APPENDIX

The draft report of the Joint FAO/WHO Expert meeting on the benefits and risks of the use of chlorine-containing disinfectants in food production and food processing. (Ann Arbor, USA, 27–30 May 2008) was made available to the Technical Meeting to facilitate its discussion, in addition to other relevant references and comments from the experts attending the meeting. The text below reflects the outcome of the discussions during the current Technical Meeting, taking into account information from the expert meeting on the use of chlorine-containing disinfectants.

1. On use of chlorine, from FAO/WHO Consultation

Washing with hypochlorite

Industrial studies by Stopforth et al. (2007) and Villarreal, Baker and Regenstein (1990) demonstrated an effect of washing carcasses in hypochlorite solution on the prevalence of *Salmonella*. However, other studies (Northcutt et al., 2005; Yang, Li and Johnson, 2001) showed that washing in water alone resulted in most of the reductions in *Salmonella* on poultry. Therefore, it is not possible to make a definitive statement on the effectiveness of hypochlorite against *Salmonella* during carcass washing on an industrial scale based on these studies. It is likely that washing in water alone is a moderately effective intervention and that hypochlorite does not provide a significant additional effect.

Laboratory based experiments have shown reductions in *Campylobacter* on carcasses of less than 2 Log units but only over extended washing times (up to 30 min). Other experiments using more practical conditions show reductions of less than 1 Log unit on *Campylobacter* in comparison with no washing. However, when compared to washing in water alone there was no additional effect on *Campylobacter* for carcasses washed in water with hypochlorite (Northcutt et al., 2005). Therefore, as with *Salmonella*, it is likely that washing in water alone is a moderately effective intervention and that hypochlorite does not provide a significant additional effect.

Summary Statement

The removal of pathogenic bacteria from poultry carcasses during physical washing procedures on an industrial scale is predominantly a feature of the physical action of the water rather than the use of hypochlorite in the water.

References cited

Stopforth. J.D., O'Connor, R., Lopes, M., Kottapalli, B., Hill, W.E. & Sampadpour, M. 2007. Validation of individual and multiple-sequential interventions for reduction of microbial populations during processing of poultry carcasses and parts. *Journal of Food Protection,* 70(6): 1393–1401.

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Northcutt, J.K., Smith, D.P., Musgrove, K.D., Ingram, K.D. & Hinton, A. Jr. 2005. Microbiological impact of spray washing broiler carcasses using different chlorine concentrations and water temperatures. *Poultry Science,* 84: 1648–1652.

Yang, H., Li, Y. & Johnson. M.G. 2001. Survival and death of *Salmonella* Typhimurium and *Campylobacter jejuni* in processing water and on chicken skin during poultry scalding and chilling. *Journal of Food Protection,* 64(6): 770–776.

2. Hypochlorite in carcass chillers

Hypochlorite is routinely used in poultry process lines in countries where chilling by water immersion is allowed. It is added to the chill water to prevent the build up of bacteria in the water during processing.

Studies evaluating the numbers of *Salmonella* on carcasses before and after chilling are few. However, Russell and Axitall (2005) noted a reduction in *Salmonella* numbers per carcass caused by the physical movement of carcasses in the chiller tank rather than the presence of hypochlorite in the chiller water. Overall the studies show that if chlorine is not present in chiller water then the prevalence of *Salmonella* increases on carcasses because of cross-contamination. Lillard (1980) also showed that the prevalence of *Salmonella* in chiller water treated with chlorine at 20 ppm and 34 ppm was reduced from 41.7% (untreated water) to 17.3% and 'not detected', respectively. Yang, Li and Johnson (2001) and Stopforth et al. (2007) demonstrated the effectiveness of chlorine in killing *Salmonella* in chill water, but not on carcasses.

