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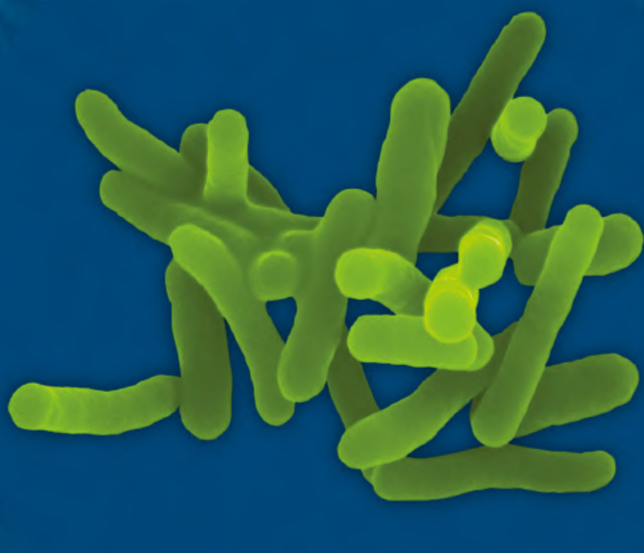
Measures for the control of *Campylobacter* spp. in chicken meat

Meeting report



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MICROBIOLOGICAL RISK
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Measures for the control of *Campylobacter* spp. in chicken meat

Meeting report

Food and Agriculture Organization of the United Nations
World Health Organization

Rome, 2024

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The preparatory work and expert meeting convened to prepare this report was coordinated by the Secretariat of the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA).

Abbreviations

CCFH	Codex Committee on Food Hygiene
CFU	Colony forming unit
DNA	deoxyribonucleic acid
FAO	Food and Agriculture Organization of the United Nations
GHP	good hygiene practices
HACCP	Hazard Analysis and Critical Control Points
JEMRA	Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment
QMRA	quantitative microbial risk assessment
WHO	World Health Organization
WOAH	World Organisation for Animal Health

Declaration of interests

All participants completed a Declaration of Interests form in advance of the meeting. All experts were not considered by FAO and WHO to have declared any interest that may be perceived as a potential conflict with regard to the objectives of the meeting.

All the declarations, together with any updates, were made known and available to all the participants at the beginning of the meeting.

All the experts participated in their individual capacities and not as representatives of their countries, governments, or organizations.

Executive summary

Scope and objectives

In response to a request from the 52nd Session of the Codex Committee on Food Hygiene (CCFH), the Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment (JEMRA) convened a meeting in Rome, Italy from 6 to 10 February 2023, to collate and assess the most recent scientific information relevant to the control of thermotolerant *Campylobacter* species *C. jejuni* and *C. coli* (hereafter *Campylobacter*) in broiler production and chicken meat, including a review of the Codex *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat* (CXG 78-2011).[1]

The scope was focused on aspects of broiler primary production from the point of chick placement into production establishments to consumer handling.

The objectives were to identify and assess control measures for *Campylobacter* in the broiler production chain. The expert committee reviewed the available data on *Campylobacter* control including scientific literature published from 2008 to October 2022 and data submitted in response to a call for data for this meeting. The experts: 1) determined the quality and quantity of evidence of control measures for *Campylobacter,* 2) evaluated the impact of measures to control *Campylobacter* in the broiler production chain, 3) determined which hazard-based interventions pertained specifically to *Campylobacter* and which were general to the control of foodborne pathogens in the pre- and post-harvest broiler production chain, and 4) reviewed and recommended revisions to the *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat* (CXG 78-2011), paragraphs 1 to 115, based on the currently available scientific evidence (Annex 3).

Control measure evaluation began at the time of chick placement since there is currently no evidence that parent flocks or hatchery practices contribute to the colonization of broiler chicks. The available literature on interventions was predominantly based on laboratory and pilot studies, with few commercial scale applications; therefore, limited conclusions could be reached. The experts recommend the use of a combination of multiple interventions (multihurdle

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1 FAO and WHO. 2011. Codex *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat* (CXG 78-2011). Rome. https://www.fao.org/fao-who-codexalimentarius/sh-proxy/de/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B78-2011%252FCXG_078e.pdf

approach) suitable to production and processing stages to lower *Campylobacter* contamination on chicken meat.

Conclusions

Several interventions were identified through primary production to post-processing stages. The expert consultation concluded the following in each stage of production:

Assessment of primary production interventions for the control of *Campylobacter*

Biosecurity and management approaches

- Using strict biosecurity measures (hygienic practices and sanitation) can enhance the control of *Campylobacter* in broiler flocks.
- Risk factors for *Campylobacter* contamination at primary production establishments, such as partial depopulation, litter management, down period length, proximity to other livestock and slaughter age can help guide intervention strategies.

Vaccination-based approaches

- Currently, there are no commercial vaccines for *Campylobacter* readily available for any stage of primary production, and vaccination studies were limited to *C. jejuni* only.
- Several potential vaccine candidates are in the proof-of-concept phase but cannot be considered yet as an intervention.
- Some vaccines induced a cellular or humoral response in the chicken host, but this did not always translate to reduced caecal colonization by *Campylobacter* in pilot studies.

Bacteriophage-based approaches

- There are currently no commercial products available for use in primary production.
- The effects of phage therapy may be transitory and prone to resistance.

Feed and water additives

Organic acids

- In feed, short- and medium-chain fatty acids, and in particular, caprylic acid, show promise as feed additives in reducing *Campylobacter* in pilot studies.

- In drinking water, organic acids reduced *Campylobacter* in caecal/faecal specimens at the end of the primary production period; however, the effects were not sustained to the end of production in pilot studies.

Probiotics

- In feed, there is inconsistent evidence on the efficacy of probiotics as an intervention for reducing *Campylobacter* in broilers at primary production level.

Plant-based additives

- In feed, the efficacy of some plant-based molecules in *in vivo* pilot studies showed limited reduction of *Campylobacte*r in caecal/faecal specimens at the end of the primary production period.

Assessment of processing interventions for the control of *Campylobacter*

- Good hygienic practices (GHP) during processing are important in minimizing *Campylobacter* contamination on meat.
- The effectiveness of interventions during processing is dependent upon the incoming flock prevalence and concentration of *Campylobacter* in the gastrointestinal tract and on the bird.
- The impact of processing practices can be enhanced by a combination of a multihurdle approach, processing effects, physical and/or chemical interventions.

Processing effects

- Logistic slaughter scheduling can reduce *Campylobacte*r cross-contamination.
- Qualitative and quantitative targets for *Campylobacter* may be used to optimize process control.
- Scalding reduces the carcass surface concentration and prevalence of *Campylobacter*, The result depends on the temperature, and dilution effect.
- Defeathering and evisceration may increase both prevalence and concentration of *Campylobacter* on carcasses.
- Immersion chilling can reduce (dilute) the carcass concentration of *Campylobacter*; however, this is dependent on the initial *Campylobacter* load on the incoming birds.
- In combination with processing aids, immersion chilling may reduce the carcass prevalence of *Campylobacter*.

- Air chilling may reduce concentration of *Campylobacter*, but the efficacy of air chilling in reducing prevalence of *Campylobacter* when used without other processing aids is inconclusive.

Physical

- Irradiation is effective at eliminating *Campylobacter* on meat.
- Freezing meat reduces the concentration of *Campylobacter.*
- Steam, ultrasonication, high-intensity light pulse, visible light, UV-C and other technologies have shown promise either at the laboratory or pilot scale, but their impact is unknown at commercial scale.

Chemical

- Processing aids such as chlorine derivatives, peroxyacetic acids, and organic acids added to water used for washing and/or dipping may reduce *Campylobacter* on carcasses.
- Some marination ingredients have shown reductions in *Campylobacter* on meat.

Post-processing interventions for the control of *Campylobacter*

- Thorough cooking is effective at eliminating *Campylobacter* on meat.
- The application of GHPs is important in reducing *Campylobacter* on meat.
- Freezing meat reduces the concentration of *Campylobacter.*
- Some marination ingredients have shown reductions in *Campylobacter* on meat.

Available evidence for the reduction of *Campylobacter* was primarily focused on *C. jejuni* and *C. coli.* Interventions aimed at foodborne pathogens such as irradiation or thorough cooking are effective in eliminating *Campylobacter* on meat. Hazard-based interventions, good agriculture practices and hygienic practices for the general control of foodborne pathogens may be effective for the reduction of *Campylobacter*. There are no interventions that **specifically** control *Campylobacter* on meat.

The experts recognize further data gaps exist and that new technologies may offer promising approaches to reducing *Campylobacter* on chicken meat. Further global changes to the industry, the growth of global populations, climate change, and increased demand for animal protein in specific regions will guide the need for further control measure assessments.

1 Introduction

1.1 REQUEST FROM CODEX

Campylobacteriosis is among the most frequently reported foodborne diseases worldwide (Havelaar *et al.*, 2015; Tack *et al.*, 2019). In response to the requests from Codex for scientific advice, FAO and WHO have undertaken risk assessments of foodborne pathogens in various foods since 1999 (FAO and WHO, 1999). In the past, the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA) have conducted risk assessments of *Campylobacter* spp. in broiler chickens (FAO and WHO, 2008, 2009b) and evaluated intervention measures being used in the production of chicken meat (FAO and WHO, 2009a).

In its report on the global burden of foodborne disease, the World Health Organization (WHO) estimated that in 2010 foodborne *Campylobacter* spp. caused more than 95 million illnesses, 21 374 deaths, and nearly 2 142 000 DALYs (Havelaar *et al.*, 2015). While numerous potential vehicles of transmission exist, commercial chicken meat has been identified as one of the most important food transmission vehicles for *Campylobacter* spp.

At its 52nd session in 2022, the Codex Committee on Food Hygiene (CCFH) requested that JEMRA collate relevant scientific information on *Salmonella* and *Campylobacter* in chicken meat in preparation for a potential update of the existing *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat* (CXG 78-2011).

To meet the request of the CCFH, FAO and WHO convened this expert meeting on the pre- and postharvest control of *Campylobacter* spp. in broiler chicken meat from 6 to 10 February 2023 at FAO headquarters, Rome. The goal of the meeting was to gather and evaluate recent data, evidence and scientific opinions on the topic. The output aim was to provide expert opinion on intervention strategies for the control of *Campylobacter* in pre- and post-production chicken meat.

1.2 CONSUMPTION AND PRODUCTION

1.2.1 Global consumption of chicken meat

According to FAO, the global poultry population was 27.9 billion head in 2019, with chickens accounting for 93 percent. Poultry refers to all domesticated birds raised for meat, eggs or feathers, while chicken meat (broiler chicken) production includes species of chickens raised for meat consumption. The number of chickens worldwide has more than doubled since 1990 with poultry accounting for more than 40 percent of all meat produced for human consumption (OECD and FAO, 2021).

The Agricultural Outlook 2021–2030 suggests that the global meat supply will continue to expand over the next projection period reaching 374 million tons by 2030 (OECD and FAO, 2021). The overall global expansion of meat production is driven by production in China, the Americas and Africa. China alone is expected to account for the greatest increase in meat production followed by Brazil and the United States of America. The global consumption of meat protein from any animal species is also projected to increase by 14 percent by 2030, from the 2018–2020 projections (OECD and FAO, 2021). Factors influencing meat consumption include population growth and demographics, urbanization, income, meat prices, cultural norms, environmental aspects, animal welfare and people's personal health.

Chicken meat production and availability are expected to grow by 18 percent globally due to the relative affordability for middle-income consumers. International trade has also helped improve access to chicken products worldwide and increasingly so in Asia and the Near East where demand has outpaced production (OECD and FAO, 2021). Reasons for broiler chicken production growth are multifactorial and include: 1) the short birth to slaughter time compared to other meat-producing animals, 2) the ability for lower income families to gain a higher quality of life by raising birds in small-farm holdings, and 3) the overall increase in chicken meat demand as a result of population growth and growth in income levels.

As a result of the continued growth of the broiler chicken market, it is necessary to review pre- and post-production practices from hatchlings to final chicken meat products to help ensure the safety and quality of this important protein source for the world's population.

1.2.2 Intensification of broiler chicken production to meet growing needs

In many high-income countries, broiler chicken production has been intensified by increasing farm and flock sizes, developing rapidly growing chicken breeds, creating a global supply of parental stocks, and investing in optimal feeding (Li *et al.,* 2021; Jeni *et al.,* 2021). Typically, commercial farms receive day-old chicks, raise them to a designated age of slaughter and transport the whole flock to an abattoir. In many low- and middle-income countries, small to medium-size enterprises, backyard farming and live-bird markets dominate domestic broiler chicken meat production (Delabouglise *et al.,* 2019; Wong *et al.,* 2017). Biosecurity is a challenge for the entire chicken production industry but especially so for enterprises with birds raised in backyard systems and sold at live-bird markets. These less intensive chicken production systems rarely apply strict biosecurity and good husbandry practices. When farms are transitioning to increased intensification, the education and motivation of farmers in management and biosecurity is crucial.

In the commercial systems, market forces such as an increased demand for chicken meat products, demand for organically raised products, animal welfare considerations, and housing requirements all need to be taken into account when designing *Campylobacter* spp. control strategies. Such control strategies should be designed, implemented and monitored with consideration to specific production conditions.

1.3 SCOPE OF THIS REPORT

The purpose of the experts meeting was to collect, review and discuss relevant measures for control of *Campylobacte*r spp. in broiler chicken production, from the primary production stage to consumption.

The scope of the meeting included, but was not limited to, aspects of primary broiler chicken production, processing, distribution, product handling, preparation, retail and consumption of chicken meat. Emphasis was placed on the identification and evaluation of control measures to reduce campylobacteriosis associated with consumption of chicken meat, taking into consideration the effectiveness and practicalities of measures.

The objectives of this meeting were:

- To review publicly available literature and guidelines from competent authorities and industry associations (e.g. compliance guidelines, code of practices, and so on) to assess the current state of knowledge in controlling *Campylobacter* spp. in chicken meat.

- To review mitigation/intervention measures being used at different points along the food chain and assess their effectiveness at reducing *Campylobacter* spp. in chicken meat.

1.4 LITERATURE SURVEY

A review of the available scientific literature targeting changes in knowledge since 2008 was used to develop a bibliography. Scientific articles were selected from two databases (*Web of Science* and *PubMed*), and as there was a need to consider studies published in languages other than English, data from member countries and expert opinions were also relied upon.

The records from *Web of Science* (n = 2498) and *PubMed* (n = 1964) were added into *Distiller*. The function "Duplication Detection" was used by comparing the Title, Author and Abstract. A total of 915 duplicate articles were found. The "Smart Quarantine" feature in *Distiller* was used to remove these duplicates resulting in 3547 (2498 + 1964 – 915) publications which were used to establish the working database for the meeting. The search was carried out on 23 October 2022. The keywords used for searching the literature are detailed in Annex 1.

The database was further refined using a two-step process for the relevance screening and confirmation of the 3547 articles, which were prepared in a dataset for the experts to review. The details of this procedure were presented to the experts for their further review and are included in Annex 2.

The experts had a further review of these publications during the meeting, to finalize whether the literature was considered control measures or not. They provided recommendations and conclusions based on the included scientific literature as well as their expert opinions. Literature with applicability to a commercial setting was considered. The final reviewed papers, not necessarily cited, are listed in the bibliography at the end of the report.

2

Control measures

2.1 CONTROLS DURING PRIMARY PRODUCTION

2.1.1 Biosecurity, management and awareness of *Campylobacter* prevalence addressed in approaches to control *Campylobacter* spp.

To complete the assessment of control measures during primary production, experts reviewed 45 papers from the literature survey (listed in Annex 4.1.1). The following sections highlight the findings.

- **Biosecurity**

Biosecurity measures appropriate for the control of *Campylobacter* cover multiple factors, including good production practices such as strict biosecurity and sanitation (Hansson *et al.,* 2010; Henry *et al.,* 2011; Jonsson *et al.,* 2012; Hasan *et al.,* 2020; Sandberg *et al.,* 2017; Hertogs *et al.,* 2021; Schweitzer *et al.,* 2021; Golden and Mishra, 2020; Georgiev, Beauvais and Guitian, 2017). These measures remain the single most effective tool to reduce *Campylobacter* contamination at all stages of primary production and should form the foundation of any intervention strategy.

- **Management**

The partial depopulation (thinning) has been found to have an opposite effect with an increased risk of breaching biosecurity measures and is evidenced to be a contributing factor to *Campylobacter* contamination of broiler chicken flocks (Crotta, Georgiev and Guitian, 2016; EFSA, 2020; van Wagenberg *et al.,* 2016;

Smith *et al.,* 2016; Allen *et al*., 2008; Higham *et al*., 2018; Georgiev, Beauvais and Guitian, 2017). Estimates of relative risk reductions from discontinued thinning range from 2–33 percent (Crotta, Georgiev and Guitian, 2016; Georgiev, Beauvais and Guitian, 2017; van Wagenberg *et al.,* 2016). Alternately, adequate cleaning and disinfection practices, as well as a "resting period", to decontaminate housing between flocks have been associated with lower *Campylobacter* contamination of subsequent flocks (Zbrun *et al*., 2021; Bailey *et al.,* 2022; Reichelt *et al.,* 2022; Agunos *et al.,* 2014).

- **Awareness of *Campylobacter* prevalence in primary production**

Campylobacter prevalence amongst broiler flocks varies by season and is dependent on the region. Temperature and humidity in countries with both temperate and warm climates has been associated with changes in prevalence (Urdaneta *et al.,* 2023; Guerin *et al.,* 2008; Chowdhury *et al*., 2013; Iannetti *et al.,* 2020; Sindiyo *et al*., 2018; Seman, Gregova and Korin, 2020; Higham *et al.,* 2018; Wanja *et al*., 2022). In addition, ventilation type was associated with *Campylobacter* prevalence in a Spanish study (Urdaneta *et al*., 2023). Older birds are more likely to be infected by *Campylobacter*, though evidence regarding prevalence of *Campylobacter* amongst conventional *versus* organic flocks, as well as breed, flock size and stocking density was mixed (Iannetti *et al*., 2020; Rawson, Dawkins and Bonsall, 2019; Lassen *et al*., 2022; McKenna *et al*., 2020; Seman, Gregova and Korim, 2020; Golden and Mishra, 2020; Higham *et al*., 2018; Borck Høg *et al.,* 2016; Williams *et al.,* 2013; Russell *et al.,* 2021; Babacan *et al.,* 2020; Griekspoor *et al*., 2013; van Wagenberg *et al.,* 2016).

There is a limited number of studies investigating the effect of conventional *versus* extensive and antibiotic-free production systems on *Campylobacter* species presence, antibiotic resistance and animal welfare (Hansson *et al.,* 2010; Iannetti *et al*., 2020; Babacan *et al*., 2020; Bailey *et al.,* 2019; Bull *et al.,* 2008; El-Shibiny, Connerton, P.L. and Connerton, I.F., 2005). Of those studies reviewed, five reported lower *Campylobacter* prevalence in flocks with higher welfare scores, amongst both conventional and extensive flocks (Bull *et al.,* 2008; Williams *et al.,* 2013; Colles *et al.,* 2016; Ianetti et al., 2020; Di Marcantonio *et al*., 2022). Older birds raised in extensive production systems were more frequently colonized by *C. coli* (El-Shibiny, Connerton, P.L. and Connerton, I.F., 2005; Babacan *et al*., 2020). Organically raised flocks were associated with lower levels of Antimicrobial Resistance (AMR) in primary production (Luangtongkum *et al.,* 2006; Bailey *et al.,* 2019; Hansson *et al.,* 2021). More research is needed to understand complex interactions between rearing system, chicken age/breed and welfare in determining *Campylobacter* prevalence and risk to human health (Ianetti *et al.,* 2020; Di Marcantonio *et al.,* 2022).

- **Sources of *Campylobacter* contamination into primary production settings and management interventions**

The age of a broiler house, number of houses on the property, house layout including ante-room(s), water sources and drinker type, proximity to other farms, livestock and other animals were all identified as risk factors for contaminating the birds by various studies (Torralbo *et al.,* 2014; Borck Høg *et al.,* 2016; Torralbo *et al.,* 2014; van Wagenberg *et al.,* 2016; Hertogs *et al.,* 2021). Genomic typing data indicates some *Campylobacter* lineages are associated with specific livestock species (including broiler chickens) and wild birds, with little overlap between the *Campylobacter* lineage types (Colles *et al*., 2008; De Haan *et al.,* 2010; Griekspoor *et al.,* 2013; Sheppard *et al*., 2010). *Campylobacter* prevalence in wild birds appears to be associated with feeding guild, with *Campylobacter* genotype overriding geographic signals (Griekspoor *et al.,* 2013; Hald *et al*., 2016). Transport was assessed by a few studies. The effects of transport on *Campylobacter* presence in broiler flocks were mixed with no clear indication of an increase or decrease (Mendes *et al.,* 2020; Sevilla-Navarro *et al*., 2020).

The impact of litter type on *Campylobacter* colonization of broiler flocks is of interest. Some evidence suggests a high incidence of foot lesions derived from wet litter conditions, which may in turn be predictive of higher *Campylobacter* contamination load in the flock (Williams *et al.,* 2013; Alpigiani *et al.,* 2017). Litter quality is included in the internationally recognized WelfareQuality® protocol and was considered a risk factor in some of the previously mentioned studies investigating links between flock welfare and *Campylobacter* prevalence (Ianetti *et al.,* 2016; Di Marcantonio *et al.,* 2022). The practice of re-use and treatment of litter between flocks varies globally, however no recommendations for best practice can be made at the current time (Rothrock *et al.,* 2008; Bailey *et al.,* 2022).

There was evidence from Denmark and Iceland that fly screens were associated with lower prevalence of *Campylobacter* in flocks if high level of biosecurity measures were already in place (Tustin *et al.,* 2010); however, no further evidence is available since the original publication.

There is sparse information regarding the role of hatcheries and breeder flocks as sources of transmission of *Campylobacter* to primary production flocks. Vertical transmission of *Campylobacter* through eggs is largely rejected by the scientific community, though there are occasional reports of *Campylobacter* detected in the reproductive tract of breeding birds (Battersby *et al.,* 2016). Broiler flocks are usually colonized with different strains than the parent flock (Al Hakeem *et al.,* 2022). *Campylobacter* DNA has been detected from commercial broiler chicks less than 8 days old, suggesting that early routes of contamination might have an impact in some instances, however viable culture could not be recovered (Colles *et al.,* 2021). Vertical transmission remains a topic of investigation for some studies (Lu *et al.*, 2021). To date, quality evidence to support this as a transmission route is lacking.

Many risk factors contribute to *Campylobacter* spp. colonization of broiler flocks, indicating the difficulties in maintaining effective countermeasures against its entry into the broiler environment (Natsos *et al*., 2020). Studies have indicated that horizontal transmission from environmental sources is the most significant cause of dissemination into primary production flocks. Newer precision based genotyping studies will continue to provide further evidence to understand and refine all forms of transmission routes.

It is challenging to determine the extent of impact that farm personnel or professionals visiting farms as a control measure. One study concluded disinfection of broiler houses by unskilled personnel was a risk factor for *Campylobacter* colonization (Natsos *et al.,* 2020) whereas another study found no effect on *Campylobacter* prevalence (Näther *et al.* 2009). In a UK specific study, financial incentive for farmers resulted in farmers producing a greater number of flocks with lower levels of *Campylobacter* contamination (Higham *et al*., 2018). In a US-based questionnaire study of broiler industry stakeholders, it was concluded that many survey participants were unfamiliar with *Campylobacter* specific risk factors (Hwang and Singer, 2020). Without further assessment, the impact of personnel on the introduction and levels of *Campylobacter* contamination is inconclusive.

Conclusions

Strict biosecurity and sanitation measures are a key requirement by which to control *Campylobacter* and should form the foundation for any on-farm based interventions. There is some evidence that management practices can influence *Campylobacter* population; however, other impact factors such as seasonal *Campylobacter* population variation in specific geographical regions, breed of birds, and age of birds at slaughter cannot be easily controlled by management practices alone. Transmission route analyses will be helped by tools such as rapid molecular assays and genomic sequencing that will in turn contribute evidence used to guide future intervention recommendations and refinement of biosecurity measures. The genomic profiling of *Campylobacter* strain lineages in broiler chicken production will also enable assessment of impact when studying interactions between the chickens and environmental microbiomes.

Important considerations for on-farm assessments include:

- whether it is necessary to partially depopulate ("thin") flocks;
- down time between flocks;
- litter management and welfare of flocks;
- housing, including age/ability to disinfect, ventilation and layout (ante-room[s]); and
- training and compliance of staff and visitors on strict biosecurity measures.

2.1.2 Vaccine- and bacteriophage-based approaches for the control of *Campylobacter* spp.

Vaccines are agents or portions of a bacterial cell that are used to prevent *Campylobacter* colonization in broiler birds and to decrease the potential for *Campylobacter* transmission to meat products. Vaccines against *Campylobacter* have been investigated over many years. A number of different vaccine types that have been investigated include attenuated, subunit, inactivated, conjugate, DNA, vector and recombinant vaccines. While efforts in developing effective *Campylobacter* vaccines have been made, there is currently no single vaccine approved for use in broiler bird production.

Bacteriophages, the viruses that specifically infect target bacteria, thereby killing the host bacterial cell, have also been investigated for their potential to control *Campylobacter*. The field of *Campylobacter* specific bacteriophages (phages) is relatively limited with very few published data available.

2.1.2.1 Vaccination-based approaches to control *Campylobacter*

The experts reviewed 23 papers related to vaccine studies for *Campylobacter* control with 14 directly applicable to the current review (Annex 4.1.2). The following sections highlight evidence pertaining to vaccination as an approach to *Campylobacter* control in broiler birds.

- **Quality of evidence**

Currently, there are no commercial vaccines for *Campylobacter* readily available. Potential candidates (e.g. reverse vaccinology approach) are on the horizon; however, most trials at present are in a "proof-of-concept phase" or have reported findings from laboratory or pilot-scale level studies. The quality of the papers was satisfactory in terms of methodology and study design that incorporate controls and challenge groups. Assessed trial studies also had a satisfactory level of statistical analysis to determine measurable effects. A range of vaccine methods and types (glycans, inserted proteins, flagellin, subunit, *in ovo*, and live attenuated) were included in the literature assessed (Layton *et al.*, 2011; Jeon *et al.*, 2022;

Gloanec *et al.,* 2022). Some approaches included an alternative vector expressing *Campylobacter* proteins to deliver antigens to the poultry host, e.g. *Salmonella* (Buckley *et al.,* 2010; Sahin *et al.,* 2015) and *Eimeria* (Clark *et al.,* 2012), yet conclusions could not be reached on the approaches as control measures.

The literature reviewed was in the proof-of-concept stage, with no papers indicating any commercial-level trials or follow-up studies, demonstrating the infancy of the field of vaccine development for *Campylobacter* control in broilers.

- **The measure of effectiveness**

The measure of effectiveness to control *Campylobacter* was reported as log level reductions in the ceca or gut (quantitative) or number of birds positive following vaccination and challenge (prevalence). Reported vaccine effects varied from no reductions of *Campylobacter* noted (Meunier *et al.,* 2018; Mauri *et al.,* 2021; Vandeputte *et al.,* 2019) to low level reductions of 1–2 logs or less (Łaniewski *et al.,* 2014; Buckley *et al.,* 2010; Chintoan-Uta, Cassady-Cain and Stevens, 2016; Gloanec *et al.,* 2022), while a few studies reported high level reductions (up to 4 logs) (Layton *et al.,* 2011; Cui *et al.* 2022; Nothaft *et al.,* 2021).

There was evidence that some of the candidate vaccines appear to be promising; however, further research is warranted to examine the candidates on a larger scale, e.g. commercial farms (Cui *et al.* 2022; Layton *et al.,* 2011). There is also limited evidence as to the practicality of vaccine production for these candidates on a larger scale or as to wider industry vaccination strategy.

Some candidate vaccines were found to induce cellular or humoral response in the chicken host, meaning that the host immune response recognized *Campylobacter,* but in terms of elimination of *Campylobacter* from the chicken host this did not translate to stable (rather than transient) caecal colonization or reductions levels (> 2 logs) (Radomska *et al.,* 2016; Cui *et al.* 2022; Gloanec *et al.,* 2022), suggesting that the effects were not consistent and unlikely to be permanent.

Most studies assessed used a homologous challenge approach (i.e. single strain, typically a *C. jejuni*) with no studies using a heterologous challenge (i.e. using diverse *Campylobacter* strains). No studies to date investigated the ability of a vaccine candidate to provide cross protection against diverse *Campylobacter* species. Additional studies are warranted to understand the levels and types of cross protection provided by potential vaccine candidates.

- **Scalability or applicability (practicability)**

Further studies are required for extensive scale application of candidate vaccines, i.e. farm-level production. All studies reviewed were currently at the lab or pilot-scale (research farm) level only with no indication for larger pilot-scale studies such as commercial farm or production-level studies and no indication of commercial vaccine trials. Such large-scale trials will be necessary to assess the scalability and potential impact of candidate vaccines for full implementation in broiler production.

- **Geographical representation of the studies**

All vaccine candidate studies were conducted only in high-income countries or regions of the world; therefore, the translation of these studies to underdeveloped regions will warrant additional studies in specific regions to assess efficacy and practicality.

Conclusion

Vaccines for *Campylobacter* control continues to be an emerging field and warrants further investigation and investment to take proof-of-concept studies to commercial trial phases.

2.1.2.2 Bacteriophage-based approaches for the control of *Campylobacter* spp.

The experts reviewed ten papers (Annex 4.1.2) on the use of bacteriophages as an intervention measure for *Campylobacter* colonization in broilers.

- **Quality of evidence**

There are currently no commercial products available for use in primary production. The bacteriophages used in the studies reviewed varied among studies, with some well-characterized bacteriophages. Of the six experimental studies reviewed, all had treatment groups and control groups, allowing assessment of the effect of phage treatment in a statistically sound manner.

- **The measure of effectiveness**

Some studies used a single phage strain (Fischer *et al.,* 2013; Furuta *et al.,* 2017; El-Shibiny *et al.,* 2009), whereas others used multiple (a cocktail of) phage strains (Carvalho *et al.,* 2010; Kittler *et al.,* 2013; Richards, Connerton, P.L. and Connerton, I.F., 2019; Hammerl *et al.,* 2014; D'Angelantonio *et al.,* 2021; Chinivasagam *et al.,* 2020). Treatment was typically via drinking water or gavage. The effects of phage treatment on reductions of *Campylobacter* ranged from a 1 log to a > 3 log reduction of *Campylobacter* colonization in faecal droppings or caecal contents after necropsy. The effect was most evident a few days post treatment; however, *Campylobacter* colonization levels increased over time post treatment. In some studies, *Campylobacter* strains were screened for resistance to phages after treatment. Resistance was reported; however, these strains did not overgrow susceptible strains. In some studies, there was considerable variation between groups/barns used in the study. A reduction of 3 log is considered relevant for public health, based on a risk assessment by Rosenquist *et al.* (2003).

