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Salmonella and *Campylobacter* in chicken meat

MEETING REPORT

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Declarations of interest

All participants completed a Declaration of Interest form in advance of the meeting. Eight of the experts who participated in the meeting declared an interest in the topics under consideration.

- Vivien Allen's research unit has received support for research on delivery methods for Salmonella vaccines.
- Ayachi Ammar's research unit is providing consultancy services and has received research support from the National Agency for the Development of Research in Health.
- Elyakum Berman's work is partly funded by the Israel egg and poultry board.
- Dane Bernard is an employee of a food company that includes broiler production operations.
- Charles L. Hofacre provides consulting services to a poultry breeding company.
- Geoffrey Charles Mead provides independent consultancy services as the Chairman of the technical advisory board for a farm assurance company.
- Stephen Jon Moore is an employee of a poultry processing company.
- Vladimir Pinheiro do Nascimento provides consulting services to a poultry producing company.

Upon detailed review of these declarations, it was considered that the interests declared by these experts should not prevent them from participating fully in the deliberations of the meeting. Their activities were not considered to represent a potential conflict of interest in the meeting. Nevertheless, for the purpose of transparency, the declarations were made known to all the participants at the beginning of the meeting. All the experts participated in their individual capacity and not as representatives of their country, government or organizations.

Abbreviations

ASC	Acidified Sodium Chlorite
CAC	Codex Alimentarius Commission
CCFH	Codex Committee on Food Hygiene
CE	Competitive Exclusion
cfu	colony-forming units
EU	European Union
FAC	Free Available Chlorine
FAO	Food and Agriculture Organization of the United Nations
FSA	Food Standards Agency [United Kingdom]
GHP	Good Hygiene Practice
HACCP	Hazard Analysis and Critical Control Points
IOBW	Inside/Outside Body Wash
JEMRA	Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment
MRA	Microbiological Risk Assessment
OIE	World Organisation for Animal Health
OLR	On-line reprocessing
PIF	Powdered Infant Formula
ppm	parts per million
TSP	Trisodium Phosphate
WHO	World Health Organization

Foreword

The Members of the Food and Agriculture Organization of the United Nations (FAO) and of the World Health Organization (WHO) have expressed concern regarding the level of safety of food at both the national and international levels due to increasing foodborne disease incidence caused by microorganisms in food. This concern has been voiced in meetings of the Governing Bodies of both Organizations and in the Codex Alimentarius Commission. It is not easy to decide whether the suggested increase is real or an artefact of changes in other areas, such as improved disease surveillance or better detection methods for microorganisms in foods. However, the important issue is whether new tools or revised and improved actions can contribute to our ability to lower the disease burden and provide safer food. Fortunately, new tools, which can facilitate actions, seem to be on their way.

Over the past decade, Risk Analysis—a process consisting of risk assessment, risk management and risk communication—has emerged as a structured model for improving our food control systems, with the objectives of producing safer food, reducing the numbers of foodborne illnesses and facilitating domestic and international trade in food. Furthermore we are moving towards a more holistic approach to food safety where the entire food chain needs to be considered in efforts to produce safer food.

As with any model, tools are needed for the implementation of the risk analysis paradigm. Risk assessment is the science-based component of risk analysis. Science today provides us with in-depth information on life in the world we live in. It has allowed us to accumulate a wealth of knowledge on microscopic organisms, their growth, survival and death, even their genetic make-up. It has given us an understanding of food production, processing and preservation, and the link between the microscopic and the macroscopic worlds and how we can benefit from as well as suffer from these microorganisms. Risk assessment provides us with a framework for organizing all this data and information and to better understand the interaction between microorganisms, food and human illness. It provides us with the ability to estimate the risk to human health from specific microorganisms in foods and gives us a tool with which we can compare and evaluate different scenarios as well as identify what types of data are necessary for estimating and optimizing mitigating interventions.

Microbiological risk assessment (MRA) can be considered as a tool that can be used in the management of the risks posed by foodborne pathogens and in the elaboration of standards for food in international trade. However, undertaking an MRA, particularly quantitative MRA, is recognized as a resource-intensive task requiring a multidisciplinary approach. Yet foodborne illness is among the most widespread public health problems, creating social and economic burdens as well as leading to human suffering, making it a concern that all countries need to address. As risk assessment can also be used to justify the introduction of more stringent standards for imported foods, a knowledge of MRA is important for trade purposes, and there is a need to provide countries with the tools for understanding and, if possible, undertaking MRA. This need, combined with that of the Codex Alimentarius for risk-based scientific advice, led FAO and WHO to undertake a programme of activities on MRA at the international level.

The Nutrition and Consumer Protection Division, FAO, and the Department of Food Safety and Zoonoses, WHO, are the lead units responsible for this initiative. The two groups have worked together to develop the area of MRA at the international level for application at both the national and international levels. This work has been greatly facilitated by the contribution of

people from around the world with expertise in microbiology, mathematical modelling, epidemiology and food technology, to name but a few.

This Microbiological Risk Assessment series provides a range of data and information to those who need to understand MRA. It comprises risk assessment of particular pathogen-commodity combinations, interpretive summaries of the risk assessments, guidelines for undertaking and using risk assessment, and reports addressing other pertinent aspects of MRA.

We hope that this series will provide a greater insight into MRA, how it is undertaken and how it can be used. We strongly believe that this is an area that should be developed in the international sphere, and have already from the present work clear indications that an international approach and early agreement in this area will strengthen the future potential of use of this tool in all parts of the world, as well as in international standard setting. We would welcome comments and feedback on any document within this series so that we can endeavour to provide Member States, Codex Alimentarius and other users of this material with the information they need to use risk-based tools, with the ultimate objective of ensuring that safe food is available for all consumers.

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Executive summary

Salmonellosis and campylobacteriosis are among the most frequently reported foodborne diseases worldwide. While numerous potential vehicles of transmission exist, commercial chicken meat has been identified as one of the most important food vehicles for these organisms. Although specific data on the burden of foodborne disease associated with *Salmonella* and *Campylobacter* in poultry is limited, the role of poultry is considered to be significant in this respect; however, the risk in different countries varies according to control measures and practices implemented along the chain from primary production to final preparation of the meat for consumption.

In 2007, the Codex Alimentarius Commission agreed that the development of guidelines for the control of *Salmonella* and *Campylobacter* in poultry was a priority. The elaboration of these guidelines was initiated at the 39th Session of the Codex Committee on Food Hygiene (CCFH), in late 2007. The guidelines consist of three sections: one addressing good hygiene practices (GHP); another covering hazard-based control measures; and a third focusing on risk-based control measures. In the course of the following year, much work was undertaken on the first section, and this is nearing completion. Work also began on the hazard-based control measures; however, the limited availability of data on the quantification of effect and practical implementation of such measures had implications for this section of the guidelines. The third section was intended for use in conjunction with a user-friendly Web-based risk-management decision-support tool, to be developed by the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA), which would allow the risk manager to input data specific to their own production and processing systems and thereby evaluate measures that might be most effective for risk reduction in those particular conditions.

In order to continue with their work and ensure that it was underpinned with the most robust scientific data, the 40th Session of CCFH requested FAO and WHO to provide them with the necessary scientific advice. In response to that request, FAO and WHO convened an *ad hoc* Technical Meeting from 4 to 8 May 2009 in Rome, Italy. This report documents the discussions and the outcome of that meeting.

At the Technical Meeting, the experts carried out an independent assessment and review of all available scientific information on control of *Campylobacter* and *Salmonella* at relevant stages of the broiler supply chain. This entailed an evaluation of the scientific basis of the possible control measures described in the draft guidelines as prepared by the CCFH Working Group to date, and thereafter adding further interventions that had not been included. For every step of the production chain, an attempt was made to evaluate the interventions in quantitative terms i.e. according to their likely effects in reducing the prevalence and/or concentration of the hazard in each case. Particular attention was given to the likely outcome of hazard reduction in a commercial setting. For this purpose, the Experts decided to draw upon all available and documented expert data and evidence in support of the interventions described. Thus, the latest scientific evidence was used to supplement and expand the semi-systematic literature review that had formed the basis of the draft guidelines developed by the CCFH Working Group.

The Experts found that there were no quantitative data available on the effects of specific interventions applied during live animal production on the prevalence and/or level of contamination with *Salmonella* and *Campylobacter.* Furthermore, the effects of any

interventions aimed at primary production had not been validated fully in a commercial setting[1]. Therefore, interventions for application in the pre-harvest phase of poultry production were all classed as GHPs.

The GHP measures described in the Codex draft guidelines regarding scalding, de-feathering and evisceration were supported by the Technical Meeting. No further scientific data was presented by the Experts to warrant description of potential hazard-based control measures.

The GHP measures described in the Codex draft guidelines regarding washing and chilling, and also retail and consumer handling were also supported by the Technical Meeting. Quantitative data on potential hazard-based controls on account of their likely impact on prevalence and/or concentration of hazards on the carcass were reviewed and considered appropriate by the Technical Meeting, with additional data being provided in some cases.

In relation to the risk-management questions posed by CCFH, the feasibility of developing a Web-based risk-management decision-support tool was discussed and considered to be an appropriate next step by the Technical Meeting. The primary application of the tool would be to demonstrate in a simplified manner the relative effects of different control measures, either alone or in combination, on hazard reduction and consequently relative levels of foodborne illness. This would enable countries to evaluate combinations of control measures available within their processing systems using a risk-based approach. The decision tool should also be of considerable benefit to industry in designing HACCP plans and choosing critical limits for hazard-based control measures. In order to proceed with the development of the web-based risk-management tool a subgroup was formed to identify modelling challenges and discuss the benefits and limitations of different modelling approaches. Development of the prototype is now in progress, and initial outcomes will be presented at the forthcoming CCFH session.

1. The apparent absence of peer-reviewed scientific publications on the efficacy of specific interventions in commercial poultry flocks in terms of food safety of broiler meat needs to be seen in context. Such interventions have been widely used in many countries as part of national control programmes for *Salmonella* and, over a period of time, have been associated with significant reductions in prevalence of pathogens at the pre-harvest stage of broiler production. The countries include Finland, Sweden, Denmark and The Netherlands, and the effectiveness of their respective control strategies is described in peer-reviewed scientific publications and in national reports that include surveillance data for *Salmonella* in poultry. See, for example, Wegener et al., 2003; Maijala et al., 2005; Van der Fels-Klerx et al., 2009.

MEETING REPORT

1. Introduction

1.1 Background

Salmonellosis and campylobacteriosis are among the most frequently reported foodborne diseases worldwide. While numerous potential vehicles of transmission exist, commercial chicken meat has been identified as one of the most important food vehicles for these organisms. In the light of their importance, FAO and WHO have already undertaken risk assessments on *Salmonella* and *Campylobacter* in broiler chickens (FAO, 2003; FAO/WHO, 2002; FAO/WHO, 2009). At the time of their completion, these risk assessments provided both an overview of the available knowledge on these organisms and a risk assessment framework to facilitate the evaluation of various interventions to address the risks associated with these pathogens in broiler chicken meat at the point of consumption.

Although specific data on the burden of foodborne disease associated with *Salmonella* and *Campylobacter* in poultry is limited, it is considered to be significant; however, the risk varies according to control measures and practices implemented along the chain from primary production to final preparation for consumption. Furthermore, the presence of these organisms in poultry is also affecting trade, and recently the detection of *Salmonella* in poultry products led to rejection of large consignments of raw poultry meat. While the scientific basis for such actions is not always clear, the economic impacts can be extensive. Thus the impact on human health and the associated costs, the trade disruptions and the cost of implementing effective control measures has meant that the Codex Alimentarius Commission (CAC) in 2007 agreed that the development of guidelines for the control of *Salmonella* and *Campylobacter* in poultry was a priority. Later that year, at its 39th Session, the Codex Committee on Food Hygiene (CCFH) agreed on the approach to be taken in the development of the draft guidelines. Essentially the guidelines are to consist of three sections: one that addresses good hygiene practices (GHP); one that addresses hazard-based control measures; and a third that focuses on risk-based control measures. In the past year much work has been undertaken to address the first section, and this is nearing completion. Work has also begun on the hazard-based control measures; however, the availability of data on the practical implementation of such measures has implications for this section of the guidelines. The third section of the guidelines is envisaged to be used in conjunction with a user friendly Web-based risk-management decision-support tool, to be developed by the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA), which will allow the risk manager to input data specific to their production and processing system and thereby evaluate measures that might be most effective for risk reduction in those particular conditions.

In order to continue with their work and ensure that it is underpinned with the most robust scientific data, the 40th Session of CCFH requested FAO and WHO to provide them with the necessary scientific advice. In response to that request, FAO and WHO convened an ad hoc Technical Meeting from 4 to 8 May 2009, in Rome, Italy.

