Intervention Strategies for Reducing Salmonella Prevalence on Ready-to-Cook Chicken
Contents

Introduction .......................................................... 3
Hatching ............................................................... 3
Growout ............................................................... 4
Coop Disinfection .................................................... 6
Sanitation ............................................................. 6
Water ................................................................. 7
Ice ................................................................. 7
Air Supply ........................................................... 8
Employee Hygiene .................................................. 8
Processing ........................................................... 9
  Incoming Birds ................................................... 9
  Scalder ............................................................ 9
  Feed Withdrawal ................................................. 10
  Venter/Opener/Eviscerator ..................................... 11
  Cropper .......................................................... 11
  Inside/Outside Bird Washer and Other Washers or Rinses ............................................. 11
  Automated Reprocessing Systems ........................................ 11
  Chiller ............................................................ 12
  Management ...................................................... 13
Conclusion .......................................................... 13
References .......................................................... 14
Intervention Strategies for Reducing *Salmonella* Prevalence On Ready-to-Cook Chicken

Scott M. Russell, Ph.D.
Associate Professor, Poultry Science

According to the United States Department of Agriculture-Food Safety and Inspection Service’s (USDA-FSIS) regulations, poultry slaughter facilities must be evaluated for *Salmonella* on an intermittent basis. A USDA Inspector in Charge (IIC) will receive notification that he or she should begin testing and the following will occur:

1. One carcass per day will be selected, rinsed, and the rinse will be mailed to the USDA-FSIS and tested for the presence of *Salmonella*.
2. Carcasses will be selected and tested for approximately 51 processing days or until 51 carcasses have been evaluated. In some cases, carcass rinses must be discarded and more rinses are collected. For example, if carcass rinses are temperature abused or lost during shipment, they would not be tested.
3. Thirteen or more positives out of 51 samples (>23.5 percent) results in a failure.
4. Once the first failure occurs, the plant is given 30 days to make corrections, and the testing series (51 samples) begins again.
5. After a second failure, the company must write an action plan detailing corrective actions that will be taken to prevent the problem from recurring.
6. Testing resumes 30 days after the second testing series has been completed.
7. Once the third failure has occurred, inspection will be withdrawn, which effectively closes the processing plant (USDA, 1996). This action by the USDA would result in layoffs, loss of reputation, and lost business. In addition, flocks must be processed by another plant that is owned by the same company or the birds must be sold to another processor.

These regulations have caused enormous problems within the poultry industry. Initial baseline studies by the USDA indicated that nationwide, raw broiler chicken carcasses were 20 percent positive for *Salmonella*. Thus, the USDA set the maximum limit for *Salmonella* on chicken carcasses at 23 percent. By taking the average prevalence nationwide, and making it the new maximum level for prevalence, the USDA effectively made a rule in which almost 50 percent of the processors in the country were producing carcasses out of specification for *Salmonella* prevalence. Since that time, researchers and poultry companies have been trying to institute numerous intervention approaches to lower *Salmonella* prevalence on carcasses. Due to the confidential nature of this subject, some of the suggestions in this article are not based on published data; however, they have been shown to be effective in field settings by individual companies.

Reducing *Salmonella* on finished carcasses requires a comprehensive, multi-hurdle approach. No individual procedure is adequate to accomplish this task. The USDA stated that “intervention strategies aimed at reducing fecal contamination and other sources of *Salmonella* on raw product should be effective against other pathogens” (USDA, 1996). This statement is misleading in that reducing fecal contamination has not been sufficient to reduce *Salmonella* prevalence. Reducing fecal contamination may be effective for reducing the number of *Salmonella* on each carcass; however, only one *Salmonella* cell is required on a carcass to produce a “positive” result. Thus, unless all *Salmonella* are eliminated, the carcass will still remain positive.

Moreover, the USDA also stated that “slaughter establishments concerned that they might not meet the pathogen reduction performance standard have available a wide range of technologies shown to reduce the levels of pathogens that may be on the surface of carcasses” (USDA, 1996). This is not true since many strategies must be used together to realize reductions in *Salmonella*.

