Salmonella Control in Poultry Processing

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SALMONELLA IN POULTRY AND FOODBORNE ILLNESS

Campylobacter spp., and *Salmonella* spp. are major foodborne pathogens contributing significantly to an estimated 9.4 million food-related illnesses, 55,961 hospitalizations, and 1,351 deaths and costing USD 48 billion every year in United States (Scallan et al., 2011). According to The Foodborne Diseases Active Surveillance Network (FoodNet, CDC) in 2010, *Salmonella* infection was the most commonly reported foodborne illness with 8,256 infections at a rate of 17.6 cases per 100,000 people. *Salmonella* infections in 2010 were also responsible for the largest number of hospitalizations and deaths. According to the CDC the top ten *Salmonella* serotypes linked to foodborne illness were Typhimurium, Enteritidis, Newport, Heidleberg, Javana, Saintpaul, Muechen, Montevideo and Infantis (FoodNet, CDC). The top ten serotypes combined represented 72% of the reported cases of salmonellosis. In broilers, the top 5 serotypes collected by FSIS in 2010 from HACCP verification samples included Kentucky, Enteritidis, Typhimuirium, Heildleberg and Tyhimurium-5 (USDA, 2011). While Kentucky is not among the top 10 serotypes linked to foodborne illnesses, Enteritidis, Typhimurium and Heildleberg are, and to the point, an outbreak in ground turkey linked to *Salmonella* Heidelberg was responsible for 77 illnesses resulting in one death (CDC, 2011).

It is important to note that serotypes of *Salmonella* in poultry have changed since 1998 with Enteritidis rising to the top five in 2010 (USDA, 2011). Typhimirium and Heidleberg have remained in the top over the years. This likely indicates that certain serotypes out compete others in poultry, and that certain serotypes will continue to be dominant in the future.

Salmonella and *Campylobacter* commonly occur in live poultry, contaminate the meat during slaughter and get transferred to further processing areas. Although *Salmonella* spp. is commonly associated with poultry (Izat et al., 1990; Bailey et al., 1987) other sources may include raw meats, eggs, milk and dairy products, fish, shrimp, frog legs, coconut and peanut butter. Poultry are asymptomatic carrier of most serotypes of *Salmonella* aside from *S*. Pullorum and *S*. Gallinarum. Most cases of salmonellosis attributed to poultry occur when poultry products are inadequately cooked or cross contamination occurs.

USDA-FSIS NEW PERFORMANCE STANDARDS

In-spite of stringent government regulations and improved industry measures; rates of salmonellosis are above Healthy People 2010 targets (Table 1). Because targets for illness associated with *Salmonella* and *Campylobacter* have not been met and USDA has collected newer microbiological baseline data, USDA has issued new performance standards for *Salmonella* and *Campylobacter* on post-chill poultry samples. According to the Nationwide Microbiological Baseline Study conducted by UDSA-FSIS, *Salmonella* decreased from re-hang to post-chill (40.70% down to 5.19%) indicating that antimicrobial interventions were resulting in pathogen reductions. In addition, the data collected gave USDA an opportunity to estimate prevalence of *Salmonella* on post-chill poultry carcasses at 7.5%. The prevalence data was used to establish the new performance standards which were published in Federal Register Notice entitled "*New Performance Standards for Salmonella and Campylobacter in Chilled Carcasses at Young Chicken and Turkey Slaughter Establishments* (75 FR 27288). The notice indicates that establishments will pass the new *Salmonella* performance standards if FSIS finds no more than five positive samples in the 51-sample set for young chickens and no more than four positive samples in a 56-sample set for turkeys. The performance standards are lower than the 20% initially established by USDA (2005) for young chickens. USDA had previously started motivating the broiler industry to lower *Salmonella* levels by creating Categories for poultry establishments based on their Salmonella positive samples from their HACCP verification sets. The idea was that the top or Category 1 facilities would have *Salmonella* levels below 10%. Categories 1 (<10%), 2 (between 10-20%) and 3 (> 20%, not passing) were posted by FSIS in 2008 and remained until the new performance standards were established in 2011.

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Table 1. U.S. Healthy People 2010 targets for Salmonella spp. and other pathogens

Pathogen	1997 Baseline Case Rate*	2006-2008 Baseline Case Rate	2009 FoodNet Case Rate	HP2010 Target
Campylobacter	24.6	12.71	13.02	12.3
E. coli O157:H7	2.1	1.2	0.99	1
L. monocytogenes	0.47	0.29	0.34	0.24
Salmonella	13.6	15.25	15.19	6.8

Data Source: Chapter 10 - http://www.healthypeople.gov/document/pdf/Volume1/10Food.pdf
*Case Rate based on cases per 100,000 people.