1.2 Scope

The scope of the work to be undertaken by FAO and WHO, through the Technical Meeting, was defined by the series of issues that CCFH asked both organizations to address, as listed below.

- To carry out an independent assessment and review of available scientific information on control of *Campylobacter* and *Salmonella* at relevant steps through the broiler chain.

- To evaluate quantitative aspects of hazard reductions in terms of prevalence and concentration following specific interventions.
- To evaluate likely outcomes in terms of hazard reductions in the commercial setting.
- To assess the feasibility of developing a Web-based risk-management decision-support tool.
- To develop a framework and identify data needs that might be required for the Web-based risk-management decision-support tool to be developed by JEMRA.

This Meeting report summarizes the results of the Joint FAO/WHO Technical Meeting on *Salmonella* and *Campylobacter* in Chicken Meat, held at FAO, Rome, from 4 to 8 May 2009, noting the data sources used and drawing out the main conclusions. In response to the questions posed by CCFH to FAO and WHO, a number of recommendations were made. Special attention was drawn to areas where further research and data collection were required for extending the Web-based risk assessment tool to be more comprehensive and reliable.

1.3 Data sources and objectives

The objective of the meeting was to make an independent assessment of the measures internationally available for the control of *Campylobacter* and *Salmonella* spp. in chicken meat, based on scientific information on the control of these microorganisms at different steps of the broiler production chain. The assessment included the review of quantitative aspects of hazard reduction in terms of prevalence and concentration in the commercial setting, and the assessment of the feasibility of developing a Web-based risk-management support tool that could assist managers in the evaluation of measures that might be most effective for risk reduction in their production and processing systems.

FAO/WHO initiated this assessment through the implementation of an extensive literature search and by issuing a call for relevant data using various routes, with 24 replies received from different countries in response. Data and information was submitted by national authorities and non-governmental organizations, including academic institutions and poultry production groups. Additionally, data used during this meeting were collected through the review made by the CCFH Working Group as part of the work carried out for the preparation of the Proposed Draft Guidelines for the Control of *Campylobacter* and *Salmonella* spp. in chicken meat. Furthermore, specific experts attending the meeting were asked to prepare a short background paper describing regional differences in chicken meat production, with special emphasis on detection and control of *Salmonella* and *Campylobacter*.

For the Technical meeting to address the request made by CCFH, the Good Hygiene Practices (GHP) and hazard reduction measures mentioned in the Draft Guidelines provided by the CCFH Working Group were used as a starting point, with the Experts assessing different interventions at specific steps in the processing chain. The measures mentioned in the guideline were assessed from the perspective of their scientific basis. Thereafter, appropriate additional intervention measures were assessed. Special emphasis was laid on the presence of quantitative data, which were considered when assessing the feasibility of the Web-based decision tool (See Chapter 6).

2. Differences in the nature of chicken meat production and the implications for *Salmonella* and *Campylobacter*

2.1 General characteristics of chicken meat production and processing systems

One of the objectives of the request made by the CCFH to FAO and WHO was to investigate the feasibility of developing a Web-based decision tool that could assist managers in the evaluation of measures that could be most effective for risk reduction in their production and processing systems.

In order to meet this request, the Experts had to consider regional differences that could have critical impacts on the implementation of such a tool. Therefore, the first day of the Technical Meeting was dedicated to the discussion of these differences.

In spite of the extensive regional differences in broiler production, a substantial part of the chicken meat production at "industrial level" has some common aspects. For instance, the breeding stocks used all over the world are produced by a small number of companies, meaning that these sell to purchasers worldwide. This can lead to the widescale spread of *Salmonella* if the breeding stocks are infected. It is therefore especially important to control *Salmonella* in the breeder flocks, and as a consequence *Salmonella* control in primary breeder flocks is of a high standard (Allen, pers. comm.). Where the aim is to control specific serotypes, a zero-tolerance policy with respect to these organisms may give a false sense of security, because the predominant serotypes in poultry flocks are likely to change over time.

The trend seems to be towards production becoming more integrated in the future, and many small farms will be replaced by fewer, bigger farms, which will allow a greater integration. As an example, integrated poultry production is very widespread in the United States of America and in Russia, where the producers also control feed, rearing and processing. This high degree of integration can therefore lead to better control of *Salmonella* and *Campylobacter*. These control options can also be applied to less integrated systems; it is just more difficult, even though the principles for control should be the same.

Despite differences between countries, the characteristics of "industrial" broiler chicken meat production are broadly generic. This facilitates development of a modular risk assessment that focuses on shared food chain characteristics, but also provides for national inputs where there may be significant variation, such as in primary processing, distribution pathways, and handling of products by the consumer. For *Salmonella*, the peer reviewed literature indicates that the four most important control measures at primary production are: (1) the elimination of *Salmonella* in grandparent and parent flocks; (2) all-in all-out production at the broiler farm, to avoid any carry over during processing; (3) logistic slaughter planning scheduled to avoid pathogens being transferred from contaminated processing equipment to another flock; and, finally, (4) satisfactory cleaning of transport crates. For *Campylobacter* biosecurity at farm level, it is reported that prevention of the entry of *Campylobacter* is the most important control measure, but it is also important to prevent transfer of the organism from previous flocks. At present, the epidemiology is not completely clear, and there are also country differences to consider.

During processing, additional interventions can be applied. Application of GHP during processing helps to ensure that the contamination of broiler carcasses remains as low as possible. Essential practices include the removal of faecal matter, feathers, etc., from carcasses and equipment. Most important are procedures that keep the faecal spread to an absolute minimum.

Operations known to increase the contamination are scalding, plucking and evisceration. The feather plucker is the most important critical control point in the process in relation to contamination, but also evisceration can pose a big risk as a consequence of gut rupture. The problem in this step is that the carcasses are not entirely uniform in size and some may be damaged by the evisceration machinery. To reduce carcass contamination, decontamination measures can be applied. These can be physical or chemical, and aim to reduce the concentration. Contamination of carcasses with *Campylobacter* can be reduced by dipping or spraying of carcasses using chlorinated water, acidified sodium chlorite (ASC) or acetic or lactic acids. Trisodium phosphate (TSP) has also been widely used, but due to processing and environmental problems its use is now minimal. Regarding these decontamination measures, there are some regional differences to be considered, since chemical treatment is not accepted in the EU at the moment, but is widely used in other parts of the world, e.g. in the United States of America and New Zealand. Physical treatments that reduce *Campylobacter* counts on carcasses include freezing; crust freezing; heat treatment; steam-ultrasound; steam or hot water spray; forced air chilling; and irradiation.

The experts emphasized the differences between countries, and considered the fact that specific measures taken in one country might not work in another. In a Web-based risk assessment tool, countries would have to add national data in order to assess the relative risk for their country.

2.2 Regional perspectives: identification and consideration of critical differences

The regional differences were too comprehensive to be considered in the present report. However, this section provides an introduction to some of the critical differences among countries, for the industrial settings.

2.2.1 Primary production

The most prominent differences presented at the Technical Meeting were found in the primary production sector. The particular region has a great influence on this matter as well as variation in the size of broiler production. Thus differences in number of birds produced range from 9.02 billion in the United States of America to 75 million in Sweden. The climate in a region can have great effect on the type of housing chosen. The housing can be open or closed. Also the number of birds in the houses varies, since the heat generated by the chickens can be crucial. Also, other husbandry differences exist, and especially floor type and management can vary. A further account of these differences will not be given here since it is not the aim of this report, but the effect on hazard reduction will be reviewed in Chapter 4.

The amount and type of ventilation of the houses differs among the different regions and the different production types. The type and degree of ventilation used is very much dependent on the climate and the housing type, since hotter climates and closed houses requires more ventilation. As will be explained in Chapter 4, the ventilation can be an important source of *Campylobacter* introduction, and studies have been made in several Nordic countries on provision of fly-screens in the ventilation to prevent introduction of *Campylobacter* with flies.

Thinning may result in infection of the remaining birds with *Campylobacter* due to the temporary breakdown in biosecurity.

2.2.2 Slaughterhouse

Most processing procedures are similar in the different regions, but there are differences in processing practices, since the product wanted by the consumers can vary a lot between the different regions. In many places, marketing can be said to drive the production system. This can reflect differences in legislation. The EU has a top-down approach, whereas in the United States of America current practice is that the primary control is applied in the processing plant. As mentioned in the previous section, the decontamination step will also show some differences among the countries as a result of the local legislation. Thus demands under European Union legislation differ from that required by, for instance, the United States of America legislation.

2.2.3 Data for risk assessment

Besides the differences mentioned above, there are other challenges to be considered regarding the Web-based tool. One of the big difficulties is to get data representative for a country, due to different production systems within the country. For example, in Brazil, the big export companies are in the south, whereas the smaller companies in the north produce for the home market. There are challenges when comparing data within a country, but it is far more difficult to compare data between countries. Another big challenge is that different methods for analysis in monitoring and research give different results. Furthermore, the legislation and financial support for additional and systematic sampling will vary greatly within the different country. Standardized analysis for *Campylobacter* will pose a special problem in many countries.

3. Review of available scientific information on control of *Salmonella* and *Campylobacter:* occurrence and challenges, and state of the science

3.1 Primary production

The apparent absence of peer-reviewed scientific publications on the efficacy of specific interventions in commercial poultry flocks in terms of food safety of broiler meat needs to be seen in context. Such interventions have been widely used in many countries as part of national control programmes for *Salmonella* and, over a period of time, have been associated with significant reductions in prevalence of pathogens at the pre-harvest stage of broiler production. The countries include Finland, Sweden, Denmark and The Netherlands, and the effectiveness of their respective control strategies is described in peer-reviewed scientific publications and in national reports that include surveillance data for *Salmonella* in poultry. See, for example, Wegener et al., 2003; Maijala et al., 2005; Van der Fels-Klerx et al., 2008.

3.1.1 *Salmonella*

In primary production, control of *Salmonella* within broiler flocks relies on knowledge of the source of infection (FAO/WHO, 2002). Possible sources include water, feed, litter, farm staff and the environment, both inside and outside the broiler house (Davies, 2005). Furthermore, hatcheries are possible sources of infection, as is vertical transmission (FAO/WHO, 2002). Data on the number of *Salmonella* organisms in feed, litter, etc., and the numbers of the organism to which the bird has been exposed, are still limited or unknown. Therefore many of the current risk assessment models today start at the point of estimating the prevalence of contaminated *Salmonella*-positive birds as the birds enter the slaughterhouses, and this means that on-farm control strategies are very poorly investigated at the present time (FAO/WHO, 2002). In relation to this meeting, a call for data was sent out, asking *inter alia* for data regarding prevalence and effect of on-farm control measures. This call for data did not reveal any new information on the effect of on-farm interventions as no quantitative information was presented for this step of the chicken production chain. Enumeration of *Salmonella* is laborious and time consuming, and is rarely carried out in practice.

3.1.2 *Campylobacter*

The principal reservoir of pathogenic *Campylobacter* spp. is the alimentary tract of wild and domesticated mammals and birds. Several countries have monitoring programmes to determine the prevalence of *Campylobacter* in food producing animals and birds. A seasonality of broiler flock colonization has been shown in some countries, leading to a peak in the flock prevalence during the warm summer months (Newell and Davidson, 2003; Kapperud et al., 1993; Jacobs-Reitsma, Bolder and Mulder, 1994; Rosenquist et al., 2009). However, studies in other parts of the world (for instance the United Kingdom and North America) have not shown any evidence of seasonality (Nadeau, Messier and Quessy, 2002). It is believed that the observed influence of season may be associated with the increased ventilation of houses and the increased numbers of insects during the warm summer and autumn months. If large volumes of air are introduced, it is conceivable that flies with *Campylobacter* from the outside are introduced into the flock. In Denmark and Iceland, studies have investigated the effect of using fly-screens to prevent the

introduction of *Campylobacter* in the flock. This has shown promising results in lowering the prevalence of *Campylobacter* (Hald, Sommer and Skovgard, 2007). However, more intervention studies must be conducted in order to measure the effect on prevalence and level of contamination, using also control farms. The efficacy of fly-screens also needs to be tested in countries with climatic conditions different from those in the Nordic countries.

Campylobacter shed in faeces from the gastrointestinal tract are able to survive for considerable periods in the environment, but are not known to grow under those conditions. Survival is enhanced by cool, but not freezing, moist and dark environments. As many mammals and birds (wild and domestic) are known hosts for *Campylobacter*, which can be asymptomatically excreted in significant numbers, then the environment (soil, water, pasture, etc.) must be frequently contaminated with this organism. A conventional poultry house that is modern and well maintained and with limited access should be considered a biosecure premise. Passive transgressions of the biosecurity perimeter in such a house may be by essential commodities like water, feed and air. Active transgressions require the carriage of *Campylobacter* from the external environment, which may occur by vectors such as vermin or flying and crawling insects, but the most visible vehicles are humans (Ridley et al., 2008).