The effects of chlorinated chill water on *Campylobacter* seemed to be greater than the effect on *Salmonella*, but reports are inconsistent. Small reductions in both numbers and prevalence of *Campylobacter* on carcasses were observed when chill water was chlorinated. In a 2004 study by Bashor et al. a reduction in *Campylobacter* of 0.13 $\log_{10}$ cfu/carcass was achieved after chilling in water with 25 ppm chlorine, and the prevalence of *Campylobacter* positive carcasses was reduced from 80% post-wash to 73.3% post-chill. In a second plant, using a chill tank with a higher level of chlorinated water, at 35 ppm, a reduction in *Campylobacter* of 0.25 $\log_{10}$ cfu/carcass was observed after chilling. The prevalence of *Campylobacter*-positive carcasses was reduced from 80% post-wash to 70% post-chill.

In another study on naturally contaminated poultry in a commercial plant, a chiller with chlorinated water resulted in a *Campylobacter* reduction of 1.09 $\log_{10}$ cfu/carcass (statistically significant) and 1.3 $\log_{10}$ cfu/carcass (statistically significant) in two experiments. Prevalence of *Campylobacter*-contaminated carcasses was not affected in the first experiment, but reduced from 95% to 77.5% in the second experiment (Oyarzabal et al., 2004). However no un-chlorinated water chill controls were evaluated.

The effect of chlorine in chill water on the death kinetics of inoculated *Campylobacter jejuni* was studied on chicken skin (Yang, Li and Johnson, 2001). Chilling in chlorinated water with 50 ppm added chlorine (20–30 ppm residual chlorine) resulted in inactivation rate of *Campylobacter* on skin of D-value 73 minutes. However, using older chill water initially with 50 ppm chlorine, where organic material had built up, the residual concentration of free chlorine was approximately zero. Chilling in this water resulted in a D-value for *Campylobacter* on chicken skin of 344.8 minutes. A similar result was seen with *Salmonella,* confirming the need to maintain residual chlorine levels in chill water during processing. However, Yang, Li and Johnson (2001) showed that chlorine was effective at killing *Campylobacter* in chill water, but did not examine the effect this might have had on prevalence.

Summary Statement

The use of chlorine in the chill tank may not act as a decontaminating agent by acting directly on the contaminated carcass; however, there would be a washing-off effect by the water itself, and the addition of chlorine at a level sufficient to maintain a free residual in the water would then inactivate pathogens washed off, preventing re-attachment and cross-contamination.

References cited

Bashor, M.P., Curtis, P.A., Keener, K.M., Sheldon, B.W., Kathariou, S. & Osborne, J.A. 2004. Effects of carcass washers on *Campylobacter* contamination in large broiler processing plants. *Poultry Science,* 83: 1232–1239.

Lillard, H.S. 1980. Effect on broiler carcasses and water of treating chiller water with chlorine and chlorine dioxide. *Poultry Science,* 59: 1761–1766.

Oyarzabal, O.A., Hawk, C., Bilgili, S.F., Warf, C.C. & Kemp, G.K. 2004. Effects of postchill application of acidified sodium chlorite to control *Campylobacter* spp. and *Escherichia coli* on commercial broiler carcasses. *Journal of Food Protection*, 67(10): 2288–2291.

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3. Summary of expert subgroup discussion on use of chlorine

The following scientific discussion was in relation to Section 9.7.1.2 of the proposed draft Guidelines for Control of *Campylobacter* and *Salmonella* spp. in Chicken Meat, where it states: "Immersion chilling of carcasses should incorporate: Total available chlorine maintained at 50–70 ppm, available free chlorine maintained at 0.4–5.0 ppm, and pH maintained at 6.0–6.5."

Immersion chilling of carcasses is believed to result in limiting cross-contamination and/or reduction of pathogens if managed properly. However, a scientific discussion developed around the following: Is there scientific evidence supporting *whether* the observed reduction was due to water alone (dilution, removal of loosely attached organisms) or due to the addition of chlorine (bactericidal, decreased re-attachment/cross-contamination of bacteria) in the chiller?

The draft report of the Joint FAO/WHO Expert meeting on the benefits and risks of the use of chlorine-containing disinfectants in food production and food processing [in preparation] supports that chlorine has a measurable benefit when used in the immersion chilling process. The extent of any effect of chlorine may depend on the precise condition of chilling[16].