CONTROLLING SALMONELLA IN POULTRY AND CHALLENGES PRE-AND POST-HARVEST

Poultry represents a natural reservoir for *Salmonella* and *Campylobacter*. Both pathogens are commonly found in the gastrointestinal track of poultry and are considered to be commensal microorganisms. Although the prominent modes of transmission are not well understood, it is known that *Salmonella* may be spread through horizontal transmission from environmental sources (Stern, 2002) and through vertical transmission from breeder flocks (Hiett et al., 2002; Cox et al., 2005). Further evidence of potential vertical transmission is demonstrated by studies showing *Salmonella* from poultry hatchery samples. Specifically, Cox et al. (1991) recovered *Salmonella* from shell egg fragments, chick pads and chick fluff in poultry hatcheries. Environmental samples indicating horizontal spread of *Salmonella* at the farm level includes factor such as litter, feed, water, insects, humans, animals and rodents (Jones et al., 1991; Hoover et al., 1997; Amick-Morris,1998).

In a survey conducted by McKee (2012), the industry indicated best practices for controlling *Salmonella* in poultry during live production. The survey represented best practices on 10,000 + poultry farms. One common note shared is that there was no single control but rather multiple controls. Best practices identified included vaccinating breeder flocks, litter management/treatment, stringent biosecurity, feed/heat treatment, poultry water treatments (PWT) (McKee, 2012). Poultry feed and water treatments generally included acid supplement. Research conducted by Byrd et al. (2001) found that acid application in drinking water could reduce *Salmonella* in poultry crops by identified 80%. It is imperative that on-farm controls are identified and implemented because birds are processed and all enter the poultry facility where many points of cross-contamination occur.

Poultry processing is a highly automated industry where many points exist for cross contamination if *Salmonella*-positive birds enter the processing plant. Therefore, intervention strategies require multiple approaches during processing to prevent *Salmonella* from spreading throughout processing. Since *Salmonella* are present in the feces of carrier birds, carcass picking and evisceration can be major sites in processing where bacteria are transferred from the intestines to the skin. Studies have indicated cross contamination during picking, scalding and chilling (Lillard, 1989). Picking and viscera removal are processing steps generally associated with having higher microbial levels when compared to the processing steps immediately prior to picking and viscera removal (Izat et al., 1990). Reports indicate 1 to 50% of birds become contaminated with pathogens such as *Salmonella, Campylobacter, Listeria, Clostridium perfrigens*, and *Staphyloccocus aureus* during the normal course of processing (CDC, 1984). Furthermore, it has been estimated between 20% (USDA, 1995) and 35% (Lillard, 1989) ready-to-market broilers tested positive for *Salmonella*; whereas only 3-4% entering the plant were *Salmonella* positive. Thus, cross-contamination during normal processing and ways to alleviate it are important issues to poultry processors and consumer alike.

To address the multiple points where birds may be contaminated, a number of antimicrobial controls are applied at various steps during processing. This multi-hurdle approach generally results in multiple chemicals being used as antimicrobial interventions. Generally, sites where antimicrobials are applied include online reprocessing (OLR) or inside outside bird washes (IOBW), the poultry chiller and post-chill applications. OLR or IOBW is generally a spray application and the effectiveness of antimicrobial is limited by a short contact time and inadequate coverage. Ideally, it would be a benefit to get a 1 log reduction at this step. In reality, most commercial applications of antimicrobials result in about a 0.5 log reduction at this step. The exception would be using cetylpyridium chloride (CPC) in a drench cabinet. CPC and the drench cabinet application provide much better pathogen reductions compared to traditional spray cabinets.

The second area where antimicrobials have traditionally been applied are at the poultry chiller. Poultry chilling is an immersion chill process where antimicrobials can be added. The volume of water being treated is 25,000 + gal-

lons of water, and the general contact time for birds in the chiller is 1-2 hours. Depending on the size of the operation, poultry processers generate 750,000 to 1,500,000 gallons of waste water per day (Yiu, 2006). Historically, chlorine has been used in poultry chillers and is regulated between 20-50 ppm for that application. Other antimicrobials have been approved which offer better reductions in *Salmonella* compared to chlorine.