It is widely assumed that thinning or partial depopulation is a significant risk factor for flock colonization. The risks include the passive transfer of organisms from previously-visited farms or the processing plant on clothes, boots, crates and vehicles on to the farm, and subsequently into the broiler house during catching. Thinning may result in infection of the remaining birds with *Campylobacter* within 2 to 6 days due to the temporary breakdown in biosecurity (Allen et al., 2007).

3.2 Processing

3.2.1 *Salmonella*

Differences in prevalence resulting from different practices are considered in several studies. In particular, these studies have focused on differences in water-immersion scalding and chilling (with and without chemical additives). Those concerned with the effect of chemical additives generally report a reduction in the prevalence (FAO/WHO, 2002). Data on prevalence and numbers of organisms are available for individual production steps, but most often using these data to estimate level of reduction requires additional assumptions since there are differences in the way the data are obtained. Conducting a baseline study would provide a more certain estimation (FAO/WHO, 2002). The call for data in support of this meeting provided additional data on this production step, but, as is the case for previous studies, the data from different studies are difficult to compare, due to differences in sampling and methods of analysis. Therefore estimates based on these data sources will also contain a certain level of uncertainty. Whereas data on the prevalence of *Salmonella* on poultry meat at the end of processing or at retail were available, very few surveys have been undertaken where the number of organisms has been quantified (Anon., 2005). Data provided by Libya in response to the data call describe the effect of radiation and storage temperature upon growth of *Salmonella* in fresh chicken carcasses, but, as is the case with the previously mentioned investigations, more work needs to be done in order to standardize these studies in a way that renders them comparable among countries. As a consequence, it is very difficult to combine the existing data in a risk assessment model to be used when developing the Web-based decision tool.

3.2.2 *Campylobacter*

Since *Campylobacter* is a common inhabitant of the intestinal tract of warm-blooded animals, the organism can be expected to contaminate meat during slaughter and evisceration as a result

of faecal contamination (FAO, 2003). Therefore, the main goal in controlling *Campylobacter* contamination of chicken carcasses during processing is to minimize the spread of faecal material. The process operations that have been considered in risk assessments are: scalding, de-feathering, evisceration, washing and chilling (FAO, 2003; Nauta et al., 2009). A study performed in Denmark on the numbers of *Campylobacter* during specific slaughter operations has revealed that the evisceration operation may lead to increased *Campylobacter* concentrations on the carcasses, whereas air- and water-chilling can lead to reductions of 0.8–1.0 $\log_{10}$ cfu/g. Furthermore, it has been shown that freezing causes an additional reduction of 1.4 $\log_{10}$ cfu/g before further frozen storage (Rosenquist et al., 2006). Because scalding washes much of the dirt and faeces off the carcass exterior, more microorganisms can be removed during scalding than during any other process step (USDA-FSIS, 2008; Cason and Hinton, 2006; Hinton et al 2004a, 2004b). The scald process cannot eliminate excessively high numbers of microorganisms entering the process, and the effect of scalding is very dependent on the method used, since immersion scalding has been shown to increase the level of contamination in cases where the operating conditions are poor. This was probably caused by an accumulation of dirt and faeces in the scald water due to an inadequate flow of fresh water into the tank, making the scald tank a source of cross-contamination for subsequent carcasses (USDA-FSIS, 2008; Cason and Hinton, 2006; Hinton et al 2004a, 2004b). The scalding process is a major site of cross-contamination for *Salmonella,* but is less important in this respect for *Campylobacter* because prevalence and numbers of the organism tend to be much higher in positive flocks.

3.3 Distribution, handling and preparation

3.3.1 *Salmonella*

Most often, interventions at these stages are assessed using growth models that take account of levels of contamination when carcasses leave the processing plant, thereafter using inputs for storage time in retail stores, transport time, storage times in homes, and the temperatures carcasses were exposed to during each of these periods. The presence and level of *Salmonella* in this step is very much country specific, since the level of infection when leaving the processing step will vary between the countries in relation to the methods used at the processing plant. Therefore national data must be used when estimating levels of contamination (FAO/WHO, 2002).

The call for data sent out in conjunction with the Technical Meeting revealed that many of the contributors do investigate the prevalence of *Salmonella* in the chicken meat, but often this is not done for the level of contamination. Furthermore, the analyses are not done in a standardized manner and the results will be very hard to use for comparison between countries, and even within regions of the same country.

3.3.2 *Campylobacter*

Reports from the European Union (EU), as well as other countries, reveal that fresh poultry meat is the food vehicle most frequently contaminated with *Campylobacter*. In some EU member states in 2007 the prevalence in retail products was as high as 83%. In Iran, a prevalence of 63% has been reported, and in Japan 45.8% of retail poultry was contaminated with *Campylobacter* (FAO, 2003). A study performed in Denmark uses simulations designed to predict the effect of different mitigation strategies, which showed that the incidence of campylobacteriosis associated with consumption of chicken meals could be reduced 30 times by achieving a 2 Log reduction in the number of *Campylobacter* on the chicken carcasses. To obtain a similar reduction of the incidence, the flock prevalence should be reduced approximately 30 times, or the kitchen hygiene improved approximately 30-fold (Rosenquist et al., 2003). A study from Germany investigated the transfer of *Campylobacter,* using simulations

of some typical situations in kitchens and quantification of the *Campylobacter* transfer from naturally contaminated chicken parts most commonly used in Germany. One scenario simulated the seasoning of five chicken legs and the re-use of the same plate for cooked meat. In another, five chicken breast fillets were cut into small slices on a wooden board where, without intermediate cleaning, a cucumber was sliced. Average transfer rates from hands or kitchen utensils to ready-to-eat foods ranged from 2.9 to 27.5% (Luber et al., 2006). It is generally believed that cross-contamination, not undercooking, is the dominant route of exposure to humans (Nauta et al., 2009). However, in some special, minimally processed meat products, this may be otherwise. Exposure is a consequence of insufficient food hygiene by the person preparing the food. The vast majority of consumers in a study in the Netherlands have been shown to be unable to prevent cross-contamination; the effect of consumer information on the prevention of cross-contamination as a control measure is very small (Nauta et al., 2008).

4. Examples of possible interventions for hazard reduction

One of the objectives of the meeting was to prepare an independent assessment and review of available scientific information on control measures. This was performed by the Experts through a review of the scientific basis of the interventions mentioned in the Codex draft Guidelines (CCFH Draft Guidelines for control of *Campylobacter* and *Salmonella* spp. in chicken meat).[2] For each step in the production chain, possible additional interventions were included.

In support of the meeting's deliberations, reference was made to either information available on the OIE Web site or to material provided in draft form for the use of the Technical Meeting. In particular the draft *Guidelines on the Detection Control and Prevention of* Salmonella *spp. in Poultry* were brought to the attention of the meeting[3]. These have already been considered by the CCFH working group in their deliberations and both the OIE and Codex documents are intended to be complementary to each other.

This chapter will follow the process flow outlined in the Codex draft Guideline document provided by the Codex working group. Comments and Expert Group opinions are given at the various steps outlined in these draft Guidelines when these are step specific, while comments and opinions covering several steps of the process (e.g. decontamination) are provided in the appendix to this report. The relevant text from the Codex draft Guidelines is provided immediately before the comments of the Experts.

The Experts wish to stress that although individual intervention methods have been reported to yield scientifically documented reduction effects when applied as the sole measure, multiple interventions are not always additive.

The Experts identified two horizontal issues with the potential to affect several steps in the processing segment of the document, the use of chlorination, and, the effectiveness of washing with water or water containing chemical processing aids.

The Experts drew on all available and documented data and evidence in support of the interventions described, with the purpose of including up-to-date relevant scientific evidence in order to supplement and expand the semi-systematic literature review that forms the basis of the draft Guidelines provided by the Codex working group. This chapter documents the review of the scientific underpinning of the Codex draft Guidelines. Where the expert meeting considered that the guidance was appropriate given the current knowledge base and scientific evidence, no further comment is given. However, in those cases where the guidance was considered to be incomplete or inappropriate given the available scientific evidence, the basis for such an opinion is provided.

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2. It must be stressed that this was a draft and therefore expected to change in the light of subsequent comments. The text on which the meeting's deliberations was based can be found at: ftp://ftp.fao.org/codex/ccfh40/fh40_06e.pdf

3. At the time of the Meeting, the primary OIE document was still technically a draft but due to go for adoption to be included in the 2009 Terrestrial Animal Health Code at the OIE General Session in the last week of May, 2009. Once adopted it would become part of Terrestrial Animal Health Code. Until that time it would be available as Annex XIII of the Report of the Terrestrial Animal Health Standards Commission. See pp. 157–162, in: http://www.oie.int/downld/SC/2009/A_TAHSC_March2009_PartA.pdf

4.1 Primary production

The Experts agreed that control measures applied at primary production are important for the control of *Salmonella* and *Campylobacter* throughout the production process and noted that they have been undertaken in a number of countries. However, due to the lack of quantification of the effect on prevalence or level of contamination on broiler carcasses, there are no validated hazard based control measures for *Salmonella* or *Campylobacter* in primary production. All of the following would be considered as GHPs by the Expert Group.

General control measures for Steps 1 to 11 (Production)

> The OIE Terrestrial Animal Health Code (March 2008) Appendix 3.4.1, Annex VI, *Hygiene and Biosecurity Procedures in Poultry Production*, provides considerable detail on control measures that apply to most production steps and should be referred to in application of these more specific Guidelines. The OIE Terrestrial Animal Health Code (March 2008) Annex V, *Guidelines on the Detection Control and Prevention of* Salmonella *spp. in Poultry*, should be referred to when applying Steps 1, 9, 10, 11 and 12. *Codex draft Guidelines*

The Experts were aware that the draft *Guidelines on the Detection Control and Prevention of* Salmonella *spp. in Poultry* has been revised and the new version had been approved by the OIE Code Commission, and was to be presented to the general meeting of OIE in May 2009.

The *Hygiene and Biosecurity Procedures in Poultry Production* draft had not yet been agreed and could be substantially revised.

Further comments are given at relevant steps of relevant interventions.

> In addition to following this general guidance, people entering the live bird production areas should not have close contact with any other birds. If such contact is unavoidable, they should not be permitted to enter live bird production areas for a specified time after the contact, and then only after the application of appropriate hygiene measures.
>
> People and vehicles who need to move in reverse of the production flow, i.e. towards Step 1, should be required to apply sufficient hygiene measures to avoid the introduction of *Campylobacter* and *Salmonella* earlier in production. People and vehicles who need to move to production areas from a feed mill or processing premises should apply appropriate hygiene measures to minimize the introduction of *Campylobacter* and *Salmonella* into production.
>
> *Codex draft Guidelines*

The Experts considered this text was appropriate given the current knowledge base and had no further additions or comments.

Step 1: Manage grandparent flocks

> Control of *Campylobacter* and *Salmonella* in grandparent flocks is achieved by the application of a combination of biosecurity and personnel hygiene measures. The particular combination of control measures adopted at a national level should be determined by the Competent Authority, in consultation with industry.
>
> Farms should be sited away from other poultry farms, livestock operations, abattoirs and identified sources of contamination. Pest control programmes, particularly to manage rodents, flies and beetles, should be in place. Wild birds should be discouraged by immediate clean-up of any feed spills, and keeping doors closed when not in use.
>
> Equipment and feeders should be designed to minimize contamination from the birds.
>
> Litter should be obtained from an uncontaminated source or be sanitized.
>
> Any equipment taken into a poultry house should be cleaned and sanitized beforehand (including equipment used for maintenance and repairs). Vehicles should be washed and sanitized at the site entrance.

> All eggs intended for incubation should be sanitized as soon as possible after lay.
>
> *Codex draft Guidelines*

In this context, it was the opinion of the Experts that there should be more details on pest control programmes, e.g. to cover domestic animals, arthropods, reptiles, flies, mites and wildlife. It was considered that the OIE guidelines covered this appropriately except for the control of arthropods.

Furthermore, it was the opinion of the Experts that microbiological sampling and testing for *Salmonella* was not adequately covered by the Codex draft Guidelines. It was considered that the OIE guidelines covered this appropriately. Also it was found that drinking water was not adequately covered in the Codex draft Guidelines, although this was found to be covered appropriately by the OIE guidelines. It was the opinion of the Experts that sanitization of eggs can have a negative effect on *Salmonella* status, chick hatchability and chick quality if the dip solution becomes contaminated or if improper temperature of the sanitizing solution is used (Williams and Dillard, 1973; Hutchison et al., 2004).