**Hatching**

To reduce the prevalence of *Salmonella* on poultry carcasses during processing, a number of approaches have proven useful; however, to be truly successful at controlling *Salmonella*, intervention strategies should be implemented during the breeding, hatching, grow-out and transportation phases of poultry production as well. *Salmonella* spp. may be found in the nest boxes of breeder chickens, cold egg storage rooms at the farm,
on the hatchery truck, or in the hatchery environment (Cox et al., 2000). These bacteria may then be spread to fertilized hatching eggs on the shell or, in some cases, may penetrate the shell and reside just beneath the surface of the eggshell.

Research has demonstrated that contamination of raw poultry products with *Salmonella* spp. may be attributable to cross-contamination in the hatchery from *Salmonella* infected eggs or surfaces to uninfected baby chicks during the hatching process. Cox et al. (1990 and 1991) reported that broiler and breeder hatcheries were highly contaminated with *Salmonella* spp. Within the broiler hatchery, 71 percent of eggshell fragments, 80 percent of chick conveyor belts swabs, and 74 percent of pad samples placed under newly hatched chicks contained *Salmonella* spp. (Cox et al., 1990).

Cason et al. (1994) reported that, although fertile hatching eggs were contaminated with high levels of *Salmonella typhimurium*, they were still able to hatch. The authors stated that paratyphoid salmonellae do not cause adverse health effects to the developing and hatching chick. During the hatching process, *Salmonella* spp. is readily spread throughout the hatching cabinet due to rapid air movement by circulation fans. When eggs were inoculated with a marker strain of *Salmonella* during hatching, greater than 80 percent of the chicks in the trays above and below the inoculated eggs were contaminated (Cason et al., 1994). In an earlier study, Cason et al. (1993) demonstrated that salmonellae on the exterior of eggs or in eggshell membranes could be transmitted to baby chicks during pipping.

*Salmonella* may persist in hatchery environments for long periods of time. When chick fluff contaminated with *Salmonella* was held for 4 years at room temperature, up to 1,000,000 *Salmonella* cells per gram could be recovered from these samples (Muira et al., 1964).

Researchers have demonstrated a link between cross-contamination in the hatchery and contaminated carcasses during processing. Goren et al. (1988) isolated salmonellae from three different commercial hatcheries in Europe and reported that the same serotypes found in the hatcheries could be found on processed broiler chicken carcass skin. Thus, proper disinfection of the hatchery environment and fertile hatching eggs is essential for reducing *Salmonella* on ready-to-cook carcasses. Suggestions for elimination of *Salmonella* in the hatchery include:

1. Install a disinfectant fogging system or electrostatic spraying system in the hatchery plenum (Figure 1), setters and hatchers (Figure 2) that are linked to a timer system.

2. Spray disinfectant every 30 minutes during setting and hatching to prevent cross-contamination.

3. Thoroughly clean and sanitize setters and hatchers regularly using documented sanitation standard operating procedures (SSOPs).

4. Regularly monitor eggshell fragments, chick paper pads, and chick dander from the bottom of the hatching cabinet for *Salmonella*.

**Growout**

The modern broiler chicken has been bred over the years to be a veritable “eating machine.” During grow-out, broiler chickens eat approximately every 4 hours. Frequent eating is advantageous because birds that eat this frequently gain weight and put on edible muscle rapidly. This attribute may be considered a disadvan-
tage for maintaining the sanitary quality of the bird during processing.

At the end of the growout period, prior to catching the birds and cooping them for transportation to the processing plant, the feed is removed from the birds for a period of approximately 3 to 7 hours. During this time, birds become hungry and begin to search for food. Because no food is available to them in the feeders, they begin to search for feed on the floor, which may be contaminated. This activity has been demonstrated to significantly contribute to the level of Salmonella on processed carcasses (Byrd et al., 2001). Studies have shown that many birds entering the processing plant have high levels of Salmonella in their crops as a result of this litter pecking (Byrd et al., 2001) (Figure 3).

Salmonella in the crops of chickens that have consumed litter may be spread from carcass to carcass during the crop removal process (Hargis et al., 1995, and Barnhart et al., 1999). During cropping, the cropper piston is inserted into the vent area of the carcass and continues through the entire carcass, spinning as it goes (Figure 4).