Over the last decade or more, there has not appeared to be any technical progress in the experimental approaches used for the application of phages for *Campylobacter* control. Studies do not address the variability between *Campylobacter* strains and the applicability or practicality of phages for field or commercial purposes.

- **Scalability or applicability (practicality) and geographical representation studies**

Except for two studies performed on-farm (Australia and Germany) (Chinivasagam *et al.,* 2020; Kittler *et al.,* 2013) with naturally colonized flocks, studies were performed in experimental, controlled settings. Applicability could therefore not be assessed for commercial settings. One field study was conducted in Australia (Chinivasagam *et al.,* 2020); all other studies were performed in Europe, and therefore there is no indication of how bacteriophage approaches would be applicable in other regions.

Phages are variable depending on the strain type and vary in the level of activity. Additionally, the potential for *Campylobacter* to develop resistance to the phage is considerable. Bacteriophage approaches to control *Campylobacter* are not clear. In conclusion, no recommendation on the use of bacteriophages can be made at this time.

2.1.3 Feed and drinking water additives approaches for the control of *Campylobacter* spp.

Feed and water additives are chemical or biological supplements that can be added to water or feed formulations. Additives as a control measure of *Campylobacter* have been assessed for effectiveness and scalability. In-feed and in-water additives applied at the primary stage of production (farms) were reviewed.

- **Quality of evidence**

The experts reviewed a total of 89 papers by first screening and then further subdividing them into relevant subheadings of organic acids, probiotics and plant-based additives. The quality of evidence varied with most of the available literature containing laboratory and pilot stage studies. Although some studies have provided promising results as to the effects of organic acid additives, extrapolation of the evidence to the commercial scale of production systems could not readily be made.

- **Organic acids: measure of effectiveness**

Seven papers reported on the impacts of medium chain fatty acids (caprylic acid) supplementation in feed. The supplementation of medium chain fatty acids in feed is considered a promising tool for the reduction of *Campylobacter* colonization in commercial broiler flocks (Van Gerwe *et al*., 2010). Therapeutic supplementation of caprylic acid at 0.7 percent in the feed for 3 or 7 days before slaughter showed a consistent 3 to 4 log reduction in caecal *C. jejuni* counts in market-aged broiler chickens (De Los Santos *et al.*, 2010). The results of this study indicate that caprylic acid's ability to reduce *Campylobacter* does not appear to be due to changes in caecal microflora or a decrease in intestinal pH. It is hypothesized that caprylic acid may compromise the outer membrane determinants in *Campylobacter* which are needed for bacterial adaptation to host environment and colonization. It is also possible that caprylic acid has a direct inhibitory effect on the expression of virulence factors necessary for *C. jejuni* colonization in chicks.

The in-water supplementation of caprylic acid at various concentration levels did not reduce *Campylobacter* shedding due to the changes in adsorption and caprylic concentrations reaching the lower intestinal tract (Metcalf *et al.,* 2011). The addition of sorbic acid, benzoic acid, propionic acid, and acetic acid in drinking water reduced the *Campylobacter* shedding reaching a maximum 2 log reduction during the rearing period (Gharib Naseri, Rahimi and Khaki, 2012); however, the drinking water additive failed to diminish *Campylobacter* colonization in the intestinal colonic and caecal contents at the time of slaughter (Szott *et al.,* 2022). Therefore, the benefits of drinking water treatment to controlling *Campylobacter* shedding and transmission was not significantly evidenced and would need further investigation.

Other organic acid and medium chain fatty acids showed *in vitro* study reductions (Greene *et al.,* 2022); however, the efficacy in *in vivo* pilot and commercial scale studies were not performed, as there were negative bird performance effects in treatment groups. Ferric tyrosine added to the feed at 0.02, 0.05 and 0.20 g/kg can reduce *Campylobacter* in the ceca at 42 days up to 3 log (Currie *et al*., 2018), but other studies showed lower reductions (i.e. 2 log reduction) (Khattak *et al.,* 2018).

- **Probiotics: measure of effectiveness**

The use of in-feed probiotic additives as a measure to control *Campylobacter* in birds at the primary production level was addressed in 19 papers assessed by the experts. Probiotic bacteria are thought to reduce pathogenic bacteria (including *Campylobacter*) in the gut through competition for shared attachment sites in the mucosa (Lu and Walker, 2001) or through production of antimicrobial metabolites (Oelschlaeger, 2010; Neal-McKinney *et al.,* 2012). The overall lasting reduction effect by probiotic treatment on *Campylobacter* presence was inconsistent across the literature. Administration of feed additives at specific stages of growth demonstrated some reduction of *Campylobacter* presence at midgrowth stage (day 18–21) (Ghareeb *et al.,* 2012); however, those reductions were not sustained to the end of production. Some pilot studies demonstrated that administration of *Lactobacillus casei* overexpresses myosin-cross-reactive antigen (LC) in the feed and reduced *C. jejuni* colonization in the cecum, ileum and jejunum, by more than 1 log CFU/g when compared to the no-probiotic control group (Tabashsum *et al.,* 2020). The strain was able to generate bioactive compounds including conjugated linoleic acid. Commercial or large-scale trials would be required to demonstrate applicability to large-scale farming. The literature predominantly reported on *C. jejuni* strains. Probiotic administration did not demonstrate an effect in reducing *C. coli* levels in caeca (Mortada *et al.,* 2020).

- **Plant-based additives: measures of effectiveness**

Plant-based molecules added to feed and water vary in type, concentration of administration and timing of administration. Twenty-five papers addressed plant-based additives as a strategy for reducing *Campylobacter* within the lower gut of birds. Molecules such as *trans*-cinnamaldehyde, eugenol, carvacrol, and thymol demonstrated *Campylobacter* reduction of up to 4 logs *in vitro* (Kollanoor Johny *et al.,* 2010) but to a lower extent (approximately a 2 log reduction) *in vivo* (Allaoua *et al.,* 2022). In addition, other plant-molecules, such as glycyrrhiza glabra (licorice) extract, beta-resorcylic acid, and thymol were tested in pilot *in vivo* studies, showing limited efficacy in the reduction of *Campylobacter* in caecal/faecal counts (~1–2 log reduction) (Wagle *et al.,* 2017; Ibrahim *et al.,* 2020; Epps *et al.* 2015).

- **Other additives and combination of additives: measure of effectiveness**

In papers applying multiple strategies, it is difficult to assess the specific impact of individual components, and the overall effect cannot be attributed to the administration of an additive molecule. For example, up to 1 log CFU/g fewer *Campylobacter* were recovered from broilers administered either direct-fed *Bacillus* culture, prebiotic, refined functional carbohydrates (including mannooligosaccharides (MOS), b-glucans, and mannose), or symbiotic when compared to the untreated control group (Froebel *et al.,* 2020). Refined functional carbohydrates, including MOS, b-glucans and mannose, are important to the pathogen inhibiting functionality of prebiotics (Oyofo *et al.,* 1989; Spring *et al.,* 2000). These carbohydrates are thought to bind to bacterial surface adhesins thereby inactivating the bacteria's ability to infect the host (Fernandez *et al.,* 2002; Walker *et al.,* 2018).

Furthermore, the reported reduction effect of *Campylobacter* using a combination of in-feed additives (microencapsulated propionic, sorbic acids and pure botanicals) at different concentrations administered at various stages of growth resulted in a synergistic action between organic acids and pure botanicals (Grilli *et al.,* 2013). Greene *et al.* (2022) reported the anti-*Campylobacter* properties of nine compounds belonging to organic acids, medium chain fatty acids and essential oils in *in vitro* experiments; however, it was concluded that while the tested compounds are effective against *Campylobacter* in laboratory model studies, the negative effects on broiler performance metrics deem the approach ineligible for use *in vivo.*

Further large-scale *in vivo* studies are required to adequately evaluate the efficacy of a multi-additive approach to reducing *Campylobacter* in the lower gut of birds at the end stage of primary production.

The field of other natural additives is expanding, and further work is required to evaluate the impacts on *Campylobacter* reduction in experimental, pilot and large-scale commercial trials. Other additive candidates include whey powder, which when applied in feed, may affect the physico-chemical integrity of intestinal digesta and improve the balance of intestinal microbiota (Tsiouris *et al.,* 2020; Wilson *et al.,* 2018) However, the existing evidence showed that the effect on the reduction of *Campylobacter* in caecal contents was limited based on studies conducted under both experimental and field settings.

- **Scalability, applicability, and geographical representation**

The scalability and applicability of in-feed and in-water additives is limited at this time. Smaller scale *in vivo* studies were conducted in some investigations; however, large-scale commercial-level studies are required to assess the efficacy of interventions at scale.

Primary-source pilot studies were predominantly conducted in one region. Multiregional and commercial-scale studies were not identified in the assessed literature, limiting extrapolation of findings beyond the pilot study site.

Conclusions

The evidence for clear reductions to *Campylobacter* colonization in the lower gut of birds at various stages of primary production was inconsistent. The use of caprylic acid (in-feed) demonstrated promise in pilot studies, yet further commercial-scale evaluation is needed to assess broad-scale application. With the evidence available, probiotic and plant-based in-feed additives showed limited and inconsistent reductions to *Campylobacter* in pilot studies.

To fully assess additives as an intervention strategy at the primary production stage, important considerations for assessment are:

- fully addressing the start and end of the additive administration and timing of measured reduction levels;
- addressing whether measured reductions are calculated on naturally contaminated birds or challenged birds; and
- compulsorily measuring intervention impact at the end of the rearing cycle in commercial scale conditions to appropriately assess the true reduction of *Campylobacter.*

2.2 CONTROL MEASURES DURING PROCESSING

Experts reviewed 141 papers from the literature survey related to *Campylobacter* control during broiler processing. These papers include both primary studies and systematic reviews, listed in Annex 4.2.

In addition to control measures developed for the primary production stage, a range of processing steps and interventions during the primary and secondary processing stages have been developed to reduce *Campylobacter* contamination on/in broiler chicken carcasses and parts. Such intervention measures include general hygienic improvements, technological advancement in processing operations, and decontamination strategies applied throughout or at specific processing steps. In this section, the effectiveness of different processing steps and interventions to reduce the prevalence and/or concentration of *Campylobacter* were critically reviewed considering the quality of evidence, practicability of the evaluated measures, and the geographical representation.

- **Effectiveness of good hygiene practices**

Good hygienic practices (GHP) are important in minimizing *Campylobacter* contamination during processing. Once *Campylobacter* is introduced in the slaughter line, it can spread to the chicken meat, especially at the defeathering and evisceration steps (Cools *et al*., 2005). Some *Campylobacter* strains may also survive after cleaning and disinfection in a slaughter environment, thus persisting longer and becoming a source of cross-contamination over time (García-Sánchez *et al.*, 2017). The implementation and compliance of GHPs as well as following Hazard Analysis and Critical Control Points (HACCP) principles at the processing establishment is a systematic way to maintain cleanliness, control the presence and levels of *Campylobacter*, and minimize contamination during chicken processing. The rigorous implementation of systematic approaches can significantly enhance the integrity and wholesomeness of a food safety management system in broiler processing, thereby leading to the reduction of *Campylobacter* contamination in broiler chicken products and a subsequent decrease in associated public health risks linked to chicken consumption (EFSA Panel on Biological Hazards, 2011).

The effectiveness of good hygiene practices at the processing establishment is in part dependent upon incoming flock prevalence and concentration of *Campylobacter* in the gastrointestinal tract and on the bird. Elevated levels of *Campylobacter* on the exterior and within the intestinal contents of broilers can exert greater pressure on a good hygiene management system. A study investigating risk factors for *Campylobacter* contamination on broiler carcasses after slaughter found a significant correlation between the presence and quantity of *Campylobacter* in caecal contents and on birds arriving at the processing establishment (Hue *et al.,* 2010). Similar finding was evidenced in an EU-wide baseline survey of *Campylobacter* on broiler carcasses, revealing an approximately thirtyfold increase in the probability of obtaining a *Campylobacter*-positive carcass post slaughter from a batch of live birds colonized with the pathogen (EFSA, 2010). Good hygiene practices alone during slaughter and processing will have limited impact on reduction levels if incoming bird contamination is high.

- **Effectiveness of a multihurdle approach**

Employing a combination of processing effects that include physical and/or chemical interventions can enhance the impact of *Campylobacter* control measures. It is common to employ a multihurdle approach for a synergistic reduction of *Campylobacter* contamination in chicken processing. For example, processing steps such as scalding and chilling of carcasses have been shown to decrease the number of *Campylobacter* (Rasschaert *et al.,* 2020). In some countries, decontaminants, such as chlorine, added to the chilling water also effectively reduce the total bacterial load on carcasses (Bucher *et al.,* 2015). Furthermore, following an implementation of crust freezing combined with logistic slaughter, a lower prevalence was observed in fresh, chilled broiler meat in Denmark. Recently published research has evaluated the cumulative effect of combining two or more chemical and/or physical interventions in a risk assessment, which revealed that the multihurdle approach can advance the control of *Campylobacter* contamination in chicken products (Dogan *et al*., 2019). Additionally, alternative approaches in processing were evaluated. The ultrasonication of chicken drumsticks was more effective in combination with chemical processing aids, compared to chemical treatments used on their own (Koolman *et al.,* 2014a; 2014b), or in combination with a vacuum and a water resonance system (Vetchapitak *et al.,* 2020). Greater effectiveness was not guaranteed with the use of crust freezing and UV in combination, giving no additional benefit over the use of crust freezing alone (Haughton *et al*., 2012). Some may not yet be practical in a commercial plant or when used alone

(Gunther, Phillips and Sommers, 2016; Isohanni and Lyhs, 2009).

2.2.1 Effectiveness of specific processing procedures

- **Logistic slaughter**

Logistic slaughter employs a method of scheduling known colonized flocks to be slaughtered only after non-colonized flocks, at the end of a slaughter day or week. Logistic slaughter can reduce *Campylobacte*r cross-contamination between flocks through the exposure to contaminated equipment (e.g. processing lines), as evidenced by a study where fewer positive samples were recovered from birds slaughtered after *Campylobacter* negative flocks compared to *Campylobacter* positive flocks (Reich *et al*., 2008). Norway, Iceland and Denmark have fully implemented logistic slaughter in national *Campylobacter* control programmes (Rosenquist *et al*., 2009). However, the impact of logistic slaughter on reducing the risk of *Campylobacter* infections in humans has not been fully evaluated (Nauta *et al*., 2009).

- **Qualitative and quantitative target incentives**

Setting qualitative and quantitative targets for *Campylobacter* at the processing plant may be used to optimize process control. Setting quantitative limits (e.g. *Campylobacter* colonies per gram of fresh meat) could provide incentive to reduce the occurrence of highly contaminated carcasses. In New Zealand, setting a quantitative regulatory limit for chilled chicken carcasses was introduced to reduce *Campylobacter* levels in processed chicken. This measure was also used to evaluate the effectiveness of implemented processing measures on reduction levels of *Campylobacter* (Wagenaar, French and Havelaar, 2013). These practices are further supported by a risk assessment of *Campylobacter* in chicken. Reducing the levels of *Campylobacter* on meat prior to reaching the consumer would be effective in reducing campylobacteriosis incidence (Nauta *et al*., 2009).

- **Scalding**

Reduction in *Campylobacter* contamination on chicken carcasses can occur at the scalding step through physical removal and cell inactivation under elevated temperatures (hard scalding). Based on a recent systematic review and meta-analysis, hard scalding with higher temperature exerts a consistent log reduction (mean: 1.85 log CFU, 95 percent CI [1.60, 2.09]) (Dogan *et al.,* 2022), while soft scalding with lower temperature was associated with a lower log reduction. Decreased prevalence of *Campylobacter* on broiler carcasses associated with scalding has been consistently observed (OR: 0.18, 95 percent CI [0.11, 0.30]). Furthermore, a multihurdle approach of scalding, and using chemical additives, such as chloride, had a greater reduction in both concentration and prevalence at the end of this processing step (Berrang and Dickens, 2000; Berrang *et al.,* 2003; Berrang, Windham and Meinersmann, 2011). These findings were primarily based on studies measuring the naturally occurring contamination of *Campylobacter* before and after the scalding step in the pilot or processing scale.

- **Defeathering and evisceration**

The defeathering and evisceration steps during processing are associated with an increased prevalence and concentration of carcass *Campylobacter* contamination, implying these are critical points in broiler processing for *Campylobacter* contamination of downstream products (Dogan *et al.,* 2022; Gruntar *et al*., 2015; Zweifel, Althaus and Stephan, 2015; Huang *et al*., 2017; Reich *et al*., 2008; Gichure *et al.,* 2022). The increase in carcass contamination after evisceration is due to the leakage of faecal contents from pressure applied onto carcasses and visceral rupture. Primary studies suggest an overall increase in *Campylobacter* concentration (mean: 0.88 log CFU, 95 percent CI [0.54, 1.23]) and prevalence (OR: 5.8, 95 percent CI [1.15, 29.42]) following the defeathering step, with similar increases observed after evisceration. However, variation was observed between individual studies. The variation may be related to differences in initial contamination levels and procedural differences between processing establishment (Luning *et al*., 2011; Zweifel, Althaus and Stephan, 2015; Pacholewicz *et al*., 2016). Interventions such as organic acid injection into the cloaca and cloacal plugging have been tested and seem to be promising approaches (Berrang *et al.,* 2001; Berrang, Smith and Hinton 2006a, 2006b; Berrang, Windham and Meinersmann, 2011). However, the feasibility of their applications on a broader scale for the industry is uncertain.

- **Chilling during processing**

During immersion chilling, broiler carcasses are dipped into cold water with or without aids to cool down processed carcasses as rapidly as possible, thereby minimizing microbial growth in the cold-water bath. The reports on the effect of immersion chilling on *Campylobacter* contamination of carcasses vary. In some studies, a decrease in *Campylobacter* concentration was consistently observed regardless of the use of processing aids to cool the carcasses (0.70–4.12 log CFU) (Dogan *et al.,* 2022). Immersion chilling without chemical additives decreased *Campylobacter* 1.25 log CFU (95 percent CI [0.96, 1.55]) – a mean of 1.95 log CFU, (95 percent CI [1.46, 2.45]) when the chemical additive chloride was added, indicating that the addition of chlorine may control the concentration of *Campylobacter* on carcasses post chilling more effectively. Other studies report the opposite effect of immersion chilling without chemical aids with an increase in prevalence observed (OR: 1.55, 95 percent CI [0.81, 2.96]) (Dogan *et al.,* 2022). The increased prevalence may be explained by a cross-contamination effect of dipping carcasses into contaminated chilling water. Still, immersion chilling with chemical additives may compensate for the water contamination effect and minimally reduced prevalence (OR: 0.71, 95 percent CI [0.28, 0.61]) (Dogan *et al.,* 2022). Adding chemical processing aids to chilling water can control the transmission of *Campylobacter* across carcasses during the immersion chilling process.

As an alternative approach, air chilling presents some advantages over immersion chilling in product quality, thus gaining popularity in broiler processing. In terms of *Campylobacter* control, most studies reported a slight decrease in *Campylobacter* concentration associated with air chilling, showing a mean log reduction of 1 log CFU based on studies conducted at pilot or processing scale. However, most studies reported no significant effect based on studies evaluating challenged or naturally occurring contamination at either pilot or processing scale (Dogan *et al.,* 2022).

As with control measures to reduce *Campylobacter* during chilling, immersion chilling is more effective than air chilling in terms of reducing the exterior surface concentration of *Campylobacter* on broiler chicken, regardless of the use of processing aids.

- **Alternative *Campylobacter* reduction approaches**

Freezing and ionizing (gamma) irradiation have been shown to be effective in reducing *Campylobacter* contamination on chicken carcasses but are not recommended as the primary method of pathogen control (Umaraw *et al*., 2017; Gellynck *et al.,* 2008; Gunther *et al*., 2019; Cox and Pavic, 2010). Experimental trials have shown that crust freezing of chicken meat portions may reduce *Campylobacter* by up to 1.5 log CFU with minimal impact on the colour of treated skin (Haughton *et al.,* 2012). In addition, flesh temperature may be maintained above – 2 °C (Burfoot *et al.,* 2016) consistent with the EU target for selling fresh, rather than frozen, meat.

Steam, ultrasonication, high-intensity light pulse, visible light, and UV-C among others have shown promise either at the laboratory or pilot scale, but their impact is unknown at commercial scale (Sorro *et al.,* 2020; Chun *et al.,* 2010; Koolman *et al.,* 2014a, 2014b; Vetchapitak *et al.,* 2020; Haughton *et al.,* 2012; Moazzami, Fernström and Hansson, 2021).

- **Chemical additives as a *Campylobacter* reduction approach**

In the countries and regions where chemical processing aids are permitted for use in chicken processing, common examples include chlorine, chlorine derivatives (e.g. chlorine dioxide, acidified sodium chlorite), peroxyacetic acids (PAA), organic acids (e.g. lactic acid [LA]), and quaternary ammonium compound (e.g. cetylpyridinium chloride [CPC]) (Ebel, Williams and Tameru, 2019). These chemical aids are added to water used for spray and/or immersion, with the aim of reducing *Campylobacter* on broiler carcasses and parts. Studies have documented variation in the effectiveness of chemical processing aids, reporting factors such as initial contamination, amount of organic matter on the bird and carcass and chemical application conditions responsible for variation in *Campylobacter* reduction levels. Among the different classes of chemical processing aids, chlorine may be less effective as an intervention in decontaminating carcasses containing *Campylobacter* in comparison to PAA, during the pre-chill, chill or post-chill immersion or spray application step (Cano, Meneses and Chaves, 2021). Organic acid such as lactic acid is a chemical control option considered during post-chill treatments, as it has fewer occupational concerns. Peroxyacetic acids and lactic acid demonstrate comparable reduction levels in *Campylobacter* contamination in immersion studies, while the comparison for spray applications is inconclusive. Effectiveness of PAA was comparable to or higher than that of CPC, depending on specific product type and treatment conditions (Cano, Meneses and Chaves, 2021; Dogan *et al*., 2022). Unlike physical processing effects, the effectiveness of chemical processing aids has mostly been investigated in challenge studies conducted in laboratory settings or pilot plants, which may introduce uncertainty when extrapolating the impact of such aids on naturally occurring contamination at a broader processing scale.

Marinades are commonly used to enhance the sensory characteristics of meat, yet studies have also demonstrated their potential to reduce *Campylobacter* on chicken meat. Marinades typically contain water, salt, spices, sugar, wine, and acidic ingredients like vinegar, lemon, or lime juice (Lopes, Da Silva and Tondo, 2022). The use of marinades for chicken cuts such as breast, fillets and wings reduced *Campylobacter* contamination from 0.5 to 3 log CFU (Park, Hong and Yoon, 2014; Birk *et al.*, 2010; Zakarienė *et al.*, 2015; Isohanni *et al.*, 2010), with some studies reporting reductions of up to 6 log CFU (Thanissery and Smith, 2014). pH was identified as the most significant factor influencing *Campylobacter* inactivation, although other factors such as specific ingredients' compounds and storage temperature also played a role. Currently available evidence was collected from studies conducted in laboratory settings using inoculated chicken cuts and parts.

2.3 CONTROLS DURING POST-PROCESSING, RETAIL AND CONSUMER LEVELS

The experts reviewed 77 papers, of which 19 were strictly related to post-processing stages of chicken meat production. Control measures were evaluated and highlighted in the next section (Annex 4.3).

2.3.2 Effectiveness of specific retail/post-processing measures

- **Freezing of meat product**

Laboratory-based studies found that freezing chicken meat for 1 week at 20 °C significantly decreased *Campylobacter* counts on meat by 1.73 log CFU/g (Bolton *et al.,* 2014). Continued storage resulted in additional reductions, but the greatest reductions occurred after the first week. Other studies have also reported freezing at – 20 °C resulting in reductions of 2.2–2.6 logs within 9 days of storage (El-Shibiny, Connerton, P. and Connerton, I., 2009). Variability was noted in the survival of strains examined, suggesting that *Campylobacter* strains have varying levels of freezing resistance. Where studies of contaminated cooked product were undertaken, low level contamination (50 CFU/g) could not be detected on 70 percent of frozen samples after storage for 7 days and was detectable at reduced levels on 92.5 percent of samples inoculated with 500 CFU/g, suggesting that the organism can survive freezing (Eideh and AlQadiri, 2011), posing a potential health risk where cross-contamination of cooked product occurs. Freezing is an effective control measure for reducing *Campylobacter;* however, this measure does not reduce levels to zero.

- **Cross-contamination awareness**

Prevention of cross-contamination by replacing cutlery and cutting boards used for food preparation after handling raw chicken and the prevention of hand contact with other foodstuffs after handling contaminated chicken meat considerably reduced *Campylobacter* contamination to other foods (Jong *et al*., 2008; Verhoeff-Bakkenes *et al.,* 2008). Washing cutting boards and cutlery in hot water and detergent have greater effects on reducing *Campylobacter* contamination than using cold water (Jong *et al*., 2008). Reducing cross-contamination between materials contaminated with *Campylobacter* and other foods that may not receive further treatment (e.g. salad preparation) is especially important to preventing risks of infection (Verhoeff-Bakkenes *et al.,* 2008).

- **Consumer education**

A large study showed that international recommendations to consumers is difficult. Particularly in terms of the lack of easy "rule-of-thumb" guidelines or tools to check safe cooking conditions at home. The study concluded that regional differences in contamination levels, food culture and regional economies are challenges to developing international recommendations that ensure consumer food safety specific to *Campylobacter* infection risk that could be easily implemented by each country (Langsrud *et al.*, 2020).

Evaluation of web-based information interventions designed and tested on participant motivation and intentions to cook more safely was conducted (Nauta *et al.,* 2008). The intervention supported by the emotion "disgust" was selected as the most promising information intervention. Alone, this intervention has no effect on infection risk but together with instructions for meal preparation, it was found that the risk decreased (Nauta *et al.,* 2008).

- **Control measures in commercial kitchens**

Examination of *Campylobacter* contamination in restaurant kitchens reported that the prevalence of *Campylobacter* increased after raw meat handling. The prevalence of *Campylobacter* on food contact surfaces also increased, and in some cases the organism was present on food surfaces prior to raw meat preparation (Lai *et al.,* 2021). Washing of boards and utensils in hot water and detergent was reported to reduce contamination, but poor washing hygiene practices did not reduce contamination (Lai *et al.,* 2021; Jong *et al*., 2008). For commercial kitchens, poor sanitation offers greater opportunities for cross-contamination and *Campylobacter* transmission during preparation of chicken dishes (Lai *et al*., 2021). Use of neutral electrolyzed water (NEW), quaternary ammonium (QUAT), and lactic acid-based solutions on the surfaces of inoculated scarred polypropylene and wooden food-cutting boards reduced *C. jejuni* levels (Al-Qadiri *et al.,* 2016). The reduction was dependent on contact time and the type of surface. These agents were found to cause reductions of 3 log on boards within the first minute of application and > 5 log reductions within 5 minutes of application. Reduction levels were lower on boards made of wood compared to polypropylene.

In conclusion, the use of good hygiene practices and appropriate training of food handlers in food preparation kitchens that cater to mass events (restaurants) are essential to reduce the risk of cross-contamination between raw meats and finished (cooked products), and ultimately reduce the exposure of *Campylobacter* to consumers. In addition, the use of appropriate sanitizing agents and washing procedures for chopping boards, surfaces and kitchen tools is essential to reduce the risk of cross-contamination and human exposure.

- **Heating**

Studies using naturally contaminated chicken meat provide a more realistic model of treatments or interventions (e.g. cooking or processing) (Vaz *et al.* 2021).

Cooking at 70 °C was found to reduce *Campylobacter* levels by > 1.5 logs within 30 minutes (Vaz *et al*., 2021), but the organism survival persisted following initial reductions indicating that a core temperature is necessary to reduce *Campylobacter* to negligible levels. Heating to a core temperature > 74 °C has been shown to be required to reduce *Campylobacter* levels in cooked products (Sampers *et al*., 2010; FAO and WHO, 2011).

- **Marinades post-processing**

As with marination at broiler meat processing stage, marination of chicken products post-processing (e.g. consumer-based level) can reduce consumer risk of *Campylobacter* exposure. Some studies suggest *Campylobacter* reductions of 1–2 logs were possible using marinades, but such reductions are dependent on the concentration and type of ingredients used in the marinade (e.g. tartaric acid, oregano, thymol; essential oils). In one study, the effects of thyme oil extract in the marinade appeared to enhance the killing effect of *Campylobacter* resulting in a > 1 log reduction in inoculated chicken wings held at 4 °C for 168 h (Zakarienė *et al.,* 2015).

The spread of tartaric acid solutions (2, 4, 6 and 10 percent) on chicken meat was found to reduce the level of *Campylobacter* by 0.5 to 2 logs after storage for 3 days at 4 °C, but the studies were carried out *in vitro* and significant variation was observed among the 14 strains exposed to this acid (Birk *et al.,* 2010).

Apple-based edible films containing carvacrol and cinnamaldehyde were evaluated for bactericidal activity against antibiotic resistant and susceptible *C. jejuni* strains on chicken meat. Retail chicken breast samples inoculated with antibiotic resistant strains and a susceptible strain were wrapped in apple films containing cinnamaldehyde or carvacrol at 0.5 percent, 1.5 percent and 3 percent concentrations, and incubated at 4 or 23 °C for 72 h. The antimicrobial films exhibited dose- and temperature-dependent bactericidal activity against all tested strains. The films with cinnamaldehyde were more effective than carvacrol films, and reductions at 23 °C were greater than those at 4 °C. Populations of all strains were reduced to below detection level at 23 °C after 72 h exposure. At 4 °C cinnamaldehyde exposure reduced *Campylobacter* levels between 0.2 to 2.5 logs and 1.8 to 6.0 logs at concentrations of 1.5 percent and 3.0 percent, respectively (Mild *et al.,* 2011).

Interactions of *Campylobacter* with the microbial community throughout pre- and post-production processing are not yet well identified. A better understanding of the interactions between *Campylobacter* and the surrounding microbiota may further guide control measures support information used in qualitative and quantitative microbial risk assessments (QMRA) (Chintoan-Uta *et al.,* 2022; Ijaz *et al*., 2018).