Strategies to reduce faecal contamination of eggs such as not incubating floor eggs, keeping nest boxes clean and sanitation of egg trays should be encouraged. The OIE guidelines covered this appropriately, except for floor eggs (Saeed et al., 1999). The Experts recommend that this should be considered by the CCFH working group.

When reviewing the Codex draft Guidelines, it was the opinion of the Experts that these were light on biosecurity measures. However, they found that these were appropriately covered by the OIE codes, especially for:

- cleaning and disinfection of houses and immediate surrounds or other areas of the farm that may present a reservoir for *Salmonella* or *Campylobacter*;
- staff, visitor and catcher clothing;
- vehicle parking;
- disinfection if it is necessary to enter the farm; and
- restriction on equipment shared between houses.

> For *Campylobacter:* Because of the possibility of vertical transmission, Competent Authorities may choose to apply preventative measures as a precautionary measure.
>
> *Codex draft Guidelines*

The Experts agreed that the statement regarding the possibility of vertical transmission of *Campylobacter* should be deleted, as at present there is no strong evidence that *Campylobacter* is vertically transmitted (Callicott et al., 2006). *Campylobacter* control prior to broiler farms was therefore not considered to be necessary.

> For *Salmonella:* The breeder production flock should be kept free from *Salmonella* to prevent vertical spread of infection.
>
> Incoming flocks should be screened and monitored according to a statistically-based sampling plan. Until results are available, the birds may be kept in quarantine. During rearing and production the birds should be tested according to specified sampling schemes.
>
> Where a flock is found to be *Salmonella*-positive the houses should be meticulously cleaned and disinfected before new birds are introduced. Sampling from various locations and equipment should verify that no *Salmonella* infection persists.
>
> Feed should be heat-treated or subjected to other bactericidal treatment. Breeder feed should preferably be delivered in dedicated vehicles used only for feed transport.
>
> *Codex draft Guidelines*

The Experts wanted to emphasize the value of culling positive flocks, and it was found that the OIE document covers this appropriately.

The Experts agreed that feed should be heat treated and could be subjected to other bactericidal treatment.

> For *Salmonella:* Other measures that have been evaluated in experimental or very limited commercial settings include vaccines, competitive exclusion, and feed or water additives. A Competent Authority may need to validate such measures in the national setting before advocating their use. Such measures must however not be seen as alternatives to good hygienic practices. *Codex draft Guidelines*

There are live vaccines and killed vaccines that can be used.

It was the opinion of the Experts that live *Salmonella* vaccines demonstrate non-serotype-specific and rapid protection for breeder pullets. Live vaccines also give immunity against specific serotypes. The inactivated *Salmonella* vaccines produce immunity only against specific serotypes. Combination of live and killed vaccines gives protection to the hen and maternal antibodies to the broiler. All of these are widely used commercially. Despite this, the Experts did not consider it to be a hazard control measure as the effect had not been well enough quantified regarding the impact on the resulting broilers.

The Experts stated that probiotics are defined products, whereas competitive exclusion (CE) mixtures are undefined intestinal flora. It was the opinion of the experts that the use of undefined CE products could be effective for *Salmonella* control in combination with other interventions. It decreases or prevents *Salmonella* colonization of other birds in the flock and results in a decreased concentration of *Salmonella* in caecal contents of birds that become colonized. It was accepted by the meeting that CE was in wide commercial use.

Probiotics are live microbial feed supplements that are not pathogenic for the host and able to modulate the immune response and change or stabilize microbial activities. Prebiotics are non-digestible substances with a beneficial physiological effect on the host due to the beneficial effect on the gut flora of the host. There are many publications on pre- and probiotics. Currently, there was no evidence that they could be commercially developed as effective intervention agents for *Salmonella*.

There is a great variety of feed and water additives, including organic acids, plant derivatives and enzymes (e.g. xylanase). For *Salmonella* control, there are numerous feed and water additives that have been successful when used experimentally. The opinion of the Experts was that these were not currently effective commercially, with the exception of organic acids or formaldehyde in feed. The use of organic acids in water (Dibner and Buttin, 2002) and organic acids and formaldehyde in feed reduces the concentration of *Salmonella* in the water, and also reduces the risk of contamination of feed post-heat treatment (Davies and Hinton, 2000).

It was noted that the effects of organic acids in feed are not apparent until the treated feed has been consumed by the bird and wetted in the crop.

The experimental results of bacteriocin controls for *Salmonella* looked very promising, but there had been no published field trials, so the experts considered it too early to recommend it as an effective intervention in a commercial setting. Also, the experimental results for bacteriophage therapy for *Salmonella* looked very promising, but there had been no published field trials. There were commercial companies investigating this, but it was too early to recommend it as an effective intervention in a commercial setting (Atterbury et al., 2007). Research into genetic resistance to *Salmonella* colonization showed that this had some effectiveness, but it was not a viable, cost-effective option in the near future (Wigley et al., 2006).

There had been limited experimental success for *Salmonella* control using immuno-stimulators, but it was still too early to give a recommendation as to whether this could be used as an effective intervention in a commercial setting.

The Experts furthermore stated that antimicrobials do decrease *Salmonella* concentration both in the gut and systemically, but that it would not always completely eliminate contamination. They should not be used as a *Salmonella* control measure in breeders except for salvaging valuable genetic lines, due to the risk of development of resistant *Salmonella* strains. In such cases, it should be followed by a CE product to restore the micro flora (Goren, 1993; Reynolds, 1997).

Negative air ionization had been demonstrated in research to be effective in reducing the level of *Salmonella* in the air in breeder houses, but it had not yet been applied successfully in a commercial setting.

There were many commercially available treatments to acidify the litter. Research had shown that short-term reduction in bacterial populations could be achieved. It appeared to have a limited long-term effect. The experts were not aware of any current commercial use for *Salmonella* control.

Step 2: Transport eggs to hatchery

For *Salmonella:* Egg trolleys should be cleaned and sanitized before use. They should be stored in an enclosed storage area.

Vehicles used for transporting eggs should preferably be dedicated for that purpose. The driver should, on arrival, wear protective clothing, use the boot dips provided and should not enter any livestock buildings.

Eggs from each flock should be packed into separate trays and should be identifiable. Egg trays should be labelled with the appropriate flock code and date.

Only eggs from *Salmonella*-negative flocks should be sent for incubation. When this is not feasible eggs from *Salmonella*-positive flocks should be transported well separated from eggs from negative flocks. *Codex draft Guidelines*

The Experts were in agreement with the appropriateness of the above guidance; however they noted that although it is common practice to use foot dips they are not always effective, especially in the presence of organic matter. This organic matter can result in inactivation of the disinfectant and subsequent boots can become contaminated with *Salmonella*. It might be better to suggest a change of footwear when entering the house (Amass et al., 2000).

Step 3: Parent hatchery

For *Salmonella*: The control measures as described at Step 1 also apply at this Step where relevant to a hatchery.

Each setter or hatcher should only contain eggs from one flock.

If possible, only eggs from *Salmonella*-negative flocks should be incubated as it has been scientifically demonstrated that only one *Salmonella*-contaminated egg can contaminate all eggs and newly hatched chicks within a hatching cabinet.

Where the use of eggs from flocks that are known to be contaminated is unavoidable, they should be kept separate and hatched separately from eggs from other flocks. Trace-back of infection to the contaminated breeding flocks should be performed and control measures should be reviewed.

Sampling programmes for detection of *Salmonella*, including testing dead chicks, chicken fluff, meconium and shells, should be in place. *Codex draft Guidelines*

The Experts suggested revising the text so that the types of samples listed were shown as options rather than inclusive, this meaning that at least one of the listed options should be used to monitor for *Salmonella* from the hatchery.

UV irradiation of hatching eggs has been very effective for *Salmonella* control under experimental conditions as a way to sterilize the surface of the egg. There is no commercial application as yet, probably due to staff safety issues and the negative effect on plastics.

Air sanitation in hatchers using ozone, hydrogen peroxide and phenol is effective experimentally against *Salmonella,* but commercial use is limited due to other practical concerns. Formaldehyde is still commonly used as long as staff precautions are taken.

Step 4: Transport day-old chicks to parent farm

For *Salmonella*: Personnel should follow the same hygiene routine as for collection of hatching eggs. Transport of day-old chicks should be in vehicles or containers preferably used only for that purpose. Chicks should be traceable to a hatchery. The driver should not enter any livestock buildings.

Codex draft Guidelines

Step 5: Manage parent flocks

For Salmonella: The control measures described at Step 1 apply at this Step.

Codex draft Guidelines

Step 6: Transport eggs to hatchery

For *Salmonella:* The control measures described at Step 2 apply at this Step.

Codex draft Guidelines

Step 7: Hatchery

For *Salmonella:* The control measures described at Step 3 apply at this Step.

Codex draft Guidelines

The Experts considered that the guidance provided is Steps 4 – 7 was appropriate given the current knowledge base, and had no further additions or comments.

Step 8: Transport day-old chicks to grower sheds

For *Salmonella:* The control measures described at Step 4 apply at this Step.

Codex draft Guidelines

While the Experts were in agreement that the guidance provided was appropriate they also highlighted the need to address traceability from breeder farms to hatchery.

Step 9: Manage chickens

The control measures described at Step 1, where relevant to growing farms, apply at this Step.

Unusually high levels of mortality or morbidity should be investigated.

Stand down periods for personnel are advisable during which there is no contact with birds of any type. Personnel protective clothing should be under the control of the company.

Any equipment that must be taken into a shed should be cleaned and sanitized beforehand (this includes equipment used for repairs and maintenance).

> Pest control programmes should be used outside sheds and inside the annex as necessary. Specific pests such as flies and litter beetles should be controlled to the highest level practicable. Where practicable, fly-screens may be useful in reducing the prevalence of *Campylobacter* or *Salmonella* contamination in flocks. Doors should be kept closed.
>
> Sheds should be single purpose - single species operations, and ideally an all-in all-out single-age-group principle should be adopted. Where several flocks are maintained on one farm, the individual flocks should be managed as separate epidemiological units.
>
> Where there is a detection of pathogen-positive flocks, control measures applied at processing should be considered, e.g. heat treatment or freezing of chicken meat derived from positive flocks to reduce the concentration of *Salmonella* and/or *Campylobacter.*
>
> For *Salmonella:* Feed and water additives have been used (alone or in combination with competitive exclusion) in experimental or very limited commercial settings to reduce colonization of the chickens. A Competent Authority may need to validate such measures in the national setting before advocating their use. *Codex draft Guidelines*

While agreeing on the appropriateness of the above guidance, the Experts noted that mortality during the first two weeks could be indicative of *Salmonella* infection from the breeder farms. Furthermore, the Experts were concerned at the possible effect of litter moisture on *Salmonella* (Eriksson et al., 2001) but considered this to be appropriately covered under the OIE text.

It was the opinion of the Experts that the guideline was light on biosecurity measures. However, they found that biosecurity was appropriately covered by the OIE codes, especially for:

- cleaning and disinfection of houses, their immediate surrounds and other areas of the farm that might present a reservoir for *Salmonella* or *Campylobacter*;
- staff, visitor and catchers' clothing;
- vehicle parking, and disinfection if necessary to enter farm; and
- restriction on equipment shared between houses.

> For *Salmonella*: Competitive exclusion treatments may reduce *Salmonella* flock prevalence by up to 70–85% or more. *Codex draft Guidelines*

While the Experts were in agreement with the intent of the above guidance on the utility of competitive exclusion, it was considered that it would benefit from greater clarity in terms of the efficacy of such a treatment and suggested a more appropriate statement would be "Competitive exclusion may reduce the prevalence of *Salmonella*-positive flocks and / or levels of intestinal colonisation, but the extent of any reduction can vary". Furthermore it was advised that CE be administered after antimicrobials are used for treatment of other diseases, to restore the normal gut flora (Smith and Tucker, 1975).

In addition to the GHP measures mentioned above, the meeting considered other potential interventions for implementation during broiler growing in terms of their potential practical utility in reducing *Campylobacter* and *Salmonella*. The outcome of these deliberations is documented below.

Several potential *Campylobacter* vaccines had been tested but the results were poorly reproducible. Obviously, new approaches were needed to develop effective vaccines. The opinion of the Experts was that it would take many years before a commercial vaccine would be available. There were live vaccines that could be used to control *Salmonella* in broilers, but these had not proven to be effective commercially.

