Cause analysis and risk evaluation of the occurrence of *Campylobacter* spp. in the broiler production chain

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**ABSTRACT**

Tendencies of foodborne outbreaks show that the number of illnesses caused by *Campylobacter* spp. has been increasing recently in the European Union and in Hungary as well. However, the epidemiological statuses of Member States are diverse. There are several aspects to be investigated by competent authorities before the introduction of interventions. Methods supporting food safety decision making range from quick and easy techniques to complex, resource consuming approaches. The aim of the present study was the implementation of an evaluation and ranking system for a risk and its causes occurring in the broiler production chain. Data and information available in scientific literature were converted to a structured easy-to-use evaluation that supports decision making and helps structured data processing.

**KEYWORDS**

campylobacter spp., food chain, intervention, cause analysis

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1. INTRODUCTION

Number of illnesses caused by Campylobacter spp. has been increasing recently in the European Union. According to the Zoonoses Report (EFSA-ECDC, 2019), campylobacteriosis was the most frequently reported zoonoses in the EU, and the number of cases is exceeding salmonellosis. Its symptoms can vary from mild gastroenteritis to long-term complications such as Guillain-Barré syndrome or reactive arthritis (EFSA, 2012). Member States attempt to manage the problem at different points of the food chain, in line with the structure of industry and the diverse prevalence. Multiple intervention points can be identified through the food chain, e.g. reduction of the levels of Campylobacter contamination in flocks and in fresh broiler meat (EFSA, 2020). Poultry flocks, especially broiler chickens, are considered to be the major cause of spreading Campylobacter spp. in the food chain (EFSA, 2011).

The amount of broiler chickens accounts for 81% of all poultry meat produced in the EU. Broilers are mainly raised in indoor intensive farming system, and the breeding is divided into steps performed in specialised establishments (Augère-Granier, 2019). Grandparent and parent flocks seem to be irrelevant as vertical transmission is insignificant (EFSA, 2020). Therefore, horizontal spread of Campylobacter in the Gallus gallus breeding and production chain was investigated.

There are several studies evaluating the risk associated with Campylobacter spp. in the food chain, differing in the covered processing stages (EFSA, 2020) and in the methodology applied. Assessment methods vary in their resource demand, e.g. time, data, knowledge, etc., which factors can be limiting in practice. Although, data and results of previous evaluations have enormous information value that has to be processed and integrated into decision making, especially when resources are restricted. Thus, the study aimed to implement a literature-based, structured evaluation approach supporting official decision making.

2. MATERIALS AND METHODS

2.1. Mapping of broiler production process

Narrative literature review has been carried out by means of scientific databases and the internet (Baker, 2016). Collection of information was limited to data on broiler chicken farming and processing. Actions significantly influencing the entry of Campylobacter spp. into the food chain were studied. The process describing the whole production chain was outlined, and stages proven to be irrelevant were excluded. In order to identify causes contributing to the spread of the pathogen, all remaining process steps were examined by the use of 3 questions, considering Campylobacter as the object of each event: 'What can happen?'; 'What was the cause?'; 'What interventions would mitigate the risk?'.
Tables 1, 3–4 (as shown in Results and discussion), were extracted from the literature and matched with causes identified. Since data on the target microorganism were not based on uniform mathematical models (Crotta et al., 2017), conversion and weighting were necessary. Where numerical data were available, values were matched with scores between 1 and 3 both for the conversion to a severity value (mild to severe), representing the extent of contamination, and an occurrence value (low to high), representing the probability of pathogen occurrence. Where numerical data were lacking, assumptions and scoring were made on the basis of information available. Risk value was obtained by the multiplication of the former two values resulting in a number between 1 and 9, forming 6 different categories: negligible, low, mild, moderate, major, and high.

During the evaluation hygiene and legal rules, good practices, subsequent disinfection possibilities, as well as the complexity of each step were investigated. Both scoring and risk value calculations were based on the data reviewed by the expert panel consisting of the Authors, including the consideration of the role of the process and the severity attributed to it. After the definition of risk values, corrective actions and possibilities for the elimination of arisen problems were examined.

3. RESULTS AND DISCUSSION

3.1. Mapping of broiler production process

In order to identify all possibly occurring causes, investigation covered all steps from broiler eggs to meat consumption and a process consisting of 21 stages have been set up (Fig. 1).
Grandparent flocks and consumption together with the delivery to households were excluded from the model, because the role of breeding is negligible in the spread of *Campylobacter* spp., and handling by consumers is out of the scope of competent authorities.