3

Review of the Code of Practice

The expert committee was tasked with a review of the current code of practice with the view of assessing whether the current code of practice requires updates in light of new information or research or changes that require addressing or revision.

The experts evaluated the impact or efficacy of control measures relevant to *Campylobacter* spp. in the broiler production chain, noting the variability of the impact reviewed and recommended revisions to the *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat (CXG 78-2011),* paragraphs 1 to 115, based on the currently available evidence (Annex 3).

4

Concluding remarks

Since the first publications in the early 1970s showed an association between "Vibrios" (now named *Campylobacters*) in poultry and stool samples of humans with enteritis, tremendous efforts have been made to understand the infection from both the pathogen and the animal host side. Within broiler chicken production systems, various interventions throughout the process have been developed and evaluated. Although some successes have been reported, effective *Campylobacter* interventions are still very limited. Continuous research, innovation and collaboration among stakeholders are essential to further improve intervention strategies. The currently available interventions in broiler chicken pre- and post-production systems have been reviewed in this report as control measures for *Campylobacter*. As most of the burden of campylobacteriosis in humans is caused by *C. jejuni* and *C. coli*, the majority of available evidence is primarily reported on *C. jejuni* and *C. coli* species. For this report, the experts concentrated on the review and assessment of intervention measures to these two species.

Several interventions have been proposed and tested, including the use of bacteriophages, vaccination, probiotics, and disinfectants, among others. Studies have also explored the effects of processing techniques, such as air chilling versus water chilling.

Overall, the results of these studies have been mixed, with some interventions showing promise in reducing the prevalence of *Campylobacter* in specific stages of production, while others have had little to no effect. It is important to note that interventions that have been successful in one study may not necessarily be effective in other settings, as the prevalence and characteristics of *Campylobacter* can vary widely between different processing facilities.

The broader interventions at the primary production stage include precise biosecurity measures, such as strict hygiene practices and control of wildlife access to chicken farms. Targeted hazard-based interventions in the post-processing stages of production and good agriculture practices and hygienic practices for the general control of foodborne pathogens throughout the production system may be effective for the reduction of *Campylobacter;* however, there are no interventions that **specifically** control *Campylobacter* on meat.

The experts recognize further data gaps exist and that some new technologies may offer promising approaches to reducing *Campylobacter* in pre- and post-production of chicken meat. Further global changes to the industry, growing of global populations, climate change, and increased demand for animal protein in specific regions will guide the need for further control measure assessments.

In conclusion, while interventions to reduce *Campylobacter* in chicken processing have shown some promise, further research is needed to identify effective interventions that can be implemented on a large scale. It is also important to note that a multifaceted approach involving both pre- and post-harvest interventions is necessary to effectively control *Campylobacter* in chicken production systems, and an implementation of robust monitoring and surveillance systems to track *Campylobacter* throughout the system is crucial to evaluating the effectiveness of interventions and identifying emerging trends.

5

Intervention summary synopsis

A number of interventions were identified through primary production to post-processing stages. The expert consultation concluded the following in each stage of production:

Assessment of primary production interventions for the control of *Campylobacter*

Biosecurity and management approaches

- Using strict biosecurity measures (hygiene practices and sanitation) can enhance the control of *Campylobacter* in broiler flocks.
- Risk factors for *Campylobacter* contamination at primary production establishments, such as partial depopulation, litter management, down period length, proximity to other livestock and slaughter age can help guide intervention strategies.

Vaccination-based approaches

- Currently, there are no commercial vaccines for *Campylobacter* readily available for any stage of primary production, and vaccination studies were limited to *C. jejuni* only.
- Several potential vaccine candidates are in the proof-of-concept phase but cannot yet be considered as an intervention.
- Some vaccines induced a cellular or humoral response in the chicken host, but this did not always translate to reduced caecal colonization by *Campylobacter* in pilot studies.

Bacteriophage-based approaches

- There are currently no commercial products available for use in primary production.
- The effects of phage therapy may be transitory and prone to resistance.

Feed and water additives

Organic acids

- In feed, short- and medium-chain fatty acids, and in particular, caprylic acid show promise as feed additives in reducing *Campylobacter* in pilot studies.
- In water, organic acids reduced *Campylobacter* in caecal/faecal specimens at the end of the primary production period; however, the effects were not sustained to the end of production in pilot studies.

Probiotics

- In feed, there is inconsistent evidence on the efficacy of probiotics as an intervention for reducing *Campylobacter* in broilers at primary production level.

Plant-based additives

- In feed, the efficacy of some plant-based molecules in *in vivo* pilot studies showed limited reduction of *Campylobacte*r in caecal/faecal specimens at the end of the primary production period.

Assessment of processing interventions for the control of *Campylobacter*

- Good hygiene practices during processing are important in minimizing *Campylobacter* contamination on meat.
- The effectiveness of interventions during processing is dependent upon the incoming flock prevalence and concentration of *Campylobacter* in the gastrointestinal tract and on the bird.
- The impact of processing practices can be enhanced by a combination of a multihurdle approach, processing effects, physical, and/or chemical interventions.

Processing procedures

- Logistic slaughter scheduling can reduce *Campylobacte*r cross-contamination.
- Scalding reduces the carcass surface concentration and prevalence of *Campylobacter*; however, the effect depends on the temperature, and dilution effect.

- Defeathering and evisceration may increase both prevalence and concentration of *Campylobacter* on carcasses.
- Immersion chilling can reduce the carcass concentration of *Campylobacter*; however, this is dependent on the initial *Campylobacter* load of incoming birds.
- In combination with processing aids, immersion chilling may reduce the carcass prevalence of *Campylobacter*.
- Air chilling may reduce concentration of *Campylobacter,* but the efficacy of air chilling in reducing the prevalence of *Campylobacter* when used without other processing aids is inconclusive.

Physical

- Irradiation is effective at eliminating *Campylobacter* on meat.
- Freezing meat reduces the concentration of *Campylobacter.*
- Steam, ultrasonication, high-intensity light pulse, visible light, UV-C and other technologies have shown promise either at the laboratory or pilot scale, but their impact is unknown at commercial scale.

Chemical

- Processing aids such as chlorine derivatives, peroxyacetic acids, and organic acids added to water used for washing and or dipping may reduce *Campylobacter* on carcasses.
- Some marination ingredients have shown reductions in *Campylobacter* on meat.

Assessment of post-processing interventions for the control of *Campylobacter*

- Thorough cooking is effective at eliminating *Campylobacter* on meat.
- The application of good hygiene practices is important in reducing *Campylobacter* on meat.
- Freezing meat reduces the concentration of *Campylobacter.*
- Some marination ingredients have shown reductions in *Campylobacter* on meat.

6

References

Agunos, A., Waddell, L., Léger, D. & Taboada, E. 2014. A systematic review characterizing on-farm sources of *Campylobacter* spp. for broiler chickens. *PLoS ONE*, 9(8): e104905. https://doi.org/10.1371/journal.pone.0104905

Al Hakeem, W.G., Fathima, S., Shanmugasundaram, R. & Selvaraj, R.K. 2022. *Campylobacter jejuni* in poultry: pathogenesis and control strategies. *Microorganisms*, 10(11): 2134. https://doi.org/10.3390/microorganisms10112134

Al-Qadiri, H.M., Ovissipour, M., Al-Alami, N., Govindan, B.N., Shiroodi, S.G. & Rasco, B. 2016. Efficacy of neutral electrolyzed water, quaternary ammonium and lactic acid-based solutions in controlling microbial contamination of food cutting boards using a manual spraying technique. *Journal of Food Science*, 81(5). https://doi.org/10.1111/1750-3841.13275

Allaoua, M., Bonnafé, E., Etienne, P., Noirot, V., Gabarrou, J.-F., Castinel, A., Pascal, G. *et al.* 2022. A carvacrol-based product reduces *Campylobacter jejuni* load and alters microbiota composition in the caeca of chickens. *Journal of Applied Microbiology*, 132(6): 4501–4516. https://doi.org/10.1111/jam.15521

Allen, V.M., Weaver, H., Ridley, A.M., Harris, J.A., Sharma, M., Emery, J., Sparks, N., Lewis, M. & Edge, S. 2008. Sources and spread of thermophilic *Campylobacter* spp. during partial depopulation of broiler chicken flocks. *Journal of Food Protection*, 71(2): 264–270. https://doi.org/10.4315/0362-028X-71.2.264

Alpigiani, I., Abrahantes, J.C., Michel, V., Huneau-Salaün, A., Chemaly, M., Keeling, L.J., Gervelmeyer, A. *et al.* 2017. Associations between animal welfare indicators and *Campylobacter* spp. in broiler chickens under commercial settings: A case study. *Preventive Veterinary Medicine*, 147: 186–193. https://doi.org/10.1016/j.prevetmed.2017.09.005

Babacan, O., Harris, S.A., Pinho, R.M., Hedges, A., Jørgensen, F. & Corry, J.E.L. 2020. Factors affecting the species of *Campylobacter* colonizing chickens reared for meat. *Journal of Applied Microbiology*, 129(4): 1071–1078. https://doi.org/10.1111/jam.14651

Bailey, M.A., Bourassa, D.V., Krehling, J.T., Munoz, L., Chasteen, K.S., Escobar, C. & Macklin, K.S. 2022. Effects of common litter management practices on the prevalence of *Campylobacter jejuni* in broilers. *Animals*, 12(7): 858. https://doi.org/10.3390/ani12070858

Bailey, M.A., Taylor, R.M., Brar, J.S., Corkran, S.C., Velásquez, C., Novoa Rama, E., Oliver, H.F. & Singh, M. 2019. Prevalence and antimicrobial resistance of *Campylobacter* from antibiotic-free broilers during organic and conventional processing. *Poultry Science*, 98(3): 1447–1454. https://doi.org/10.3382/ps/pey486

Battersby, T., Whyte, P. & Bolton, D.J. 2016. The pattern of *Campylobacter* contamination on broiler farms; external and internal sources. *Journal of Applied Microbiology*, 120(4): 1108–1118. https://doi.org/10.1111/jam.13066

Berrang, M., Meinersmann, R., Buhr, R., Reimer, N., Philips, R. & Harrison, M. 2003. Presence of *Campylobacter* in the respiratory tract of broiler carcasses before and after commercial scalding. *Poultry Science*, 82(12): 1995–1999. https://doi.org/10.1093/ps/82.12.1995

Berrang, M.E. & Dickens, J.A. 2000. Presence and level of *Campylobacter* spp. on broiler carcasses throughout the processing plant. *Journal of Applied Poultry Research*, 9(1): 43–47. https://doi.org/10.1093/japr/9.1.43

Berrang, M.E., Buhr, R.J., Cason, J.A. & Dickens, J.A. 2001. Broiler carcass contamination with *Campylobacter* from feces during defeathering. *Journal of Food Protection*, 64(12): 2063–2066. https://doi.org/10.4315/0362-028X-64.12.2063

Berrang, M.E., Meinersmann, R.J., Cox, N.A. & Fedorka-Cray, P.J. 2011. Application of chlorine dioxide to lessen bacterial contamination during broiler defeathering. *Journal of Applied Poultry Research*, 20(1): 33–39. https://doi.org/10.3382/japr.2010-00178

Berrang, M.E., Smith, D.P. & Hinton, A. 2006a. Application of distilled white vinegar in the Cloaca to counter the increase in *Campylobacter* numbers on broiler skin during feather removal. *Journal of Food Protection*, 69(2): 425–427. https://doi.org/10.4315/0362-028X-69.2.425

Berrang, M.E., Smith, D.P. & Hinton, A. 2006b. Organic acids placed into the Cloaca to reduce *Campylobacter* contamination of broiler skin during defeathering. *Journal of Applied Poultry Research*, 15(2): 287–291. https://doi.org/10.1093/japr/15.2.287

Berrang, M.E., Windham, W.R. & Meinersmann, R.J. 2011. *Campylobacter, Salmonella,* and *Escherichia coli* on broiler carcasses subjected to a high pH scald and low pH postpick chlorine dip. *Poultry Science*, 90(4): 896–900. https://doi.org/10.3382/ps.2010-00900

Birk, T., Grønlund, A.C., Christensen, B.B., Knøchel, S., Lohse, K. & Rosenquist, H. 2010. Effect of organic acids and marination ingredients on the survival of *Campylobacter jejuni* on Meat. *Journal of Food Protection*, 73(2): 258–265. https://doi.org/10.4315/0362-028X-73.2.258

Bolton, D., Meredith, H., Walsh, D. & McDowell, D. 2014. Poultry food safety control interventions in the domestic kitchen. *Journal of Food Safety*, 34(1): 34–41. https://doi.org/10.1111/jfs.12092

Borck Høg, B., Sommer, H.M., Larsen, L.S., Sørensen, A.I.V., David, B., Hofshagen, M. & Rosenquist, H. 2016. Farm specific risk factors for *Campylobacter* colonisation in Danish and Norwegian broilers. *Preventive Veterinary Medicine*, 130: 137–145. https://doi.org/10.1016/j.prevetmed.2016.04.002

Bucher, O., Waddell, L., Greig, J. & Smith, B.A. 2015. Systematic review-meta-analysis of the effect of chilling on *Campylobacter* spp. during primary processing of broilers. *Food Control*, 56: 211–217. https://doi.org/10.1016/j.foodcont.2015.03.032

Buckley, A.M., Wang, J., Hudson, D.L., Grant, A.J., Jones, M.A., Maskell, D.J. & Stevens, M.P. 2010. Evaluation of live-attenuated *Salmonella* vaccines expressing *Campylobacter* antigens for control of *C. jejuni* in poultry. *Vaccine*, 28(4): 1094–1105. https://doi.org/10.1016/j.vaccine.2009.10.018

Bull, S.A., Thomas, A., Humphrey, T., Ellis-Iversen, J., Cook, A.J., Lovell, R. & Jorgensen, F. 2008. Flock health indicators and *Campylobacter* spp. in commercial housed broilers reared in Great Britain. *Applied and Environmental Microbiology*, 74(17): 5408–5413. https://doi.org/10.1128/AEM.00462-08

Burfoot, D., Hall, J., Nicholson, K., Holmes, K., Hanson, C., Handley, S. & Mulvey, E. 2016. Effect of rapid surface cooling on *Campylobacter* numbers on poultry carcasses. *Food Control*, 70: 293–301. https://doi.org/10.1016/j.foodcont.2016.05.041

Cano, C., Meneses, Y. & Chaves, B.D. 2021. Application of peroxyacetic acid for decontamination of raw poultry products and comparison to other commonly used chemical antimicrobial interventions: a review. *Journal of Food Protection*, 84(10): 1772–1783. https://doi.org/10.4315/JFP-21-107

Chinivasagam, H.N., Estella, W., Maddock, L., Mayer, D.G., Weyand, C., Connerton, P.L. & Connerton, I.F. 2020. Bacteriophages to control *Campylobacter* in commercially farmed broiler chickens, in Australia. *Frontiers in Microbiology*, 11: 632. https://doi.org/10.3389/fmicb.2020.00632

Chintoan-Uta, C., Wisedchanwet, T., Glendinning, L., Bremner, A., Psifidi, A., Vervelde, L., Watson, K., Watson, M. & Stevens, M.P. 2020. Role of cecal microbiota in the differential resistance of inbred chicken lines to colonization by *Campylobacter jejuni*. *Applied and Environmental Microbiology*, 86(7): e02607-19. https://doi.org/10.1128/AEM.02607-19

Chowdhury, S., Themudo, G.E., Sandberg, M. & Ersbøll, A.K. 2013. Spatio-temporal patterns of *Campylobacter* colonization in Danish broilers. *Epidemiology and Infection*, 141(5): 997–1008. https://doi.org/10.1017/S0950268812001446

Chun, H.H., Kim, J.Y., Lee, B.D., Yu, D.J. & Song, K.B. 2010. Effect of UV-C irradiation on the inactivation of inoculated pathogens and quality of chicken breasts during storage. *Food Control*, 21(3): 276–280. https://doi.org/10.1016/j.foodcont.2009.06.006

Clark, J.D., Oakes, R.D., Redhead, K., Crouch, C.F., Francis, M.J., Tomley, F.M. & Blake, D.P. 2012. Eimeria species parasites as novel vaccine delivery vectors: Anti-*Campylobacter jejuni* protective immunity induced by Eimeria tenella-delivered CjaA. *Vaccine*, 30(16): 2683–2688. https://doi.org/10.1016/j.vaccine.2012.02.002

Colles, F.M., Cain, R.J., Nickson, T., Smith, A.L., Roberts, S.J., Maiden, M.C.J., Lunn, D. & Dawkins, M.S. 2016. Monitoring chicken flock behaviour provides early warning of infection by human pathogen *Campylobacter*. *Proceedings of the Royal Society B: Biological Sciences*, 283(1822): 20152323. https://doi.org/10.1098/rspb.2015.2323

Colles, F.M., Dingle, K.E., Cody, A.J. & Maiden, M.C.J. 2008. Comparison of *Campylobacter* populations in wild geese with those in starlings and free-range poultry on the same farm. *Applied and Environmental Microbiology*, 74(11): 3583–3590. https://doi.org/10.1128/AEM.02491-07

Colles, F.M., Hedges, S.J., Dixon, R., Preston, S.G., Thornhill, P., Barfod, K.K., Gebhardt-Henrich, S.G. *et al.* 2021. Parallel sequencing reveals *Campylobacter* spp. in commercial meat chickens less than 8 days old. *Applied and Environmental Microbiology*, 87(23): e01060-21. https://doi.org/10.1128/AEM.01060-21

Cools, I., Uyttendaele, M., Cerpentier, J., D'Haese, E., Nelis, H.J. & Debevere, J. 2005. Persistence of *Campylobacter jejuni* on surfaces in a processing environment and on cutting boards. *Letters in Applied Microbiology*, 40(6): 418–423. https://doi.org/10.1111/j.1472-765X.2005.01694.x

Cox, J.M. and Pavic, A., 2010. Advances in enteropathogen control in poultry production. *Journal of Applied Microbiology*, 108(3): 745–755. 10.1111/j.1365-2672.2009.04456.x

Crotta, M., Georgiev, M. & Guitian, J. 2017. Quantitative risk assessment of *Campylobacter* in broiler chickens – Assessing interventions to reduce the level of contamination at the end of the rearing period. *Food Control*, 75: 29–39. https://doi.org/10.1016/j.foodcont.2016.12.024

Currie, D., Green, M., Dufailu, O.A., Matthaios, P., Soultanas, P., McCartney, E., Lester, H. *et al.* 2018. Dietary supplementation with ferric tyrosine improves zootechnical performance and reduces caecal *Campylobacter* spp. load in broilers. *British Poultry Science*, 59(6): 646–653. https://doi.org/10.1080/00071668.2018.1507015

D'Angelantonio, D., Scattolini, S., Boni, A., Neri, D., Di Serafino, G., Connerton, P., Connerton, I. *et al.* 2021. Bacteriophage therapy to reduce colonization of *Campylobacter jejuni* in broiler chickens before slaughter. *Viruses*, 13(8): 1428. https://doi.org/10.3390/v13081428

De Haan, C.P.A., Kivistö, R., Hakkinen, M., Rautelin, H. & Hänninen, M. L. 2010. Decreasing trend of overlapping multilocus sequence types between human and chicken *Campylobacter jejuni* isolates over a decade in Finland. *Applied and Environmental Microbiology*, 76(15): 5228–5236. https://doi.org/10.1128/AEM.00581-10

De Los Santos, F.S., Hume, M., Venkitanarayanan, K., Donoghue, A.M., Hanning, I., Slavik, M.F., Aguiar, V.F. *et al.* 2010. Caprylic acid reduces enteric *Campylobacter* colonization in market-aged broiler chickens but does not appear to alter cecal microbial populations. *Journal of Food Protection*, 73(2): 251–257. https://doi.org/10.4315/0362-028X-73.2.251.

Delabouglise, A., Nguyen-Van-Yen, B., Thanh, N.T.L., Xuyen, H.T.A., Tuyet, P.N., Lam, H.M. & Boni, M.F. 2019. Poultry population dynamics and mortality risks in smallholder farms of the Mekong river delta region. *BMC Veterinary Research*, 15(1): 205. https://doi.org/10.1186/s12917-019-1949-y

Di Marcantonio, L., Marotta, F., Vulpiani, M.P., Sonntag, Q., Iannetti, L., Janowicz, A., Serafino, G.D., Di Giannatale, E. & Garofolo, G. 2022. Investigating the cecal microbiota in broiler poultry farms and its potential relationships with animal welfare. *Research in Veterinary Science*, 144: 115–125. https://doi.org/10.1016/j.rvsc.2022.01.020

Dogan, O.B., Aditya, A., Ortuzar, J., Clarke, J. & Wang, B. 2022. A systematic review and meta-analysis of the efficacy of processing stages and interventions for controlling *Campylobacter* contamination during broiler chicken processing. *Comprehensive Reviews in Food Science and Food Safety*, 21(1): 227–271. 10.1111/1541-4337.12860

Dogan, O.B., Clarke, J., Mattos, F. & Wang, B. 2019. A quantitative microbial risk assessment model of *Campylobacter* in broiler chickens: Evaluating processing interventions. *Food Control*, 100: 97–110. https://doi.org/10.1016/j.foodcont.2019.01.003

Ebel, E.D., Williams, M.S. & Tameru, B. 2019. Relatedness of *Salmonella* contamination frequency on chicken carcasses and parts when processed in the same establishment. *Food Control*, 100: 198–203. https://doi.org/10.1016/j.foodcont.2018.12.031

EFSA (European Food Safety Authority). 2010. Analysis of the baseline survey on the prevalence of *Campylobacter* in broiler batches and of *Campylobacter* and *Salmonella* on broiler carcasses, in the EU, 2008. *EFSA Journal*, 8(8): 1522. https://doi.org/10.2903/j.efsa.2010.1522

EFSA Panel on Biological Hazards (BIOHAZ). 2011. Scientific opinion on *Campylobacter* in broiler meat production: control options and performance objectives and/or targets at different stages of the food chain. *EFSA Journal* 2011, 9(4): 2105. https://doi.org/10.2903/j.efsa.2011.2105

EFSA. 2020. Update and review of control options for *Campylobacter* in broilers at primary production. *EFSA Journal 2020*, 18(4): 6090.

Eideh, A.M.F. & Al-Qadiri, H.M. 2011. Effect of refrigerated and frozen storage on the survival of *Campylobacter jejuni* in cooked chicken meat breast. *Journal of Food Science*, 76(1). https://doi.org/10.1111/j.1750-3841.2010.01924.x

El-Shibiny, A., Connerton, P. & Connerton, I. 2009. Survival at refrigeration and freezing temperatures of *Campylobacter coli* and *Campylobacter jejuni* on chicken skin applied as axenic and mixed inoculums. *International Journal of Food Microbiology*, 131(2–3): 197–202. https://doi.org/10.1016/j.ijfoodmicro.2009.02.024

El-Shibiny, A., Connerton, P.L. & Connerton, I.F. 2005. Enumeration and diversity of *Campylobacters* and Bacteriophages isolated during the rearing cycles of free-range and organic chickens. *Applied and Environmental Microbiology*, 71(3): 1259–1266. https://doi.org/10.1128/AEM.71.3.1259-1266.2005

El-Shibiny, A., Scott, A., Timms, A., Metawea, Y., Connerton, P. & Connerton, I. 2009. Application of a group II *Campylobacter* bacteriophage to reduce strains of *Campylobacter jejun*i and *Campylobacter coli* colonizing broiler chickens. *Journal of Food Protection*, 72(4): 733–740. https://doi.org/10.4315/0362-028X-72.4.733

Epps, S.V.R., Harvey, R.B., Byrd, J.A., Petrujkić, B.T., Sedej, I., Beier, R.C., Phillips, T.D. *et al.* 2015. Comparative effect of thymol or its glucose conjugate, thymol-β- d -glucopyranoside, on *Campylobacter* in avian gut contents. *Journal of Environmental Science and Health, Part B*, 50(1): 55–61. https://doi.org/10.1080/03601234.2015.965634E

FAO & WHO (World Health Organization). 1999. *Codex Alimentarius Commission. Report of the thirty second session of the Codex Committee on Food Hygiene. Washington DC, 29 November-4 December 1999.* Rome. https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-712-32%252FAl01_13e.pdf

FAO & WHO. 2008. Risk assessment of *Campylobacter* spp. in broiler chickens. Interpretative summary. Microbiological Risk Assessment Series, No. 11. Rome. https://www.fao.org/3/a1468e/a1468e.pdf

FAO & WHO. 2009a. *Salmonella* and *Campylobacter* in chicken meat. Meeting report. Microbiological Risk Assessment Series, No. 19. Rome. https://www.fao.org/3/i1133e/i1133e.pdf

FAO & WHO. 2009b. Risk assessment of *Campylobacter* spp. in broiler chickens. Technical report. Microbiological Risk Assessment Series, No. 12. Rome. https://www.fao.org/3/a1469e/a1469e.pdf

FAO & WHO. 2011. Codex *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat* (CXG 78-2011). Rome. https://www.fao.org/fao-who-codexalimentarius/sh-proxy/de/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B78-2011%252FCXG_078e.pdf

Fernandez, F., Hinton, M. & Gils, B.V. 2002. Dietary mannan-oligosaccharides and their effect on chicken caecal microflora in relation to *Salmonella* Enteritidis colonization. *Avian Pathology*, 31(1): 49–58. https://doi.org/10.1080/03079450120106000

Fischer, S., Kittler, S., Klein, G. & Glünder, G. 2013. Impact of a single phage and a phage cocktail application in broilers on reduction of *Campylobacter jejuni* and development of resistance. *PLoS ONE*, 8(10): e78543. https://doi.org/10.1371/journal.pone.0078543

Froebel, L.K., Jalukar, S., Lavergne, T.A., Coufal, C.D. & Duong, T. 2020. Administration of direct-fed Bacillus cultures and refined functional carbohydrates to broiler chickens improves growth performance and promotes positive shifts in gastrointestinal microbiota. *Journal of Applied Poultry Research*, 29(4): 765–774. https://doi.org/10.1016/j.japr.2020.06.004

Furuta, M., Nasu, T., Umeki, K., Hoang Minh, D., Honjoh, K.-I. & Miyamoto, T. 2017. Characterization and application of Lytic bacteriophages against *Campylobacter jejuni* isolated from poultry in Japan. *Biocontrol Science*, 22(4): 213–221. https://doi.org/10.4265/bio.22.213

García-Sánchez, L., Melero, B., Jaime, I., Hänninen, M.-L., Rossi, M. & Rovira, J. 2017. *Campylobacter jejuni* survival in a poultry processing plant environment. *Food Microbiology*, 65: 185–192. https://doi.org/10.1016/j.fm.2017.02.009

Gellynck, X., Messens, W., Halet, D., Grijspeerdt, K., Hartnett, E. & Viaene, J. 2008. Economics of reducing *Campylobacter* at different levels within the Belgian Poultry Meat Chain. *Journal of Food Protection*, 71(3): 479–485. https://doi.org/10.4315/0362-028X-71.3.479

Georgiev, M., Beauvais, W. & Guitian, J. 2017. Effect of enhanced biosecurity and selected on-farm factors on *Campylobacter* colonization of chicken broilers. *Epidemiology and Infection*, 145(3): 553–567. https://doi.org/10.1017/S095026881600251X

Ghareeb, K., Awad, W.A., Mohnl, M., Porta, R., Biarnés, M., Böhm, J. & Schatzmayr, G. 2012. Evaluating the efficacy of an avian-specific probiotic to reduce the colonization of *Campylobacter jejuni* in broiler chickens. *Poultry Science*, 91(8): 1825–1832. https://doi.org/10.3382/ps.2012-02168

Gharib Naseri, K., Rahimi, S. & Khaki, P. 2012. Comparison of the effects of probiotic, organic acid and medicinal plant on *Campylobacter jejuni* challenged broiler chickens. *Journal of Agricultural Science and Technology*, 14(7): 1485–1496.