Experimental studies on CE for control of *Campylobacter* showed contradictory results: some of them claimed effectiveness while others did not. Furthermore, the Experts raised the concern that there might be an under-reporting of studies showing no effect. Currently there was little evidence that CE would work against *Campylobacter*, and to the current knowledge of the Experts there was no expectation that products used against *Campylobacter* would be developed in the near future.

Organic acids appeared to be a promising feed or water additive for control of *Campylobacter*. However, large-scale field trials had yet to be performed to assess effectiveness on-farm. Other substances (e.g. monocaprin and caprylic acid, some enzymes and egg yolk powder) did not give reproducible results. The Experts concluded that the effect of these required field trials.

For *Salmonella* control, there were numerous feed and water additives that had been successful when used experimentally. At the time of writing these were not used commercially, with the exception of organic acids in pre-slaughter drinking water, and organic acids or formaldehyde in feed. The organic acids in pre-slaughter drinking water have been shown experimentally to decrease *Salmonella* concentration in crop and caeca, which may result in lower contamination on the carcass. The use of organic acids or formaldehyde in feed reduces the concentration of *Salmonella* in the feed and reduces the risk of post-heat-treatment contamination (Dibner and Buttin, 2002).

Bacteriocins are substances produced by bacteria, having anti-bacterial activity against specific other bacterial species. One research group reported promising results using these peptides against *Campylobacter* (Stern et al., 1995). There is an Intellectual Property dimension to these findings (i.e. patents). To the meeting's knowledge, only experimental data had been published. The studies to date looked very promising, but on-farm trials were needed to investigate efficacy and reproducibility under commercial conditions.

Experimental results for *Salmonella* control looked very promising, but on-farm studies had yet to be published, so it was too early to recommend it as an effective intervention in a commercial setting.

Bacteriophages are viruses able to kill specific bacterial species. Experimental studies from different research groups have shown the effectiveness on *Campylobacter* and *Salmonella*. Due to their short-term effect, the application would be limited to a small time window just before slaughter. There is only proof of principle, and on-farm studies had not yet been performed. Practical application might be hampered by lack of broad-host phages, resistance and environmental contamination issues. Phage therapy was promising, but development and application of a commercial product would need much extensive research (Atterbury et al., 2007)

There had been limited experimental success for control of *Campylobacter* or *Salmonella* using immunostimulators, but it was too early to recommend it as an effective intervention in a commercial setting.

There was no role for the use of antimicrobials in the control of *Campylobacter*. First, because of the issue of the threat of increasing antimicrobial resistance and hence the need for restricted use, and, second, because of the impossibility of practical application with regard to residues (when treatment is close to slaughter) and re-infection when the withdrawal period is respected.

The opinion of the Experts was that antimicrobials decrease *Salmonella* concentration in the gut and systemically, but would not always completely eliminate contamination. It should not be used as a *Salmonella* control measure in broilers.

Housing conditions and biosecurity are a form of prevention, controlling the introduction of infectious agents by use of hygiene measures, for example. Increasing biosecurity has definitively a role in the prevention of *Campylobacter* colonization of broilers. However, quantifying the effect is difficult and most probably dependent on regional and seasonal differences. In northern European countries (e.g. Denmark, Iceland) there is a strong suggestion that improvement of biosecurity resulted in a reduction of *Campylobacter* prevalence. However, control groups are lacking. The effect of specific measures such as fly-screens has been reported from Denmark, and is very promising. The effect of this approach in other geographical areas (e.g. other climates or ventilation systems) should be confirmed.

In the meeting's opinion, biosecurity had a (major) role to play in the reduction of the prevalence of *Campylobacter* and *Salmonella*, but quantitative prediction of the effect was difficult to ascertain.

Although various litter treatments had been used in experimental trials, in the case of *Campylobacter* there appeared to be no reduction of microbial load on the final product. The conclusion of the Experts was that there was insufficient evidence that this approach would be effective.

There are many commercially available treatments to acidify the litter. Research has shown that short-term reduction in bacterial populations can be achieved. It appears to have a limited long-term effect. The Experts were not aware of any commercial use for *Salmonella* control.

Step 10: Depopulate (full or partial)

> Full depopulation should be carried out where possible. Where this is not practicable and partial depopulation is practised, particular attention should be paid to strict biosecurity and general hygiene. This includes the prior cleaning of equipment such as transport vehicles and their tyres, forklifts, pallets/modules, catcher's boots, and transport crates. It is preferable that sheds being partially depopulated are scheduled for catching prior to those being fully depopulated on the same day. This may assist in minimizing contamination of remaining birds. Catching crews should adopt good biosecurity practices and facilities should be provided to enable them to do so.
>
> When feed withdrawal is practised, water additives such as lactic acid that may lower post-harvest crop contamination may be considered. *Codex draft Guidelines*

The Experts were in agreement with the appropriateness of the above guidance.

An agreed microbiological testing regime followed by scheduled slaughter (with positive flocks being processed separately or after negative flocks to reduce cross-contamination) or sent for further treatment post-slaughter will significantly reduce the microbial load and/or the prevalence on the carcass. Sampling should be carried out as close to slaughter as possible, taking into account the time for results to be available. This can only be done for *Campylobacter* if the flock prevalence is sufficiently low (EFSA, 2009).

Step 11: Transport to slaughterhouse

> Stress to live birds increases shedding of *Salmonella* and *Campylobacter* and should be minimized during transport by:
>
> - Giving each bird sufficient space to rest and stand up without restriction.
> - Protecting birds from undue fluctuations in temperature, humidity or air pressure.
> - Sheltering birds from extremes of weather.
>
> All live bird transport vehicles, crates, modules and associated equipment should:
>
> - Be designed, constructed and maintained to allow effective cleaning.

- Be effectively washed and sanitized, away from processing and bird holding areas so as to minimize cross-contamination, and be visibly clean.

- Be dried if practical and achievable before use in the case of crates and modules.

Codex draft Guidelines

While agreeing with the appropriateness of the above guidance, the Experts suggested that air velocity may be a more fitting term to use than air pressure.

4.2 Processing

4.2.1 Handling of crates and pre-scalding

Information on flocks presented for slaughter should be provided in a timely manner to enable optimal slaughter and processing procedures. Supplier statements or supplier guarantees covering information on flock health, e.g. relating to the use of veterinary drugs or ante-mortem inspection results, should be required upon receipt of flocks and any other materials received by the slaughterhouse.

Stress to birds should be minimized, e.g. by dim lighting, minimal handling and avoiding delays in processing. Information on flocks presented for slaughter should be provided in a timely manner to enable optimal slaughter and processing procedures

For *Salmonella:* If flocks are known positive for *Salmonella*, they should be presented for slaughter in a manner that minimizes cross-contamination to known negative flocks, e.g. by slaughtering them at the end of the day, or all on one day and preferably the last day(s) of the week. *Codex draft Guidelines*

While agreeing with the intent and to a large extent the appropriateness of the above guidance, the Experts considered the section on supplier statements or guarantees might not be necessary.

Furthermore, emphasis is put on the importance of scheduling based on information on feed withdrawal period, due to its impact on the level of carcass contamination during slaughter. Thus slaughtering flocks 8 to 12 hours after feed withdrawal will reduce likelihood of contamination of carcasses by faecal material and\or ingesta. Flock information should include details on feed withdrawal period for appropriate scheduling purposes (Northcutt, Savage and Vest, 1997; Wabeck, 1972, 1992; Warriss et al., 2004).

Step 13: Ante-mortem inspection

Moribund, unhealthy or otherwise unsuitable poultry should not be processed.

Where numbers of birds that are dead on arrival, moribund, unhealthy or otherwise unsuitable for processing exceed expected levels, the processor should notify the relevant responsible person, e.g. the farmer, veterinarian, catcher or transportation company, so that appropriate preventative and/or corrective action can be taken. *Codex draft Guidelines*

The Experts considered that the guidance provided was appropriate given the current knowledge base, and had no further additions or comments.

Step 14: Slaughter

Where practicable, known positive flocks may be diverted for specific processing and/or treatment according to national food safety policies.

Measures should be taken to minimize bird stress at hanging, e.g. use of blue light, breast comforter, suitable line speed.

Bleeding should be substantially completed before scalding in order to prevent inhalation of scald water and to reduce the amount of blood entering the scalder. *Codex draft Guidelines*

While agreeing with the appropriateness of the above guidance, the Experts highlighted that minimizing stress at hanging applied only to live hanging-on operations, and did not cover, for example, controlled atmosphere stunning/killing.

Step 15: Dress

So as to minimize contamination[4] of carcasses, control measures can include:

– Washing at key process steps to minimize attachment of *Campylobacter* and *Salmonella* to carcasses.[5]

– Trimming, to minimize visible contamination.

– Other approved chemical[6] and physical methods.

These methods can be applied alone or in combination at different process steps during processing.

Where re-hang of carcasses is necessary, it is preferable that this is done mechanically so as to reduce cross-contamination.

All birds which drop on the floor should be condemned, or reprocessed under specific conditions as determined by the Competent Authority. Any dropped products should trigger corrective actions as appropriate. *Codex draft Guidelines*

Washing at key process steps will reduce contamination by *Campylobacter* and *Salmonella*, but the Experts disagreed that this applied specifically to attachment. Trimming, washing or other measures applied to minimize visible contamination with faecal materials or ingesta on carcasses should be initiated by inspection, be it visual or automated inspection, which is becoming more common practice in industry.

4.2.2 Scalding, de-feathering and evisceration

Contamination during scalding can be minimized by:

– the use of counter-current flow;

– addition of as much fresh water as possible;

– having the scald temperature as high as possible to minimize levels of *Campylobacter* and Salmonella; and

– use of approved[7] chemicals, e.g. pH regulators.

Other factors that should be taken into account when designing process control systems that minimize contamination during scalding include:

– degree of agitation;

– use of multi-staged tanks;

– pre-scald brush and wash systems;

– raising the temperature of scald tanks to 70°C at breaks;

– tanks being emptied and cleaned at end of a processing period; and

– hygiene measures applied to re-used/recycled water. *Codex draft Guidelines*

4. Decontamination of carcasses will probably reduce, but not eliminate *Salmonella* and *Campylobacter* bacteria on broiler carcasses and broiler meat.
5. Washing with water alone may achieve a decrease in *Campylobacter* and *Salmonella* but has little effect on cells attached to the carcass surface. Further, the extent of the decrease may depend on the efficacy of previous washes.
6. Chemical decontaminants should be approved by the Competent Authority.
7. Processing aids should be approved by the Competent Authority.

Addition of as much fresh water as possible is a vague statement, and also counteracts water conservation measures by industry. It was suggested that the process should instead be specified as: *High flow rates of water with adequate agitation*. Raising the temperature of scald tanks at breaks is a sound measure, but various temperatures are applied in the industry according to plant, company and region. So the specific recommendation of 70°C is too rigorous, but could be used as an example. It should be clear that the purpose is to raise water temperature high enough for a long enough time to kill *Salmonella* and *Campylobacter* in the scalders.

Cross-contamination at de-feathering can be minimized by:
– guarantee of appropriate fasting of birds prior to slaughter;
– prevention of feather build-up on equipment;
– continuous rinsing of equipment and carcasses;
– regular adjustment and maintenance of equipment;
– particular attention to cleaning moving parts; and
– regular replacement of plucker fingers. *Codex draft Guidelines*

While agreeing with the appropriateness of the above guidance the Experts noted that the first bullet was already covered under Step 12 *Receipt at slaughterhouse*. Furthermore the importance of appropriate feed withdrawal time for impact on carcass contamination should be stressed.

4.2.3 Head pulling

Head pulling should be carried out in such a manner that leakage from the crop is prevented. Heads should be pulled downwards to reduce contamination due to crop rupture. *Codex draft Guidelines*

4.2.4 Evisceration

Rupture of the viscera and spread of faeces can be minimized by:
– limiting size variation in batches so that birds of similar size are processed together; and
– careful adjustment and regular maintenance of machinery. *Codex draft Guidelines*

The Experts considered that the guidance provided on head pulling and eviceration was appropriate given the current knowledge base, and had no further additions or comments

4.2.5 Crop removal

Where possible, crops should be extracted in a manner that is likely to reduce/limit carcass contamination. *Codex draft Guidelines*

The Experts found that there was no scientific evidence supporting the statement that specific methods for the removal of the crop would reduce carcass contamination.

4.2.6 Decontamination (washing)

Washing/rinsing with abundant potable water may be sufficient to reduce cross-contamination with *Campylobacter* and *Salmonella.* *Codex draft Guidelines*

The Experts questioned the use of the word *sufficient*, considering that there was not an established level for cross-contamination reduction. It was suggested that "*may assist in reducing*" might be more appropriate. Also, the group suggested the word *contamination* to replace *cross-contamination*. In addition, it was the opinion of the group that this was a GHP measure rather than a specific control measure.