The piston has sharp grooves on the end of it that pick up the crop and wraps the crop around the end of the cropper piston (Figure 5). As the piston moves through the neck opening, the cropper piston comes in contact with a brush that removes the crop from the piston (Figure 6). Then the piston, while spinning, goes back through the entire carcass.

If the crop breaks during this removal process, the contents leak onto the cropper piston and are transferred to the interior and exterior of the carcass, possibly spreading Salmonella (Figure 7).

Studies have been conducted by Dr. Allen Byrd of the USDA-Agricultural Research Service (ARS) in which the crops of live birds were filled with

Figure 3. Fecal material in crop of chicken upon arrival at back dock of processing plant.

Figure 4. Crop removal machine.

Figure 5. Cropper piston removing crop.

Figure 6. Crop removal brush.

Figure 7. Liquid in the crop that may contaminate carcass.
fluorescein dye. After 30 minutes, the birds were processed. By examining the carcasses at different stages of processing under a black light, crop contents that were transferred to the inside or outside of the carcass could be clearly visualized. These studies have shown that commercial croppers result in a large amount of contamination of the inside and outside of the carcasses. Thus, efforts should be made to control *Salmonella* in the crop prior to the crop removal process.

Some companies have been successful at controlling *Salmonella* in the crop by acidifying the birds drinking water during the feed withdrawal process. Acetic, citric and lactic acids have all been used at low concentrations (0.3 to 0.5 percent) to acidify the crop to the extent that *Salmonella* are unable to survive. Byrd *et al.* (2001) found that lactic acid was most effective and that 0.44 percent lactic acid in the waterers of broilers during the feed withdrawal period reduced *Salmonella* contaminated crops by 80 percent. This effect carried over to the pre-chill carcasses on which the prevalence of *Salmonella* was reduced by 52.4 percent (Byrd *et al.*, 2001). When acidifying drinking water using lactic acid, it is best to gradually expose the birds to higher and higher levels of acid in the water the week before birds are to be caught. The key is to make the lactic acid concentration as high as possible while insuring that the birds continue drinking the water. Suggestions for elimination of *Salmonella* in the crop prior to processing are as follows:

1. Apply lactic acid to drinking water of the chickens before the feed withdrawal period.
2. Begin by applying small amounts and gradually increase levels until they reach 0.5 percent (0.64 oz. of lactic acid/gallon of water).
3. Occasionally have the QA employees check the pH of the crops of birds at the plant to insure that they are being acidified.

Coop Disinfection

Conventional cage-dump systems used in the poultry industry are very difficult to clean and sanitize (Figure 8).

If transportation coops are to be cleaned, they must be thoroughly washed and sanitized. Remove dry excreta before washing if possible. Some companies have implemented rinsing systems that do not thoroughly clean excreta off coops. This rehydrates the excreta, allowing *Salmonella* to proliferate. All of the environmental conditions (nutrients, pH, moisture and temperature) that *Salmonella* require to multiply are available if the company simply rinses the coops. If disinfection systems are used, be sure they are capable of thoroughly removing excreta prior to sanitizing the coops.

Sanitation

All poultry companies in the United States are required to operate using guidelines spelled out in their SSOP manual. These SSOPs describe exactly how each piece of equipment and processing area (walls and floors) should be cleaned and sanitized. Prior to initiation of production, evaluate processing equipment surfaces to ensure that they have been properly sanitized. Equipment surfaces should be clean and free of processing residue. Different companies consider sanitation in a tremendous variety of ways. Recently a company claimed that they “do not have time for sanitation.” With the United States being a country of extreme litigation in cases of food-borne illness where negligence has been established, it is untenable that some companies take this approach.