Gichure, J.N., Kamau Njage, P.M., Wambui, J.M., Dykes, G.A., Buys, E.M. & Coorey, R. 2022. Systematic-review and meta-analysis on effect of decontamination interventions on prevalence and concentration of *Campylobacter* spp. during primary processing of broiler chickens. *Food Microbiology*, 102: 103923. https://doi.org/10.1016/j.fm.2021.103923

Gloanec, N., Dory, D., Quesne, S., Béven, V., Poezevara, T., Keita, A., Chemaly, M. & Guyard-Nicodème, M. 2022. Impact of DNA prime/protein boost vaccination against *Campylobacter jejuni* on immune responses and gut microbiota in chickens. *Vaccines*, 10(6): 981. https://doi.org/10.3390/vaccines10060981

Golden, C.E. & Mishra, A. 2020. Prevalence of *Salmonella* and *Campylobacter* spp. in alternative and conventionally produced chicken in the United States: A systematic review and meta-analysis. *Journal of Food Protection*, 83(7): 1181–1197. https://doi.org/10.4315/JFP-19-538

Greene, G., Koolman, L., Whyte, P., Lynch, H., Coffey, A., Lucey, B., Egan, J., O'Connor, L. & Bolton, D. 2022. The efficacy of organic acid, medium chain fatty acid and essential oil based broiler treatments; *in vitro* anti-*Campylobacter jejuni* activity and the effect of these chemical-based treatments on broiler performance. *Journal of Applied Microbiology*, 132(1): 687–695. https://doi.org/10.1111/jam.15204

Griekspoor, P., Colles, F.M., McCarthy, N.D., Hansbro, P.M., Ashhurst-Smith, C., Olsen, B., Hasselquist, D., Maiden, M.C.J. & Waldenström, J. 2013. Marked host specificity and lack of phylogeographic population structure of *Campylobacter jejuni* in wild birds. *Molecular Ecology*, 22(5): 1463–1472. https://doi.org/10.1111/mec.12144

Grilli, E., Vitari, F., Domeneghini, C., Palmonari, A., Tosi, G., Fantinati, P., Massi, P. & Piva, A. 2013. Development of a feed additive to reduce caecal *Campylobacter jejuni* in broilers at slaughter age: from *in vitro* to *in vivo* , a proof of concept. *Journal of Applied Microbiology*, 114(2): 308–317. https://doi.org/10.1111/jam.12053

Gruntar, I., Biasizzo, M., Kušar, D., Pate, M. & Ocepek, M. 2015. *Campylobacter jejuni* contamination of broiler carcasses: Population dynamics and genetic profiles at slaughterhouse level. *Food Microbiology*, 50: 97–101. https://doi.org/10.1016/j.fm.2015.03.007

Guerin, M.T., Martin, S.W., Reiersen, J., Berke, O., McEwen, S.A., Friðriksdóttir, V., Bisaillon, J.-R. & Lowman, R. 2008. Temperature-related risk factors associated with the colonization of broiler-chicken flocks with *Campylobacter* spp. in Iceland, 2001–2004. *Preventive Veterinary Medicine*, 86(1–2): 14–29. https://doi.org/10.1016/j.prevetmed.2008.02.015

Gunther, N.W., Abdul-Wakeel, A., Scullen, O.J. & Sommers, C. 2019. The evaluation of gamma irradiation and cold storage for the reduction of *Campylobacter jejuni* in chicken livers. *Food Microbiology*, 82: 249–253. https://doi.org/10.1016/j.fm.2019.02.014

Gunther, N.W., Phillips, J.G. & Sommers, C. 2016. The effects of 405-nm visible light on the survival of *Campylobacter* on chicken skin and stainless steel. *Foodborne Pathogens and Disease*, 13(5): 245–250. https://doi.org/10.1089/fpd.2015.2084

Hald, T., Aspinall, W., Devleesschauwer, B., Cooke, R., Corrigan, T., Havelaar, A.H., Gibb, H.J., Torgerson, P.R., Kirk, M.D., Angulo, F.J. & Lake, R.J., 2016. World Health Organization estimates of the relative contributions of food to the burden of disease due to selected foodborne hazards: a structured expert elicitation. *PLoS ONE,* 11(1): e0145839. https://doi.org/10.1371/journal.pone.0145839

Hammerl, J.A., Jäckel, C., Alter, T., Janzcyk, P., Stingl, K., Knüver, M.T. & Hertwig, S. 2014. Reduction of *Campylobacter jejuni* in broiler chicken by successive application of group II and group III phages. *PLoS ONE*, 9(12): e114785. https://doi.org/10.1371/journal.pone.0114785

Hansson, I., Engvall, E.O., Vågsholm, I. & Nyman, A. 2010. Risk factors associated with the presence of *Campylobacter*-positive broiler flocks in Sweden. *Preventive Veterinary Medicine*, 96(1–2): 114–121. https://doi.org/10.1016/j.prevetmed.2010.05.007

Hansson, I., Tamminen, L.-M., Frosth, S. Fernström, L.-L., Emanuelson, U. & Boqvist, S. 2021. Occurrence of *Campylobacter* spp. in Swedish calves, common sequence types and antibiotic resistance patterns. *Journal of Applied Microbiology*, 130: 2111–2122. https://doi.org/10.1111/jam.14914

Hasan, Md.M., Talukder, S., Mandal, A.K., Tasmim, S.T., Parvin, Mst.S., Ali, Md.Y., Sikder, M.H. & Islam, Md.T. 2020. Prevalence and risk factors of *Campylobacter* infection in broiler and cockerel flocks in Mymensingh and Gazipur districts of Bangladesh. *Preventive Veterinary Medicine*, 180: 105034. https://doi.org/10.1016/j.prevetmed.2020.105034

Haughton, P.N., Lyng, J., Cronin, D., Fanning, S. & Whyte, P. 2012. Effect of crust freezing applied alone and in combination with ultraviolet light on the survival of *Campylobacter* on raw chicken. *Food Microbiology*, 32(1): 147–151. https://doi.org/10.1016/j.fm.2012.05.004

Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T., Lake, R.J., Praet, N. *et al.* 2015. World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLOS Medicine*, 12(12): e1001923. https://doi.org/10.1371/journal.pmed.1001923

Henry, I., Reichardt, J., Denis, M. & Cardinale, E. 2011. Prevalence and risk factors for *Campylobacter* spp. in chicken broiler flocks in Reunion Island (Indian Ocean). *Preventive Veterinary Medicine*, 100(1): 64–70. https://doi.org/10.1016/j.prevetmed.2011.03.007

Hertogs, K., Haegeman, A., Schaumont, D., Gelaude, P., De Zutter, L., Dewulf, J., Heyndrickx, M. & Rasschaert, G. 2021. Contamination sources and transmission routes for *Campylobacter* on (mixed) broiler farms in Belgium, and comparison of the gut microbiota of flocks colonized and uncolonized with *Campylobacter. Pathogens*, 10(1): 66. https://doi.org/10.3390/pathogens10010066

Higham, L.E., Scott, C., Akehurst, K., Dring, D., Parnham, A., Waterman, M. & Bright, A. 2018. Effects of financial incentives and cessation of thinning on prevalence of *Campylobacter*: a longitudinal monitoring study on commercial broiler farms in the UK. *Veterinary Record*, 183(19): 595–595. https://doi.org/10.1136/vr.104823

Higham, L.E., Scott, C., Akehurst, K., Dring, D., Parnham, A., Waterman, M. & Bright, A. 2018. Effects of financial incentives and cessation of thinning on prevalence of *Campylobacter*: a longitudinal monitoring study on commercial broiler farms in the UK. *Veterinary Record*, 183(19): 595–595. https://doi.org/10.1136/vr.104823

Huang, J., Zang, X., Zhai, W., Guan, C., Lei, T. & Jiao, X. 2017. Quantitative analysis of *Campylobacter* spp. contamination in chicken slaughtering lines by "label tracking method" in eastern China. *Food Control*, 80: 67–73. https://doi.org/10.1016/j.foodcont.2017.03.052

Hue, O., Le Bouquin, S., Laisney, M.-J., Allain, V., Lalande, F., Petetin, I., Rouxel, S. *et al.* 2010. Prevalence of and risk factors for *Campylobacter* spp. contamination of broiler chicken carcasses at the slaughterhouse. *Food Microbiology*, 27(8): 992–999. https://doi.org/10.1016/j.fm.2010.06.004

Hwang, H. & Singer, R.S. 2020. Survey of the U.S. broiler industry regarding pre- and postharvest interventions targeted to mitigate *Campylobacter* contamination on broiler chicken products. *Journal of Food Protection*, 83(7): 1137–1148. https://doi.org/10.4315/JFP-19-527

Iannetti, L., Neri, D., Santarelli, G.A., Cotturone, G., Podaliri Vulpiani, M., Salini, R., Antoci, S. *et al.* 2020. Animal welfare and microbiological safety of poultry meat: Impact of different at-farm animal welfare levels on at-slaughterhouse *Campylobacter* and *Salmonella* contamination. *Food Control*, 109: 106921. https://doi.org/10.1016/j.foodcont.2019.106921

Ibrahim, D., Sewid, A.H., Arisha, A.H., Abd El-fattah, A.H., Abdelaziz, A.M., Al-Jabr, O.A. & Kishawy, A.T.Y. 2020. Influence of Glycyrrhiza glabra extract on growth, gene expression of gut integrity, and *Campylobacter jejuni* colonization in broiler chickens. *Frontiers in Veterinary Science*, 7: 612063. https://doi.org/10.3389/fvets.2020.612063

Ijaz, U.Z., Sivaloganathan, L., McKenna, A., Richmond, A., Kelly, C., Linton, M., Stratakos, A.Ch. *et al.* 2018. Comprehensive longitudinal microbiome analysis of the chicken cecum reveals a shift from competitive to environmental drivers and a window of opportunity for *Campylobacter. Frontiers in Microbiology*, 9: 2452. https://doi.org/10.3389/fmicb.2018.02452

Isohanni, P., Alter, T., Saris, P. & Lyhs, U. 2010. Wines as possible meat marinade ingredients possess antimicrobial potential against *Campylobacter*. *Poultry Science*, 89(12): 2704–2710. https://doi.org/10.3382/ps.2009-00521

Isohanni, P.M.I. & Lyhs, U. 2009. Use of ultraviolet irradiation to reduce *Campylobacter jejuni* on broiler meat. *Poultry Science*, 88(3): 661–668. https://doi.org/10.3382/ps.2008-00259

Jeni, R.E., Dittoe, D.K., Olson, E.G., Lourenco, J., Corcionivoschi, N., Ricke, S.C. & Callaway, T.R. 2021. Probiotics and potential applications for alternative poultry production systems. *Poultry Science*, 100(7): 101156. https://doi.org/10.1016/j.psj.2021.101156

Jeon, B., Saisom, T., Sasipreeyajan, J. & Luangtongkum, T. 2022. Live-attenuated oral vaccines to reduce *Campylobacter* colonization in poultry. *Vaccines*, 10(5): 685. https://doi.org/10.3390/vaccines10050685

Jong, A.E.I., Verhoeff-Bakkenes, L., Nauta, M.J. & De Jonge, R. 2008. Cross-contamination in the kitchen: effect of hygiene measures. *Journal of Applied Microbiology*, 105(2): 615–624. https://doi.org/10.1111/j.1365-2672.2008.03778.x

Jonsson, M.E., Chriél, M., Norström, M. & Hofshagen, M. 2012. Effect of climate and farm environment on *Campylobacter* spp. colonisation in Norwegian broiler flocks. *Preventive Veterinary Medicine*, 107(1–2): 95–104. https://doi.org/10.1016/j.prevetmed.2012.05.002

Khattak, F., Paschalis, V., Green, M., Houdijk, J.G.M., Soultanas, P. & Mahdavi, J. 2018. TYPLEX® Chelate, a novel feed additive, inhibits *Campylobacter jejuni* biofilm formation and cecal colonization in broiler chickens. *Poultry Science*, 97(4): 1391–1399. https://doi.org/10.3382/ps/pex413

Kittler, S., Fischer, S., Abdulmawjood, A., Glünder, G. & Klein, G. 2013. Effect of bacteriophage application on *Campylobacter jejuni* loads in commercial broiler flocks. *Applied and Environmental Microbiology*, 79(23): 7525–7533. https://doi.org/10.1128/AEM.02703-13

Kollanoor Johny, A., Darre, M.J., Donoghue, A.M., Donoghue, D.J. & Venkitanarayanan, K. 2010. Antibacterial effect of trans-cinnamaldehyde, eugenol, carvacrol, and thymol on *Salmonella* Enteritidis and *Campylobacter jejuni* in chicken cecal contents in vitro. *Journal of Applied Poultry Research*, 19(3): 237–244. https://doi.org/10.3382/japr.2010-00181

Koolman, L., Whyte, P., Meade, J., Lyng, J. & Bolton, D. 2014a. A combination of chemical and ultrasonication treatments to reduce *Campylobacter jejuni* on raw poultry. *Food and Bioprocess Technology*, 7(12): 3602–3607. https://doi.org/10.1007/s11947-014-1370-2

Lai, H., Tang, Y., Ren, F., Li, Z., Li, F., Cui, C., Jiao, X. & Huang, J. 2021. An investigation into the critical factors influencing the spread of *Campylobacter* during chicken handling in commercial kitchens in China. *Microorganisms*, 9(6): 1164. https://doi.org/10.3390/microorganisms9061164

Langsrud, S., Sørheim, O., Skuland, S.E., Almli, V.L., Jensen, M.R., Grøvlen, M.S., Ueland, Ø. & Møretrø, T. 2020. Cooking chicken at home: Common or recommended approaches to judge doneness may not assure sufficient inactivation of pathogens. *PLoS ONE*, 15(4): e0230928. https://doi.org/10.1371/journal.pone.0230928

Łaniewski, P., Kuczkowski, M., Chrząstek, K., Woźniak, A., Wyszyńska, A., Wieliczko, A. & Jagusztyn-Krynicka, E.K. 2014. Evaluation of the immunogenicity of *Campylobacter jejuni* CjaA protein delivered by *Salmonella* enterica sv. Typhimurium strain with regulated delayed attenuation in chickens. *World Journal of Microbiology and Biotechnology*, 30(1): 281–292. https://doi.org/10.1007/s11274-013-1447-5

Lassen, B., Helwigh, B., Kahl Petersen, C. & Ellis-Iversen, J. 2022. Systematic review of products with potential application for use in the control of *Campylobacter* spp. in organic and free-range broilers. *Acta Veterinaria Scandinavica*, 64(1): 24. https://doi.org/10.1186/s13028-022-00644-z

Layton, S.L., Morgan, M.J., Cole, K., Kwon, Y.M., Donoghue, D.J., Hargis, B.M. & Pumford, N.R. 2011. Evaluation of *Salmonella*-vectored *Campylobacter* peptide epitopes for reduction of *Campylobacter jejuni* in broiler chickens. *Clinical and Vaccine Immunology*, 18(3): 449–454. https://doi.org/10.1128/CVI.00379-10

Li, S., He, Y., Mann, D.A. & Deng, X. 2021. Global spread of *Salmonella* Enteritidis via centralized sourcing and international trade of poultry breeding stocks. *Nature Communications*, 12(1): 5109. https://doi.org/10.1038/s41467-021-25319-7

Lopes, S.M., Da Silva, D.C. & Tondo, E.C. 2022. Bactericidal effect of marinades on meats against different pathogens: a review. *Critical Reviews in Food Science and Nutrition*, 62(27): 7650–7658. https://doi.org/10.1080/10408398.2021.1916734

Lu, L. & Walker, W.A. 2001. Pathologic and physiologic interactions of bacteria with the gastrointestinal epithelium. *The American Journal of Clinical Nutrition*, 73(6): 1124S-1130S. https://doi.org/10.1093/ajcn/73.6.1124S

Lu, T., Marmion, M., Ferone, M., Wall, P. & Scannell, A.G.M. 2021. On farm interventions to minimise *Campylobacter* spp. contamination in chicken. *British Poultry Science*, 62(1): 53–67. https://doi.org/10.1080/00071668.2020.1813253

Luangtongkum, T., Morishita, T.Y., Ison, A.J., Huang, S., McDermott, P.F. & Zhang, Q. 2006. Effect of conventional and organic production practices on the prevalence and antimicrobial resistance of *Campylobacter* spp. in poultry. *Applied and Environmental Microbiology*, 72(5): 3600–3607. doi: 10.1128/AEM.72.5.3600-3607.2006

Luning, P.A., Jacxsens, L., Rovira, J., Osés, S.M., Uyttendaele, M. & Marcelis, W.J. 2011. A concurrent diagnosis of microbiological food safety output and food safety management system performance: Cases from meat processing industries. *Food Control*, 22(3–4): 555–565. https://doi.org/10.1016/j.foodcont.2010.10.003

Mauri, M., Sannasiddappa, T.H., Vohra, P., Corona-Torres, R., Smith, A.A., Chintoan-Uta, C., Bremner, A. *et al.* 2021. Multivalent poultry vaccine development using protein glycan coupling technology. *Microbial Cell Factories*, 20(1): 193. https://doi.org/10.1186/s12934-021-01682-4

McKenna, A., Ijaz, U.Z., Kelly, C., Linton, M., Sloan, W.T., Green, B.D., Lavery, U. *et al.* 2020. Impact of industrial production system parameters on chicken microbiomes: mechanisms to improve performance and reduce *Campylobacter*. *Microbiome*, 8(1): 128. https://doi.org/10.1186/s40168-020-00908-8

Mendes, Â.J., Santos-Ferreira, N.L., Costa, F.M., Lopes, E.P., Freitas-Silva, J., Inácio, Â.S., Moreira, F. & Martins Da Costa, P. 2020. External contamination of broilers by *Campylobacter* spp. increases from the farm to the slaughterhouse. *British Poultry Science*, 61(4): 400–407. https://doi.org/10.1080/00071668.2020.1736264

Metcalf, J.H., Donoghue, A.M., Venkitanarayanan, K., Reyes-Herrera, I., Aguiar, V.F., Blore, P.J. & Donoghue, D.J. 2011. Water administration of the medium-chain fatty acid caprylic acid produced variable efficacy against enteric *Campylobacter* colonization in broilers 1, 2. *Poultry Science*, 90(2): 494–497. https://doi.org/10.3382/ps.2010-00891

Meunier, M., Guyard-Nicodème, M., Vigouroux, E., Poezevara, T., Béven, V., Quesne, S., Amelot, M. et al. 2018. A DNA prime/protein boost vaccine protocol developed against *Campylobacter jejuni* for poultry. *Vaccine*, 36(16): 2119–2125. https://doi.org/10.1016/j.vaccine.2018.03.004

Mild, R.M., Joens, L.A., Friedman, M., Olsen, C.W., McHugh, T.H., Law, B. & Ravishankar, S. 2011. Antimicrobial edible apple films inactivate antibiotic resistant and susceptible *Campylobacter jejuni* strains on chicken breast. *Journal of Food Science*, 76(3). https://doi.org/10.1111/j.1750-3841.2011.02065.x

Moazzami, M., Fernström, L.-L. & Hansson, I. 2021. Reducing *Campylobacter jejuni, Enterobacteriaceae* and total aerobic bacteria on transport crates for chickens by irradiation with 265-nm ultraviolet light (UV–C LED). *Food Control*, 119: 107424. https://doi.org/10.1016/j.foodcont.2020.107424

Mortada, M., Cosby, D.E., Shanmugasundaram, R. & Selvaraj, R.K. 2020. In vivo and in vitro assessment of commercial probiotic and organic acid feed additives in broilers challenged with *Campylobacter coli. Journal of Applied Poultry Research*, 29(2): 435–446. https://doi.org/10.1016/j.japr.2020.02.001

Näther, G., Alter, T., Martin, A. & Ellerbroek, L. 2009. Analysis of risk factors for *Campylobacter* species infection in broiler flocks. *Poultry Science*, 88(6): 1299–1305. https://doi.org/10.3382/ps.2008-00389

Natsos, G., Mouttotou, N.K., Magiorkinis, E., Ioannidis, A., Rodi-Burriel, A., Chatzipanagiotou, S. & Koutoulis, K.C. 2020. Prevalence of and risk factors for *Campylobacter* spp. colonization of broiler chicken flocks in Greece. *Foodborne Pathogens and Disease*, 17(11): 679–686. https://doi.org/10.1089/fpd.2020.2795

Nauta, M. J., Fischer, A. R., Van Asselt, E. D., De Jong, A. E., Frewer, L. J., & De Jonge, R. 2008. Food safety in the domestic environment: the effect of consumer risk information on human disease risks. *Risk Analysis: An International Journal*, 28(1): 179–192. 10.1111/j.1539-6924.2008.01012.x

Nauta, M., Hill, A., Rosenquist, H., Brynestad, S., Fetsch, A., Van Der Logt, P., Fazil, A. *et al.* 2009. A comparison of risk assessments on *Campylobacter* in broiler meat. *International Journal of Food Microbiology*, 129(2): 107–123. https://doi.org/10.1016/j.ijfoodmicro.2008.12.001

Neal-McKinney, J.M., Lu, X., Duong, T., Larson, C.L., Call, D.R., Shah, D.H. & Konkel, M.E. 2012. Production of organic acids by probiotic lactobacilli can be used to reduce pathogen load in poultry. *PLoS ONE,* 7(9): e43928. https://doi.org/10.1371/journal.pone.0043928

Oelschlaeger, T.A. 2010. Mechanisms of probiotic actions – A review. *International Journal of Medical Microbiology,* 300(1): 57–62. https://doi.org/10.1016/j.ijmm.2009.08.005

Oyofo, B.A., DeLoach, J.R., Corrier, D.E., Norman, J.O., Ziprin, R.L. & Mollenhauer, H.H. 1989. Prevention of *Salmonella* typhimurium colonization of broilers with D-mannose. *Poultry Science,* 68(10): 1357–1360. https://doi.org/10.3382/ps.0681357

Organisation for Economic Co-operation and Development (OECD) & FAO. 2021. *OECD-FAO Agricultural Outlook 2021-203*0. Paris, OECD Publishing. https://www.fao.org/publications/card/en/c/CB5332EN/

Pacholewicz, E., Sura Barus, S.A., Swart, A., Havelaar, A.H., Lipman, L.J.A. & Luning, P.A. 2016. Influence of food handlers' compliance with procedures of poultry carcasses contamination: A case study concerning evisceration in broiler slaughterhouses. *Food Control*, 68: 367–378. https://doi.org/10.1016/j.foodcont.2016.04.009

Park, N.Y., Hong, S.H. & Yoon, K.S. 2014. Effects of commercial marinade seasoning and a natural blend of cultured sugar and vinegar on *Campylobacter jejuni* and *Salmonella* Typhimurium and the texture of chicken breasts. *Poultry Science*, 93(3): 719–727. https://doi.org/10.3382/ps.2013-03595

Rasschaert, G., De Zutter, L., Herman, L. & Heyndrickx, M. 2020. *Campylobacter* contamination of broilers: the role of transport and slaughterhouse. *International Journal of Food Microbiology*, 322: 108564. https://doi.org/10.1016/j.ijfoodmicro.2020.108564

Rawson, T., Dawkins, M.S. & Bonsall, M.B. 2019. A mathematical model of *Campylobacter* dynamics within a broiler flock. *Frontiers in Microbiology*, 10: 1940. https://doi.org/10.3389/fmicb.2019.01940

Reich, F., Atanassova, V., Haunhorst, E. & Klein, G. 2008. The effects of *Campylobacter* numbers in caeca on the contamination of broiler carcasses with *Campylobacter. International Journal of Food Microbiology*, 127(1–2): 116–120. https://doi.org/10.1016/j.ijfoodmicro.2008.06.018

Reichelt, B., Szott, V., Epping, L., Semmler, T., Merle, R., Roesler, U. & Friese, A. 2022. Transmission pathways of *Campylobacter* spp. at broiler farms and their environment in Brandenburg, Germany. *Frontiers in Microbiology*, 13: 982693. https://doi.org/10.3389/fmicb.2022.982693

Richards, P.J., Connerton, P.L. & Connerton, I.F. 2019. Phage biocontrol of *Campylobacter jejuni* in chickens does not produce collateral effects on the gut microbiota. *Frontiers in Microbiology*, 10: 476. https://doi.org/10.3389/fmicb.2019.00476

Rosenquist, H., Boysen, L., Galliano, C., Nordentoft, S., Ethelberg, S. & Borck, B. 2009. Danish strategies to control *Campylobacter* in broilers and broiler meat: facts and effects. *Epidemiology and Infection*, 137(12): 1742–1750. https://doi.org/10.1017/S0950268809002684

Rosenquist, H., Nielsen, N.L., Sommer, H.M., Nørrung, B. & Christensen, B.B. 2003. Quantitative risk assessment of human campylobacteriosis associated with thermophilic *Campylobacter* species in chickens. *International Journal of Food Microbiology*, 83(1): 87–103. https://doi.org/10.1016/S0168-1605(02)00317-3

Rothrock, M.J., Cook, K.L., Warren, J.G. & Sistani, K. 2008. The effect of alum addition on microbial communities in poultry litter. *Poultry Science*, 87(8): 1493–1503. https://doi.org/10.3382/ps.2007-00491

Russell, K.M., Smith, J., Bremner, A., Chintoan-Uta, C., Vervelde, L., Psifidi, A. & Stevens, M.P. 2021. Transcriptomic analysis of caecal tissue in inbred chicken lines that exhibit heritable differences in resistance to *Campylobacter jejuni. BMC Genomics*, 22(1): 411. https://doi.org/10.1186/s12864-021-07748-2

Sahin, O., Kassem, I.I., Shen, Z., Lin, J., Rajashekara, G. & Zhang, Q. 2015. *Campylobacter* in poultry: ecology and potential interventions. *Avian Diseases*, 59(2): 185–200. https://doi.org/10.1637/11072-032315-Review

Sampers, I., Habib, I., De Zutter, L., Dumoulin, A. & Uyttendaele, M. 2010. Survival of *Campylobacter* spp. in poultry meat preparations subjected to freezing, refrigeration, minor salt concentration, and heat treatment. *International Journal of Food Microbiology*, 137(2–3): 147–153. https://doi.org/10.1016/j.ijfoodmicro.2009.11.013

Sandberg, M., Dahl, J., Lindegaard, L.L. & Pedersen, J.R. 2017. Compliance/non-compliance with biosecurity rules specified in the Danish Quality Assurance system (KIK) and *Campylobacter*- positive broiler flocks 2012 and 2013. *Poultry Science*, 96(1): 184–191. https://doi.org/10.3382/ps/pew277

Schweitzer, P.M., Susta, L., Varga, C., Brash, M.L. & Guerin, M.T. 2021. Demographic, husbandry, and biosecurity factors associated with the presence of *Campylobacter* spp. in small poultry flocks in Ontario, Canada. *Pathogens*, 10(11): 1471. https://doi.org/10.3390/pathogens10111471

Seman, M., Gregova, G. & Korim, P. 2020. Comparison of *Campylobacter* spp. and flock health indicators of broilers in Iceland. *Annals of Agricultural and Environmental Medicine*, 27(4): 579–584. https://doi.org/10.26444/aaem/127181

Sevilla-Navarro, S., Marin, C., Cortés, V., García, C. & Catalá-Gregori, P. 2020. *Campylobacter* prevalence and risk factors associated with exceeding allowable limits in poultry slaughterhouses in Spain. *Veterinary Record*, 186(13): 415–415. https://doi.org/10.1136/vr.105558

Sheppard, S.K., Colles, F., Richardson, J., Cody, A.J., Elson, R., Lawson, A., Brick, G. *et al.* 2010. Host association of *Campylobacter* genotypes transcends geographic variation. *Applied and Environmental Microbiology*, 76(15): 5269–5277. https://doi.org/10.1128/AEM.00124-10

Sindiyo, E., Maganga, R., Thomas, K.M., Benschop, J., Swai, E., Shirima, G. & Zadoks, R.N. 2018. Food safety, health management, and biosecurity characteristics of poultry farms in Arusha City, Northern Tanzania, along a gradient of intensification. *The East African Health Research Journal*, 2(2): 168–180. https://doi.org/10.24248/EAHRJ-D-18-00034

Smith, S., Messam, L.L.McV., Meade, J., Gibbons, J., McGill, K., Bolton, D. & Whyte, P. 2016. The impact of biosecurity and partial depopulation on *Campylobacter* prevalence in Irish broiler flocks with differing levels of hygiene and economic performance. *Infection Ecology & Epidemiology*, 6(1): 31454. https://doi.org/10.3402/iee.v6.31454

Spring P., Wenk C., Dawson K.A., Newman K.E. 200. The effects of dietary mannanoligosaccharides on cecal parameters and the concentrations of enteric bacteria in the ceca of *Salmonella*-challenged broiler chicks. *Poultry Science,* 79(2): 205–211. https://doi.org/10.1093/ps/79.2.205

Szott, V., Peh, E., Friese, A., Roesler, U., Kehrenberg, C., Ploetz, M. & Kittler, S. 2022. Antimicrobial effect of a drinking water additive comprising four organic acids on *Campylobacter* load in broilers and monitoring of bacterial susceptibility. *Poultry Science*, 101(12): 102209. https://doi.org/10.1016/j.psj.2022.102209

Tabashsum, Z., Peng, M., Alvarado-Martinez, Z., Aditya, A., Bhatti, J., Romo, P.B., Young, A. & Biswas, D. 2020. Competitive reduction of poultry-borne enteric bacterial pathogens in chicken gut with bioactive *Lactobacillus casei. Scientific Reports*, 10(1): 16259. https://doi.org/10.1038/s41598-020-73316-5

Tack, D.M., Marder, E.P., Griffin, P.M., Cieslak, P.R., Dunn, J., Hurd, S., Scallan, E. *et al.* 2019. Preliminary incidence and trends of infections with pathogens transmitted commonly through food – foodborne diseases active surveillance network, 10 U.S. sites, 2015–2018. *MMWR. Morbidity and Mortality Weekly Report*, 68(16): 369–373. https://doi.org/10.15585/mmwr.mm6816a2

Thanissery, R. & Smith, D.P. 2014. Marinade with thyme and orange oils reduces *Salmonella* Enteritidis and *Campylobacter coli* on inoculated broiler breast fillets and whole wings. *Poultry Science*, 93(5): 1258–1262. https://doi.org/10.3382/ps.2013-03697

Torralbo, A., Borge, C., Allepuz, A., García-Bocanegra, I., Sheppard, S.K., Perea, A. & Carbonero, A. 2014. Prevalence and risk factors of *Campylobacter* infection in broiler flocks from southern Spain. *Preventive Veterinary Medicine*, 114(2): 106–113. https://doi.org/10.1016/j.prevetmed.2014.01.019

Tsiouris, V., Kontominas, M.G., Filioussis, G., Chalvatzi, S., Giannenas, I., Papadopoulos, G., Koutoulis, K., Fortomaris, P. & Georgopoulou, I. 2020. The effect of whey on performance, gut health and bone morphology parameters in broiler chicks. *Foods*, 9(5): 588. doi: 10.3390/foods9050588

Tustin, J., Laberge, K., Michel, P., Reiersen, J., Dađadóttir, S., Briem, H., Harđardóttir, H. *et al.* 2011. A national epidemic of Campylobacteriosis in Iceland, lessons learned. *Zoonoses and Public Health*, 58(6): 440–447. https://doi.org/10.1111/j.1863-2378.2010.01387.x

Umaraw, P., Prajapati, A., Verma, A.K., Pathak, V. & Singh, V.P. 2017. Control of *campylobacter* in poultry industry from farm to poultry processing unit: A review. *Critical Reviews in Food Science and Nutrition*, 57(4): 659–665. https://doi.org/10.1080/10408398.2014.935847

Urdaneta, S., Lorca-Oró, C., Dolz, R., López-Soria, S. & Cerdà-Cuéllar, M. 2023. In a warm climate, ventilation, indoor temperature and outdoor relative humidity have significant effects on *Campylobacter* spp. colonization in chicken broiler farms which can occur in only 2 days. *Food Microbiology*, 109: 104118. https://doi.org/10.1016/j.fm.2022.104118

Van Gerwe, T., Bouma, A., Klinkenberg, D., Wagenaar, J.A., Jacobs-Reitsma, W.F. & Stegeman, A. 2010. Medium chain fatty acid feed supplementation reduces the probability of *Campylobacter jejuni* colonization in broilers. *Veterinary Microbiology*, 143(2–4): 314–318. https://doi.org/10.1016/j.vetmic.2009.11.029

van Wagenberg, C.P.A., Van Horne, P.L.M., Sommer, H.M. & Nauta, M.J. 2016. Cost-effectiveness of *Campylobacter* interventions on broiler farms in six European countries. *Microbial Risk Analysis*, 2–3: 53–62. https://doi.org/10.1016/j.mran.2016.05.003

Vandeputte, J., Martel, A., Van Rysselberghe, N., Antonissen, G., Verlinden, M., De Zutter, L., Heyndrickx, M. *et al.* 2019. In ovo vaccination of broilers against *Campylobacter jejuni* using a bacterin and subunit vaccine. *Poultry Science*, 98(11): 5999–6004. https://doi.org/10.3382/ps/pez402