> Chlorination of water used for carcass washing, e.g. 25 ppm, has been shown to reduce *Campylobacter* levels on skin by 0.5 $\log_{10}$ cfu/g. *Codex draft Guidelines*

The Experts questioned whether the reported reduction is due to presence of chlorine in the wash water. The draft report of the *FAO/WHO Expert Consultation on the benefits and risks of the use of chlorine-containing disinfectants in food production and food processing (*See Appendix) noted that 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.[8]"

> Dipping of carcasses in solutions containing processing aids, e.g. 10% solution of trisodium phosphate (TSP) at pH 12 for 15 seconds, has been shown to reduce *Campylobacter* levels on skin by up to 1.7 $\log_{10}$ cfu/g. *Codex draft Guidelines*

It was the opinion of the Experts that references to the use of TSP should be removed from the document, considering that TSP was rarely used in commercial poultry processing. Some arguments include the negative environmental impacts of phosphates and the counteracting effect of the alkaline compound on the effectiveness of chlorine in chillers, e.g. chlorine performs better in pH lower than 7 (Smart, 2009).

> For *Salmonella*: Multiple-sequential washing steps have been shown to reduce the Salmonella incidence on broiler carcasses by 40 to 90%, the proportion depending on number and nature of washing interventions. *Codex draft Guidelines*

It was the opinion of the Experts that the quoted 40 to 90% was overly optimistic. However, between 4 to 8% reductions were reported in the same document for each individual washer. In two other studies, Lillard (1989, 1990) (discussed in the Appendix) showed that reductions from sequential washing steps are not additive, since limited effects of sequential washings were obtained.

The experts recommended that the Codex working group refer to reductions at individual steps when redrafting the document.

> On-line reprocessing of contaminated carcasses using TSP can significantly reduce the presence of *Salmonella*, with some reports of almost 100% of carcasses being test negative. *Codex draft Guidelines*

It was the opinion of the Experts that references to the use of TSP should be removed from the document, considering that TSP was rarely used in commercial poultry processing.

Step 16: Inside/outside body wash

It was the view of the experts that On-line reprocessing should be dealt with as a subset of washing.

> The inside and outside of all carcasses should be thoroughly washed, using pressure sufficient to remove visible contamination. Appropriate equipment should be used to ensure direct water contact with the carcass. *Codex draft Guidelines*

The Experts were in agreement with the appropriateness of the above guidance but noted that in commercial practice, the physical force needed to remove visible contaminants may be aided by the use of brushing apparatus installed in line with the inside/outside body wash (IOBW).

8. 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.

> For *Campylobacter*: Washing systems. Using water alone has been shown to reduce levels of *Campylobacter* by up to 0.5 $\log_{10}$ cfu/ml of whole carcass rinse sample.[1)] *Codex draft Guidelines*

This statement is incorrect according to the reference cited as it includes 3 sequential washings with 25 ppm chlorinated water.

> Use of an inside/outside wash followed by an on-line spray system incorporating a processing aid, e.g. acidified sodium chlorite (ASC) and citric acid[9], has been shown to reduce *Campylobacter* in the whole carcass rinse sample by 1.7 $\log_{10}$ cfu/ml.
>
> [1)] Washing systems using TSP or ASC may further reduce average *Campylobacter* levels by 1.0 $\log_{10}$ cfu/ml of whole carcass rinse sample. *Codex draft Guidelines*

As noted previously it was the opinion of the expert meeting that references to the use of TSP should be removed from the document, considering that TSP was rarely used in commercial poultry processing. Further, it was suggested to review the second sentence as footnote [1)] was incorrectly placed according to the literature provided. The sentence belongs to the previous section.

The Experts found that the reference to 1.7 $\log_{10}$ reduction is not correct, and this statement should be reviewed by the Codex working group.

> For *Salmonella:* Use of an inside/outside wash, including processing aids as desired has been shown to reduce *Salmonella*-positive carcases by up to 60%. *Codex draft Guidelines*

The Experts suggested revising the statement to include conditions of application and specific agents to support it.

> Inside/outside washing using a spray application of 20–50 ppm chlorinated water may reduce the prevalence of *Salmonella*-positive broiler carcasses by 20%. A second inside/outside washing following immediately upon the first may result in a further 25% reduction. *Codex draft Guidelines*

In the opinion of the Experts a new section should be added to include practices known as On-line reprocessing (OLR) to replace the above paragraph.

To clarify the OLR process: it occurs that in certain areas of the world an additional washing step has been added following the Inside/Outside Body Wash (IOBW). This has been designated as "On-line reprocessing" and, where permitted by National Authorities, this may be used in lieu of trimming or washing off-line as a remediation for faecal or ingesta contamination. The concept was described by Blankenship et al. (1993). Kemp et al. (2001) demonstrated a better level of microbial control than that provided by Off-line reprocessing when using ASC in OLR.

Hazard-specific control for *Salmonella*: Unpublished data were presented to and accepted by the Expert Group that validated the use of ASC (750 ppm, pH ~2.5, spray application) in an OLR application. In plant trials, reductions in *Salmonella* prevalence from 48% to zero and 56% to zero were achieved (Bernard and Natrajan, pers. comm.). Another unpublished data submission indicated 18.4% reductions of *Salmonella* prevalence by the use of ASC spray washes at 700–900 ppm, pH ~2.5 (Sanchez-Plata, pers. comm.).

Step 17: Postmortem inspection

> Line speeds should be appropriate for effective post mortem inspection of carcasses for visible contamination, organoleptic defects and relevant gross pathology.
>
> *Codex draft Guidelines*

9. Reported specifications are: 15-second on-line spray system incorporating ASC at 1100 ppm and citric acid at 9000 ppm giving a pH of 2.5 at 14–18ºC.

The Experts were in agreement with the appropriateness of the above and had no further additions or comments.

4.2.7 Chilling

> Poultry meat should be chilled as quickly as possible to limit the growth of microorganisms on the carcass.[10] Chemicals that may be added to the chiller water should be approved by the Competent Authority and include, among others: *Codex draft Guidelines*

The Experts suggested that the footnote at this stage needs to be deleted because conditions of application affect the performance of chlorination. Without specifying the conditions of use, the reference is incomplete.

> – Chlorine
>
> – Chlorine dioxide and other chlorine derivatives (in the form of sodium-hypochlorite, calcium hypochlorite tablets or chlorine gas or electrolytically generated hypochlorous acid) – TSP
>
> – Organic acids (e.g. lactic acid). *Codex draft Guidelines*

The Experts suggested revision of the list of actual organic acids, to include citric acid, which is more frequently used commercially. See previous comments about TSP used in commercial settings.

4.2.7.1 Air Chilling

> Prior to air chilling, carcasses may be sprayed or dipped, e.g. chlorinated water, lactic acid or TSP, to assist cooling.
>
> During air chilling, carcasses may be sprayed with chlorinated water, lactic acid or TSP to assist cooling and reduce the level of contamination. Spraying cabinets should be installed in downflow chilling tunnels. *Codex draft Guidelines*

The Experts recommended the deletion of the two above paragraphs as there was no evidence to indicate that the use of water sprays, with or without chemicals, had a beneficial effect, and could be in fact detrimental. Added water sprays are likely to retain enough moisture during the storage to allow for survival of *Campylobacter* and withstand the drying process of the chiller (Mead et al., 2000; Allen et al., 2000a, b, 2007).

The Experts did recognize that the process of air chilling, in the reduction of the carcass temperature, would minimize the likely growth of *Salmonella* if present. The meeting asked the CCFH working group to consider the findings 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 (FAO/WHO, 2008)

4.2.7.2 Immersion Chilling

> Water (including recirculated water) should be potable and the chilling system may comprise one or more tanks. Chilled water can be used or ice may be added to it. Water flow should be counter-current and may be agitated to assist cooling.
>
> Immersion chilling of carcasses should incorporate:
>
> – total available chlorine maintained at 50–70 ppm, and available free chlorine maintained at 0.4–5.0 ppm; and
>
> – pH maintained at 6.0–6.5.

10. The time necessary to eliminate *Salmonella* or *Campylobacter* in the chiller water increases with decreasing free available chlorine, e.g. it takes 120 minutes to eliminate both organisms at 10 ppm but only 6 minutes at 50 ppm total available chlorine.

> Following chilling, any excess water should be allowed to drain away from the carcasses to minimize cross-contamination of carcasses at subsequent steps in the processing chain.
>
> *Codex draft Guidelines*

The Experts disagreed that chlorine should always be used with immersion chilling. Where necessary for control of *Salmonella* and *Campylobacter,* processing aids (e.g. chlorine compounds, acidulants and other approved agents) may be considered.

It was the opinion of the Experts that the GHP as written was too prescriptive and parameters should be validated in the particular circumstances (See Appendix).

> For *Campylobacter*: Air chilling may significantly reduce numbers of *Campylobacter* depending on chilling rate and humidity.[11] *Codex draft Guidelines*

Forced air chilling (Blast chilling) can be a hazard control measure for *Campylobacter* due to the drying out of the surface. The Experts recommended that this paragraph be moved to a new, hazard-based control section within air chilling.

> For *Salmonella:* Immersion chilling using water with antimicrobial agents may decrease the prevalence of *Salmonella*-contaminated carcasses by up to 50%. *Codex draft Guidelines*

The subgroup did not find substantiation for the stated reduction and suggested removing "*by up to 50%*" from the statement.

The Experts spent much time discussing the role of processing aids in reducing the levels of contamination with *Salmonella* and *Campylobacter* on broilers during the immersion chilling operation. To support the discussion, 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 (FAO/WHO, 2008) were used in addition to other relevant references and personal comments.

The Experts did not reach agreement on the necessity for use of processing aids for control of *Salmonella* and *Campylobacter* on broilers during the chilling process.

Points were brought forward in support of the use of chlorine or other derivatives as inactivating agents in the chiller, but questions remained as to whether the noted effects were the result of the chlorine or the physical removal of contaminants by washing.

There was general agreement among the experts that the addition of chlorine at a level sufficient to maintain a residual in the water would inactivate pathogens washed off during the chilling process, preventing re-attachment and cross-contamination.

The point of controversy remains whether the use of chlorine in the chill tank does or does not act as a decontaminating agent by acting directly on the surface of contaminated carcasses. The same applies to application of processing aids during what has been referred to earlier as OLR.

> For *Campylobacter* and *Salmonella*: A pre-chill 15-second spray or 5- to 8-second immersion dip in acidified ASC has been shown to reduce *Campylobacter* and *Salmonella* on poultry carcasses by greater than 2 $\log_{10}$ cfu per ml of whole carcass rinse sample. Reductions of 2.6 $\log_{10}$ cfu per ml of whole carcass rinse sample can be achieved if the spray or dip is preceded by a freshwater wash.
>
> *Codex draft Guidelines*

This statement describes a processing step related to the previous section; there is no chilling done at this stage and it should be considered in the IOBW or OLR section.

---

11. *Campylobacter* spp. are relatively sensitive to drying and low humidity and die as a result of desiccation of the carcass surface.

> Use of an 8 to 12% solution of TSP in pre- or post-chiller baths has been shown to reduce *Campylobacter* and *Salmonella* by 1 to 2 $\log_{10}$ cfu per ml of whole carcass rinse sample.
>
> *Codex draft Guidelines*

As noted previously it was the opinion of the expert meeting that references to the use of TSP should be removed from the document, considering that TSP was rarely used in commercial poultry processing.

> For *Campylobacter*: Immersing whole carcasses in ASC immediately after the chiller has been shown to reduce *Campylobacter* by 2.6 $\log_{10}$ cfu/ml of whole carcass rinse sample.[12] In other commercial applications, ASC applied by dipping carcasses after exiting a screw chiller has been shown to reduce the prevalence of contaminated carcasses by up to 80%.
>
> *Codex draft Guidelines*

These interventions should be considered as Post-Chill applications. The Codex working group should consider placing this as a separate section in the revised document.

In addition, the Experts asked the Codex working group to go back to the original references, as the citations in terms of reported Log reduction for *Campylobacter* were incorrect.

> For *Salmonella*: Use of chlorine dioxide in chiller water at a level of 5 ppm (0.5–1.0 free residual chlorine dioxide) may reduce *Salmonella* on broiler carcasses by 2 $\log_{10}$ cfu per ml of whole carcass rinse sample. *Codex draft Guidelines*

The Experts noted that there was no such thing as free residual chlorine dioxide; it should be free residual chlorine.

The following hazard-specific control measure should go into the post-chill section.