Many poultry companies use old, outdated and ineffective methods for determining sanitary status of equipment. Traditional swabbing methods are slow (48 hours), expensive, inaccurate (many of the bacteria on surfaces are psychrotrophic and are not detected using a traditional plate count), and ineffective because inadequately cleaned surfaces cannot be detected prior to production. Evaluate equipment surfaces using a “real-time” contamination or bacterial detection system to determine their microbiological condition. Adenosine triphosphate (ATP) bioluminescence is a “real-time” monitoring procedure because an incubation period is not required and cleanliness can be assessed in 1 or 2 minutes. Many poultry companies are interested in this new technology because they can determine the effectiveness of their sanitation procedure immediately and make corrections such as re-cleaning and sanitizing before production begins, instead of having to discard...
product produced on inadequately sanitized processing lines. The ATP method has been made simple and inexpensive so quality control or sanitation personnel can use it daily.

Moreover, the ATP technique fits into a Hazard Analysis and Critical Control Point (HACCP) scheme. Proper cleaning and sanitation of equipment can be considered a control point that is critical to the safety of food products. Because all HACCP programs require that the processor be able to control these critical control points, it would be impossible to use traditional microbiological methods for assessing the efficiency of sanitation, since 24 to 48 hours is not an acceptable time frame for identifying improperly cleaned equipment. The need for an immediate assessment of sanitation efficiency has increased the popularity of ATP bioluminescence.

One consideration with ATP bioluminescent assays is that, when sampling food contact surfaces in a poultry processing facility, the surfaces have often just been exposed to sanitizers. Sanitizers and cleaners are formulated to kill microorganisms and/or remove processing residues from food processing equipment or food contact surfaces. Many sanitizers and cleaners contain components that break down or destroy organic material such as fats, proteins and biological membranes. Green et al. (1998 and 1999) demonstrated that exposing ATP bioluminescence reaction components directly to sanitizers and cleaners may significantly reduce ATP readings. Of the nine chemicals tested in the study, quaternary ammonia increased ATP readings (Green et al., 1999). Sodium hypochlorite (bleach) had no effect on ATP readings. Lactic acid at concentrations of 0.5 percent and higher reduced readings by 75 percent (Green et al., 1998). ATP measurements were significantly (P≤0.05) reduced by approximately 60 percent when levels of trisodium phosphate exceeded 1 percent. Hydrogen peroxide at 1 percent significantly (P≤0.05) decreased ATP measurements by approximately 60 percent. These results indicate that commercial sanitizers may negatively affect ATP readings if the sanitizer is allowed to come into direct contact with the ATP bioluminescence reagents (Green et al., 1998).

If the pH of the water is too high (>8.0), then bleach added to chlorinated rinse waters or chiller water will be ineffective, as the bleach will drive the pH up even further. At pHs above 8.0, chlorine is not found in its active form (hypochlorous acid) in high quantities and is ineffective for killing bacteria. If lye is used in the water reservoir that supplies the plant as a means of reducing the effects of acid rain, and the pipe that feeds the plant picks up this lye, then the pH of the water may be driven up to 10 or greater, causing problems with the chlorine as previously discussed. If ammonia has been added by the city to the incoming water, there is a greater likelihood that, when chlorine is added to the water, some of the chlorine will form trichloramines. Trichloramines form noxious odors and, even though the plant may be using very low levels of chlorine (<20 ppm), the inspectors and employees may complain about the odor, causing the plant to have to reduce chlorine levels, resulting in inadequate bacterial reduction. Some companies using well water have complained about decreased shelf-life of their product. These companies should evaluate their well water to determine if bacterial levels are excessive. If the wells are contaminated, they need to be shock-treated with chlorine. Evaluate well and city water to be sure no chemical or biological contaminant is present. Water hardness should be controlled because salts contained in hard water can make some disinfectants ineffective.

**Ice**

Evaluate the ice supply in the plant. In one processing facility, water from the processing floor was allowed to run freely into the fresh ice supply, to be placed back on finished ready-to-cook carcasses. In another case, a fresh ice bin was placed under the corner of a drip pan that was collecting exudate under raw chickens on the processing line. The contaminated water from the drip pan was draining into the fresh ice to be used on product. In another instance, augers used to transport ice around the plant were located on the roof of the plant and were uncovered. Birds were able to roost on the edge of the augers and defecate in the ice.