Vaz, C.S.L., Voss-Rech, D., Rebelatto, R., Duarte, S.C., Coldebella, A. & Bessa, M.C. 2021. Survival of *Campylobacter jejuni* in chicken at refrigeration and cooking temperatures. *Pesquisa Agropecuária Brasileira*, 56: e02405. https://doi.org/10.1590/s1678-3921.pab2021.v56.02405

Verhoeff-Bakkenes, L., Beumer, R.R., De Jonge, R., Van Leusden, F.M. & De Jong, A.E.I. 2008. Quantification of *Campylobacter jejuni* cross-contamination via hands, cutlery, and cutting board during preparation of a chicken fruit salad. *Journal of Food Protection*, 71(5): 1018–1022. https://doi.org/10.4315/0362-028X-71.5.1018

Vetchapitak, T., Shinki, T., Sasaki, S., Taniguchi, T., Luangtongkum, T. & Misawa, N. 2020. Evaluation of chemical treatment combined with vacuum and ultrasonication with a water resonance system for reducing *Campylobacter* on naturally contaminated chicken carcasses. *Food Control*, 112: 107087. https://doi.org/10.1016/j.foodcont.2020.107087

Wagenaar, J.A., French, N.P. & Havelaar, A.H. 2013. Preventing *Campylobacter* at the source: Why is it so difficult? *Clinical Infectious Diseases*, 57(11): 1600–1606. https://doi.org/10.1093/cid/cit555

Wagle, B.R., Arsi, K., Upadhyay, A., Shrestha, S., Venkitanarayanan, K., Donoghue, A.M. & Donoghue, D.J. 2017**.** β-Resorcylic Acid, a Phytophenolic compound, reduces *Campylobacter jejuni* in postharvest poultry. *Journal of Food Protection*, 80(8): 1243–1251. https://doi.org/10.4315/0362-028X.JFP-16-475

Walker, G.K., Jalukar, S. & Brake, J. 2018. The effect of refined functional carbohydrates from enzymatically hydrolyzed yeast on the transmission of environmental *Salmonella* Senftenberg among broilers and proliferation in broiler housing. *Poultry Science*, 97(4): 1412-1419. https://doi.org/10.3382/ps/pex430

Wanja, D.W., Mbuthia, P.G., Aboge, G.O. & Bebora, L.C. 2022. Seasonal prevalence and molecular identification of thermophilic *Campylobacter* from chicken, cattle, and respective drinking water in Kajiado County, Kenya. *International Journal of Microbiology*, 2022: 1–11. https://doi.org/10.1155/2022/1526641

Williams, L.K., Sait, L.C., Trantham, E.K., Cogan, T.A. & Humphrey, T.J. 2013. *Campylobacter* infection has different outcomes in fast- and slow-growing broiler chickens. *Avian Diseases*, 57(2): 238–241. https://doi.org/10.1637/10442-110212-Reg.1

Wong, J.T., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R. & Alders, R.G. 2017. Small-scale poultry and food security in resource-poor settings: A review. *Global Food Security*, 15: 43–52. https://doi.org/10.1016/j.gfs.2017.04.003

Zakarienė, G., Rokaitytė, A., Ramonaitė, S., Novoslavskij, A., Mulkytė, K., Zaborskienė, G. & Malakauskas, M. 2015. The antimicrobial effect of spice-based marinades against *Campylobacter jejuni* on contaminated fresh broiler wings. *Journal of Food Science*, 80(3). https://doi.org/10.1111/1750-3841.12788

Zbrun, M.V., Rossler, E., Olivero, C.R., Soto, L.P., Zimmermann, J.A., Frizzo, L.S. & Signorini, M.L. 2021. Possible reservoirs of thermotolerant *Campylobacter* at the farm between rearing periods and after the use of enrofloxacin as a therapeutic treatment. *International Journal of Food Microbiology*, 340: 109046. https://doi.org/10.1016/j.ijfoodmicro.2021.109046

Zweifel, C., Althaus, D. & Stephan, R. 2015. Effects of slaughter operations on the microbiological contamination of broiler carcasses in three abattoirs. *Food Control*, 51: 37–42. https://doi.org/10.1016/j.foodcont.2014.11.002

Annex

Annex 1

THE KEYWORDS USED FOR SEARCHING THE CONTROL MEASURES OF *CAMPYLOBACTER* SPP. IN POULTRY

Parameter	Search
1 (poultry)	poultry OR chicken* OR hen* OR broiler* OR "*Gallus gallus*" OR "*Gallus domesticus*" OR "G gallus" OR "*G domesticus*" OR "*Gallus gallus domesticus"* OR "*G gallus domesticus*" OR duck* OR turkey* OR goose OR geese OR guineafowl* OR pigeon* OR "quail" NOT layer*
2 (*Salmonella*)	Campy or campylobacter
3 (intervention)	intervention* OR antibiotic* OR antimicrobial* OR antibacterial* OR bacteriophage* OR bifidobac* OR biosecur* OR boning OR chlorine OR chill* OR "competitive exclusion" OR contamination

3 (intervention)	OR control OR cool* OR cut* OR debon* OR decontaminat* OR decreas* OR dehid* OR dehair* OR disinfect* OR dress* OR efficacy OR eviserat* OR fabricat* OR grind* OR “hot water” OR hygiene OR immunis* OR immuniz* OR inactiv* OR irradiat* OR lactob* OR “lactic acid bacteria” OR mitigat* OR pasteuriz* OR phage* OR probiotic* OR reduce* OR reducing OR reduction OR rins* OR skin* OR “sodium chlorate” OR spray* OR steam OR treatment* OR storage OR trial OR trim* OR vaccin* OR vaccum* OR wash*
4	Title/Abstract (1 AND 2 AND 3)

Annex 2

THE QUESTIONS FOR THE TWO-STEP RELEVANCE SCREENING AND CONFIRMATION

A2.1 Relevance screening

Question	Options	Key definitions
1. Does this citation describe research evaluating the efficacy and/or effectiveness (including costs or practically of implementation) of interventions to control *Campylobacter* in poultry at any stage from the primary production to consumption? **Selections 1–3 will pass the citation to the next review stage and the article will be procured.**	• Yes, primary research • Yes, systematic review/ meta-analysis • Yes, risk assessment, risk profile, or other risk-based tool (e.g. cost-benefit analysis) • No, or it is a narrative literature review on the subject (exclude)	**Primary research** is a collection of new data in a single study. **Risk assessment** is a scientifically based process consisting of the following steps: (i) hazard identification, (ii) hazard characterization, (iii) exposure assessment, and (iv) risk characterization. **Risk profile** presents the current state of knowledge related to a food safety issue, describes potential options that have been identified to date (if any), and the food safety policy context that will influence further possible actions. Other risk-based tools could include cost-benefit analyses, risk ranking, or risk prioritizations. **Systematic review** is a structured review of a clearly defined question with a transparent search strategy, relevance screening process, data extraction, risk-of-bias assessment and synthesis of results. **Meta-analysis** is a statistical technique that can be used on data collected in a systematic review. **Exclude** research on feral animals (e.g. feral pigs not produced for human consumption), and *in vitro* lab experiments.

2. What commodity is investigated?	• Chicken (*Gallus gallus domesticus*) • Duck (*Cairina sp)* • Turkey (*Meleagris)* • Goose (*Anser anser)* • Guineafowl (*Numida meleagris)* • Pigeon (*Columba livia domestica*) • Quail (*Coturnix japonica)* • Other	

A2.2 Relevance confirmation

Question	Options	Key definitions
Did the study investigate outcomes other than *Campylobacter*?	• Yes, *E. coli* (generic and/or pathogenic strains) • Yes, *Salmonella* • Yes, other bacteria • No	
In what setting was the study carried out?	• Commercial/field conditions • Research farm/pilot plant • Smallholder farm/ abattoir conditions • Laboratory conditions • Not reported	
In what country was the study conducted?	• The information is in the abstract, which is: *(COMMENT)* • Cannot tell from the abstract	**Specify country name only (not subregions, states, provinces, etc.)**
How much logarithm reduction?	• The information is in the abstract, which is *(COMMENT)* • Cannot tell from the abstract • Other way to reflect the efficiency *(COMMENT)*	

<table>
<tr>
<td>Is it at farm?
• Yes
• No</td>
<td>What is the intervention?
• Biosecurity/ management practices
• Vaccination
• Antimicrobials
• Competitive exclusion/ probiotics
• Feed/water acidification
• Feed characteristics/ management
• Bacteriophages
• Other (COMMENT)</td>
<td rowspan="4">Antimicrobials: Examples include: Fluroquinolones, cephalosporins, gentamicin, ampicillin, tetracyclines, spectinomycin, ciprofloxacin, ceftriaxone. These may be administered via feed.
Biosecurity: This includes, but is not limited to, sanitation, biosafety, disinfection, hygiene and hygiene barriers, all-in-all-out production, depopulation, staff and the environment, litter testing and treatment, pest control, etc.
Competitive exclusion: This may also be referred to as probiotics, prebiotics, and synbiotics. It may include Lactobacillus spp., bacteroides, Bifidobacterium spp., Enterococcus faecium, Aspergillus oryzae, and Saccharomyces spp. (S. cerevisiae, S. boulardii). It may be caecal contents or other materials from animals or the environment that contain many different or unknown bacterial species.
Feed/water acidification: This is the addition of organic acids, such as lactic acid, to feed or water. It would include “nutraceuticals” such as copper, chromium, zinc, betaine or carnitine.
Feed management: These are, for example, comparisons of coarse/ finely ground feed, fermented feed, or liquid feed.
Segregated/logistic slaughter: For example, slaughtering/processing of more highly contaminated lots after less contaminated lots
Standard processing procedures/good hygiene practices (GHP) refer to steps such as singeing, de-hiding, cooling, chilling, etc.</td>
</tr>
<tr>
<td>Is it from transport to slaughter?
• Yes
• No</td>
<td>What is the intervention?
(COMMENT)</td>
</tr>
<tr>
<td>Is it processing?
• Yes
• No</td>
<td>What is the intervention?
• Segregated/logistic slaughter
• Cleaning/disinfection of equipment/ environments
• Carcass/product washes, rinses, sprays
• Standard processing procedures/good hygienic practices (GHP)
• Irradiation
• Modified packaging
• Bacteriophages
• Other (COMMENT)</td>
</tr>
<tr>
<td>Is it from post-processing to consumer?
• Yes
• No</td>
<td>What is the intervention?
• Biosecurity/ management practices
• Vaccination
• Antimicrobials
• Competitive exclusion/ probiotics
• Feed/water acidification
• Feed characteristics/ management
• Bacteriophages
• Other (COMMENT)</td>
</tr>
</table>

Annex 3

REVIEW OF THE CODEX GUIDELINES

Recommended revisions to the *Guidelines for the Control of* Campylobacter *and* Salmonella *in Chicken Meat (GXG 78-2011),* as they relate specifically to the control of *Campylobacter* spp.

Para.	CAC/GL 78-2011	JEMRA Recommendations
5.	The Guidelines are presented in a flow diagram format so as to enhance practical application of a primary production-to-consumption approach to food safety. This format: • demonstrates differences and commonalities in approach for control measures for *Campylobacter* and *Salmonella;* • ... ; and • facilitates development of HACCP plans at individual premises and national levels.	• To consider updating the last bullet to read: *"Facilitate development of HACCP and **risk assessment** plans at individual premises..."*
9.	Scope	• Consider clarifying the scope to include: **thermotolerant** *Campylobacter* and **non-Typhoidal** *Salmonella*.
12.	The Guidelines systematically present GHP-based control measures and examples of hazard-based control measures. GHP is a prerequisite to making choices on hazard-based control measures... Government and industry can use choices on hazard-based control measures to inform decisions on critical control points (CCPs) when applying HACCP principles to a particular food process.	• Consider the following addition: *"...(CCPs) and relative risk reduction when applying HACCP and **risk assessment** principles to a particular food process."*

Para.	CAC/GL 78-2011	JEMRA Recommendations
4.	Definitions	Support the following recommendation from the JEMRA meeting on *Salmonella* controls: • To consider including a definition for a production lot as per the Guidelines on the management of biological foodborne outbreaks. • *Lot: A definite quantity of ingredients or of a food that is intended to have uniform character and quality, within specified limits, is produced, packaged and labelled under the same conditions, and is assigned a unique reference identification by the food business operator. It may also be referred to as a "batch".*
16.	5. PRINCIPLES APPLYING TO CONTROL OF *CAMPYLOBACTER* AND *SALMONELLA* IN CHICKEN MEAT Overarching…. i. The principles of food safety risk analysis should be incorporated wherever possible and appropriate in the control of *Campylobacter* and *Salmonella* in chicken meat from primary production to consumption. ii. Wherever possible and practical, Competent Authorities….	• Consider the following editorial change: "*5i) The principles of food safety risk analysis should be incorporated* ***to the extent possible and as appropriate…"*** and *"5ii)* ***To the extent possible and as appropriate,*** *Competent Authorities should…"*
18.	Food Safety Risk Profile for *Salmonella* species in broiler (young) chicken, June 2007. Food Safety Risk Profile for *Campylobacter* species in broiler (young) chicken, June 2007.	Support the following recommendation from the JEMRA meeting on *Salmonella* controls: • To verify that the links referenced in the footnote are current and active. • To evaluate paragraph 18 and to consider updating it, if needed.

Para.	CAC/GL 78-2011	JEMRA Recommendations
Section 7	PRIMARY PRODUCTION-TO-CONSUMPTION APPROACH TO CONTROL MEASURES	Consider the following updates to account for religious practices that do not include stunning: • Process Flow Diagram 2: Step 14 - slaughter: B1) with stunning B2) without stunning, then A) Hang, then B1) split into Gas and Electrical Consider tick marks in *Campylobacter* column in the summary table for: • Receive at Slaughterhouse (use Establishment as a term) • Dress (interventions validated for *Campylobacter* during dressing (decontamination) • Portion (interventions directed at portions/parts)
24.	Control of *Campylobacter* and *Salmonella* in grandparent flocks is strengthened 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 in consultation with relevant stakeholders.	Support the following recommendation from the JEMRA meeting on *Salmonella* controls: • Consider including a definition for biosecurity that includes personal hygiene. • Consider aligning with the WOAH definition: https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/current/glossaire.pdf. • Consider changing the text to read "*…by the application of effective biosecurity measures.*"
32.	Personnel involved in the transportation of day-old chicks to parent flocks should not enter any livestock buildings and should prevent cross-contamination of day-old chicks during loading and unloading.	• Consider updating the text to read: "*…transportation of day-old chicks to parent flock **establishments**…*''
36.	Personnel involved in the transportation of day-old chicks should not enter any livestock buildings.	• Consider changing "livestock buildings" to "*…livestock **establishments.***"

<table>
<tr><th>Para.</th><th>CAC/GL 78-2011</th><th>JEMRA Recommendations</th></tr>
<tr><td>40.</td><td>The use of fly screens to reduce or eliminate fly infestation in broiler houses has been shown to decrease the percentage of Campylobacter spp.-positive flocks from 51.4% to 15.4%.</td><td>• Consider revising this guidance as there has not been any clear evidence since the initial studies on effectiveness.
• Consider eliminating the percentages and leave the remainder of the statement.
• Consider adding a statement to include fly screens, in combination with high biosecurity measures.</td></tr>
<tr><td>41.</td><td>Full depopulation of the flock 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 hygiene of catchers and the equipment they use.</td><td>• Consider adding the following to statement paragraph 41: “Partial depopulation has been shown to be a risk factor for the increase of Campylobacter contamination” as there are several reports on thinning/depopulation and Campylobacter contamination due to biosecurity deficiencies.</td></tr>
<tr><td>45.</td><td>Where appropriate to the national situation, information about the flock, in particular about Salmonella and/or Campylobacter status should be provided in a timely manner to enable logistic slaughter and/or channelling of poultry meat to treatment.</td><td>• Consider replacing the word “treatment” with “reduced risk processing”, “intervention” or “custom processing”.</td></tr>
<tr><td>54.</td><td>Washing with abundant potable running water</td><td>Support the recommendations from the JEMRA meeting on Salmonella controls:
• Consider replacing potable water with fit for purpose water to align with CXG1-1969, paragraph 70. Text should be adjusted to fit for purpose water.</td></tr>
<tr><td>59</td><td>Other factors that should be taken into account when designing process control systems that minimize contamination during scalding include:
• degree of agitation;
• use of multistaged tanks;
• …;
• tanks being cleaned and disinfected at least daily; and
• hygiene measures applied to reused/recycled water.</td><td>• Consider replacing “daily” with “tanks being cleaned and disinfected at an adequate frequency (e.g. end of shift)”
• Consider adding the following bullet: “Directed water scalders”</td></tr>
</table>

Para.	CAC/GL 78-2011	JEMRA Recommendations
63.	9.4.1.5 Crop removal 63. Where possible, crops should be extracted in a manner that is likely to limit carcass contamination.	• Consider adding the following to section 9.4.1.5: *"**The use of cropper systems allows the release of accumulated dirty water on the carcass cavity, so efforts to remove collected water prior to chilling should be considered.**"*
67.	Carcass washing systems with 13 washers using water with 25-35 ppm total chlorine have been shown to reduce levels of *Campylobacter* by about 0.5 $\log_{10}$ CFU/ml of whole carcass rinse sample. Post-wash sprays using Acidified Sodium Chlorite (ASC) or TSP may further reduce *Campylobacter* levels by an average of 1.3 $\log_{10}$ CFU/ml or 1.0 $\log_{10}$ CFU/ml of whole carcass rinse samples respectively.	Consider adding the following statement: *"**Carcass washes with 400 ppm paracetic acid (PAA), showed 1.2 log reductions of Campylobacter prior to chilling.**"* (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2019, 2022)
69.	An on-line reprocessing spray system incorporating ASC has been shown to reduce Campylobacter in the whole carcass rinse sample by about 2.1 $\log_{10}$ CFU/ml and to reduce the prevalence of *Salmonella* positive carcasses from 37% to 10%.	Consider adding the following statement: "***Inside and outside bird washers used for online-reprocessing at 100 ppm of PAA showed 0.5 log reductions of Campylobacter.***" (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2019)
70.	Dipping carcasses in 10% TSP reduced *Campylobacter* by 1.7 $\log_{10}$ CFU/g neck skin and the MPN of *Salmonella* was reduced from 1.92 $\log_{10}$ CFU/g neck skin to undetectable levels.	• Consider removing the recommendation for TSP since it may not be as commonly used at this time. • Consider adding the following statement: "***Dip treatments in 200 ppm of PAA showed 1.4 log reductions of Campylobacter in carcass rinses***." (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2019)

Para.	CAC/GL 78-2011	JEMRA Recommendations
78.	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 *Campylobacter* and *Salmonella* washed off, preventing re-attachment and cross-contamination.	• Consider adding the following statement: ***"Immersion chillers using 225 ppm of PAA showed reductions of 1.18 log in concentration and a 76.5% reduction in prevalence of Campylobacter."*** (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2022)
81.	Forced air chilling (blast chilling) may reduce the concentration of *Campylobacter* on chicken carcasses by 0.4 $\log_{10}$ CFU/carcass.	• Consider updating the value and excluding the unit of measure: ***"up to 1 log."*** (ANSES, 2018)
82.	Immersion chilling has been shown to reduce concentrations of *Campylobacter* by 1.1–1.3 $\log_{10}$ CFU/ml of carcass rinse.	• Consider updating this text to: *"Immersion chilling reduces concentrations of Campylobacter**, and with a combination of processing aids can result in a higher log reduction."*** (Dogan *et al.*, 2022)
84.	Immersing whole carcasses in 600–800 ppm ASC at pH 2.5 to 2.7 for 15 seconds immediately post-chill, has been shown to reduce *Campylobacter* by 0.9–1.2 $\log_{10}$ CFU/ml of whole carcass rinse sample.	• Consider adding the following text: "***Post chill tank interventions using sprays of PAA at 1 000 ppm showed up to 2.1 log reductions of Campylobacter.***" (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2022)
9.10.1	<u>For *Campylobacter*</u>	• Consider adding a new paragraph for *Campylobacter* and the following text: "***Immersion of chicken wings in 1 000 ppm of PAA for 30 s has been shown to reduce 2.3 logs of Campylobacter***" (Cano, Menses and Chaves, 2021; Chousalkar *et al.,* 2019; De Villena *et al.,* 2022; Dogan *et al.,* 2022)

Para.	CAC/GL 78-2011	JEMRA Recommendations
94.	Freezing of naturally contaminated carcasses followed by 31 days of storage at –20 degrees C has been shown to reduce *Campylobacter* by 0.7 to 2.9 $\log_{10}$ CFU/g.	• Consider updating this statement to read: *"Freezing of carcasses and portions contaminated with Campylobacter followed by* ***storage at -20 degrees C has been shown to reduce*** **Campylobacter** ***by up to 2 logs"*** (Dogan *et al.,* 2022).
95.	Crust freezing using continuous carbon dioxide belt freezing of skinless breast fillets has been shown to give a reduction of *Campylobacte*r of 0.4 $\log_{10}$ CFU/fillet.	• Consider updating the statement to include all chicken meat products and not just skinless breast fillets.
108.	Chicken meat should be cooked according to a process that is capable of achieving at least a 7 log reduction in both *Campylobacter* and *Salmonella*.	• Consider updating the text to read: *"Chicken meat should be cooked according to a process that is capable of reaching an* ***internal temperature that can inactivate Salmonella and Campylobacter, for example 74 °C."***
115.	Chicken meat should be cooked according to a process that is capable of achieving at least a 7 log reduction in both *Campylobacter* and *Salmonella*.	• Consider updating the text to read: *"Chicken meat should be cooked according to a process that is capable of reaching an* ***internal temperature that can inactivate Salmonella and Campylobacter, for example 74 °C."***

References:

ANSES. 2018. State of knowledge relating to the contamination of broilers with *Campylobacter* and assessment of the impact of interventions at different stages of the food chain in France. *Collective Expert Appraisal Report.* 2016-SA-0183. Maisons-Alfort Cedex, France. https://www.anses.fr/en/system/files/BIORISK2016SA0183RaEN.pdf

Cano, C., Meneses, Y. & Chaves, B.D. 2021. Application of Peroxyacetic Acid for decontamination of raw poultry products and comparison to other commonly used chemical antimicrobial interventions: A review. *Journal of Food Protection*, 84(10): 1772–1783. https://doi.org/10.4315/JFP-21-107

Chousalkar, K., Sims, S., McWhorter, A., Khan, S. & Sexton, M. 2019. The effect of sanitizers on microbial levels of chicken meat collected from commercial processing plants. *International Journal of Environmental Research and Public Health,* 16(23): 4807. https://doi.org/10.3390/ijerph16234807

De Villena, J.F., Vargas, D.A., Bueno López, R., Chávez-Velado, D.R., Casas, D.E., Jiménez, R.L. & Sanchez-Plata, M.X. 2022. Bio-mapping indicators and pathogen loads in a commercial broiler processing facility operating with high and low antimicrobial intervention levels. *Foods*, 11(6): 775. https://doi.org/10.3390/foods11060775

Dogan, O.B., Aditya, A., Ortuzar, J., Clark, J. & Wang, B. 2022. A systematic review and meta-analysis of the efficacy of processing stages and interventions for controlling Campylobacter contamination during broiler chicken processing. *Comprehensive Reviews in Food Science and Food Safety*, 21(1): 227–271. https://doi.org/10.1111/1541-4337.12860

Dogan, O.B., Clarke, J., Mattos, F. & Wang, B. 2019. A quantitative microbial risk assessment model of Campylobacter in broiler chickens: Evaluating processing interventions. *Food Control*, 100: 97–110. https://doi.org/10.1016/j.foodcont.2019.01.003

Annex 4

BIBLIOGRAPHY USED FOR SCOPING REVIEW

A 4.1 Primary

A4.1.1 Biosecurity and management approaches

Agunos, A., Waddell, L., Léger, D. & Taboada, E. 2014. A systematic review characterizing on-farm sources of *Campylobacter* spp. for broiler chickens. *PLoS ONE*, 9(8): e104905. https://doi.org/10.1371/journal.pone.0104905

Al Hakeem, W.G., Fathima, S., Shanmugasundaram, R. & Selvaraj, R.K. 2022. *Campylobacter jejuni* in poultry: pathogenesis and control strategies. *Microorganisms*, 10(11): 2134. https://doi.org/10.3390/microorganisms10112134

Allen, V.M., Weaver, H., Ridley, A.M., Harris, J.A., Sharma, M., Emery, J., Sparks, N., Lewis, M. & Edge, S. 2008. Sources and spread of thermophilic *Campylobacter* spp. during partial depopulation of broiler chicken flocks. *Journal of Food Protection*, 71(2): 264–270. https://doi.org/10.4315/0362-028X-71.2.264

Alpigiani, I., Abrahantes, J.C., Michel, V., Huneau-Salaün, A., Chemaly, M., Keeling, L.J., Gervelmeyer, A. *et al.* 2017. Associations between animal welfare indicators and *Campylobacter* spp. in broiler chickens under commercial settings: A case study. *Preventive Veterinary Medicine*, 147: 186–193. https://doi.org/10.1016/j.prevetmed.2017.09.005

Babacan, O., Harris, S.A., Pinho, R.M., Hedges, A., Jørgensen, F. & Corry, J.E.L. 2020. Factors affecting the species of *Campylobacter* colonizing chickens reared for meat. *Journal of Applied Microbiology*, 129(4): 1071–1078. https://doi.org/10.1111/jam.14651

Bailey, M.A., Bourassa, D.V., Krehling, J.T., Munoz, L., Chasteen, K.S., Escobar, C. & Macklin, K.S. 2022. Effects of common litter management practices on the prevalence of *Campylobacter jejuni* in broilers. *Animals*, 12(7): 858. https://doi.org/10.3390/ani12070858

Battersby, T., Whyte, P. & Bolton, D.J. 2016. The pattern of *Campylobacter* contamination on broiler farms; external and internal sources. *Journal of Applied Microbiology*, 120(4): 1108–1118. https://doi.org/10.1111/jam.13066

Borck Høg, B., Sommer, H.M., Larsen, L.S., Sørensen, A.I.V., David, B., Hofshagen, M. & Rosenquist, H. 2016. Farm specific risk factors for *Campylobacter* colonisation in Danish and Norwegian broilers. *Preventive Veterinary Medicine*, 130: 137–145. https://doi.org/10.1016/j.prevetmed.2016.04.002

Chowdhury, S., Themudo, G.E., Sandberg, M. & Ersbøll, A.K. 2013. Spatio-temporal patterns of *Campylobacter* colonization in Danish broilers. *Epidemiology and Infection*, 141(5): 997–1008. https://doi.org/10.1017/S0950268812001446

Colles, F.M., Cain, R.J., Nickson, T., Smith, A.L., Roberts, S.J., Maiden, M.C.J., Lunn, D. & Dawkins, M.S. 2016. Monitoring chicken flock behaviour provides early warning of infection by human pathogen *Campylobacter*. *Proceedings of the Royal Society B: Biological Sciences*, 283(1822): 20152323. https://doi.org/10.1098/rspb.2015.2323

Colles, F.M., Dingle, K.E., Cody, A.J. & Maiden, M.C.J. 2008. Comparison of *Campylobacter* populations in wild geese with those in starlings and free-range poultry on the same farm. *Applied and Environmental Microbiology*, 74(11): 3583–3590. https://doi.org/10.1128/AEM.02491-07

Crotta, M., Georgiev, M. & Guitian, J. 2017. Quantitative risk assessment of *Campylobacter* in broiler chickens – Assessing interventions to reduce the level of contamination at the end of the rearing period. *Food Control*, 75: 29–39. https://doi.org/10.1016/j.foodcont.2016.12.024

Di Marcantonio, L., Marotta, F., Vulpiani, M.P., Sonntag, Q., Iannetti, L., Janowicz, A., Serafino, G.D., Di Giannatale, E. & Garofolo, G. 2022. Investigating the cecal microbiota in broiler poultry farms and its potential relationships with animal welfare. *Research in Veterinary Science*, 144: 115–125. https://doi.org/10.1016/j.rvsc.2022.01.020

Georgiev, M., Beauvais, W. & Guitian, J. 2017. Effect of enhanced biosecurity and selected on-farm factors on *Campylobacter* colonization of chicken broilers. *Epidemiology and Infection*, 145(3): 553–567. https://doi.org/10.1017/S095026881600251X

Golden, C.E. & Mishra, A. 2020. Prevalence of *Salmonella* and *Campylobacter* spp. in alternative and conventionally produced chicken in the United States: a systematic review and meta-analysis. *Journal of Food Protection*, 83(7): 1181–1197. https://doi.org/10.4315/JFP-19-538

Griekspoor, P., Colles, F.M., McCarthy, N.D., Hansbro, P.M., Ashhurst-Smith, C., Olsen, B., Hasselquist, D., Maiden, M.C.J. & Waldenström, J. 2013. Marked host specificity and lack of phylogeographic population structure of *Campylobacter jejuni* in wild birds. *Molecular Ecology*, 22(5): 1463–1472. https://doi.org/10.1111/mec.12144

Guerin, M.T., Martin, S.W., Reiersen, J., Berke, O., McEwen, S.A., Friðriksdóttir, V., Bisaillon, J.-R. & Lowman, R. 2008. Temperature-related risk factors associated with the colonization of broiler-chicken flocks with *Campylobacter* spp. in Iceland, 2001–2004. *Preventive Veterinary Medicine*, 86(1–2): 14–29. https://doi.org/10.1016/j.prevetmed.2008.02.015

Hansson, I., Olsson Engvall, E., Vågsholm, I. & Nyman, A. 2010. Risk factors associated with the presence of *Campylobacter*-positive broiler flocks in Sweden. *Preventive Veterinary Medicine,* 96:114-121. doi: 10.1016/j.prevetmed.2010.05.007

Hasan, Md.M., Talukder, S., Mandal, A.K., Tasmim, S.T., Parvin, Mst.S., Ali, Md.Y., Sikder, M.H. & Islam, Md.T. 2020. Prevalence and risk factors of *Campylobacter* infection in broiler and cockerel flocks in Mymensingh and Gazipur districts of Bangladesh. *Preventive Veterinary Medicine*, 180: 105034. https://doi.org/10.1016/j.prevetmed.2020.105034

Henry, I., Reichardt, J., Denis, M. & Cardinale, E. 2011. Prevalence and risk factors for *Campylobacter* spp. in chicken broiler flocks in Reunion Island (Indian Ocean). *Preventive Veterinary Medicine*, 100(1): 64–70. https://doi.org/10.1016/j.prevetmed.2011.03.007