Currently approved antimicrobials for poultry include acidified sodium chlorite, bromine, chlorine dioxide, cetyl pyridium chloride, organic acids, peracetic acid (PAA), trisodium phosphate, sodium metasilicate, monochloramine, electrolyzed water, and hypochlorous acid (chlorine) (Bilgili, 2009). The animal and poultry industries recognize the need for a multi-hurdle approach for addressing pathogens in processing environments. As such, it is not uncommon for multiple chemicals to be used at various steps in processing. The challenge is identifying antimicrobials that are effective for controlling not only *Salmonella* but also *Campylobacter* which is also part of the new performance standard. Of these antimicrobials listed above, organic acids and peracetic acid are two of the most environmentally friendly. While organic acids can be effective antimicrobials, they have been reported to cause negative flavor and color changes in product (Blankenship et al., 1990). To avoid the negative quality changes associated with organic acids, the ideal approach is to combine antimicrobials. Peracetic acid combined with hydrogen peroxide is an example of a combination that offers synergistic benefits. Studies conducted have shown PAA to be effective against Salmonella (Bauermeister et al., 2008, Table 2). While these results are encouraging, treating poultry chiller water is an expensive proposition, and there is a greater chance of negative product quality effects from antimicrobials because of the extended contact time (1-2 hours). Ideally, running the lowest level of antimicrobial in the chiller and following with an antimicrobial intervention would be the most efficient strategy in terms of maintaining product quality and reducing cost associated with antimicrobial applications during chilling.

Table 2. Reduction of Salmonella positive carcasses treated with PAA (peracetic acid) or chlorine during chilling in a commercial*

Chill Water Treatment	Carcass Sampling Point	*Salmonella* % Positive	% Reduction
85 ppm PAA	Pre-Chill	30.5[a]	91.8
	Post-Chill	2.5[c]	
30 ppm Chlorine	Pre-Chill	25.5[a]	91.8
	Post-Chill	11.0[b]	

[a-c] Means with no common superscript differ significantly ($P < 0.05$).

*Bauermeister, L. J., J. W. Bowers, J. C. Townsend, and S. R. McKee, 2008. Validating the efficacy of peracetic acid mixture as an antimicrobial in poultry chillers. J Food Prot., Vol 71 (6): 1119-1122.

Indeed, post-chill antimicrobial applications are the new strategy in antimicrobial control in the poultry industry. In a survey conducted by McKee (2011), a majority of poultry establishments indicated using post-chill antimicrobial applications. The post-chill applications included using a post-chill dip tank, Finishing Chiller, or drench cabinet depending on the antimicrobial used. These pieces of equipment are placed immediately after the primary chiller but are much smaller pieces of equipment compared to a large chiller. The benefit of a post-chill antimicrobial application is that birds come into contact with clean water, and an effective antimicrobial can be added at this step to reduce both *Salmonella* and *Campylobacter* on poultry carcasses. Additionally, higher levels of chemicals can be used, and the contact time is generally less than 30 seconds so negative product quality effects are not observed. Also, smaller volumes of water are used (around 400 gallons) so the antimicrobial application is much more cost effective than treating the large volume of water in the chiller. From the industry survey, results also suggested that PAA was the predominant antimicrobial used in these post-chill applications (McKee, 2011). PAA is approved up to 2000 ppm for finishing chiller applications (USDA-FSIS Directive 7120); however, concentrations between 400-700 ppm have been found to be effective in reducing *Salmonella* and *Campylobacter* on post-chill carcasses. When drench cabinets were used in post-chill applications, cetylpyridium chloride was predominant antimicrobial used. Cetylpyridium chloride is approved up to 0.8% (USDA-FSIS Directive 7120), but survey responses indicated usage levels were anywhere between 0.3 -0.6% depending on the food safety challenges facilities were facing. Chlorine not chosen one of the major post-chill antimicrobials used. This is likely due to the fact that chlorine would not be as effective as the other antimicrobials because the dwell time (<30 sec) of the application is short, and chlorine tends to be more effective with longer contact times as those typical in poultry chilling.

There are many opportunities for pathogen introduction and spread throughout the poultry production and processing. Managing food safety in poultry requires a systems approach where each level of production and processing is evaluated so that effective antimicrobials can be implemented. To determine which steps pose the greatest risks, microbial testing and data analysis (biomapping) should be used to determine which farms are likely *Salmonella* positive and what processing steps pose the greatest problems in terms of cross-contamination. Once those steps are identified, effective antimicrobial strategies need to be implemented. It is extremely important that these antimicrobial applications be validated at that step they are applied and as a part of the over all food safety strategy. In addition to implementing effective antimicrobial controls, it is essential that a team with representatives from each phase of the production and processing system document food safety policies and practices and share these doc-

umented policies so that food safety practices are communicated, understood and implemented throughout the poultry production and processing continuum.

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