Carefully store and transport fresh ice to be used on product to ensure that it does not become contaminated prior to being used on product. Evaluate the following with regard to fresh ice:

1. Ice is transported using covered augers.
2. Ice containers are protected from contamination by covering them with plastic.
3. Ice house is protected from contamination by employees or other sources.

**Water**

Evaluate process water frequently to determine its characteristics. Evaluate incoming water for the following:

1. pH
2. Ammonia
3. Contaminants
4. Hardness
4. Ice chutes (Figure 9) are evaluated occasionally for microbial contamination using psychrotrophic plate counts.

Air Supply

Thoroughly evaluate the air supply for the plant to determine its source and whether there is positive or negative pressure inside the plant. In one processing facility, all of the air within the plant was flowing through the inside of a trash compactor. In another instance, the air being blown onto the live birds outside to keep them cool was coming directly into the plant and onto finished ready-to-cook carcasses. In another plant, the wastewater facility was only 30 yards from the door of the processing room and the plant had negative air pressure. All of these conditions may greatly contribute to contamination. Abu-Ruwaida et al. (1994) demonstrated that *Salmonella* spp. were frequently isolated from air samples where live birds carrying the organisms were handled.

It is important to go to each plant exit doorway, crack it slightly, and try to determine if the air is going into or out of the processing plant. It should be going out. If it is flowing into the plant, then the plant has negative pressure and it needs to have more clean make-up air pumped into the plant. Otherwise, all contaminants outside will be pulled into the plant. Some strategies for ensuring that the air supply is clean are:

1. Evaluate the environmental air make-up to ensure that it is clean.
2. Determine if each room has positive or negative air pressure and strive for positive pressure.
3. Evaluate the air supply for compressors that feed air to areas such as the chiller for bacterial contaminants.
4. Evaluate total air volume coming into the plant and make sure the temperature of the air is controlled, even during the summer months.

Employee Hygiene

Employee hygiene is also an important part of keeping contamination down in the plant. Some poultry processing plants employ individuals that have cattle farms. These employees have cattle in their yards at home and are allowed to wear their street clothes and boots into the plant. Any *Salmonella* on their clothes or boots from the cows may be transmitted to the product. All plants should be equipped with mandatory hand-washing/sanitizing stations that are refreshed frequently. There should be no access to restrooms directly from the processing floor. Each employee should begin his or her shift with a clean, long smock, hairnet and gloves (Figure 10).

Examine employees daily for illness. Send visibly sick employees home. Briefly interview foreign employees returning from their home country to determine if they have had any food-borne illnesses. They may be asymptomatic carriers similar to Typhoid Mary, who was infected with typhoid fever in 1900. She worked as a cook and spread the disease to 22 people between 1900 and 1907, causing one death. Later, she became a cook at a hospital and 25 more people became infected and two people died. These individuals may be carrying *Salmonella* or *Shigella* and not be aware of the risk they pose to the consumer. Only 10 cells of *Shigella* are required to cause a severe, life-threatening food-borne infection.

Many Central or South American employees of modest social background are unfamiliar with U.S. hygiene customs. They often discard used toilet paper on the floor in the restroom next to the toilet because they believe it will clog the plumbing. Although this is

Figure 9. Ice chute in poultry processing plant.

Figure 10. Employees wearing proper clothing.
a common practice in processing plants today, it is completely unacceptable and every employee must be retrained intermittently to discontinue this practice. Anyone who may step on toilet paper from an asymptomatic Salmonella carrier will track the organism into the plant and it will likely make its way onto product. Strategies for controlling the hygiene of personnel are:

1. Control personnel flow (i.e., they should not go from the kill room to the deboning area or from a cattle farm into the processing plant).
2. Control personal hygiene using written standard operating procedures that are spelled out for each area and monitored by managers daily.
3. Managers should evaluate employee health daily.
4. Managers should question employees returning from foreign countries about food-borne illness.
5. Employees must be held accountable for their failures to use hygienic practices.
6. Managers should train employees regularly concerning proper hygiene.