Hertogs, K., Haegeman, A., Schaumont, D., Gelaude, P., De Zutter, L., Dewulf, J., Heyndrickx, M. & Rasschaert, G. 2021. Contamination sources and transmission routes for *Campylobacter* on (mixed) broiler farms in Belgium, and comparison of the gut microbiota of flocks colonized and uncolonized with *Campylobacter. Pathogens*, 10(1): 66. https://doi.org/10.3390/pathogens10010066

Higham, L.E., Scott, C., Akehurst, K., Dring, D., Parnham, A., Waterman, M. & Bright, A. 2018. Effects of financial incentives and cessation of thinning on prevalence of *Campylobacter*: a longitudinal monitoring study on commercial broiler farms in the UK. *Veterinary Record*, 183(19): 595–595. https://doi.org/10.1136/vr.104823

Higham, L.E., Scott, C., Akehurst, K., Dring, D., Parnham, A., Waterman, M. & Bright, A. 2018. Effects of financial incentives and cessation of thinning on prevalence of *Campylobacter* : a longitudinal monitoring study on commercial broiler farms in the UK. *Veterinary Record*, 183(19): 595–595. https://doi.org/10.1136/vr.104823

Hwang, H. & Singer, R.S. 2020. Survey of the U.S. broiler industry regarding pre- and postharvest interventions targeted to mitigate *Campylobacter* contamination on broiler chicken products. *Journal of Food Protection*, 83(7): 1137–1148. https://doi.org/10.4315/JFP-19-527

Iannetti, L., Neri, D., Santarelli, G.A., Cotturone, G., Podaliri Vulpiani, M., Salini, R., Antoci, S. *et al.* 2020. Animal welfare and microbiological safety of poultry meat: Impact of different at-farm animal welfare levels on at-slaughterhouse *Campylobacter* and *Salmonella* contamination. *Food Control*, 109: 106921. https://doi.org/10.1016/j.foodcont.2019.106921

Jonsson, M.E., Chriél, M., Norström, M. & Hofshagen, M. 2012. Effect of climate and farm environment on *Campylobacter* spp. colonisation in Norwegian broiler flocks. *Preventive Veterinary Medicine*, 107(1–2): 95–104. https://doi.org/10.1016/j.prevetmed.2012.05.002

Lassen, B., Helwigh, B., Kahl Petersen, C. & Ellis-Iversen, J. 2022. Systematic review of products with potential application for use in the control of *Campylobacter* spp. in organic and free-range broilers. *Acta Veterinaria Scandinavica*, 64(1): 24. https://doi.org/10.1186/s13028-022-00644-z

McKenna, A., Ijaz, U.Z., Kelly, C., Linton, M., Sloan, W.T., Green, B.D., Lavery, U. *et al.* 2020. Impact of industrial production system parameters on chicken microbiomes: mechanisms to improve performance and reduce *Campylobacter*. *Microbiome*, 8(1): 128. https://doi.org/10.1186/s40168-020-00908-8

Mendes, Â.J., Santos-Ferreira, N.L., Costa, F.M., Lopes, E.P., Freitas-Silva, J., Inácio, Â.S., Moreira, F. & Martins Da Costa, P. 2020. External contamination of broilers by *Campylobacter* spp. increases from the farm to the slaughterhouse. *British Poultry Science*, 61(4): 400–407. https://doi.org/10.1080/00071668.2020.1736264

Näther, G., Alter, T., Martin, A. & Ellerbroek, L. 2009. Analysis of risk factors for *Campylobacter* species infection in broiler flocks. *Poultry Science*, 88(6): 1299–1305. https://doi.org/10.3382/ps.2008-00389

Natsos, G., Mouttotou, N.K., Magiorkinis, E., Ioannidis, A., Rodi-Burriel, A., Chatzipanagiotou, S. & Koutoulis, K.C. 2020. Prevalence of and risk factors for *Campylobacter* spp. colonization of broiler chicken flocks in Greece. *Foodborne Pathogens and Disease*, 17(11): 679–686. https://doi.org/10.1089/fpd.2020.2795

Rawson, T., Dawkins, M.S. & Bonsall, M.B. 2019. A mathematical model of *Campylobacter* dynamics within a broiler flock. *Frontiers in Microbiology*, 10: 1940. https://doi.org/10.3389/fmicb.2019.01940

Reichelt, B., Szott, V., Epping, L., Semmler, T., Merle, R., Roesler, U. & Friese, A. 2022. Transmission pathways of *Campylobacter* spp. at broiler farms and their environment in Brandenburg, Germany. *Frontiers in Microbiology*, 13: 982693. https://doi.org/10.3389/fmicb.2022.982693

Rothrock, M.J., Cook, K.L., Warren, J.G. & Sistani, K. 2008. The effect of alum addition on microbial communities in poultry litter. *Poultry Science*, 87(8): 1493–1503. https://doi.org/10.3382/ps.2007-00491

Sandberg, M., Dahl, J., Lindegaard, L.L. & Pedersen, J.R. 2017. Compliance/non-compliance with biosecurity rules specified in the Danish Quality Assurance system (KIK) and *Campylobacter*- positive broiler flocks 2012 and 2013. *Poultry Science*, 96(1): 184–191. https://doi.org/10.3382/ps/pew277

Schweitzer, P.M., Susta, L., Varga, C., Brash, M.L. & Guerin, M.T. 2021. Demographic, husbandry, and biosecurity factors associated with the presence of *Campylobacter* spp. in small poultry flocks in Ontario, Canada. *Pathogens*, 10(11): 1471. https://doi.org/10.3390/pathogens10111471

Sevilla-Navarro, S., Marin, C., Cortés, V., García, C. & Catalá-Gregori, P. 2020. *Campylobacter* prevalence and risk factors associated with exceeding allowable limits in poultry slaughterhouses in Spain. *Veterinary Record*, 186(13): 415–415. https://doi.org/10.1136/vr.105558

Sheppard, S.K., Colles, F., Richardson, J., Cody, A.J., Elson, R., Lawson, A., Brick, G. *et al.* 2010. Host association of *Campylobacter* genotypes transcends geographic variation. *Applied and Environmental Microbiology*, 76(15): 5269–5277. https://doi.org/10.1128/AEM.00124-10

Smith, S., Messam, L.L.McV., Meade, J., Gibbons, J., McGill, K., Bolton, D. & Whyte, P. 2016. The impact of biosecurity and partial depopulation on *Campylobacter* prevalence in Irish broiler flocks with differing levels of hygiene and economic performance. *Infection Ecology & Epidemiology*, 6(1): 31454. https://doi.org/10.3402/iee.v6.31454

Torralbo, A., Borge, C., Allepuz, A., García-Bocanegra, I., Sheppard, S.K., Perea, A. & Carbonero, A. 2014. Prevalence and risk factors of *Campylobacter* infection in broiler flocks from southern Spain. *Preventive Veterinary Medicine*, 114(2): 106–113. https://doi.org/10.1016/j.prevetmed.2014.01.019

Urdaneta, S., Lorca-Oró, C., Dolz, R., López-Soria, S. & Cerdà-Cuéllar, M. 2023. In a warm climate, ventilation, indoor temperature and outdoor relative humidity have significant effects on *Campylobacter* spp. colonization in chicken broiler farms which can occur in only 2 days. *Food Microbiology*, 109: 104118. https://doi.org/10.1016/j.fm.2022.104118

van Wagenberg, C.P.A., Van Horne, P.L.M., Sommer, H.M. & Nauta, M.J. 2016. Cost-effectiveness of *Campylobacter* interventions on broiler farms in six European countries. *Microbial Risk Analysis*, 2–3: 53–62. https://doi.org/10.1016/j.mran.2016.05.003

Wanja, D.W., Mbuthia, P.G., Aboge, G.O. & Bebora, L.C. 2022. Seasonal prevalence and molecular identification of thermophilic *Campylobacter* from chicken, cattle, and respective drinking water in Kajiado County, Kenya. *International Journal of Microbiology*, 2022: 1–11. https://doi.org/10.1155/2022/1526641

Williams, L.K., Sait, L.C., Trantham, E.K., Cogan, T.A. & Humphrey, T.J. 2013. *Campylobacter* infection has different outcomes in fast- and slow-growing broiler chickens. *Avian Diseases*, 57(2): 238–241. https://doi.org/10.1637/10442-110212-Reg.1

Zbrun, M.V., Rossler, E., Olivero, C.R., Soto, L.P., Zimmermann, J.A., Frizzo, L.S. & Signorini, M.L. 2021. Possible reservoirs of thermotolerant *Campylobacter* at the farm between rearing periods and after the use of enrofloxacin as a therapeutic treatment. *International Journal of Food Microbiology*, 340: 109046. https://doi.org/10.1016/j.ijfoodmicro.2021.109046

A4.1.2 Vaccine and phage-based approaches

Vaccine

Buckley, A.M., Wang, J., Hudson, D.L., Grant, A.J., Jones, M.A., Maskell, D.J. & Stevens, M.P. 2010. Evaluation of live-attenuated *Salmonella* vaccines expressing *Campylobacter* antigens for control of *C. jejuni* in poultry. *Vaccine*, 28(4): 1094–1105. https://doi.org/10.1016/j.vaccine.2009.10.018

Chintoan-Uta, C., Cassady-Cain, R.L. & Stevens, M.P. 2016. Evaluation of flagellum-related proteins FliD and FspA as subunit vaccines against *Campylobacter jejuni* colonisation in chickens. *Vaccine*, 34(15): 1739–1743. https://doi.org/10.1016/j.vaccine.2016.02.052

Clark, J.D., Oakes, R.D., Redhead, K., Crouch, C.F., Francis, M.J., Tomley, F.M. & Blake, D.P. 2012. Eimeria species parasites as novel vaccine delivery vectors: Anti-*Campylobacter jejuni* protective immunity induced by Eimeria tenella-delivered CjaA. *Vaccine*, 30(16): 2683–2688. https://doi.org/10.1016/j.vaccine.2012.02.002

Cui, Y., Guo, F., Guo, J., Cao, X., Wang, H., Yang, B., Zhou, H. *et al.* 2020. Immunization of chickens with the Enterobactin conjugate vaccine reduced *Campylobacter jejuni* colonization in the intestine. *Vaccines*, 8(4): 747. https://doi.org/10.3390/vaccines8040747

Gloanec, N., Dory, D., Quesne, S., Béven, V., Poezevara, T., Keita, A., Chemaly, M. & Guyard-Nicodème, M. 2022. Impact of DNA prime/protein boost vaccination against *Campylobacter jejuni* on immune responses and gut microbiota in chickens. *Vaccines*, 10(6): 981. https://doi.org/10.3390/vaccines10060981

Jeon, B., Saisom, T., Sasipreeyajan, J. & Luangtongkum, T. 2022. Live-attenuated oral vaccines to reduce *Campylobacter* colonization in poultry. *Vaccines*, 10(5): 685. https://doi.org/10.3390/vaccines10050685

Łaniewski, P., Kuczkowski, M., Chrząstek, K., Woźniak, A., Wyszyńska, A., Wieliczko, A. & Jagusztyn-Krynicka, E.K. 2014. Evaluation of the immunogenicity of *Campylobacter jejuni* CjaA protein delivered by *Salmonella* enterica sv. Typhimurium strain with regulated delayed attenuation in chickens. *World Journal of Microbiology and Biotechnology*, 30(1): 281–292. https://doi.org/10.1007/s11274-013-1447-5

Layton, S.L., Morgan, M.J., Cole, K., Kwon, Y.M., Donoghue, D.J., Hargis, B.M. & Pumford, N.R. 2011. Evaluation of *Salmonella*-vectored *Campylobacter* peptide epitopes for reduction of *Campylobacter jejuni* in broiler chickens. *Clinical and Vaccine Immunology*, 18(3): 449–454. https://doi.org/10.1128/CVI.00379-10

Mauri, M., Sannasiddappa, T.H., Vohra, P., Corona-Torres, R., Smith, A.A., Chintoan-Uta, C., Bremner, A. *et al.* 2021. Multivalent poultry vaccine development using Protein Glycan Coupling Technology. *Microbial Cell Factories*, 20(1): 193. https://doi.org/10.1186/s12934-021-01682-4

Meunier, M., Guyard-Nicodème, M., Vigouroux, E., Poezevara, T., Béven, V., Quesne, S., Amelot, M. *et al.* 2018. A DNA prime/protein boost vaccine protocol developed against *Campylobacter jejuni* for poultry. *Vaccine,* 36(16): 2119–2125. https://doi.org/10.1016/j.vaccine.2018.03.004

Nothaft, H., Perez-Muñoz, M.E., Yang, T., Murugan, A.V.M., Miller, M., Kolarich, D., Plastow, G.S., Walter, J. & Szymanski, C.M. 2021. Improving chicken responses to glycoconjugate vaccination against *Campylobacter jejuni. Frontiers in Microbiology*, 12: 734526. https://doi.org/10.3389/fmicb.2021.734526

Radomska, K.A., Vaezirad, M.M., Verstappen, K.M., Wösten, M.M.S.M., Wagenaar, J.A. & Van Putten, J.P.M. 2016. Chicken immune response after In Ovo immunization with Chimeric TLR5 activating flagellin of *Campylobacter jejuni. PLoS ONE*, 11(10): e0164837. https://doi.org/10.1371/journal.pone.0164837

Thibodeau, A., Fravalo, P., Perron, A., Lewandowski, S.L.- & Letellier, A. 2017. Production and characterization of anti-*Campylobacter jejuni* IgY derived from egg yolks. *Acta Veterinaria Scandinavica*, 59(1): 80. https://doi.org/10.1186/s13028-017-0346-4

Vandeputte, J., Martel, A., Van Rysselberghe, N., Antonissen, G., Verlinden, M., De Zutter, L., Heyndrickx, M. *et al.* 2019. In ovo vaccination of broilers against *Campylobacter jejuni* using a bacterin and subunit vaccine. *Poultry Science*, 98(11): 5999–6004. https://doi.org/10.3382/ps/pez402

Phage

Carvalho, C.M., Gannon, B.W., Halfhide, D.E., Santos, S.B., Hayes, C.M., Roe, J.M. & Azeredo, J. 2010. The in vivo efficacy of two administration routes of a phage cocktail to reduce numbers of *Campylobacter coli* and *Campylobacter jejuni* in chickens. *BMC Microbiology*, 10(1): 232. https://doi.org/10.1186/1471-2180-10-232

Chinivasagam, H.N., Estella, W., Maddock, L., Mayer, D.G., Weyand, C., Connerton, P.L. & Connerton, I.F. 2020. Bacteriophages to control *Campylobacter* in commercially farmed broiler chickens, in Australia. *Frontiers in Microbiology*, 11: 632. https://doi.org/10.3389/fmicb.2020.00632

D'Angelantonio, D., Scattolini, S., Boni, A., Neri, D., Di Serafino, G., Connerton, P., Connerton, I. *et al.* 2021. Bacteriophage therapy to reduce colonization of *Campylobacter jejuni* in broiler chickens before slaughter. *Viruses*, 13(8): 1428. https://doi.org/10.3390/v13081428

El-Shibiny, A., Scott, A., Timms, A., Metawea, Y., Connerton, P. & Connerton, I. 2009. Application of a group II *Campylobacter* bacteriophage to reduce strains of *Campylobacter jejuni* and *Campylobacter coli* colonizing broiler chickens. *Journal of Food Protection*, 72(4): 733–740. https://doi.org/10.4315/0362-028X-72.4.733

Fischer, S., Kittler, S., Klein, G. & Glünder, G. 2013. Impact of a single phage and a phage cocktail application in broilers on reduction of *Campylobacter jejuni* and development of resistance. *PLoS ONE*, 8(10): e78543. https://doi.org/10.1371/journal.pone.0078543

Furuta, M., Nasu, T., Umeki, K., Hoang Minh, D., Honjoh, K.-I. & Miyamoto, T. 2017. Characterization and application of Lytic bacteriophages against *Campylobacter jejuni* isolated from poultry in Japan. *Biocontrol Science*, 22(4): 213–221. https://doi.org/10.4265/bio.22.213

Hammerl, J.A., Jäckel, C., Alter, T., Janzcyk, P., Stingl, K., Knüver, M.T. & Hertwig, S. 2014. Reduction of *Campylobacter jejuni* in broiler chicken by successive application of group II and group III phages. *PLoS ONE*, 9(12): e114785. https://doi.org/10.1371/journal.pone.0114785

Kittler, S., Fischer, S., Abdulmawjood, A., Glünder, G. & Klein, G. 2013. Effect of bacteriophage application on *Campylobacter jejuni* loads in commercial broiler flocks. *Applied and Environmental Microbiology*, 79(23): 7525–7533. https://doi.org/10.1128/AEM.02703-13

Richards, P.J., Connerton, P.L. & Connerton, I.F. 2019. Phage biocontrol of *Campylobacter jejuni* in chickens does not produce collateral effects on the gut microbiota. *Frontiers in Microbiology*, 10: 476. https://doi.org/10.3389/fmicb.2019.00476

A4.1.3 Feed and water additives approaches

Caprylic acid and other organic acids

Currie, D., Green, M., Dufailu, O.A., Matthaios, P., Soultanas, P., McCartney, E., Lester, H. *et al.* 2018. Dietary supplementation with ferric tyrosine improves zootechnical performance and reduces caecal *Campylobacter* spp. load in broilers. *British Poultry Science*, 59(6): 646–653. https://doi.org/10.1080/00071668.2018.1507015

De Los Santos, F.S., Donoghue, A.M., Venkitanarayanan, K., Dirain, M.L., Reyes-Herrera, I., Blore, P.J. & Donoghue, D.J. 2008. Caprylic acid supplemented in feed reduces Enteric *Campylobacter jejuni* colonization in ten-day-old broiler chickens. *Poultry Science*, 87(4): 800–804. https://doi.org/10.3382/ps.2007-00280

De Los Santos, F.S., Donoghue, A.M., Venkitanarayanan, K., Metcalf, J.H., Reyes-Herrera, I., Dirain, M.L., Aguiar, V.F., Blore, P.J. & Donoghue, D.J. 2009. The natural feed additive caprylic acid decreases *Campylobacter jejuni* colonization in market-aged broiler chickens. *Poultry Science*, 88(1): 61–64. https://doi.org/10.3382/ps.2008-00228

De Los Santos, F.S., Donoghue, A.M., Venkitanarayanan, K., Reyes-Herrera, I., Metcalf, J.H., Dirain, M.L., Aguiar, V.F., Blore, P.J. & Donoghue, D.J. 2008. Therapeutic supplementation of caprylic acid in feed reduces *Campylobacter jejuni* colonization in broiler chicks. *Applied and Environmental Microbiology*, 74(14): 4564–4566. https://doi.org/10.1128/AEM.02528-07

De Los Santos, F.S., Hume, M., Venkitanarayanan, K., Donoghue, A.M., Hanning, I., Slavik, M.F., Aguiar, V.F. *et al.* 2010. Caprylic acid reduces enteric *Campylobacter* colonization in market-aged broiler chickens but does not appear to alter cecal microbial populations. *Journal of Food Protection*, 73(2): 251–257. https://doi.org/10.4315/0362-028X-73.2.251

Greene, G., Koolman, L., Whyte, P., Lynch, H., Coffey, A., Lucey, B., Egan, J., O'Connor, L. & Bolton, D. 2022. The efficacy of organic acid, medium chain fatty acid and essential oil based broiler treatments; *in vitro* anti-*Campylobacter jejuni* activity and the effect of these chemical-based treatments on broiler performance. *Journal of Applied Microbiology*, 132(1): 687–695. https://doi.org/10.1111/jam.15204

Hovorková, P. & Skřivanová, E. 2015. Use of Caprylic acid in broiler chickens: effect on *Campylobacter jejuni*. *Foodborne Pathogens and Disease*, 12(8): 712–718. https://doi.org/10.1089/fpd.2015.1978

Khattak, F., Paschalis, V., Green, M., Houdijk, J.G.M., Soultanas, P. & Mahdavi, J. 2018. TYPLEX® Chelate, a novel feed additive, inhibits *Campylobacter jejuni* biofilm formation and cecal colonization in broiler chickens. *Poultry Science*, 97(4): 1391–1399. https://doi.org/10.3382/ps/pex413

Metcalf, J.H., Donoghue, A.M., Venkitanarayanan, K., Reyes-Herrera, I., Aguiar, V.F., Blore, P.J. & Donoghue, D.J. 2011. Water administration of the medium-chain fatty acid caprylic acid produced variable efficacy against enteric *Campylobacter* colonization in broilers 1, 2. *Poultry Science*, 90(2): 494–497. https://doi.org/10.3382/ps.2010-00891

Probiotics

Arsi, K., Donoghue, A.M., Woo-Ming, A., Blore, P.J. & Donoghue, D.J. 2015. The efficacy of selected probiotic and prebiotic combinations in reducing *Campylobacter* colonization in broiler chickens. *Journal of Applied Poultry Research*, 24(3): 327–334. https://doi.org/10.3382/japr/pfv032

Cean, A., Stef, L., Simiz, E., Julean, C., Dumitrescu, G., Vasile, A., Pet, E., Drinceanu, D. & Corcionivoschi, N. 2015. Effect of human isolated probiotic bacteria on preventing *Campylobacter jejuni* colonization of poultry. *Foodborne Pathogens and Disease*, 12(2): 122–130. https://doi.org/10.1089/fpd.2014.1849

Dec, M., Nowaczek, A., Urban-Chmiel, R., Stępień-Pyśniak, D. & Wernicki, A. 2018. Probiotic potential of *Lactobacillus* isolates of chicken origin with anti-*Campylobacter* activity. *Journal of Veterinary Medical Science*, 80(8): 1195–1203. https://doi.org/10.1292/jvms.18-0092

Froebel, L.K., Jalukar, S., Lavergne, T.A., Coufal, C.D. & Duong, T. 2020. Administration of direct-fed *Bacillus cultures* and refined functional carbohydrates to broiler chickens improves growth performance and promotes positive shifts in gastrointestinal microbiota. *Journal of Applied Poultry Research*, 29(4): 765–774. https://doi.org/10.1016/j.japr.2020.06.004

Ghareeb, K., Awad, W.A., Mohnl, M., Porta, R., Biarnés, M., Böhm, J. & Schatzmayr, G. 2012. Evaluating the efficacy of an avian-specific probiotic to reduce the colonization of *Campylobacter jejuni* in broiler chickens. *Poultry Science*, 91(8): 1825–1832. https://doi.org/10.3382/ps.2012-02168

Gharib Naseri, K., Rahimi, S. & Khaki, P. 2012. Comparison of the effects of probiotic, organic acid and medicinal plant on *Campylobacter jejuni* challenged broiler chickens. *Journal of Agricultural Science and Technology*, 14(7): 1485–1496.

Gorain, C., Singh, A., Bhattacharyya, S., Kundu, A., Lahiri, A., Gupta, S. & Mallick, A.I. 2020. Mucosal delivery of live *Lactococcus lactis* expressing functionally active JlpA antigen induces potent local immune response and prevent enteric colonization of *Campylobacter jejuni* in chickens. *Vaccine*, 38(7): 1630–1642. https://doi.org/10.1016/j.vaccine.2019.12.064

Guo, J.R., Dong, X.F., Liu, S. & Tong, J.M. 2018. High-throughput sequencing reveals the effect of Bacillus subtilis CGMCC 1.921 on the cecal microbiota and gene expression in ileum mucosa of laying hens. *Poultry Science*, 97(7): 2543–2556. https://doi.org/10.3382/ps/pey112

Khan, M. 2019. Effect of newly characterized probiotic lactobacilli on weight gain, immunomodulation and gut microbiota of *Campylobacter jejuni* challenged broiler chicken. *Pakistan Veterinary Journal*, 39(04): 473–478. https://doi.org/10.29261/pakvetj/2019.051

Massacci, F.R., Lovito, C., Tofani, S., Tentellini, M., Genovese, D.A., De Leo, A.A.P., Papa, P. *et al.* 2019. Dietary saccharomyces cerevisiae boulardii CNCM I-1079 positively affects performance and intestinal ecosystem in broilers during a *Campylobacter jejuni* infection. *Microorganisms*, 7(12): 596. https://doi.org/10.3390/microorganisms7120596

Mortada, M., Cosby, D.E., Shanmugasundaram, R. & Selvaraj, R.K. 2020. In vivo and in vitro assessment of commercial probiotic and organic acid feed additives in broilers challenged with *Campylobacter coli. Journal of Applied Poultry Research*, 29(2): 435–446. https://doi.org/10.1016/j.japr.2020.02.001

Nazef, L., Belguesmia, Y., Tani, A., Prévost, H. & Drider, D. 2008. Identification of lactic acid bacteria from poultry feces: evidence on anti-*Campylobacter* and anti-*Listeria* activities. *Poultry Science*, 87(2): 329–334. https://doi.org/10.3382/ps.2007-00282

Saint-Cyr, M.J., Haddad, N., Taminiau, B., Poezevara, T., Quesne, S., Amelot, M., Daube, G. *et al.* 2017. Use of the potential probiotic strain *Lactobacillus salivarius* SMXD51 to control *Campylobacter jejuni* in broilers. *International Journal of Food Microbiology*, 247: 9–17. https://doi.org/10.1016/j.ijfoodmicro.2016.07.003

Śmiałek, M., Kowalczyk, J. & Koncicki, A. 2021. The use of probiotics in the reduction of *Campylobacter* spp. prevalence in poultry. *Animals*, 11(5): 1355. https://doi.org/10.3390/ani11051355

Szott, V., Reichelt, B., Friese, A. & Roesler, U. 2022. A complex competitive exclusion culture reduces *Campylobacter jejuni* colonization in broiler chickens at slaughter age in vivo. *Veterinary Sciences*, 9(4): 181. https://doi.org/10.3390/vetsci9040181

Tabashsum, Z., Peng, M., Alvarado-Martinez, Z., Aditya, A., Bhatti, J., Romo, P.B., Young, A. & Biswas, D. 2020. Competitive reduction of poultry-borne enteric bacterial pathogens in chicken gut with bioactive *Lactobacillus casei. Scientific Reports*, 10(1): 16259. https://doi.org/10.1038/s41598-020-73316-5

Ty, M., Taha-Abdelaziz, K., Demey, V., Castex, M., Sharif, S. & Parkinson, J. 2022. Performance of distinct microbial based solutions in a *Campylobacter* infection challenge model in poultry. *Animal Microbiome*, 4(1): 2. https://doi.org/10.1186/s42523-021-00157-6

Willis, W.L. & Reid, L. 2008. Investigating the effects of dietary probiotic feeding regimens on broiler chicken production and *Campylobacter jejuni* presence. *Poultry Science*, 87(4): 606–611. https://doi.org/10.3382/ps.2006-00458

Yuri Kuznetsov, I.N. 2020. Evaluation lactic acid bacteria autostrains with anti-*Campylobacter jejuni* activity on broiler chickens productivity. *International Transaction Journal of Engineering*, Management: 11A15S: 15. https://doi.org/10.14456/ITJEMAST.2020.307

The addition of plant-based molecules to feed

Allaoua, M., Bonnafé, E., Etienne, P., Noirot, V., Gabarrou, J.-F., Castinel, A., Pascal, G. *et al.* 2022. A carvacrol-based product reduces *Campylobacter jejuni* load and alters microbiota composition in the caeca of chickens. *Journal of Applied Microbiology*, 132(6): 4501–4516. https://doi.org/10.1111/jam.15521

Allaoua, M., Etienne, P., Noirot, V., Carayon, J.-L., Téné, N., Bonnafé, E. & Treilhou, M. 2018. Pharmacokinetic and antimicrobial activity of a new carvacrol-based product against a human pathogen, *Campylobacter jejuni*. *Journal of Applied Microbiology*, 125(4): 1162–1174. https://doi.org/10.1111/jam.13915

Arsi, K., Donoghue, A.M., Venkitanarayanan, K., Kollanoor-Johny, A., Fanatico, A.C., Blore, P.J. & Donoghue, D.J. 2014. The efficacy of the natural plant extracts, thymol and carvacrol against *Campylobacter* colonization in broiler chickens. *Journal of Food Safety*, 34(4): 321–325. https://doi.org/10.1111/jfs.12129

Arsi, K., Donoghue, A.M., Woo-Ming, A., Blore, P.J. & Donoghue, D.J. 2015. The efficacy of selected probiotic and prebiotic combinations in reducing *Campylobacter* colonization in broiler chickens. *Journal of Applied Poultry Research*, 24(3): 327–334. https://doi.org/10.3382/japr/pfv032

Epps, S.V.R., Harvey, R.B., Byrd, J.A., Petrujkić, B.T., Sedej, I., Beier, R.C., Phillips, T.D. *et al.* 2015. Comparative effect of thymol or its glucose conjugate, thymol-β- d -glucopyranoside, on *Campylobacter* in avian gut contents. *Journal of Environmental Science and Health, Part B*, 50(1): 55–61. https://doi.org/10.1080/03601234.2015.965634

Friedman, M. 2017. Chemistry, antimicrobial mechanisms, and antibiotic activities of cinnamaldehyde against pathogenic bacteria in animal feeds and human foods. *Journal of Agricultural and Food Chemistry*, 65(48): 10406–10423. https://doi.org/10.1021/acs.jafc.7b04344

Gharib Naseri, K., Rahimi, S. & Khaki, P. 2012. Comparison of the effects of probiotic, organic acid and medicinal plant on *Campylobacter jejuni* challenged broiler chickens. *Journal of Agricultural Science and Technology*, 14(7): 1485–1496.

