiler chickens showed a successful reduction of *Campylobactor* in the gastrointestinal tract after consuming a probiotic-supplemented feed (Smialek et al., 2018). This study also reported a reduction in carcass contamination by *Campylobacter*, which may lead to increased food safety. **Table 2** provides a summary of practices and strategies to control *Salmonella* on-farm.

Table 2. *Practices and strategies to aid in controlling Salmonella in poultry*

Source: White et al., 1997; Hayes et al., 2000; Moyle et al., 2014; USDA-APHIS, 2018, 2019, 2020

Sanitation Standards	Use effective chemicals and sanitation practices	Scrub dirty tools and surfaces with water and detergent from top to bottom and rinse. Apply a disinfectant registered by the U.S. Environmental Protection Agency (EPA) that is effective against poultry diseases.
	Wash eggs	Use polyhexamethylene biguanide, hydrochloride, hydrogen peroxide, and phenolic compounds to safely wash eggs designated for hatch.
	Disinfect the environment and materials	Thoroughly clean and disinfect buildings and equipment immediately following flock removal and prior to introduction of a new flock. In hatching cabinets, use UV light, peroxide, and ozone to disinfect the air. Use bacteriologic and quantitative tests to ensure enterobacteria counts are below 103 cells per $25cm^2$.
Biosecurity Programs	Prevent horizontal transmission in the hatchery	Ensure eggs come from *Salmonella*-free flocks and avoid mixing *Salmonella* positive and negative eggs. Use different incubators when able. Keep infected and uninfected chicks separate at all times.
	Actively control pests	Pests can carry *Salmonella* and transmit between poultry houses and flocks. Rodent-proof the facilities and use rodent traps and toxic baits to restrict spread and reduce risk of litter contamination. Ensure rodents and wild birds cannot enter the facilities.

Biosecurity Programs	Monitor litter and use effective management strategies	Keep litter from becoming too wet. Reduce water activity index to below 0.84 and maintain a moisture content between 20%-25% to limit *Salmonella* presence and growth.
	Utilize effective and biosecure production strategies	All-in-all-out can help minimize the movement of birds, people, and equipment, and limit the spread of pathogens.
	Avoid contact between poultry and wild birds	Wild birds, particularly migratory waterfowl, can carry *Salmonella* and other diseases.
	Monitor cleanliness of feed and water	Use pelleted or other heat-processed feed when able (the heat kills *Salmonella* cells). Ensure feed is transported and stored in enclosed or covered spaces and keep feed off the floor. Clean up and monitor feed spills as they occur. Inspect water routinely for bacteria and use chlorination to prevent microorganism spread and growth in water.
	Monitor the movement of people, vehicles, and materials (fomites) between farms	People, vehicles, and materials can transmit pathogens from farm to farm. Limit entry to farm workers and select visitors and disinfect vehicle tires prior to entering the farm.
	Wear biosecure clothing and proper personal protection equipment (PPE)	Shower and change into fresh clothing and shoe-cover before entering a new farm and between flocks - clean and disinfect. Wear fresh PPE and discard when done. Appropriate PPE includes but is not limited to, shoe-cover (boots, booties), disposable suit or coveralls, a hairnet, mask, and disposable gloves.
	Ensure all employees are trained in biosecurity standards	Train farm employees in appropriate biosecurity protocol. Follow all rules of hygiene, including washing hands and changing clothing, footwear, and PPE. Use hand sanitizer when entering and leaving houses. Employees should not interact with birds outside of the farm where they are employed.
	Dispose of birds safely	Plan procedures ahead of time for bird disposal of both healthy and sick bird carcasses according to methods approved locally and at the State and Federal levels. Dispose onsite if able. Check birds daily and collect carcasses as soon as possible. Ensure their storage or disposal doesn't attract insects or other animals by using tight lids or adequate covering. Avoid cross contamination with equipment and vehicles.
Nutritional Strategies	Yeast	Provide a yeast-type preparation to hatching chicks. *Salmonella* prefers attachment to the yeast cell wall and can then be easily removed through host defense mechanisms.
	Probiotics	Provide other commensal microbes for long-term protection from gastrointestinal pathogen infection. Commensal microbes reduce pathogen colonizing ability in the gut through competition.

Your Responsibility is to Prevent Spread

It is important to take precautions to prevent the spread of *Salmonella* when handling live poultry and poultry products. Avoid eating or drinking around poultry and keep live poultry out of the kitchen and other areas where human food is stored or prepared (CDC, 2020a). Clean and sanitize poultry environments and materials that come in contact with poultry or poultry litter (CDC, 2020c). When preparing products, you should always follow the CDC's guidelines for safe food handling: *Clean, Separate, Cook, and Chill* (CDC, 2020d).

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