The scientific basis for reduction due to chlorine is as follows: Chlorine is bactericidal and functions as a strong oxidizing agent. When in contact with bacteria, cell damage occurs at many sites. Chlorine is most effective when there is a measurable quantity of free available chlorine (FAC) to convert to its most active form. However, chlorine readily reacts with organic matter, which may partly result in a high concentration of combined available chlorine, especially during operations such as the immersion chilling process. During processing of broilers, significant amounts of organic matter are introduced and chlorine will need to be continually added to the chillers otherwise no FAC will be available. Furthermore, the reaction resulting in production of FAC is favoured by a pH below 7.0. As the pH of the solution is reduced below 7, the reaction is driven further in the direction of production of FAC as long as the chlorine in solution is not already organically bound. The reaction toward FAC can also be driven through higher concentrations of chlorine. If the immersion chiller is maintained to have free and combined available chlorine and the pH is adequately controlled, it is the scientific view of this expert panel that chlorine use will be optimized as a bacteriocide that will inactivate both *Salmonella* and *Campylobacter*. The number of cells inactivated and the rate of inactivation depends on several factors, including the FAC content, contact time, temperature, and probably other factors not completely defined.

The supporting literature is the draft report of the Joint FAO/WHO Expert meeting on the benefits and risks of the use of chlorine-containing disinfectants in food production and food processing [in preparation][16].

Alternatively, removal of bacteria, including pathogens, in the immersion chiller may be due to physical removal of bacteria by water, a dilution effect, and/or flow rate that decreases the opportunity for attachment/re-attachment (cross-contamination). Therefore, antimicrobials, such as chlorine, may not be needed in the immersion chiller to achieve a low level of pathogens in the birds exiting the chiller. It is the scientific evaluation of this expert panel that water alone in the immersion chiller can reduce pathogen(s) levels on the carcass, but without the aid of an intervention designed to inactivate planktonic bacteria, including *Campylobacter* and *Salmonella,* cross contamination will be a concern. In this case, the removal of pathogens from

16. The report of the Expert meeting on the benefits and risks of the use of chlorine-containing disinfectants in food production and food processing is being finalized and minor wording changes may occur during technical editing.

chicken carcasses and the minimization of cross-contamination will depend on a sufficiently high water flow rate.

The supporting literature is listed below. In a pilot plant, Buhr et al. (2005) state that the water alone in the immersion chiller results in a *Campylobacter* reduction of 1.9 $\log_{10}$ and addition of chlorine had no additional effect.

Annotated bibliography

Buhr, R.J., Bourassa, D.V., Northcutt, J.K., Hinton, A. Jr., Ingram, K.D. & Carson, J.A. 2005. Processing, products and food safety. Bacteria recovery from genetically feathered and featherless broiler carcasses after immersion chilling. *Poultry Science*, 84: 1499–1504.

Lillard, H.S. 1989. Incidence and recovery of salmonellae and other bacteria from commercially processed poultry carcasses at selected pre-evisceration and post-evisceration steps. *Journal of Food protection*, 52: 88–91.
NOTE: This paper discusses the use of decontamination agents against salmonella.

Lillard, H.S. 1990. The impact of commercial processing procedures on the bacterial contamination and cross-contamination of broiler carcasses. *Journal of Food Protection*, 53(3): 202–204.
NOTE: This paper discusses the use of continuous washes (up to 40) on attached bacteria on carcass surfaces.

McMeekin T.A., Thomas, C.J. and Pennington P.I. 1984. Contamination and decontamination of poultry carcass neck tissue. *Journal of Food Safety*, 6(2): 79–88.
NOTE: This paper discusses attachment of pathogens on chicken skin and the challenges of removal by washing only.

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16 Risk assessment of *Vibrio parahaemolyticus* in seafood: Interpretative Summary and Technical Report, 2010

17 Risk characterization of microbiological hazards in food: Guidelines, 2009.

18 Enterohaemorragic Escherichia coli in meat and meat products: Meeting report. 2010

19 *Salmonella* and *Campylobacter* in chicken meat: Meeting Report. 2009

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