Unpublished data were presented to and accepted by the Expert Group that the use of ASC (750 ppm, pH ~2.5, immersion dip, post-chill application) in a plant trial gave a reduction in *Salmonella* prevalence from 16% to zero (Bernard and Natrajan, pers. comm.). Another unpublished data submission indicated 15–25% reduction in *Salmonella* prevalence by the use of a chlorine dioxide generating system applied as a dip at 5 ppm post-chill (Sanchez-Plata, pers. comm.).

> Chilled carcasses should be held in temperature controlled environments and processed as soon as possible, or with the addition of ice to minimize the growth of *Campylobacter* and *Salmonella*.
>
> *Codex draft Guidelines*

The Experts suggested that the reference to *Campylobacter* should be removed, as *Campylobacter* will not grow below 32°C (ICMSF, 1996).

The Experts considered that the addition of the following hazard-based control section for *Campylobacter* was necessary as a consequence of recent published information:

"For *Campylobacter*: Crust freezing using continuous CO_2 belt freezing of portions, skinless breast fillets, provided a reduction in *Campylobacter* of 0.42 Log (Boysen and Rosenquist, 2009). The effect of crust freezing of whole birds on reducing *Campylobacter* is supported by work carried out by Corry et al. (2003)."

Step 20: Pack

> Chilled carcasses should be held in temperature-controlled environments and processed as soon as possible, or with the addition of ice to minimize the growth of *Campylobacter* and *Salmonella*.

12. Reported specifications are: Immersion of whole carcasses in 600 to 800 ppm ASC at pH 2.5 to 2.7 for 15 seconds.

> Care should be taken when packaging to minimize external contamination of the pack. Leakproof packaging, where possible, should be leakproof. *Codex draft Guidelines*

The Experts suggested that the reference to *Campylobacter* should be removed as *Campylobacter* will not grow below 32°C (ICMSF 1996).

The Experts agreed that minimizing cross-contamination was an important aspect of packaging and could be achieved in several ways, e.g. leakproof packaging or absorbent pads. However, it was not advocated that leakproof packaging should be applied in all situations.

> For *Campylobacter*: If modified atmosphere packs are used, the atmosphere chosen should not enhance the survival of *Campylobacter.* *Codex draft Guidelines*

A high oxygen concentration (70%) reduced the survival of *Campylobacter* during chilled storage by 2.0 to 2.6 Log over 8 days of storage (Boysen, Knøchel and Rosenquist, 2007). The Experts recommended that the Codex working group consider this as a hazard-based control option. As this is being drafted, the Codex working group should take care that new measures do not create other hazards.

> For *Salmonella:* Products should at all times be stored at temperatures preventing growth of *Salmonella*.[13] *Codex draft Guidelines*

While scientifically correct, the Experts considered that this text should be moved to Section 9.11 of the Codex draft Guidelines as it refers to storage.

> For *Campylobacter* and *Salmonella*: Gamma rays or electron beams[14] applied to warm, chilled, or frozen carcasses has been shown to be effective at eliminating *Campylobacter* and *Salmonella*. Where permitted, irradiation levels should be approved by the Competent Authority. Radiation at doses of 3–5 kGy for frozen poultry and 1.5–2.5 kGy for chilled poultry has been shown to eliminate *Salmonella* and *Campylobacter.* *Codex draft Guidelines*

The Experts noted that a range of doses had been reported, and should therefore be validated in the particular situation.

Step 21: Chill/freeze

> Measures based on GHP are provided in the Code of Hygienic Practice for Meat, CAC/RCP 58-2005 [CAC, 2005] with further guidance in the International Code of Practice for the Processing and Handling of Quick Frozen Foods, CAC/RCP 8-1976, Rev. 2-2008 [CAC, 2008].
>
> *Codex draft Guidelines*

It was considered that such general statements should be included in the introduction to the draft document.

> For *Campylobacter*: Freezing of naturally contaminated carcasses followed by 31 days of storage at -20°C has been shown to reduce *Campylobacter* by 0.65 to 2.87 $\log_{10}$ cfu/g.
>
> *Codex draft Guidelines*

The Experts agreed with the note that freezing will reduce *Campylobacter* contamination (Rosenquist et al., 2006).

4.2.8 Storage

> Measures based on GHP are provided in the Code of Hygienic Practice for Meat, CAC/RCP 58-2005 [CAC, 2005] with further guidance in the International Code of Practice for the Processing and Handling of Quick Frozen Foods, CAC/RCP 8-1976, Rev. 2-2008 [CAC, 2008].

13. Packaging in modified atmosphere does not prevent growth of *Salmonella* if temperature abuse occurs.
14. Refer to Codex Standard 106-1983, Rev. 1-2003, General Standard for Irradiated Foods.

Codex draft Guidelines

It was considered that this was a general statement rather than specific guidance and should go in the introduction to the draft document.

For *Salmonella*: Products should at all times be stored at temperatures preventing growth of *Salmonella*.[15] *Codex draft Guidelines*

The Experts agreed with the appropriateness of the guidance that products should be stored below temperatures allowing growth of *Salmonella*. The Experts could not agree on the need for application of this criterion *at all times*. Growth is time and temperature dependent; there are disagreements as to the exact temperatures to prevent growth, as well as questions regarding the impact of short periods at higher temperatures (Ingham et al., 2004).

4.3 Distribution, handling and preparation

4.3.1 Temperature control

The requirements for temperature control during transportation and storage of the product are covered adequately by the Code of Hygienic Practice for Meat, CAC/RCP 58-2005 (CAC, 2005).

In relation to cooking of raw chicken, the NACMCF (2007) review specifies that cooking to a minimum internal temperature of 74°C will give a 7 $\log_{10}$ reduction in *Salmonella* and a 50 $\log_{10}$ reduction in *Campylobacter*. However, the data available to the Experts for both pathogens was based on extrapolation of data from lower temperatures and different kinds of meat. Nevertheless, it should be noted that ready-to-eat meat and poultry products sampled at manufacturing plants for regulatory compliance during 2001 and 2002 yielded only 23 samples positive for salmonellae in over 14 000 tested (Dreyfuss et al., 2007) using the mentioned temperature of 74°C.

For *Campylobacter*, there is published data on fried chicken breast (Bergsma et al., 2007) and unpublished data on *Campylobacter* and *Salmonella* on chicken breast fillets showing unusual heat resistance. It was the opinion of the Experts that further work was needed to verify this. Commercial cooking practices following the guidelines in the document have a proven performance history of minimizing the risk of *Salmonella* and *Campylobacter*. However, studies on home cooking practices were not definitive at that time.

Factors that could affect heat resistance, such as: presence of chemical additives; size and conformation of the product; type of cooking process; water activity; fat content; and pH, must be taken into account to establish a heat regime. The variable nature of survival curves is recognized in the FAO/WHO document (FAO/WHO, 2002).

4.3.2 Cross-contamination

The requirements for meat handling at retail, as specified in the Codex Draft guidelines Section 10.4.1.1) were acceptable. In relation to food service operators, it was recommended that hygiene measures should be aimed at minimizing cross-contamination between raw chicken and hands, contact surfaces and utensils, but should prevent contamination of other foods. Information to consumers on food safety requirements given by the CCFH Guidelines should also be channelled through relevant national media.

15.Packaging in modified atmosphere does not prevent growth of *Salmonella* if temperature abuse occurs.

4.4 Identification of data gaps

Main data gaps for primary production were:

- *Salmonella* and *Campylobacter* prevalence information was available for some countries worldwide, but many of these studies gave limited details of study design.
- Data were limited or missing from most countries in Africa, Asia, Latin America and the Caribbean.
- There were very limited data on the concentration of *Salmonella* on positive birds.
- The effect on *Salmonella* and *Campylobacter* prevalence and concentration of specific risk reduction interventions needs to be evaluated.

Main data gaps for processing were:

- Quantitative data were limited for several steps of processing.
- There was limited information on processing practices used in different countries.
- Many studies were old; more recent information on changes in prevalence and numbers would be beneficial.

Main data gaps for cooking and handling were:

- Quantitative data regarding cooking practices and handling are needed.
- Systematic investigations are needed of the prevalence or level of contamination in this step.

5. Evaluation of likely outcomes of specific interventions

5.1 Step 1: Depopulate and transport to slaughterhouse

5.1.1 *Salmonella* and *Campylobacter*

The Experts found that there were no current quantified effects on prevalence or level of contamination of *Salmonella* and *Campylobacter* on broiler carcasses, and that the effect of any interventions made in the primary production stage had not been validated in a commercial setting. Therefore the evaluation of likely outcomes would not be measured as a reduction in prevalence or level of contamination, but have instead to be considered as a GHP, as described in Section 4.1, above. As mentioned in Section 4.4, Data gaps, there was a need for these measures to be quantified in order to consider these interventions as hazard reductions.

5.2 Step 2: Scalding, de-feathering and evisceration

5.2.1 *Salmonella* and *Campylobacter*

The measures mentioned in the Codex draft Guideline were found to cover the step adequately. No further data or interventions were presented at the Technical Meeting, and the interventions mentioned in the Codex draft Guidelines were not qualitative in regards to measuring the effect before and after the intervention.

5.3 Step 3: Washing and chilling

5.3.1 *Salmonella*

A study (Stopforth et al., 2007) showed 4–8% reduction in connection with sequential washing steps. However two other studies by Lillard (1989, 1990) (see Appendix) showed that reductions from sequential washing steps are not additive, since limited effects were obtained from sequential washings.

Furthermore, there was a documented effect of up to 100% when dipping the carcass in solutions containing a 10% solution of TSP at pH 12 for 15 seconds (Codex draft Guidelines).

Unpublished data were presented and validated at the FAO/WHO Technical Meeting, concerning the use of ASC (750 ppm, pH~2.5 spray application) in an OLR application. In plant trials, the reduction was a decrease the prevalence from 48% or 56% to zero. Additional unpublished data showed reductions of 18.4% in *Salmonella* prevalence by the use of ASC spray wash (700–900 ppm, pH ~2.5).

ASC can also be used as a pre-chill 15-second spray washing or a 4–8-second immersion dip, which has shown to reduce *Salmonella* on poultry carcasses by more than 2 $\log_{10}$ cfu/ml of whole carcass rinse sample. If this is preceded by a freshwater wash, reduction can be increased to 2.6 $\log_{10}$ cfu/ml whole carcass rinse sample.

The use of air chilling can minimize the growth of *Salmonella* if present, possibly due to a reduction in the carcass temperature. In the case of water chilling, use of chlorine in the water at a level of 5 ppm may reduce the *Salmonella* on broiler carcasses by 2 $\log_{10}$ cfu/ml whole-carcass rinse sample.

Additional data were presented at the Technical Meeting, showing a reduction in *Salmonella* prevalence from 16% to 0% when using ASC (750 ppm, pH ~2.5, immersion dip, post-chill

application) (Bernard and Natrajan, pers. comm.), and a 15–25% reduction in *Salmonella* prevalence by the use of a chlorine dioxide generating system applied as a dip at 5 ppm post chill (Sanchez-Plata, pers. comm.).

5.3.2 *Campylobacter*

Campylobacter prevalence will be reduced by each individual wash step. Chlorinating the wash water, e.g. 25 ppm, has been shown to reduce *Campylobacter* levels on skin by 0.5 $\log_{10}$ cfu/g. *Campylobacter* levels on the carcass can be reduced by a pre-chill 15-second spray washing or 4–8-second immersion dip. Reductions for *Campylobacter* can be up to 2 $\log_{10}$ cfu/ml of whole-carcass rinse sample, and 2.6 $\log_{10}$ cfu/ml whole-carcass rinse sample if the spray is preceded by a freshwater wash.

Forced air chilling can also be a hazard reducing control measure for *Campylobacter* due to the drying out of the surface. This measure can reduce *Campylobacter* by 0.4 $\log_{10}$ cfu/g.

Besides the abovementioned interventions, new studies have shown that crust freezing using CO_2 as mentioned in Chapter 4 could reduce *Campylobacter* by 0.42 $\log_{10}$/g (Boysen and Rosenquist, 2009; Corry et al., 2003)

5.4 Step 4: Storage, retail and consumer handling

5.4.1 *Salmonella*

Cooking to a minimum internal temperature of 74°C will give a 7 $\log_{10}$ reduction in *Salmonella*.

5.4.2 *Campylobacter*

No specific hazard reducing measures have been described in the Codex draft Guidelines regarding this step, but the Experts recommended the Codex working group to consider a study showing that the use of high oxygen concentration (70%) reduced the survival of *Campylobacter* during chilled storage by 2.0 to 2.6 $\log_{10}$ over 8 days of storage (Boysen, Knøchel and Rosenquist, 2007). Also, freezing followed by 31 days of storage at -20°C has shown to have a reducing effect on *Campylobacter* prevalence in naturally contaminated carcasses (by 0.65 to 2.87 $\log_{10}$ cfu/g) (Codex draft Guidelines).