Processing

Incoming Birds

If birds coming into the plant are dirty, then install a brush system with a pressurized, chlorinated rinse to remove foreign material. In one processing plant, chickens coming into the plant were coated with excreta because the chickens were large (>7 lbs.), the weather was hot, and misting systems were used in the grow-out houses to keep the birds cool. As a result, all of the external organic material could not be removed from the birds during scalding. This condition led to excessive contamination of processing equipment and chiller water in this plant. Thus, excessive contamination early on in the process can lead to contamination of equipment downstream.

Scalder

The scalder is one of the most important areas in the processing plant in which cross-contamination with Salmonella occurs (Okrend et al., 1986). The water in most scalders in the U.S. does not move against the carcasses, going from the exit of the scalder toward the entrance (counter-current) and contains high levels of excreta (Figures 11 and 12). This opposing water flow is essential to wash the birds and remove contamination from the birds as they travel through the scalder. Counter-current flow may be accomplished by adding a steel barrier between the lines of chickens going in either direction. By separating these chickens, bacteria that are washed off of the external surface of the chickens entering the scalder are not transferred to chickens that are exiting the scalder. The rate of water flow should be high, so as to dilute the concentration of foreign material and bacteria in the scalder. There is a common adage that goes “A dilution is the solution to pollution,” and it applies in this case. Plants that are not equipped with multi-stage scalders should attempt to make their scalders multi-stage.

Some companies have found that their scalders are not long enough to thoroughly rinse caked material from the outside of the birds. These companies have added sections to their scalders to increase length. In addition, the temperature of the scalder should be maintained as high as possible without causing visible defects to finished carcasses, such as breast stripping. The water where the birds exit the scalder should be fairly clean. One company installed a water recycling system that takes all rinse water from equipment and carcass rinsers in the plant and recycles the water using diatomaceous earth filters. The water is then ozonated,
heated and returned to the scalder. In one processing plant, this system has had an enormous impact on Salmonella prevalence on finished product.

Suggestions to ensure that scalders are operating optimally with regard to decreasing cross-contamination include:

1. Make sure scald water flows in the opposite direction as the birds (counter-current).
2. Put as much fresh water into the scalder as possible to dilute Salmonella concentrations.
3. Keep scalder water temperature as high as possible without causing breast striping.

Feed Withdrawal

Prior to evisceration, carcasses should be evaluated to determine if the birds have undergone proper feed withdrawal. By examining the abdominal cavity to see if it is concave (small amount of feces in the intestines) or convex (large amount of feces in the intestines), it is possible to determine if the birds have been withdrawn from feed long enough.

Moreover, the intestinal tracts on the intestines hanging from the birds after evisceration should be flat (Figure 13) and not full of digesta or bloated with gas (Northcutt et al., 1997). In the processing plant, birds held off feed for extended periods may exhibit a higher incidence of contamination with pathogens due to loose droppings as the result of cross-contamination from bird to bird during transport. These birds may have intestines that are distended with gas which, if nicked during evisceration, may explode and disperse contents onto the carcass, other carcasses or processing machinery. Extended periods of feed withdrawal also cause the tensile strength of the intestines to become weak (Northcutt et al., 1997). Weakness increases the propensity for them to be torn during evisceration.

If birds are not held off feed long enough (<8 hours), the intestines will be full of digesta (Northcutt et al., 1997). If full intestines are nicked during evisceration, contents likely will be spread to the inside or outside of the carcass, to other carcasses and to processing equipment. Also, if pressure is applied to the outside of a bird with full intestines, the contents may come out of the vent and spread onto the carcass. Immediately after venting, if the colons are full of material, then the contents will leak onto the carcass, especially if any line jerking or swinging occurs (Figure 14). Insufficient feed withdrawal time is perhaps the most important factor in meeting the “zero tolerance” standard for contamination on carcasses entering the chiller. Reprocessing levels as high as 75 percent and line speeds as low as 20 birds/minute have been reported in plants due to excessive contamination as a result of insufficient feed withdrawal times.

Excessive contamination on incoming birds causes the water in the scalder to become dirty. This water may then be driven into the feather follicle during picking (Figure 15, page 11).

