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# Interventions to control *Salmonella* contamination during poultry, cattle and pig slaughter

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ABSTRACT

The fundamental principle of controlling microbial contamination during slaughter is based on sanitary and hygienic processes. Both choosing abattoir technologies and conducting individual operations should be approached with the primary goal of minimizing microbial load on the final product. Nevertheless, even when best hygienic abattoir practices are applied, complete prevention of all microbial contamination of carcasses is unachievable under commercial conditions. Therefore, in some situations it may be considered necessary to further reduce the microbial loads on carcasses through application of additional control interventions, i.e. decontamination treatments. Treatments applied on poultry carcasses or parts include water, steam and chemical solutions (e.g., lactic or acetic acid, chlorine-based compounds, cetylpyridinium chloride, and trisodium phosphate) and result in overall microbial reductions of 0.6–3.8 log units; antimicrobial activity of some chemicals (e.g., chlorine compounds) is reduced in the presence of organic material. Decontamination treatments of hides (pre-skinning) and/or cattle carcasses reduce *Salmonella* by <0.7–5.1 log units. *Salmonella* prevalence reductions achievable by decontamination of porcine carcasses seem to be at least two-fold. Overall *Salmonella* reductions on final carcasses and meat can be significantly improved when multiple decontamination treatments are applied sequentially during slaughter and dressing operations. It is important to note that decontamination interventions should be validated and considered as part of a hazard analysis critical control points (HACCP)-based food safety system which is subject to verification and auditing, and they should never be used as a substitute for good sanitation and proper hygiene practices.



## 1. Introduction

The microbiological hazards associated with meat originate from live animals and the environment. Meat-producing farm animals, including poultry, pigs and cattle, can be carriers of salmonellae and can shed them fecally without any signs of disease, which leads to their further spread along the meat chain. Control of animal contamination with pathogens, such as *Salmonella*, is not always or completely possible at the farm, and the live animals come to slaughter contaminated. Thus, efforts should be made to control increases and spreading of contamination during transport of all animal species to and – in case of red meat animals – lairaging before slaughter (Barham et al., 2002; Bolder, 2007; EFSA, 2006; FAO/WHO., 2005, 2009a, 2009b; FSIS/USDA., 2008, 2010). Furthermore, incoming animal-associated contamination of the abattoir environment as well as the slaughter of large numbers of animals on the same slaughter line using the same equipment and tools contributes to direct or indirect cross-contamination of carcasses during slaughter-dressing operations (Buncic, 2006; Gill, 1998; Lo Fo Wong & Hald, 2000).

To reduce cross-contamination, general control measures at the abattoir level include physical separation of "dirty" (e.g. lairage) and "clean" (e.g. slaughter line) areas so to prevent mixing of staff, equipment/tools and air between them, as well as application of proper cleaning-disinfection regimes. Generally, the abattoir-related *Salmonella* control strategies are based on the following main principles: a) primarily, the overall contamination should be prevented or at least minimized; b) if/when it occurs, the contamination should be reduced or, preferably, eliminated through decontamination; and c) the growth of the pathogen present on final carcasses should be suppressed through effective refrigeration (Sofos & Geornaras, 2010). These general principles are universally applicable to slaughtering of all food animal species.

Decontamination treatments are applied during slaughter and dressing in some countries to reduce prevalence and numbers of pathogens and other microorganisms on carcasses. According to Loretz, Stephan, and Zweifel (2010), decontamination interventions include physical, chemical and biological treatments (Bolder, 1997, 2007; Dincer & Baysal, 2004). Physical decontamination treatments are water-based, such as water-washing, hot water or steam exposure; ionizing radiation; chilling

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(water- or air-chilling); and freezing or crust-freezing. Chemical treatments include chlorine-based compounds such as chlorine, chlorine dioxide, acidified sodium chlorite, and monochloramine; organic acid solutions such as lactic, acetic, citric, and peracetic acid; phosphate-based compounds such as trisodium phosphate; cetylpyridinium chloride; and electrolyzed or ozonated water. Biological treatments have received limited consideration and include bacteriophages and microbial competitive cultures. Approaches for contamination control must primarily be based on application of good manufacturing practices (GMP), good hygiene practices (GHP), and the principles of hazard analysis critical control points (HACCP). Further, it is necessary to train food handlers and educate consumers of their role in preventing foodborne illnesses such as salmonellosis. Overall, food animal species differ in respect to their *Salmonella*-related meat safety relevance, which is in the following decreasing order: poultry, pigs, ruminants (EFSA, 2010a). In this paper, main *Salmonella* controls during slaughter of poultry, pigs and cattle are briefly overviewed.

In the European Union (EU), EC regulation No 853/2004 allows decontamination treatments to be considered if shown to be safe and effective and not used to conceal poor hygiene practices (EFSA, 2010b). Decontamination treatments must always be considered as part of an integrated food safety system and not as substitutes for proper hygiene and sanitation. Decontamination interventions with substances other than potable water need prior approval in the EU; the EU does not currently authorize any chemical decontamination treatments (Hugas & Tsagarida, 2008). If approved, following petition, it is likely that, if they are to be used as processing aids, carcasses will be required to be rinsed with water after chemical treatment (EFSA, 2010b). Chemical decontamination treatments are legally applied in the United States. Decontamination interventions considered for use, first need to be validated for their efficacy and then should be regularly verified for continuous effectiveness during implementation (Bolder, 2007; FAO/WHO., 2009a, 2009b; FSIS/USDA., 2008, 2010; NACMCF, 1997).