Hankel, J., Popp, J., Meemken, D., Zeiger, K., Beyerbach, M., Taube, V., Klein, G. & Visscher, C. 2018. Influence of lauric acid on the susceptibility of chickens to an experimental *Campylobacter jejuni* colonisation. *PLoS ONE*, 13(9): e0204483. https://doi.org/10.1371/journal.pone.0204483

Ibrahim, D., Sewid, A.H., Arisha, A.H., Abd El-fattah, A.H., Abdelaziz, A.M., Al-Jabr, O.A. & Kishawy, A.T.Y. 2020. Influence of Glycyrrhiza glabra extract on growth, gene expression of gut integrity, and *Campylobacter jejuni* colonization in broiler chickens. *Frontiers in Veterinary Science*, 7: 612063. https://doi.org/10.3389/fvets.2020.612063

Kollanoor Johny, A., Darre, M.J., Donoghue, A.M., Donoghue, D.J. & Venkitanarayanan, K. 2010. Antibacterial effect of trans-cinnamaldehyde, eugenol, carvacrol, and thymol on *Salmonella* Enteritidis and *Campylobacter jejuni* in chicken cecal contents in vitro. *Journal of Applied Poultry Research*, 19(3): 237–244. https://doi.org/10.3382/japr.2010-00181

Kurekci, C., Al Jassim, R., Hassan, E., Bishop-Hurley, S.L., Padmanabha, J. & McSweeney, C.S. 2014. Effects of feeding plant-derived agents on the colonization of *Campylobacter jejuni* in broiler chickens. *Poultry Science*, 93(9): 2337–2346. https://doi.org/10.3382/ps.2014-03950

Lee, N.-K., Jung, B.S., Na, D.S., Yu, H.H., Kim, J.-S. & Paik, H.-D. 2016. The impact of antimicrobial effect of chestnut inner shell extracts against *Campylobacter jejuni* in chicken meat. *LWT - Food Science and Technology*, 65: 746–750. https://doi.org/10.1016/j.lwt.2015.09.004

Salaheen, S., Tabashsum, Z., Gaspard, S., Dattilio, A., Tran, T.H. & Biswas, D. 2018. Reduced *Campylobacter jejuni* colonization in poultry gut with bioactive phenolics. *Food Control*, 84: 1–7. https://doi.org/10.1016/j.foodcont.2017.07.021

Szott, V., Reichelt, B., Alter, T., Friese, A. & Roesler, U. 2020. In vivo efficacy of carvacrol on *Campylobacter jejuni* prevalence in broiler chickens during an entire fattening period. *European Journal of Microbiology and Immunology*, 10(3): 131–138. https://doi.org/10.1556/1886.2020.00011

Tolnai, E., Fauszt, P., Fidler, G., Pesti-Asboth, G., Szilagyi, E., Stagel, A., Konya, J. *et al.* 2021. Nutraceuticals induced changes in the broiler gastrointestinal tract microbiota. *mSystems*, 6(2): e01124-20. https://doi.org/10.1128/mSystems.01124-20

Wagle, B.R., Donoghue, A.M., Shrestha, S., Upadhyaya, I., Arsi, K., Gupta, A., Liyanage, R. *et al.* 2020. Carvacrol attenuates *Campylobacter jejuni* colonization factors and proteome critical for persistence in the chicken gut. *Poultry Science*, 99(9): 4566–4577. https://doi.org/10.1016/j.psj.2020.06.020

Zeiger, K., Popp, J., Becker, A., Hankel, J., Visscher, C., Klein, G. & Meemken, D. 2017. Lauric acid as feed additive – An approach to reducing *Campylobacter* spp. in broiler meat. *PLoS ONE*, 12(4): e0175693. https://doi.org/10.1371/journal.pone.0175693

In water plant-based additives and organic acids

Ghareeb, K., Awad, W.A., Mohnl, M., Porta, R., Biarnés, M., Böhm, J. & Schatzmayr, G. 2012. Evaluating the efficacy of an avian-specific probiotic to reduce the colonization of *Campylobacter jejuni* in broiler chickens. *Poultry Science*, 91(8): 1825–1832. https://doi.org/10.3382/ps.2012-02168

Gharib Naseri, K., Rahimi, S. & Khaki, P. 2012. Comparison of the effects of probiotic, organic acid and medicinal plant on *Campylobacter jejuni* challenged broiler chickens. *Journal of Agricultural Science and Technology*, 14(7): 1485–1496.

Johny, A.K., Darre, M.J., Hoagland, T.A., Schreiber, D.T., Donoghue, A.M., Donoghue, D.J. & Venkitanarayanan, K. 2008. Antibacterial effect of trans-cinnamaldehyde on *Salmonella* Enteritidis and *Campylobacter jejuni* in chicken drinking water. *Journal of Applied Poultry Research*, 17(4): 490–497. https://doi.org/10.3382/japr.2008-00051

Metcalf, J.H., Donoghue, A.M., Venkitanarayanan, K., Reyes-Herrera, I., Aguiar, V.F., Blore, P.J. & Donoghue, D.J. 2011. Water administration of the medium-chain fatty acid caprylic acid produced variable efficacy against enteric *Campylobacter* colonization in broilers 1, 2. *Poultry Science*, 90(2): 494–497. https://doi.org/10.3382/ps.2010-00891

Robyn, J., Rasschaert, G., Hermans, D., Pasmans, F. & Heyndrickx, M. 2013. Is allicin able to reduce *Campylobacter jejuni* colonization in broilers when added to drinking water? *Poultry Science*, 92(5): 1408–1418. https://doi.org/10.3382/ps.2012-02863

Sparks, N.H.C. 2009. The role of the water supply system in the infection and control of *Campylobacter* in chicken. *World's Poultry Science Journal*, 65(3): 459–474. https://doi.org/10.1017/S0043933909000324

Szott, V., Peh, E., Friese, A., Roesler, U., Kehrenberg, C., Ploetz, M. & Kittler, S. 2022. Antimicrobial effect of a drinking water additive comprising four organic acids on *Campylobacter* load in broilers and monitoring of bacterial susceptibility. *Poultry Science*, 101(12): 102209. https://doi.org/10.1016/j.psj.2022.102209

Other additives and combination of additives

Froebel, L.K., Jalukar, S., Lavergne, T.A., Coufal, C.D. & Duong, T. 2020. Administration of direct-fed *Bacillus* cultures and refined functional carbohydrates to broiler chickens improves growth performance and promotes positive shifts in gastrointestinal microbiota. *Journal of Applied Poultry Research*, 29(4): 765–774. https://doi.org/10.1016/j.japr.2020.06.004

Greene, G., Koolman, L., Whyte, P., Lynch, H., Coffey, A., Lucey, B., Egan, J., O'Connor, L. & Bolton, D. 2022. The efficacy of organic acid, medium chain fatty acid and essential oil based broiler treatments; *in vitro* anti-*Campylobacter jejuni* activity and the effect of these chemical-based treatments on broiler performance. *Journal of Applied Microbiology*, 132(1): 687–695. https://doi.org/10.1111/jam.15204

Grilli, E., Vitari, F., Domeneghini, C., Palmonari, A., Tosi, G., Fantinati, P., Massi, P. & Piva, A. 2013. Development of a feed additive to reduce caecal *Campylobacter jejuni* in broilers at slaughter age: from *in vitro* to *in vivo* , a proof of concept. *Journal of Applied Microbiology*, 114(2): 308–317. https://doi.org/10.1111/jam.12053

Wilson, K.M., Bourassa, D.V., McLendon, B.L., Wilson, J.L. & Buhr, R.J. 2018. Impact of skip-a-day and every-day feeding programs for broiler breeder pullets on the recovery of *Salmonella* and *Campylobacter* following challenge. *Poultry Science*, 97(8): 2775–2784. https://doi.org/10.3382/ps/pey150

A4.2 Processing

A total of 141 studies were reviewed by the processing group, including primary studies, reviews, and risk assessments that evaluated the efficiency of interventions implemented during poultry processing for *Campylobacter* control.

Al-Qadiri, H.M., Ovissipour, M., Al-Alami, N., Govindan, B.N., Shiroodi, S.G. & Rasco, B. 2016. Efficacy of neutral electrolyzed water, quaternary ammonium and lactic acid-based solutions in controlling microbial contamination of food cutting boards using a manual spraying technique. *Journal of Food Science*, 81(5).

Bai, Y., Ding, X., Zhao, Q., Sun, H., Li, T., Li, Z., Wang, H. *et al.* 2022. Development of an organic acid compound disinfectant to control food-borne pathogens and its application in chicken slaughterhouses. *Poultry Science*, 101(6): 101842. https://doi.org/10.1016/j.psj.2022.101842

Bailey, M.A., Taylor, R.M., Brar, J.S., Corkran, S.C., Velásquez, C., Novoa Rama, E., Oliver, H.F. & Singh, M. 2019. Prevalence and antimicrobial resistance of *Campylobacter* from antibiotic-free broilers during organic and conventional processing. *Poultry Science*, 98(3): 1447–1454. https://doi.org/10.3382/ps/pey486

Balta, I., Linton, M., Pinkerton, L., Kelly, C., Ward, P., Stef, L., Pet, I. *et al.* 2021. The effect of natural antimicrobials on the *Campylobacter coli* T6SS+/− during in vitro infection assays and on their ability to adhere to chicken skin and carcasses. *International Journal of Food Microbiology*, 338: 108998. https://doi.org/10.1016/j.ijfoodmicro.2020.108998

Bauermeister, L.J., Bowers, J.W.J., Townsend, J.C. & McKee, S.R. 2008. The microbial and quality properties of poultry carcasses treated with peracetic acid as an antimicrobial treatment. *Poultry Science*, 87(11): 2390–2398. https://doi.org/10.3382/ps.2008-00087

Bauermeister, L.J., Bowers, J.W.J., Townsend, J.C. & Mckee, S.R. 2008. Validating the efficacy of peracetic acid mixture as an antimicrobial in poultry chillers. *Journal of Food Protection*, 71(6): 1119–1122. https://doi.org/10.4315/0362-028X-71.6.1119

Berrang, M.E. & Bailey, J.S. 2009. On-line brush and spray washers to lower numbers of *Campylobacter* and *Escherichia coli* and presence of *Salmonella* on broiler carcasses during processing. *Journal of Applied Poultry Research*, 18(1): 74–78. https://doi.org/10.3382/japr.2008-00067

Berrang, M.E., Meinersmann, R.J., Smith, D.P. & Zhuang, H. 2008. The effect of chilling in cold air or ice water on the microbiological quality of broiler carcasses and the population of *Campylobacter. Poultry Science*, 87(5): 992–998. https://doi.org/10.3382/ps.2007-00406

Berrang, M.E., Windham, W.R. & Meinersmann, R.J. 2011. *Campylobacter, Salmonella*, and *Escherichia coli* on broiler carcasses subjected to a high pH scald and low pH postpick chlorine dip. *Poultry Science*, 90(4): 896–900. https://doi.org/10.3382/ps.2010-00900

Bertram, R., Kehrenberg, C., Seinige, D. & Krischek, C. 2019. Peracetic acid reduces *Campylobacter* spp. numbers and total viable counts on broiler breast muscle and drumstick skins during modified atmosphere package storage. *Poultry Science*, 98(10): 5064–5073. https://doi.org/10.3382/ps/pez266

Birk, T., Grønlund, A.C., Christensen, B.B., Knøchel, S., Lohse, K. & Rosenquist, H. 2010. Effect of organic acids and marination ingredients on the survival of *Campylobacter jejuni* on Meat. *Journal of Food Protection*, 73(2): 258–265. https://doi.org/10.4315/0362-028X-73.2.258

Bourassa, D.V., Harris, C.E., Bartenfeld Josselson, L.N. & Buhr, R.J. 2021. Assessment of stabilized hydrogen peroxide for use in reducing *Campylobacter* levels and prevalence on broiler chicken wings. *Journal of Food Protection*, 84(3): 449–455. https://doi.org/10.4315/JFP-20-356

Boysen, L. & Rosenquist, H. 2009. Reduction of thermotolerant *Campylobacter* species on broiler carcasses following physical decontamination at slaughter. *Journal of Food Protection*, 72(3): 497–502. https://doi.org/10.4315/0362-028X-72.3.497

Bucher, O., Waddell, L., Greig, J. & Smith, B.A. 2015. Systematic review-meta-analysis of the effect of chilling on *Campylobacter* spp. during primary processing of broilers. *Food Control*, 56: 211–217. https://doi.org/10.1016/j.foodcont.2015.03.032

Burfoot, D. & Mulvey, E. 2011. Reducing microbial counts on chicken and turkey carcasses using lactic acid. *Food Control*, 22(11): 1729–1735. https://doi.org/10.1016/j.foodcont.2011.04.005

Burfoot, D., Allen, V., Mulvey, E., Jewell, K., Harrison, D. & Morris, V. 2015. Reducing *Campylobacter* numbers on chicken carcasses using lactic acid in processing plants. *International Journal of Food Science & Technology*, 50(11): 2451–2457. https://doi.org/10.1111/ijfs.12912

Burfoot, D., Hall, J., Nicholson, K., Holmes, K., Hanson, C., Handley, S. & Mulvey, E. 2016. Effect of rapid surface cooling on *Campylobacter* numbers on poultry carcasses. *Food Control*, 70: 293–301. https://doi.org/10.1016/j.foodcont.2016.05.041

Burfoot, D., Mulvey, E., Jewell, K., Foy, E. & Howell, M. 2015. Effect of electrolysed water on *Campylobacter* numbers on poultry carcasses under practical operating conditions at processing plants. *Food Control*, 50: 472–476. https://doi.org/10.1016/j.foodcont.2014.09.019

Cano, C., Meneses, Y. & Chaves, B.D. 2021. Application of peroxyacetic acid for decontamination of raw poultry products and comparison to other commonly used chemical antimicrobial interventions: A review. *Journal of Food Protection*, 84(10): 1772–1783. https://doi.org/10.4315/JFP-21-107

Casagrande Proietti, P., Pergola, S., Bellucci, S., Menchetti, L., Miraglia, D. & Franciosini, M.P. 2018. Occurrence and antimicrobial susceptibility of *Campylobacter* spp. on fresh and refrigerated chicken meat products in Central Italy. *Poultry Science*, 97(8): 2895–2901. https://doi.org/10.3382/ps/pey147

Chaine, A., Arnaud, E., Kondjoyan, A., Collignan, A. & Sarter, S. 2013. Effect of steam and lactic acid treatments on the survival of *Salmonella* Enteritidis and *Campylobacter jejuni* inoculated on chicken skin. *International Journal of Food Microbiology*, 162(3): 276–282. https://doi.org/10.1016/j.ijfoodmicro.2013.01.012

Chen, X., Bauermeister, L.J., Hill, G.N., Singh, M., Bilgili, S.F. & Mckee, S.R. 2014. Efficacy of various antimicrobials on reduction of *Salmonella* and *Campylobacter* and quality attributes of ground chicken obtained from poultry parts treated in a postchill decontamination tank. *Journal of Food Protection*, 77(11): 1882–1888. https://doi.org/10.4315/0362-028X.JFP-14-114

Coşansu, S. & Ayhan, K. 2010. Effects of lactic and acetic acid treatments on *Campylobacter jejuni* inoculated onto chicken leg and breast meat during storage at 4c and -18c. *Journal of Food Processing and Preservation*, 34: 98–113. https://doi.org/10.1111/j.1745-4549.2008.00320.x

De Villena, J.F., Vargas, D.A., Bueno López, R., Chávez-Velado, D.R., Casas, D.E., Jiménez, R.L. & Sanchez-Plata, M.X. 2022. Bio-mapping indicators and pathogen loads in a commercial broiler processing facility operating with high and low antimicrobial intervention levels. *Foods*, 11(6): 775. https://doi.org/10.3390/foods11060775

Deblais, L., Helmy, Y.A., Kumar, A., Antwi, J., Kathayat, D., Acuna, U.M., Huang, H. *et al.* 2019. Novel narrow spectrum benzyl thiophene sulfonamide derivatives to control *Campylobacter. The Journal of Antibiotics*, 72(7): 555–565. https://doi.org/10.1038/s41429-019-0168-x

Dirks, B.P., Dobrynin, D., Fridman, G., Mukhin, Y., Fridman, A. & Quinlan, J.J. 2012. Treatment of raw poultry with nonthermal dielectric barrier discharge plasma to reduce *Campylobacter jejuni* and *Salmonella enterica. Journal of Food Protection*, 75(1): 22–28. https://doi.org/10.4315/0362-028X.JFP-11-153

Dittoe, D.K., Feye, K.M., Peyton, B., Worlie, D., Draper, M.J. & Ricke, S.C. 2019. The addition of ViriditecTM Aqueous ozone to peracetic acid as an antimicrobial spray increases air quality while maintaining *Salmonella* Typhimurium, non-pathogenic *Escherichia coli*, and *Campylobacter jejuni* reduction on whole carcasses. *Frontiers in Microbiology*, 9: 3180. https://doi.org/10.3389/fmicb.2018.03180

Dogan, O.B., Aditya, A., Ortuzar, J., Clarke, J. & Wang, B. 2022. A systematic review and meta-analysis of the efficacy of processing stages and interventions for controlling *Campylobacter* contamination during broiler chicken processing. *Comprehensive Reviews in Food Science and Food Safety*, 21(1): 227–271. https://doi.org/10.1111/1541-4337.12860

Dogan, O.B., Clarke, J., Mattos, F. & Wang, B. 2019. A quantitative microbial risk assessment model of *Campylobacter* in broiler chickens: Evaluating processing interventions. *Food Control*, 100: 97–110. https://doi.org/10.1016/j.foodcont.2019.01.003

Duc, V.M., Kakiuchi, R., Obi, T., Asakura, H. & Chuma, T. 2022. The incidence of *Campylobacter* contamination levels through chicken-sashimi processing steps in a small-scale poultry processing plant applying the external stripping method. *Journal of Veterinary Medical Science*, 84(3): 414–419. https://doi.org/10.1292/jvms.21-0486

Duffy, L.L., Osmond-McLeod, M.J., Judy, J. & King, T. 2018. Investigation into the antibacterial activity of silver, zinc oxide and copper oxide nanoparticles against poultry-relevant isolates of *Salmonella* and *Campylobacter. Food Control*, 92: 293–300. https://doi.org/10.1016/j.foodcont.2018.05.008

Ellerbroek, L.I., Lienau, J. -A. & Klein, G. 2010. *Campylobacter* spp. in broiler flocks at farm level and the potential for cross-contamination during slaughter. *Zoonoses and Public Health*, 57(7–8). https://doi.org/10.1111/j.1863-2378.2009.01267.x

Erega, A., Stefanic, P., Dogsa, I., Danevčič, T., Simunovic, K., Klančnik, A., Smole Možina, S. & Mandic Mulec, I. 2021. Bacillaene mediates the inhibitory effect of bacillus subtilis on *Campylobacter jejuni* biofilms. *Applied and Environmental Microbiology*, 87(12): e02955-20. https://doi.org/10.1128/AEM.02955-20

Figueroa, G., Troncoso, M., López, C., Rivas, P. & Toro, M. 2009. Occurrence and enumeration of *Campylobacter* spp. during the processing of Chilean broilers. *BMC Microbiology*, 9(1): 94. https://doi.org/10.1186/1471-2180-9-94

Foddai, A., Takeuchi-Storm, N., Høg, B.B., Kjeldgaard, J.S., Andersen, J.K. & Ellis-Iversen, J. 2022. Assessing *Campylobacter* cross-contamination of Danish broiler flocks at slaughterhouses considering true flock prevalence estimates and ad-hoc sampling. *Microbial Risk Analysis*, 21: 100214. https://doi.org/10.1016/j.mran.2022.100214

Franz, E., Van Der Fels-Klerx, H.J., Thissen, J. & Van Asselt, E.D. 2012. Farm and slaughterhouse characteristics affecting the occurrence of *Salmonella* and *Campylobacter* in the broiler supply chain. *Poultry Science*, 91(9): 2376–2381. https://doi.org/10.3382/ps.2009-00367

García-Sánchez, L., Melero, B., Jaime, I., Hänninen, M.-L., Rossi, M. & Rovira, J. 2017. *Campylobacter jejuni* survival in a poultry processing plant environment. *Food Microbiology*, 65: 185–192. https://doi.org/10.1016/j.fm.2017.02.009

Gellynck, X., Messens, W., Halet, D., Grijspeerdt, K., Hartnett, E. & Viaene, J. 2008. Economics of reducing campylobacter at different levels within the Belgian Poultry Meat Chain. *Journal of Food Protection*, 71(3): 479–485. https://doi.org/10.4315/0362-028X-71.3.479

Gichure, J.N., Kamau Njage, P.M., Wambui, J.M., Dykes, G.A., Buys, E.M. & Coorey, R. 2022. Systematic-review and meta-analysis on effect of decontamination interventions on prevalence and concentration of *Campylobacte*r spp. during primary processing of broiler chickens. *Food Microbiology*, 102: 103923. https://doi.org/10.1016/j.fm.2021.103923

Golden, C.E. & Mishra, A. 2020. Prevalence of *Salmonella* and C*ampylobacter* spp. in alternative and conventionally produced chicken in the United States: A systematic review and meta-analysis. *Journal of Food Protection*, 83(7): 1181–1197. https://doi.org/10.4315/JFP-19-538

González-Fandos, E., Maya, N. & Pérez-Arnedo, I. 2015. Effect of propionic acid on *Campylobacter jejuni* attached to chicken skin during refrigerated storage. *International Microbiology*(18): 171–175. https://doi.org/10.2436/20.1501.01.247

Gonzalez, S.V., Geornaras, I., Nair, M.N. & Belk, K.E. 2021. Evaluation of immersion and spray applications of antimicrobial treatments for reduction of *Campylobacter jejuni* on chicken wings. *Foods*, 10(4): 903. https://doi.org/10.3390/foods10040903

Gruntar, I., Biasizzo, M., Kušar, D., Pate, M. & Ocepek, M. 2015. *Campylobacter jejuni* contamination of broiler carcasses: Population dynamics and genetic profiles at slaughterhouse level. *Food Microbiology*, 50: 97–101. https://doi.org/10.1016/j.fm.2015.03.007

Guirin, G.F., Brusa, V., Adriani, C.D. & Leotta, G.A. 2020. Prevalence of *Campylobacter jejuni* and *Campylobacter coli* from broilers at conventional and kosher abattoirs and retail stores. *Revista Argentina de Microbiología*, 52(3): 217–220. https://doi.org/10.1016/j.ram.2019.07.002

Gunther, N.W. 2010. Effects of polyphosphate additives on *Campylobacter* survival in processed chicken exudates. *Applied and Environmental Microbiology*, 76(8): 2419–2424. https://doi.org/10.1128/AEM.02865-09

Gunther, N.W., Phillips, J.G. & Sommers, C. 2016. The effects of 405-nm visible light on the survival of *Campylobacter* on chicken skin and stainless steel. *Foodborne Pathogens and Disease*, 13(5): 245–250. https://doi.org/10.1089/fpd.2015.2084

Hakeem, M.J. & Lu, X. 2021. Survival and control of *Campylobacter* in poultry production environment. *Frontiers in Cellular and Infection Microbiology*, 10: 615049. https://doi.org/10.3389/fcimb.2020.615049

Haughton, P.N., Lyng, J., Cronin, D., Fanning, S. & Whyte, P. 2012. Effect of crust freezing applied alone and in combination with ultraviolet light on the survival of *Campylobacter* on raw chicken. *Food Microbiology*, 32(1): 147–151. https://doi.org/10.1016/j.fm.2012.05.004

Haughton, P.N., Lyng, J.G., Cronin, D.A., Morgan, D.J., Fanning, S. & Whyte, P. 2011. Efficacy of UV light treatment for the microbiological decontamination of chicken, associated packaging, and contact surfaces. *Journal of Food Protection*, 74(4): 565–572. https://doi.org/10.4315/0362-028X.JFP-10-356

Haughton, P.N., Lyng, J.G., Morgan, D.J., Cronin, D.A., Fanning, S. & Whyte, P. 2011. Efficacy of high-intensity pulsed light for the microbiological decontamination of chicken, associated packaging, and contact surfaces. *Foodborne Pathogens and Disease*, 8(1): 109–117.

Haydar Ozdemir, G.I.C., Gorkem Cengiz, B.O. & Sen, E. 2019. Effect of lactic acid and steam treatments on *Campylobacter jejuni* on chicken skin. *Emirates Journal of Food and Agriculture*: 143. https://doi.org/10.9755/ejfa.2019.v31.i2.1915

Horiuchi, I., Kawata, H., Nagao, T., Imaohji, H., Murakami, K., Kino, Y., Yamasaki, H. *et al.* 2015. Antimicrobial activity and stability of weakly acidified chlorous acid water. *Biocontrol Science*, 20(1): 43–51. https://doi.org/10.4265/bio.20.43

Hovorková, P. & Skřivanová, E. 2015. Use of caprylic acid in broiler chickens: effect on *Campylobacter jejuni*. *Foodborne Pathogens and Disease*, 12(8): 712–718. https://doi.org/10.1089/fpd.2015.1978

Huang, J., Zang, X., Zhai, W., Guan, C., Lei, T. & Jiao, X. 2017. Quantitative analysis of *Campylobacter* spp. contamination in chicken slaughtering lines by "label tracking method" in eastern China. *Food Control*, 80: 67–73. https://doi.org/10.1016/j.foodcont.2017.03.052

Iannetti, S., Calistri, P., Di Serafino, G., Marotta, F., Alessiani, A., Antoci, S., Neri, D. *et al.* 2020. *Campylobacter jejuni* and *Campylobacter coli:* prevalence, contamination levels, genetic diversity and antibiotic resistance in Italy. *Veterinaria Italiana*, 56(1). https://doi.org/10.12834/VetIt.1819.9596

Isohanni, P., Alter, T., Saris, P. & Lyhs, U. 2010. Wines as possible meat marinade ingredients possess antimicrobial potential against *Campylobacter. Poultry Science*, 89(12): 2704–2710. https://doi.org/10.3382/ps.2009-00521

Isohanni, P.M.I. & Lyhs, U. 2009. Use of ultraviolet irradiation to reduce *Campylobacter jejuni* on broiler meat. *Poultry Science*, 88(3): 661–668. https://doi.org/10.3382/ps.2008-00259

Ivanova, M., Singh, R., Dharmasena, M., Gong, C., Krastanov, A. & Jiang, X. 2014. Rapid identification of *Campylobacter jejuni* from poultry carcasses and slaughtering environment samples by real-time PCR. *Poultry Science*, 93(6): 1587–1597. https://doi.org/10.3382/ps.2013-03736

Jackowska-Tracz, A. & Tracz, M. 2015. Effects of high hydrostatic pressure on *Campylobacter jejuni* in poultry meat. *Polish Journal of Veterinary Sciences*, 18(2): 261–266. https://doi.org/10.1515/pjvs-2015-0034

Jiang, W., Li, K., Chiu, Y.-C., Waldman, C. & Shen, C. 2020. Inactivation of *Campylobacter jejuni* in moisture enhanced non-intact chicken patties by double pan-broiling as affected by cooking set-up temperature and pump rate. *LWT*, 133: 109938. https://doi.org/10.1016/j.lwt.2020.109938

Kameyama, M., Chuma, T., Nishimoto, T., Oniki, H., Yanagitani, Y., Kanetou, R., Gotou, K. *et al.* 2012. Effect of cooled and chlorinated chiller water on *Campylobacter* and coliform counts on broiler Carcasses during chilling at a middle-size poultry processing plant. *Journal of Veterinary Medical Science*, 74(1): 129–133. https://doi.org/10.1292/jvms.11-0167

Kataria, J., Vaddu, S., Rama, E.N., Sidhu, G., Thippareddi, H. & Singh, M. 2020. Evaluating the efficacy of peracetic acid on *Salmonella* and *Campylobacter* on chicken wings at various pH levels. *Poultry Science*, 99(10): 5137–5142. https://doi.org/10.1016/j.psj.2020.06.070

Koolman, L., Whyte, P., Meade, J., Lyng, J. & Bolton, D. 2014a. A Combination of chemical and ultrasonication treatments to reduce *Campylobacter jejuni* on raw poultry. *Food and Bioprocess Technology*, 7(12): 3602–3607. https://doi.org/10.1007/s11947-014-1370-2

Koolman, L., Whyte, P., Meade, J., Lyng, J. & Bolton, D. 2014b. Use of chemical treatments applied alone and in combination to reduce *Campylobacter* on raw poultry. *Food Control*, 46: 299–303. https://doi.org/10.1016/j.foodcont.2014.05.041

Kottawatta, K., Van Bergen, M., Abeynayake, P., Wagenaar, J., Veldman, K. & Kalupahana, R. 2017. *Campylobacter* in broiler chicken and broiler meat in Sri Lanka: influence of semi-automated vs. wet market processing on *Campylobacter* contamination of broiler neck skin samples. *Foods*, 6(12): 105. https://doi.org/10.3390/foods6120105

Kumar, S., Singh, M., Cosby, D.E., Cox, N.A. & Thippareddi, H. 2020. Efficacy of peroxy acetic acid in reducing *Salmonella* and *Campylobacter* spp. populations on chicken breast fillets. *Poultry Science*, 99(5): 2655–2661. https://doi.org/10.1016/j.psj.2019.12.045

Kure, C.F., Axelsson, L., Carlehög, M., Måge, I., Jensen, M.R. & Holck, A. 2020. The effects of a pilot-scale steam decontamination system on the hygiene and sensory quality of chicken carcasses. *Food Control*, 109: 106948. https://doi.org/10.1016/j.foodcont.2019.106948

Lake, R.J., Horn, B.J., Dunn, A.H., Parris, R., Green, F.T. & McNickle, D.C. 2013. Cost-effectiveness of interventions to control *Campylobacter* in the New Zealand poultry meat food supply. *Journal of Food Protection*, 76(7): 1161–1167. https://doi.org/10.4315/0362-028X.JFP-12-481

Landrum, M.A., Cox, N.A., Cosby, D.E., Berrang, M.E., Mize, S.C. & Jackson, J.S. 2017. 879 reduction of *Campylobacter* on chicken livers using a low-acid processing aid. *Journal of Animal Science*, 95(suppl_4): 377–377. https://doi.org/10.2527/asasann.2017.879

Lecompte, J.-Y., Collignan, A., Sarter, S., Cardinale, E. & Kondjoyan, A. 2009. Decontamination of chicken skin surfaces inoculated with *Listeria innocua* , *Salmonella enteritidis* and *Campylobacter jejuni* by contact with a concentrated lactic acid solution. *British Poultry Science*, 50(3): 307–317. https://doi.org/10.1080/00071660902942742

Lee, N.-K., Jung, B.S., Na, D.S., Yu, H.H., Kim, J.-S. & Paik, H.-D. 2016. The impact of antimicrobial effect of chestnut inner shell extracts against *Campylobacter jejuni* in chicken meat. *LWT - Food Science and Technology*, 65: 746–750. https://doi.org/10.1016/j.lwt.2015.09.004

Liu, Y., Betti, M. & Gänzle, M.G. 2012. High pressure inactivation of *Escherichia coli, Campylobacter jejuni,* and spoilage microbiota on poultry meat. *Journal of Food Protection*, 75(3): 497–503. https://doi.org/10.4315/0362-028X.JFP-11-316

Luning, P.A., Jacxsens, L., Rovira, J., Osés, S.M., Uyttendaele, M. & Marcelis, W.J. 2011. A concurrent diagnosis of microbiological food safety output and food safety management system performance: Cases from meat processing industries. *Food Control*, 22(3–4): 555–565. https://doi.org/10.1016/j.foodcont.2010.10.003