The carcass then proceeds to the chiller. When exposed to the icy cold water in the chiller, the feather follicle contracts to hold the contaminated water in the follicle. This is one reason that pathogenic bacteria cannot be eliminated in the chiller simply by adding antimicrobial agents. Also, pathogenic bacteria may become encased in fat globules and may be spread from carcass to carcass during chilling. The bacteria are protected from destruction within the feather follicle or by fat globules. Therefore, to reduce Salmonella prevalence on processed carcasses, every effort must be made to reduce contamination in the field and during processing. To accomplish this, feed withdrawal regimens should be strictly followed.

Figure 13. Flat intestines indicate proper feed withdrawal time.

Figure 14. Fecal contamination due to feces leaking from colon. Line swinging caused feces to be spread to the back of the carcass.
Venter/Opener/Eviscerator

If the venter, opener or eviscerator are misadjusted, nicked or cut intestines may cause the spreading of contaminated contents to the inside and outside of the carcass (Figures 16 and 17). Make sure these pieces of equipment are adjusted properly to prevent contamination.

Cropper

Carcasses exiting the cropper should be evaluated to determine if there is evidence of ingesta from torn crops or improperly cleaned pistons on or inside the carcass. Pistons should be cleaned and sanitized each time they exit a carcass and are ready to enter another, and each time they go through a carcass and the brush removes the crop from the piston (Figures 5 and 6). This decreases cross-contamination with Salmonella from carcass to carcass because crops are often contaminated with Salmonella (Hargis et al., 1995). Moreover, the other parts of the cropper should be rinsed with chlorinated high-pressure sprays as well.

Inside/Outside Bird Washer (IOBW) and All Other Washers or Rinses

The water from these sprayers or rinses should be checked frequently to determine chlorine levels, pH, pressure and distribution. In one processing facility, the IOBWs had very little water pressure. When confronted, the maintenance manager said, “Oh, do you want this turned up? I had it turned down so that it wouldn’t spray people as they walked by.” This is a case of someone changing the process without understanding the microbiological effect on the carcass.

In another instance, a company’s E. coli results became unacceptable within one day and continued that way. The maintenance manager had swapped the nozzles in the IOBW for a different type of low flow nozzle. This had a dramatic influence on bacterial levels.

If bleach is added to spray rinses or the IOBW, the pH will rise to unacceptable levels. The pH should be monitored to ensure that it is not too high. If so, the pH of the water should be reduced using a food-grade organic acid or carbon dioxide gas. General suggestions for all washers and rinsers include:

1. Maintain proper nozzle pressure.
2. Maintain proper water pH.
3. Maintain proper chlorine level.
4. Maintain proper water distribution on the carcass or equipment.

Automated Reprocessing Systems

Trisodium phosphate (TSP)

Use of trisodium phosphate (TSP) over the years has been encouraged by the USDA as an approved method
Figure 19. Rinse cabinet installed to remove trisodium phosphate from carcasses after treatment.

Figure 18. Trisodium phosphate system (TSP).

for automated reprocessing. TSP is costly to use because of the high concentration (10 percent) used on carcasses (Figure 18). The negative aspects to using TSP in poultry processing plants should be considered.

Residual TSP on carcasses causes the chiller water pH to increase dramatically. In plants where TSP is used, the chiller water will generally be in the pH range of 9.7 to 10.5. This is extremely high and prevents chlorine from being converted to its effective form, hypochlorous acid. Hypochlorous acid forms most effectively when water is in the pH range of 6.5 to 7.5. Thus, plants using TSP are wasting their bleach. This is not a desired situation because chlorine is very effective against Salmonella.

In fact, plants in the southeastern United States that have installed a TSP system have often seen their Salmonella prevalence increase when compared to levels prior to using the TSP. This is most likely due to the TSP washing Salmonella off one carcass and onto other carcasses. Keep in mind that Salmonella washed from one carcass to another may be reducing the number of Salmonella on one carcass, but it is significantly increasing the prevalence of Salmonella on other carcasses. The USDA is only concerned with prevalence, not numbers of cells. Scientists have reported that Listeria monocytogenes is resistant to the effects of trisodium phosphate (TSP), and exposure to a high (8 percent) level of TSP for 10 minutes at room temperature is required to reduce bacterial numbers by 1 log₁₀ after a colony has grown on a surface and a protective layer (biofilm) has been formed.