### 3.2. Cause analysis and risk evaluation

#### 3.2.1. Parent flocks, transport, and hatching

At the level of primary production step by step investigation of hatching was unnecessary, however, eggs of different origin can contribute to contamination (Table 1). The only identified hazard occurring at the stage of parent flocks was contamination with *Campylobacter*. Mainly inappropriate training, lack of compliance with good manufacturing practices, and inappropriate management of technologies can be recognised as causes.

In terms of *Campylobacter* contamination, level of risk of the processes is less significant compared to the following production stages, however, correction and elimination of non-conformities as well as potential hazards are essential. A summary of the risk values is shown in Table 2. Occurrence of *Campylobacter* spp. in poultry flocks happens at the age of 2–4 weeks, namely in grow-out houses. Thus, process steps related to parent flocks, transport, and hatching are insignificant (Skarp et al., 2016). Causes of contamination at this stage can be managed by proper education, work organisation, and process control.

#### Table 1. Causes and corrective actions at the stage of parent flocks, transport, and hatching

| Food chain position | Cause                                      | Corrective action                                      | Reference          |
|---------------------|--------------------------------------------|--------------------------------------------------------|--------------------|
| Parent flocks/Egg   | Faecal contamination of egg surface        | Technology optimisation, appropriate padding            | AA (2018)          |
| collection          | Cracked shell                              | Technology optimisation, pliable surface                |                    |
|                     | Insufficient biosecurity                   | Training, continuous monitoring                        |                    |
|                     | Bad timing of egg collection               | Data collection, work organisation                     |                    |
|                     | Inadequate egg disinfection                | Technology optimisation                                |                    |
| Transport           | Improperly cleaned vehicle                 | Continuous monitoring, optimised cleaning, training     | Donofre et al. (2017) |
|                     | Inappropriate personal hygiene             | Training, continuous monitoring                        |                    |
|                     | Knowledge scarcity                         | Training, knowledge survey                             |                    |
| Hatching            | Poor hygiene and personal hygiene         | Training, continuous monitoring                        | AA (2018)          |
|                     | Product line confluence                    | Technology review and optimisation, training            |                    |
|                     | Insufficient knowledge                     | Research, knowledge survey                              |                    |
| Transport           | Poorly cleaned vehicle and crates          | Continuous monitoring, optimised cleaning, training     | Shane (2000)       |
|                     | Inappropriate personal hygiene             | Training, continuous monitoring                        |                    |
|                     | Knowledge scarcity                         | Training, knowledge survey                              |                    |
Table 2. Evaluation of risks associated with relevant process steps

| Processing stage | Nr. | Process step                  | Severity | Occurrence | Risk value | Risk category | Description                                                                 |
|------------------|-----|-------------------------------|----------|------------|------------|---------------|-----------------------------------------------------------------------------|
| Parent flocks/   | 1   | Parent flocks/Egg collection  | 1        | 1          | 1          | Negligible    | Technologies listed here do not pose a high risk to the whole production    |
| Hatchery         | 2   | Transport                     | 1        | 2          | 2          | Low           | chain, since the occurrence of *Campylobacter* in chickens is between the    |
|                  | 3   | Hatching                      | 2        | 2          | 4          | Moderate      | age of 2 and 4 weeks. Problems arisen at this stage can be managed by       |
|                  | 4   | Transport                     | 1        | 2          | 2          | Low           | proper training, work organisation, and process control.                   |
| Grow-out         | 5a  | Growing                       | 3        | 2          | 6          | Major         | Prevention of *Campylobacter* colonisation at flock level is the most        |
|                  | 5b  | Thinning                      | 3        | 3          | 9          | High          | effective way to prevent its latter appearance at the meat production chain.|
|                  | 6   | Transport                     | 1        | 2          | 2          | Low           | Besides, authorised decolonisation methods are not available yet.            |
| Processing       | 7a  | Receiving                     | 3        | 2          | 6          | Major         | The most important step is the separation of positive and negative flocks    |
|                  | 7b  | Placement to the processing   | 1        | 2          | 2          | Low           | before slaughter. It is suggested that methods less likely promoting the     |
|                  |     | line                          |          |            |            |               | spread of *Campylobacter* should be chosen.                                 |
|                  | 7c  | Stunning                      | 3        | 2          | 6          | Major         |                                                                             |
|                  | 7d  | Killing/Bleeding              | 1        | 2          | 2          | Low           |                                                                             |
|                  | 7e  | Scalding                      | 2        | 2          | 4          | Moderate      |                                                                             |
|                  | 7f  | De-feathering                 | 2        | 2          | 4          | Moderate      |                                                                             |
|                  | 7g  | Head pulling                  | 1        | 2          | 2          | Low           |                                                                             |
|                  | 7h  | Evisceration                  | 2        | 2          | 4          | Moderate      |                                                                             |
|                  | 7i  | Washing                       | 3        | 2          | 6          | Major         |                                                                             |
|                  | 7j  | Chilling                      | 3        | 2          | 6          | Major         |                                                                             |
|                  | 7k  | Cutting                       | 1        | 2          | 2          | Low           |                                                                             |
|                  | 7l  | Packaging                     | 2        | 2          | 4          | Moderate      |                                                                             |
|                  | 8   | Transport                     | 2        | 2          | 4          | Moderate      |                                                                             |
|                  | 9   | Commerce                      | 2        | 2          | 4          | Moderate      |                                                                             |
3.2.2. Grow-out farms. Before the arrival of day-old chicks to grow-out farms, cleaning, disinfection, and biosecurity measures must be applied. In order to avoid contamination, after chick placement enhanced biosecurity, safe water and feed supply, and controlled entry and exit must be ensured. When slaughter age is reached, partial or complete harvest can be carried out that means the removal of the whole flock (“all in-all out”) or a part of it (thinning). Advantage of thinning is that the remaining flock can be grown further, however, it can contribute to bacterial infections. In parallel to catching and thinning, chickens are placed on transport vehicles (McDowell et al., 2008). Feed withdrawal is necessary, and it is possible 8–12 hours prior to slaughter (Northcutt, 2010).