McWhorter, A.R., Weerasooriya, G., Willson, N.-L. & Chousalkar, K.K. 2022. Peroxyacetic acid and acidified sodium chlorite reduce microbial contamination on whole chicken carcasses obtained from two processing points. *Food Microbiology*, 106: 104035. https://doi.org/10.1016/j.fm.2022.104035

Melero, B., Vinuesa, R., Diez, A.M., Jaime, I. & Rovira, J. 2013. Application of protective cultures against *Listeria monocytogenes* and *Campylobacter jejuni* in chicken products packaged under modified atmosphere. *Poultry Science*, 92(4): 1108–1116. https://doi.org/10.3382/ps.2012-02539

Meredith, H., McDowell, D. & Bolton, D.J. 2013. An evaluation of trisodium phosphate, citric acid and lactic acid cloacal wash treatments to reduce *Campylobacter,* total viable counts (TVC) and total enterobacteriaceae counts (TEC) on broiler carcasses during processing. *Food Control*, 32(1): 149–152. https://doi.org/10.1016/j.foodcont.2012.11.026

Meredith, H., Walsh, D., McDowell, D.A. & Bolton, D.J. 2013. An investigation of the immediate and storage effects of chemical treatments on *Campylobacter* and sensory characteristics of poultry meat. *International Journal of Food Microbiology*, 166(2): 309–315. https://doi.org/10.1016/j.ijfoodmicro. 2013.07.005

Moazzami, M., Bergenkvist, E., FernströM, L.-L., Rydén, J. & Hansson, I. 2021. Reducing *Campylobacter jejuni, Enterobacteriaceae, Escherichia coli,* and total aerobic bacteria on broiler carcasses using combined ultrasound and steam. *Journal of Food Protection*, 84(4): 572–578. https://doi.org/10.4315/JFP-20-395

Moore, A., Nannapaneni, R., Kiess, A. & Sharma, C.S. 2017. Evaluation of USDA approved antimicrobials on the reduction of *Salmonella* and *Campylobacter* in ground chicken frames and their effect on meat quality. *Poultry Science*, 96(7): 2385–2392. https://doi.org/10.3382/ps/pew497

Morgan, R.B., Sierra–Arguello, Y.M., Perdoncini, G., Borges, K.A., Furian, T.Q., Gomes, M.J.P., Lima, D. *et al.* 2022. Comparison of transport crates contamination with *Campylobacter* spp. before and after the cleaning and disinfection procedure in broiler slaughterhouses. *Poultry Science*, 101(7): 101909. https://doi.org/10.1016/j.psj.2022.101909

Musavian, H.S., Krebs, N.H., Nonboe, U., Corry, J.E.L. & Purnell, G. 2014. Combined steam and ultrasound treatment of broilers at slaughter: A promising intervention to significantly reduce numbers of naturally occurring campylobacters on carcasses. *International Journal of Food Microbiology*, 176: 23–28. https://doi.org/10.1016/j.ijfoodmicro.2014.02.001

Nagel, G.M., Bauermeister, L.J., Bratcher, C.L., Singh, M. & McKee, S.R. 2013. *Salmonella* and *Campylobacter* reduction and quality characteristics of poultry carcasses treated with various antimicrobials in a post-chill immersion tank. *International Journal of Food Microbiology*, 165(3): 281–286. https://doi.org/10.1016/j.ijfoodmicro.2013.05.016

Nair, D.V.T., Nannapaneni, R., Kiess, A., Mahmoud, B. & Sharma, C.S. 2014. Antimicrobial efficacy of lauric arginate against *Campylobacter jejuni* and spoilage organisms on chicken breast fillets. *Poultry Science*, 93(10): 2636–2640. https://doi.org/10.3382/ps.2013-03858

Nannapaneni, R., Chalova, V., Crandall, P., Ricke, S., Johnson, M. & Obryan, C. 2009. *Campylobacter* and *Arcobacter* species sensitivity to commercial orange oil fractions. *International Journal of Food Microbiology*, 129(1): 43–49. https://doi.org/10.1016/j.ijfoodmicro.2008.11.008

Nauta, M., Andersen, J.K., Tuominen, P., Ranta, J. & Lindqvist, R. 2015. Risk-based microbiological criteria for *Campylobacter* in broiler meat: A comparison of two approaches. *Food Control*, 53: 177–184. https://doi.org/10.1016/j.foodcont.2015.01.019

Nauta, M.J., Sanaa, M. & Havelaar, A.H. 2012. Risk based microbiological criteria for *Campylobacter* in broiler meat in the European Union. *International Journal of Food Microbiology*, 158(3): 209–217. https://doi.org/10.1016/j.ijfoodmicro.2012.07.018

Northcutt, J.K., Cason, J.A., Ingram, K.D., Smith, D.P., Buhr, R.J. & Fletcher, D.L. 2008a. Recovery of bacteria from broiler carcasses after immersion chilling in different volumes of water, Part 2. *Poultry Science*, 87(3): 573–576. https://doi.org/10.3382/ps.2006-00444

Northcutt, J.K., McNeal, W.D., Ingram, K.D., Buhr, R.J. & Fletcher, D.L. 2008b. Microbial recovery from genetically featherless broiler carcasses after forced cloacal fecal expulsion. *Poultry Science*, 87(11): 2377–2381. https://doi.org/10.3382/ps.2007-00426

Northcutt, J.K., Smith, D., Huezo, R.I. & Ingram, K.D. 2008c. Microbiology of broiler carcasses and chemistry of chiller water as affected by water reuse. *Poultry Science*, 87(7): 1458–1463. https://doi.org/10.3382/ps.2007-00480

Olaimat, A.N., Fang, Y. & Holley, R.A. 2014. Inhibition of *Campylobacter jejuni* on fresh chicken breasts by κ-carrageenan/chitosan-based coatings containing allyl isothiocyanate or deodorized oriental mustard extract. *International Journal of Food Microbiology*, 187: 77–82. https://doi.org/10.1016/j.ijfoodmicro.2014.07.003

Ortiz-Suárez, L.E., Redondo-Solano, M., Arias-Echandi, M.L., Valenzuela-Martínez, C. & Peña-Ramos, E.A. 2021. Optimization of the in vitro bactericidal effect of a mixture of chlorine and sodium gallate against *Campylobacter* spp. and *Arcobacter butzleri*. *Journal of Food Protection*, 84(7): 1127–1135. https://doi.org/10.4315/JFP-20-181

Osiriphun, S., Iamtaweejaloen, P., Kooprasertying, P., Koetsinchai, W., Tuitemwong, K., Erickson, L.E. & Tuitemwong, P. 2011. Exposure assessment and process sensitivity analysis of the contamination of *Campylobacter* in poultry products. *Poultry Science*, 90(7): 1562–1573. https://doi.org/10.3382/ps.2009-00577

Pacholewicz, E., Sura Barus, S.A., Swart, A., Havelaar, A.H., Lipman, L.J.A. & Luning, P.A. 2016. Influence of food handlers' compliance with procedures of poultry carcasses contamination: A case study concerning evisceration in broiler slaughterhouses. *Food Control*, 68: 367–378. https://doi.org/10.1016/j.foodcont.2016.04.009

Purnell, G., James, C., James, S.J., Howell, M. & Corry, J.E.L. 2014. Comparison of acidified sodium chlorite, chlorine dioxide, peroxyacetic acid and tri-sodium phosphate spray washes for decontamination of chicken carcasses. *Food and Bioprocess Technology*, 7(7): 2093–2101. https://doi.org/10.1007/s11947-013-1211-8

Rasschaert, G., Piessens, V., Scheldeman, P., Leleu, S., Stals, A., Herman, L., Heyndrickx, M. & Messens, W. 2013. Efficacy of electrolyzed oxidizing water and lactic acid on the reduction of *Campylobacter* on naturally contaminated broiler carcasses during processing. *Poultry Science*, 92(4): 1077–1084. https://doi.org/10.3382/ps.2012-02771

Rattanachaikunsopon, P. & Phumkhachorn, P. 2010. Potential of coriander (*Coriandrum sativum*) oil as a natural antimicrobial compound in controlling *Campylobacter jejuni* in raw meat. *Bioscience, Biotechnology, and Biochemistry*, 74(1): 31–35. https://doi.org/10.1271/bbb.90409

Reich, F., Atanassova, V., Haunhorst, E. & Klein, G. 2008. The effects of *Campylobacter* numbers in caeca on the contamination of broiler carcasses with *Campylobacter. International Journal of Food Microbiology*, 127(1–2): 116–120. https://doi.org/10.1016/j.ijfoodmicro.2008.06.018

Ren, T., Hayden, M., Qiao, M., Huang, T.-S., Ren, X. & Weese, J. 2018. Absorbent pads containing *N* -Halamine compound for potential antimicrobial use for chicken breast and ground chicken. *Journal of Agricultural and Food Chemistry*, 66(8): 1941–1948. https://doi.org/10.1021/acs.jafc.7b05191

Riedel, C.T., Brøndsted, L., Rosenquist, H., Haxgart, S.N. & Christensen, B.B. 2009. Chemical decontamination of *Campylobacter jejuni* on chicken skin and meat. *Journal of Food Protection*, 72(6): 1173–1180. https://doi.org/10.4315/0362-028X-72.6.1173

Romero-Barrios, P., Hempen, M., Messens, W., Stella, P. & Hugas, M. 2013. Quantitative microbiological risk assessment (QMRA) of food-borne zoonoses at the European level. *Food Control*, 29(2): 343–349. https://doi.org/10.1016/j.foodcont.2012.05.043

Rossow, M., Ludewig, M. & Braun, P.G. 2018. Effect of cold atmospheric pressure plasma treatment on inactivation of *Campylobacter jejuni* on chicken skin and breast fillet. *LWT*, 91: 265–270. https://doi.org/10.1016/j.lwt.2018.01.052

Sahin, O., Kassem, I.I., Shen, Z., Lin, J., Rajashekara, G. & Zhang, Q. 2015. *Campylobacter* in Poultry: Ecology and Potential Interventions. *Avian Diseases*, 59(2): 185–200. https://doi.org/10.1637/11072-032315-Review

Sampers, I., Habib, I., Berkvens, D., Dumoulin, A., Zutter, L.D. & Uyttendaele, M. 2008. Processing practices contributing to *Campylobacter* contamination in Belgian chicken meat preparations. *International Journal of Food Microbiology*, 128(2): 297–303. https://doi.org/10.1016/j.ijfoodmicro.2008.08.024

Sarjit, A. & Dykes, G.A. 2015. Trisodium phosphate and sodium hypochlorite are more effective as antimicrobials against *Campylobacter* and *Salmonella* on duck as compared to chicken meat. *International Journal of Food Microbiology*, 203: 63–69. https://doi.org/10.1016/j.ijfoodmicro.2015.02.026

Sasaki, Y., Maruyama, N., Zou, B., Haruna, M., Kusukawa, M., Murakami, M., Asai, T., Tsujiyama, Y. & Yamada, Y. 2013. *Campylobacter* cross-contamination of chicken products at an abattoir. *Zoonoses and Public Health*, 60(2): 134–140. https://doi.org/10.1111/j.1863-2378.2012.01509.x

Schambach, B.T., Berrang, M.E., Harrison, M.A. & Meinersmann, R.J. 2014. Chemical additive to enhance antimicrobial efficacy of chlorine and control cross-contamination during immersion chill of broiler carcasses. *Journal of Food Protection*, 77(9): 1583–1587. https://doi.org/10.4315/0362-028X.JFP-14-092

Schroeder, M.W., Eifert, J.D., Ponder, M.A. & Schmale, D.G. 2014. Association of *Campylobacter* spp. levels between chicken grow-out environmental samples and processed carcasses. *Poultry Science*, 93(3): 734–741. https://doi.org/10.3382/ps.2013-03646

Sears, A., Baker, M.G., Wilson, N., Marshall, J., Muellner, P., Campbell, D.M., Lake, R.J. & French, N.P. 2011. Marked Campylobacteriosis decline after interventions aimed at poultry, New Zealand. *Emerging Infectious Diseases*, 17(6): 1007–1015. https://doi.org/10.3201/eid/1706.101272

Seliwiorstow, T., Baré, J., Berkvens, D., Van Damme, I., Uyttendaele, M. & De Zutter, L. 2016. Identification of risk factors for *Campylobacter* contamination levels on broiler carcasses during the slaughter process. *International Journal of Food Microbiology*, 226: 26–32. https://doi.org/10.1016/j.ijfoodmicro.2016.03.010

Sevilla-Navarro, S., Marin, C., Cortés, V., García, C. & Catalá-Gregori, P. 2020. *Campylobacter* prevalence and risk factors associated with exceeding allowable limits in poultry slaughterhouses in Spain. *Veterinary Record*, 186(13): 415–415. https://doi.org/10.1136/vr.105558

Sharma, C.S., Williams, S.K., Schneider, K.R., Schmidt, R.H. & Rodrick, G.E. 2012. Sodium metasilicate affects growth of *Campylobacter jejuni* in fresh, boneless, uncooked chicken breast fillets stored at 4 degrees Celsius for 7 days. *Poultry Science*, 91(9): 2324–2329. https://doi.org/10.3382/ps.2011-01868

Shin, D., Martin, B.C. & Sánchez-Plata, M.X. 2011. Pulsed electric field effects to reduce the level of *Campylobacter* spp. in scalder and chiller water during broiler chicken processing. *Asian-Australasian Journal of Animal Sciences*, 24(9): 1314–1317. https://doi.org/10.5713/ajas.2011.11075

Shrestha, S., Wagle, B.R., Upadhyay, A., Arsi, K., Donoghue, D.J. & Donoghue, A.M. 2019. Carvacrol antimicrobial wash treatments reduce *Campylobacter jejuni* and aerobic bacteria on broiler chicken skin. *Poultry Science*, 98(9): 4073–4083. https://doi.org/10.3382/ps/pez198

Shrestha, S., Wagle, B.R., Upadhyay, A., Arsi, K., Upadhyaya, I., Donoghue, D.J. & Donoghue, A.M. 2019. Edible coatings fortified with carvacrol reduce *Campylobacter jejuni* on chicken wingettes and modulate expression of select virulence genes. *Frontiers in Microbiology*, 10: 583. https://doi.org/10.3389/fmicb.2019.00583

Šimunović, K., Zajkoska, S., Bezek, K., Klančnik, A., Barlič Maganja, D. & Smole Možina, S. 2020. Comparison of *Campylobacter jejuni* slaughterhouse and surface-water isolates indicates better adaptation of slaughterhouse isolates to the chicken host environment. *Microorganisms*, 8(11): 1693. https://doi.org/10.3390/microorganisms8111693

Smith, J., Corkran, S., McKee, S.R., Bilgili, S.F. & Singh, M. 2015. Evaluation of post-chill applications of antimicrobials against *Campylobacter jejuni* on poultry carcasses. *Journal of Applied Poultry Research*, 24(4): 451–456. https://doi.org/10.3382/japr/pfv046

Smulders, FJM., Gleisz, B., Sofka, D., Sacher, A., Omurtag, I., Paulsen, P. & Hilbert, F. 2011. Microbial ecology on poultry carcasses along the production line* Mikrobielle Ökologie von Geflügelschlachtkörpern entlang der Fertigungslinie*. *Archiv für Lebensmittelhygiene* (Archiv für Lebensmittelhygiene 62: 5, 170-174 (2011)): 170–174. https://doi.org/10.2376/0003-925X-62-170

Soro, A.B., Whyte, P., Bolton, D.J. & Tiwari, B.K. 2020. Strategies and novel technologies to control *Campylobacter* in the poultry chain: a review. *Comprehensive Reviews in Food Science and Food Safety*, 19(4): 1353–1377. https://doi.org/10.1111/1541-4337.12544

Stella, S., Tirloni, E., Bernardi, C. & Grilli, G. 2021. Evaluation of effect of chilling steps during slaughtering on the *Campylobacter* sp. counts on broiler carcasses. *Poultry Science*, 100(3): 100866. https://doi.org/10.1016/j.psj.2020.11.043

Teh, A.H.T., Lee, S.M. & Dykes, G.A. 2019. Growth in the presence of specific antibiotics induces biofilm formation by a *Campylobacter jejuni* strain sensitive to them but not in resistant strains. *Journal of Global Antimicrobial Resistance*, 18: 55–58. https://doi.org/10.1016/j.jgar.2019.05.020

Thames, H.T., Fancher, C.A., Colvin, M.G., McAnally, M., Tucker, E., Zhang, L., Kiess, A.S., Dinh, T.T.N. & Sukumaran, A.T. 2022. The prevalence of *Salmonella* and *Campylobacter* on broiler meat at different stages of commercial poultry processing. *Animals*, 12(18): 2460. https://doi.org/10.3390/ani12182460

Thanissery, R. & Smith, D.P. 2014. Marinade with thyme and orange oils reduces *Salmonella* Enteritidis and *Campylobacter coli* on inoculated broiler breast fillets and whole wings. *Poultry Science*, 93(5): 1258–1262. https://doi.org/10.3382/ps.2013-03697

Thormar, H., Hilmarsson, H., Thráinsson, J.H., Georgsson, F., Gunnarsson, E. & Dadadóttir, S. 2011. Treatment of fresh poultry carcases with emulsions of glycerol monocaprate (monocaprin) to reduce contamination with *Campylobacter* and psychrotrophic bacteria. *British Poultry Science*, 52(1): 11–19. https://doi.org/10.1080/00071668.2010.537308

Vaddu, S., Kataria, J., Belem, T.S., Sidhu, G., Moller, A.E., Leone, C., Singh, M. & Thippareddi, H. 2021a. On-site generated peroxy acetic acid (PAA) technology reduces *Salmonella* and *Campylobacter* on chicken wings. *Poultry Science*, 100(7): 101206. https://doi.org/10.1016/j.psj.2021.101206

Vaddu, S., Kataria, J., Rama, E.N., Moller, A.E., Gouru, A., Singh, M. & Thippareddi, H. 2021b. Impact of pH on efficacy of peroxy acetic acid against *Salmonella, Campylobacter,* and *Escherichia coli* on chicken wings. *Poultry Science*, 100(1): 256–262. https://doi.org/10.1016/j.psj.2020.09.063

Vetchapitak, T., Rana, M.S., Sasaki, S., Taniguchi, T., Sugiyama, S., Soejima, J., Luangtongkum, T., Yamaguchi, Y. & Misawa, N. 2021. A new disinfectant technique for *Campylobacter jejuni* and spoilage bacteria on chicken skin using a high-pressure pulsed jet spray apparatus. *Food Control*, 125: 107989. https://doi.org/10.1016/j.foodcont.2021.107989

Vetchapitak, T., Shinki, T., Sasaki, S., Taniguchi, T., Luangtongkum, T. & Misawa, N. 2020. Evaluation of chemical treatment combined with vacuum and ultrasonication with a water resonance system for reducing *Campylobacter* on naturally contaminated chicken carcasses. *Food Control*, 112: 107087. https://doi.org/10.1016/j.foodcont.2020.107087

Viglundsson, T. I., Agustsson, O. I., Sigurdsson, H., Kristjansson, B., Josafatsson, B., Hilmarsson, H., Palsdottir, E. O. & Kristanjsson, J. K. undated. New method of processing ice slurry for improved chilling of fresh foods. *International Institute of Refrigeration (IIR)*.[Cited 3 November 2023]. https://iifiir.org/datacite_notices/144212

Wagle, B.R., Arsi, K., Shrestha, S., Upadhyay, A., Upadhyaya, I., Bhargava, K., Donoghue, A. & Donoghue, D.J. 2019. Eugenol as an antimicrobial wash treatment reduces *Campylobacter jejuni* in postharvest poultry. *Journal of Food Safety*, 39(6): e12704. https://doi.org/10.1111/jfs.12704

Wagle, B.R., Arsi, K., Upadhyay, A., Shrestha, S., Venkitanarayanan, K., Donoghue, A.M. & Donoghue, D.J. 2017. β-Resorcylic Acid, a phytophenolic compound, reduces *Campylobacter jejuni* in postharvest poultry. *Journal of Food Protection*, 80(8): 1243–1251. https://doi.org/10.4315/0362-028X.JFP-16-475

Wagle, B.R., Shrestha, S., Arsi, K., Upadhyaya, I., Donoghue, A.M. & Donoghue, D.J. 2019a. Pectin or chitosan coating fortified with eugenol reduces *Campylobacter jejuni* on chicken wingettes and modulates expression of critical survival genes. *Poultry Science*, 98(3): 1461–1471. https://doi.org/10.3382/ps/pey505

Wagle, B.R., Upadhyay, A., Upadhyaya, I., Shrestha, S., Arsi, K., Liyanage, R., Venkitanarayanan, K., Donoghue, D.J. & Donoghue, A.M. 2019b. Trans-Cinnamaldehyde, Eugenol and Carvacrol reduce *Campylobacter jejuni* biofilms and modulate expression of select genes and proteins. *Frontiers in Microbiology*, 10: 1837. https://doi.org/10.3389/fmicb.2019.01837

Weerasooriya, G., McWhorter, A.R., Khan, S. & Chousalkar, K.K. 2021. Transcriptomic response of *Campylobacter jejuni* following exposure to acidified sodium chlorite. *npj Science of Food*, 5(1): 23. https://doi.org/10.1038/s41538-021-00103-5

Wieczorek, K. & Osek, J. 2015. Poultry flocks as a source of *Campylobacter* contamination of broiler carcasses. *Polish Journal of Veterinary Sciences*, 18(1): 101–106. https://doi.org/10.1515/pjvs-2015-0013

Zampara, A., Sørensen, M.C.H., Gencay, Y.E., Grimon, D., Kristiansen, S.H., Jørgensen, L.S., Kristensen, J.R. ***et al.*** 2021. Developing innolysins against *Campylobacter jejuni* using a novel prophage receptor-binding protein. *Frontiers in Microbiology*, 12: 619028. https://doi.org/10.3389/fmicb.2021.619028

Zeiger, K., Popp, J., Becker, A., Hankel, J., Visscher, C., Klein, G. & Meemken, D. 2017. Lauric acid as feed additive – An approach to reducing *Campylobacter* spp. in broiler meat. *PLoS ONE*, 12(4): e0175693. https://doi.org/10.1371/journal.pone.0175693

Zhang, L., Garner, L.J., Mckee, S.R. & Bilgili, S.F. 2018. Effectiveness of several antimicrobials used in a postchill decontamination tank against *Salmonella* and *Campylobacter* on broiler carcass parts. *Journal of Food Protection*, 81(7): 1134–1141. https://doi.org/10.4315/0362-028X.JFP-17-507

Zhang, L., Singh, P., Lee, H.C. & Kang, I. 2013. Effect of hot water spray on broiler carcasses for reduction of loosely attached, intermediately attached, and tightly attached pathogenic (*Salmonella* and *Campylobacter)* and mesophilic aerobic bacteria. *Poultry Science*, 92(3): 804–810. https://doi.org/10.3382/ps.2012-02504

Zhao, G., Huang, X., Zhao, J., Liu, N., Li, Y., Wang, L., Gao, Y. ***et al.*** 2020. Risk prevention and control points through quantitative evaluation of *Campylobacter* in a large broiler slaughterhouse. *Frontiers in Veterinary Science*, 7: 172. https://doi.org/10.3389/fvets.2020.00172

Zweifel, C., Althaus, D. & Stephan, R. 2015. Effects of slaughter operations on the microbiological contamination of broiler carcasses in three abattoirs. *Food Control*, 51: 37–42. https://doi.org/10.1016/j.foodcont.2014.11.002

A4.3 Post-processing

Al-Qadiri, H.M., Ovissipour, M., Al-Alami, N., Govindan, B.N., Shiroodi, S.G. & Rasco, B. 2016. Efficacy of neutral electrolyzed water, quaternary ammonium and lactic acid-based solutions in controlling microbial contamination of food cutting boards using a manual spraying technique. *Journal of Food Science*, 81(5). https://doi.org/10.1111/1750-3841.13275

Birk, T., Grønlund, A.C., Christensen, B.B., Knøchel, S., Lohse, K. & Rosenquist, H. 2010. Effect of organic acids and marination ingredients on the survival of *Campylobacter jejuni* on Meat. *Journal of Food Protection*, 73(2): 258–265. https://doi.org/10.4315/0362-028X-73.2.258

Bolton, D., Meredith, H., Walsh, D. & McDowell, D. 2014. Poultry food safety control interventions in the domestic kitchen. *Journal of Food Safety*, 34(1): 34–41. https://doi.org/10.1111/jfs.12092

De Jong, A.E.I., Verhoeff-Bakkenes, L., Nauta, M.J. & De Jonge, R. 2008. Cross-contamination in the kitchen: effect of hygiene measures. *Journal of Applied Microbiology*, 105(2): 615–624. https://doi.org/10.1111/j.1365-2672.2008.03778.x

Eideh, A.M.F. & Al-Qadiri, H.M. 2011. Effect of refrigerated and frozen storage on the survival of *Campylobacter jejuni* in cooked chicken meat breast. *Journal of Food Science*, 76(1). https://doi.org/10.1111/j.1750-3841.2010.01924.x

El-Shibiny, A., Connerton, P. & Connerton, I. 2009. Survival at refrigeration and freezing temperatures of *Campylobacter coli* and *Campylobacter jejuni* on chicken skin applied as axenic and mixed inoculums. *International Journal of Food Microbiology*, 131(2–3): 197–202. https://doi.org/10.1016/j.ijfoodmicro.2009.02.024

Ivić-Kolevska, S., Miljković-Selimović, B. & Kocić, B. 2012. Survival of *Campylobacter jejuni* in chicken meat at frozen storage temperatures. *Acta Microbiologica et Immunologica Hungarica*, 59(2): 185–198. https://doi.org/10.1556/amicr.59.2012.2.4

Lahou, E., Wang, X., De Boeck, E., Verguldt, E., Geeraerd, A., Devlieghere, F. & Uyttendaele, M. 2015. Effectiveness of inactivation of foodborne pathogens during simulated home pan frying of steak, hamburger or meat strips. *International Journal of Food Microbiology*, 206: 118–129. https://doi.org/10.1016/j.ijfoodmicro.2015.04.014

Lai, H., Tang, Y., Ren, F., Li, Z., Li, F., Cui, C., Jiao, X. & Huang, J. 2021. An investigation into the critical factors influencing the spread of *Campylobacter* during chicken handling in commercial kitchens in China. *Microorganisms*, 9(6): 1164. https://doi.org/10.3390/microorganisms9061164

Langsrud, S., Sørheim, O., Skuland, S.E., Almli, V.L., Jensen, M.R., Grøvlen, M.S., Ueland, Ø. & Møretrø, T. 2020. Cooking chicken at home: Common or recommended approaches to judge doneness may not assure sufficient inactivation of pathogens. *PLoS ONE*, 15(4): e0230928. https://doi.org/10.1371/journal.pone.0230928

Maziero, M.T. & Oliveira, T.C.R.M.D. 2010. Effect of refrigeration and frozen storage on the *Campylobacter jejuni* recovery from naturally contaminated broiler carcasses. *Brazilian Journal of Microbiology*, 41(2): 501–505. https://doi.org/10.1590/S1517-83822010000200034

Mild, R.M., Joens, L.A., Friedman, M., Olsen, C.W., McHugh, T.H., Law, B. & Ravishankar, S. 2011. Antimicrobial edible apple films inactivate antibiotic resistant and susceptible *Campylobacter jejuni* strains on chicken breast. *Journal of Food Science*, 76(3). https://doi.org/10.1111/j.1750-3841.2011.02065.x

Nauta, M. J., Fischer, A. R., Van Asselt, E. D., De Jong, A. E., Frewer, L. J., & De Jonge, R. 2008. Food safety in the domestic environment: the effect of consumer risk information on human disease risks. *Risk Analysis: An International Journal*, 28(1): 179–192.10.1111/j.1539-6924.2008.01012.x

Sampers, I., Habib, I., De Zutter, L., Dumoulin, A. & Uyttendaele, M. 2010. Survival of *Campylobacter* spp. in poultry meat preparations subjected to freezing, refrigeration, minor salt concentration, and heat treatment. *International Journal of Food Microbiology*, 137(2–3): 147–153. https://doi.org/10.1016/j.ijfoodmicro.2009.11.013

Trajkovic-Pavlovic, L., Novakovic, B., Martinov-Cvejin, M., Gusman, V., Bijelovic, S., Dragnic, N. & Balac, D. 2010. How a routine checking of *Escherichia coli* in retailed food of animal origin can protect consumers against exposition to *Campylobacter* spp. and *Listeria monocytogenes*? *Vojnosanitetski pregled*, 67(8): 627–633. https://doi.org/10.2298/VSP1008627T

Vaz, Vaz, C.S.L., Voss-Rech, D., Rebelatto, R., Duarte, S.C., Coldebella, A. & Bessa, M.C. 2021. Survival of *Campylobacter jejuni* in chicken at refrigeration and cooking temperatures. *Pesquisa Agropecuária Brasileira*, 56: e02405. https://doi.org/10.1590/s1678-3921.pab2021.v56.02405

Verhoeff-Bakkenes, L., Beumer, R.R., De Jonge, R., Van Leusden, F.M. & De Jong, A.E.I. 2008. Quantification of *Campylobacter jejuni* cross-contamination via hands, cutlery, and cutting board during preparation of a chicken fruit salad. *Journal of Food Protection*, 71(5): 1018–1022. https://doi.org/10.4315/0362-028X-71.5.1018

Zakarienė, G., Rokaitytė, A., Ramonaitė, S., Novoslavskij, A., Mulkytė, K., Zaborskienė, G. & Malakauskas, M. 2015. The antimicrobial effect of spice-based marinades against *Campylobacter jejuni* on contaminated fresh broiler wings. *Journal of Food Science*, 80(3). https://doi.org/10.1111/1750-3841.12788

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Microbiological Risk Assessment Series

To collate and assess the most recent scientific information relevant to the control of thermotolerant *Campylobacter* species in broiler production and chicken meat, the Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment (JEMRA) convened a meeting in Rome, Italy in February 2023.

The expert committee reviewed the available data on *Campylobacter* control including scientific literature published from 2008 to October 2022 and data submitted in response to a call for data for this meeting. The experts: 1) determined the quality and quantity of evidence of control measures for *Campylobacter*, 2) evaluated the impact of measures to control *Campylobacter* in the broiler production chain, 3) determined which hazard-based interventions pertained specifically to *Campylobacter* and which were general to the control of foodborne pathogens in the pre- and post-harvest broiler production chain, and 4) reviewed and recommended revisions to the *Guidelines for the Control of Campylobacter and Salmonella in Chicken Meat*.

This report describes the output of this expert meeting and the advice herein is useful for both risk assessors and risk managers, at national and international levels and those in the food industry working to control the hazard in poultry.

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