If a poultry company is having trouble with high Salmonella prevalence and have an operating TSP system in place, it must make major adjustments to reduce Salmonella prevalence. CO₂ gas systems have been added to the aeration systems of chillers as a way to reduce the pH of the water so when chlorine is added, it will form hypochlorous acid. Also, post TSP treatment rinse cabinets up to 26 feet long have been installed to rinse the TSP off the carcass prior to entering the chiller (Figure 19).

**Alcide (Sanova) Acidulated Sodium Chlorite**

This product is approved as a poultry spray or dip at 500 to 1200 ppm singly or in combination with other GRAS acids to achieve a pH of 2.3 to 2.9 as an automated reprocessing method. In chiller water, sodium chlorite is limited to 50 to 150 ppm singly or in combination with other GRAS acids to achieve a pH of 2.8 to 3.2. Studies have shown that it can reduce Salmonella contamination from 31.6 percent prevalence to 10 percent prevalence (Kemp et al., 2001). Many poultry processing facilities have switched from TSP systems to Sanova as an approved automated reprocessing system because it appears to reduce Salmonella more effectively than TSP.

**Chiller**

More bacterial reduction (both numbers and prevalence) can be accomplished in a properly balanced chiller than anywhere else in the processing plant. Most studies demonstrate that the chiller can significantly reduce Salmonella prevalence (Izat et al., 1989) if operating properly. As with the scalders, the pH, temperature, flow rate, flow direction, chlorine concentration, and concentration of organic material (digesta, fat, blood) is crucial in order for the chlorine in the chiller to do its job. The pH should be 6.5 to 7.5, the temperature should be below 40 degrees F, the flow rate should be high (at least one gallon per bird), and the flow direction should be counter-current (Figure 20, page 13).

The organic material in the chiller is determined by three factors: the flow rate, flow direction and the cleanliness of the scalders. More organic material (blood, digesta, fat) in the chiller will result in less
chlorine being available to kill bacteria, as it will be bound up and rendered useless by the organic material.

It is also preferable to ozonate and filter the recycled, rechilled (redwater) to decrease organic material and to add an additional level of sanitation. Many of the chillers in the industry are more like a bath than a river. The water is stagnant and organic material builds up during the shift. Also, fat builds up on the chiller paddles and sides of the chiller. This allows for *Salmonella* to be encased in the fat, offering it protection from the sanitizers used in the chiller. Suggestions for maintaining a balanced chiller include:

1. Maintain proper water flow direction (counter-current).
2. Maintain proper water pH.
3. Maintain proper chlorine level.
4. Maintain water temperature below 40 degrees F.

**Management**

In cases of salmonella failure, each company should get someone to review its operation from the ground up and construct an appropriate solution as soon as possible; this is a difficult problem to deal with and it requires someone with knowledge of the entire poultry operation and knowledge of how to implement strategies throughout an operation.

A serious need exists for highly informed Directors of Food Safety at the corporate level of each poultry company who are familiar with all aspects of production and processing that affect the safety of the finished product. At the present time, very few companies have such an individual. This person should be familiar with the pH and chlorine level of the chiller and the concentration and type of chemical used to disinfect eggs in the hatchery on a daily basis. In order for a company to get handle a problem such as a *Salmonella* failure, a person of this caliber should be hired and should be supported by upper management.

**Conclusion**

Reducing *Salmonella* prevalence requires a multi-hurdle approach at all stages of breeding, hatching, growout, transportation and processing. No “silver bullets” can be added at a single point in production or processing that will completely eliminate *Salmonella* on chickens.

Numerous studies are being conducted by the poultry industry, academe and the USDA, attempting to devise solutions to this problem. We hope that intervention at all stages of poultry production coupled with innovative sanitizers and disinfection processes will dramatically reduce the prevalence and level of *Salmonella* on processed chicken carcasses and, at the same time, decrease the prevalence of salmonellosis in the population.
References