## 2. Poultry slaughter and *Salmonella*-control interventions

### 2.1. Poultry processing chain

The poultry meat processing chain involves a multistep sequence of activities, including: bird catching and transportation to the abattoir; holding before slaughter; ante-mortem official inspection; slaughtering, which consists of hanging, stunning, neck cutting, and bleeding; dressing, which involves scalding, defeathering, head-pulling, hock-cutting, venting, evisceration, crop removal, neck-cracking and cutting of neck flap, washing; inside/outside carcass washing, decontamination, and on-line reprocessing (if allowed); post-mortem official inspection; and chilling of carcasses before cutting, packaging or further processing (Bolder, 2007; EFSA, 2011a,b; FAO/WHO, 2005, 2009a,b; FSIS/USDA., 2008, 2010).

Although it is known that external contamination of birds with *Salmonella* may increase during transportation as well as during holding at the abattoir, before slaughter, the numerous steps, variables and confounding factors involved in this chain make quantification of cross-contamination difficult (EFSA, 2011a,b). Thus, it is important to minimize transportation and holding time before slaughter for microbiological, product quality, economical, and animal welfare reasons (Allen et al., 2008; Allen et al., 2008; Tinker, Burton, & Allen, 2005). Handling of birds should be such as to minimize stressing during transportation because exposure to stress may increase contamination shedding and cross-contamination. In general, stressing of birds should be minimized through means such as proper housing, dim lighting, minimal handling, and timely processing (Bilgili, 2002; Bolder, 2007; EFSA, 2011a,b; FSIS/USDA., 2008, 2010; Keener, Bashor, Curtis, Sheldon, & Kathariou, 2004; NCC, 1992).

### 2.2. Pre-harvest considerations for contamination control

Contamination control interventions applied at the farm level can be useful provided that their use is widespread and in place for an adequate length of time (EFSA, 2011a,b). Poultry producers should obtain their birds from approved hatcheries, especially from those that apply pre-harvest foodborne pathogen control strategies such as good management practices and biosecurity measures (sanitation, pest control, hygiene barriers, fly screens, litter control); potable water; feed from approved sources; approved and effective probiotics or competitive exclusion products; vaccination; feed and water additives; bacteriocins; and bacteriophages (EFSA, 2011a,b; FSIS/USDA., 2008, 2010).

Feed withdrawal before shipment of birds to the abattoir may contribute to lower levels of contamination at slaughter as it may reduce amounts of contaminated contents in the gastrointestinal tract, limit defecation during transport, and facilitate sanitary evisceration of birds with empty intestines (NCC, 1992; NTF, 2004). Slaughtering flocks within 8 to 12 h after feed withdrawal should reduce the likelihood of carcass contamination with fecal material (EFSA, 2011a,b; FAO/WHO., 2009a, 2009b). Further, EU Council Directive 2007/43/EC limits feed withdrawal time to a maximum of 12 h for animal welfare reasons. Feed withdrawal for more than 12 h may cause thinning of the intestinal wall and increase the fluidity of the ingesta, thus, increasing the potential for contamination during bird evisceration (Warriss, Wilkins, Brown, Phillips, & Allen, 2004).

Feed withdrawal practices vary due to differences in production practices and volumes, slaughter procedures, and inspection programs. Drinking water additives such as lactic acid or ingredients (e.g., sugars) enhancing acid production in the crop during feed withdrawal may reduce *Salmonella* levels in the crop as well as post-harvest contamination, thus, potentially optimizing the benefits of feed withdrawal and avoiding potential negative effects (Byrd et al., 2003, 2001). Overall, however, available data are inadequate and the complexity of variables and confounding factors involved make it difficult to assess the effect of feed withdrawal or GHP during bird transportation and holding before slaughter on the eventual microbiological contamination of poultry meat (EFSA, 2011a,b).

Contamination should be controlled through the use of clean and disinfected bird transport containers from the farm to the abattoir (Corry, Allen, Hudson, Breslin, & Davies, 2002; Heyndrickx et al., 2002; Slader et al., 2002; Tinker et al., 2005). Transportation procedures for birds from the farm to the abattoir depend on factors such as company strategy and distance between the farm and the abattoir. Birds are mostly transported in crates, containers or cages, which are placed in metal frames (EFSA, 2011a). Crates are quickly contaminated with pathogens of fecal origin such as *Salmonella*, leading to cross-contamination of the exterior of other birds, as well as of the abattoir environment and processed carcasses (Rasschaert, Houf, & De Zutter, 2007; Slader et al., 2002). Excessive contamination of birds with *Salmonella* before slaughter may overwhelm the capacity of antimicrobial interventions during slaughter.

Water washing and disinfection of transport crates reduces, but does not eliminate, pathogen biofilms present in niches and harbourage sites found in damaged surfaces. Other reasons for presence of pathogens, such as *Salmonella*, on crates after cleaning include human error, incorrect application of chemicals, or recontamination and cross-contamination. Crate washing and disinfection effectiveness may be improved through improved crate design that facilitates cleaning, construction with non-corrosive materials, cleaning and sanitation of crates in facilities separated from bird processing, better crate washing systems (e.g., soaking tank with brushes), frequent crate washing water replacement, use of biodegradable crates or crate liners to avoid cross-contamination, or application of ultrasonic treatments during washing (Allen, Burton, et al., 2008; Allen, Whyte, et al., 2008; EFSA, 2011a,b). Research indicates that washing bird transport cages with water and