Cooking to a minimum internal temperature of 74°C has shown to give a 7 $\log_{10}$ reduction in *Campylobacter*.

6. Development of a Web-based risk-management tool

6.1 Background

In response to the risk-management questions posed by CCFH, the primary application of a risk-management decision tool would be to demonstrate in a simplified manner the proportional effect of different control measures, either alone or in combination, on likely reductions in foodborne illness. This should allow countries to evaluate combinations of control measures by applying a risk-based approach. This decision tool should also be of considerable benefit to industry in designing HACCP plans.

Requested features of the web-based tool specified by CCFH were:

- simplified modelling of risks associated with final product without selected interventions;
- simplified modelling of risks associated with final product with selected interventions;
- comparison of different food chain scenarios;
- the proportionality of risk reduction associated with various control measures; and
- modelling of "what-if" scenarios.

In order to meet this request, an electronic discussion group was formed by FAO/WHO prior to the Technical Meeting. The aim of this e-group was to discuss the possibilities for development of a prototype user-friendly risk-assessment tool for *Salmonella* and *Campylobacter* in chicken meat. While the technology exists to develop these tools, there are a number of questions to be addressed in relation to their scope and limitations, functionality and performance.

Specifically, the following questions were considered by the electronic discussion group:

- Is this really a feasible list of requirements?
- How "simplified" would such a tool have to be to meet these requirements, and would it ultimately still have a value?
- Should we be considering this as one unique tool covering the whole chain, or a series of tools that focus on one segment of the chain, e.g. one for production, one for processing, etc., which may or may not be linked?

Based on discussions in the electronic discussion group, the following were put forward at the Technical Meeting:

- It is a feasible list of requirements.
- The level of simplification required and appropriate is still under consideration.
- The tool will consist of one unique tool.
- The tool will deal only with industrial processing.
- There are many existing detailed and complex risk assessment models (e.g. FAO, Netherlands, UK, Canada).
- The goal for this tool is to create a user friendly risk-management tool suitable for use via the Web.

- The model should be developed in such a manner so as to:
  - Enable users to input initial contamination levels at a common starting point.
  - Allow exploration of various assumptions about what happens during evisceration and chilling (and other specific steps to be named).
  - Provide default values for certain interventions.
  - Allow the user to override these with their own data or assumptions.
  - Provide only relative risk reduction compared to a baseline scenario.
  - Allow the user to compare or rank the effectiveness of different intervention options.

6.1.1 Examples of existing tools

Two recently developed Web-based tools were briefly introduced to the group.

- Food Standards Agency (FSA) Slaughterhouse Hygiene Assessment Tool.
- FAO/WHO (JEMRA) Risk Assessment for *Cronobacter* spp. in Powdered Infant Formula Tool.

6.1.1.1 Food Standards Agency (FSA) Slaughterhouse Hygiene Assessment Tool

The tool would be used to record measures in place to control *Salmonella* and *Campylobacter* from farm to carcass chill. It was developed by the FSA in consultation with the United Kingdom industry, to be used by United Kingdom poultry processors as a self audit. The tool was still in development, and only a limited example was seen by the group. The tool sets specific questions at each process step and the user had a choice of possible interventions. The questions were based on interventions for which there is literature support for controlling *Salmonella* and/or *Campylobacter*. The scores given for each answer reflect the degree of control. The total score for each set of questions within a section are multiplied by a "stage multiplier". The value of the multiplier is a reflection of the degree of risk at that step. Access through the Web would be linked directly to literature that supports each intervention, when the tool came online.

6.1.1.2 FAO/WHO (JEMRA) Risk Assessment for *Cronobacter* spp. in Powdered Infant Formula

This is an online risk assessment tool. The tool explicitly examines the impact of different preparation and handling strategies on *Cronobacter* spp. in Powdered Infant Formula (PIF) and describes the outputs in terms of the relative risk posed to infants. In addition to explicitly considering the preparation and handling of PIF, it provides tools to explore the possible impact of microbiological criteria through the specification of sampling plans for *Cronobacter* spp in PIF. The microbiological criteria can be explored in isolation or in combination with the preparation and handling tools to determine the impacts upon risk.

Users enter parameters such as concentration values, preparation and handling, and sampling plan information. The tool then uses a risk assessment model to produce a report showing the relative risk of the scenarios provided.

The tool is publicly available at www.mramodels.org/esak.

6.1.2 Prototype tool for a *Campylobacter/Salmonella* Web-based tool

An early prototype was presented to the experts for the purpose of generating discussion. The prototype included a few sample processing steps with options to input initial concentration and prevalence levels, identify process changes such as growth and cross-contamination, and introduce interventions.

The main features demonstrated by the prototype tool were:

- a user friendly interface (Web-based) for the end user; and
- a user friendly model development tool for the risk modeller.

The user would have the option to use default data, where available, based on the CCFH document and other literature. The user could also override those inputs with their own data. The software then uses those inputs to produce a risk-based report.

The prototype tool models changes in concentration and prevalence during processing. It currently starts after de-feathering, but this could be changed if found appropriate. The final concentration is used to compute two doses: one considering the interventions selected and a baseline dose assuming no interventions. These doses were applied to a dose-response model. The relative risk reduction between the result with interventions and without interventions is reported back to the user, as well as the mean concentration and prevalence values at each step.

Comments from individual experts on what the model developers should consider in the further development of the prototype tool included the following:

- It should make recommendations on sampling schemes and microbiological methods for users to determine input data so that inputs are comparable between users.
- The model should start further up the chain (e.g. pre-harvest) to expand the choices of management options.
- The model should be expanded to include consumer handling (e.g. cooking, cross-contamination).
- Have the model account for interactions between applying multiple interventions (synergistic, antagonistic, reduced effectiveness).
- The model should account for cross-contamination.
- The model should account for multiple flocks (e.g. cross-contamination between flocks).
- The implication of uneven carcass size within a flock should be considered.
- The model should account for the use of different scalding procedures.
- Different products should be included – e.g. cut-up products.

The following concerns from individual experts were raised:

- Who will be using the model? Will it be used by industry, government, and/or risk managers, and for what purpose?
- Which questions will the tool ask the users in order to provide input to the model?
- There is currently a lack of data (e.g. concentration data for *Salmonella*) to fill into the model. Would this prevent the tool from being usefully used?
- How will the model be validated?
- There is currently no consensus model on which to build the tool.
- Will the tool be updated as new information becomes available?
- It is difficult to rely on one model covering all plants with all the different machinery and GHPs in place.
- The *Campylobacter* issue is much more complicated than the *Cronobacter* spp issue, thus the model will be more complicated.
- Could the model be used for comparisons between countries?
- Different serovars may require different dose-response models.

Mechanisms by which to address some of these concerns include the following:

- The tool will provide default data, which can be used if the user has no data of their own. The data will be based on the best available information.
- The same dose response model will be used for all *Salmonella* serovars. Statistically, there are no differences between dose response models for different *Salmonella* serovars.
- Using relative risk makes the influence of the dose response less important.
- The model will be designed to compare different scenarios. Countries can add input data sampled for different situations, such as climate.
- The tool can be updated with new information when available and models can be adjusted if necessary.

6.2 Suitability of outputs of the meeting for the prototype tool development

The Experts agreed that the prototype tool was feasible and that the work on further development of a prototype should continue, based on the following arguments:

- We need this kind of tool for risk-based management.
- There are potential users, both governments and stakeholders. For developing countries, the tool would also be of value. It can be used to train industry and government at the same time used to encourage discussion of risk management.
- The tool will help countries that have targets or market demands, to explore which interventions could be applied.
- The tool might help with trade situations by providing a common framework.
- The tool will be useful for ranking the effectiveness of interventions.
- The tool will be useful for exploring the combining effects of interventions.
- A model is never complete as is it always a simplification that uses science, assumptions and expert opinions, but it is the best that can be provided to assist management decisions. Countries cannot do experiments with all interventions and so models are useful to help evaluate interventions.
- The model captures the best consensus knowledge on the processes and the interventions.

Next steps:

- A prototype tool will be delivered to the CCFH working group through the JEMRA process.
- The current version of the prototype tool will be expanded to start at the entry to slaughter and include all processing steps described in the Codex draft guidelines. It will allow for the hazard-based controls agreed upon in the CCFH document and other hazard-based controls compatible with the model to be compared for their impact on relative risk reduction.
- The modellers need to consider
  - how to model microbiological effects that may occur at each step (e.g. cross-contamination, growth, and inactivation);
  - how to model synergistic, antagonistic and reduced effectiveness of multiple interventions; and
  - can an effective model for *Salmonella* be developed using only prevalence data?

- The prototype requires inputs for initial carcass-level contamination (Log cfu/carcass); between-flock prevalence; and within-flock prevalence. The modellers will not provide guidance on determining those inputs from sample data.
- The prototype should provide estimated default values for microbiological effects (e.g. Log reduction; cross-contamination during scalding) for the prototype to assist the evaluation of the model.
- Evaluation of the scientific data of baseline values and other interventions not currently included as hazard-based controls should be determined by subject-matter experts, and should not be the responsibility of the modellers.
- Model development will require interaction with risk managers and subsequent peer review.

7. Summarized considerations of CCFH request

In response to the request made by the CCFH to FAO/WHO, this chapter summarizes considerations agreed on by the invited experts during the Joint FAO/WHO Technical Meeting on *Salmonella* and *Campylobacter* in chicken meat.

Independent assessment and review of available scientific information on control measures

- Relevant literature was reviewed in Chapter 3. The information received as a response to the call for data preceding the Technical Meeting was of critical value for this report, with additional references provided by the experts attending the meeting.

Evaluate quantitative aspects of hazards reduction in terms of prevalence and concentration (specific interventions)

- The Experts evaluated and commented on the interventions identified in the Codex draft Guidelines. In Chapter 4, more interventions were added where data were available. These should not be considered as standalone interventions, and not all of the mentioned interventions will be effective for both pathogens.

Primary production

- The Experts considered the control measures mentioned in the primary production part of the production chain to be a part of GHP. Additional measures were added, but the group emphasized that the impact of these must be further investigated in order to quantify their effect.

Additional measures

- Increased pest control.
- Treatment of drinking water.
- Sanitation of eggs.
- Biosecurity measures.
- Culling of *Salmonella*-positive flocks.
- Heat treatment of feed.
- Vaccination.
- Probiotics.
- Competitive exclusion (CE).
- Feed and water additives.
- Bacteriocins.
- Bacteriophages.
- Negative air ionization.
- UV irradiation of hatching eggs.
- Scheduled slaughter.

Processing

The following measures were proposed as additional interventions to the CCFH document:

- Use of ASC (acidified sodium chlorite) in On-line reprocessing (OLR).

- Air chilling as a measure to reduce carcass temperature.*
- Forced air chilling (Blast chilling).*
- Crust freezing.
- High oxygen concentration during chilled storage.

NOTE: * Effective for *Campylobacter* due to drying, but not effective for *Salmonella* reduction.

Distribution and Preparation

- No additional hazard reducing measures were mentioned during the Technical Meeting, but the Experts stated that further studies were needed in order to determine the effect of heat treatment and home cooking practices.
- Some specific interventions could not be executed in all regions due to legislation differences. With regard to this, see Appendix concerning washing with water and use of chemical additives.

Evaluate likely outcomes in terms of hazard reductions in the commercial setting

- The outcomes of the specific interventions have been mentioned in regard to their scientific validity and their quantitative effect on level of contamination and prevalence. The repetition of these can be found as Chapter 5, above.

Assess the feasibility of developing a Web-based risk-management decision-support tool

- The Web-based risk-management tool was discussed by the Experts, and was found to be feasible. A subgroup was formed to help the developers of the Web-based tool regarding the limitations and the modelling, and aspects of developing this prototype tool were discussed. The Experts agreed on the terms described in Chapter 6. The subgroup was to work with the tool developers on the production of the prototype Web-based tool, and this work was to be presented at the next CCFH meeting.

Develop a framework and identify data needs for the Web-based risk-management decision-support tool

- Prior to the Technical Meeting, a subgroup of experts was invited to participate in a Web discussion forum set up by the JEMRA Secretariat. This forum was used prior to the meeting to discuss both feasibility and the advantages and limitations of such a tool. During the Technical Meeting this subgroup of experts continued their work on the terms of development. After the decision in plenum that the prototype tool was found to be feasible, this subgroup continued their work on the development of the model and the Web tool. The electronic discussion forum will remain one possible way of communication, but e-mail will also be used as a means of communication. The data needs to develop a prototype Web-based tool have been described in Section 4.4, above.

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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.

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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.

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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.

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