Processes at grow-out farms are of key importance as the likelihood of Campylobacter infection is the highest at flock level (McDowell et al., 2008). Thus, controls at farm level are considered to be the most effective way for the reduction of human campylobacteriosis (EFSA, 2020). Implementation of most of the preventive actions belonging to this stage requires only increased attention and appropriate knowledge from the farm staff.

Causes identified at growing can be grouped into 6 categories that are most likely to be eliminated along with enhanced biosecurity measure (Table 3). Although, long-term effects and costs have to be preliminarily evaluated.

Risk evaluation has been carried out (Table 2), and the resulting higher values are due to the process complexity and the fact that infection of broiler flocks is most likely to occur during growing. Carcass disinfection is not allowed in poultry processing in the EU (EC, 2004), so the problem has to be addressed at a pre-slaughter stage: continuous sampling and testing should be applied in order to isolate Campylobacter positive flocks during both transport and slaughter, as well as reconsideration of the harvesting practice (thinning or all in-all out) is also necessary.

3.2.3. Processing. As for poultry processing, slaughter and processing take place within one plant, with a high degree of automation. Live animals are usually delivered in open crates, and after arrival, birds are taken to the processing line, where they are hung upside down on a conveyor belt, that is followed by stunning, neck cutting, and bleeding. As next, carcasses are scalded, plucked, decapitated, eviscerated, prechilled, and then packaged whole or in pieces (FAO/WHO, 2009).

Hazards occurring at processing are listed in Table 4. Highest risk can be associated with inadequate scheduling, as if a Campylobacter positive flock gets on the line at first, it will contaminate all equipment and previously uninfected carcasses. In general, training can make both hazard recognition and management more effective.

3.2.4. Evaluation of risks. Several processing steps received high risk values (Table 2), because these stages are involved in the spread of contamination. For this reason, continuous monitoring is of paramount importance, as is the increased training of the staff. Reevaluation of processes with a value of 6 or 9 is strongly recommended, and available legal procedures for minimising contamination should be examined also. Most of the hazards arisen can be avoided by process control, proper training and communication, appropriate information distribution, and compliance with relevant legislation and requirements. In many cases, impact of people who come into contact with product during processing is not given sufficient attention, however, staff should be dealt as part of the process. Many causes can be eliminated with the management of “customary law” by properly trained and motivated staff.
### Table 3. Causes and corrective actions at grow-out farms

| Food chain position | Cause category | Cause | Corrective action | Reference |
|---------------------|----------------|-------|-------------------|-----------|
| Grow-out farm       | Isolation      | Other animals at farm/Rodent control | Non – only if necessary (safety distances)/Regular, planned and compliant | McDowell et al. (2008), Borck Høg et al. (2016) |
|                     | Number of barns |                                | Proper farm organisation, safety distances |          |
|                     | Poultry and other farms nearby | | Application of safety distances (500–2000 m) |          |
| Hygiene             | Use of detergents and disinfectants | | Approved substances only | McDowell et al. (2008) |
|                     | Overall cleanliness (especially entrance) | | Enhanced, controlled cleaning |          |
|                     | Application of footbath, boot change | | Compulsory – water and boot changes several times a day |          |
| Architectural features | Material of curtains | | Not supporting microbial growth, appropriate barn design | Torralbo et al. (2014) |
|                     | Hallway in front of the barn | | Compulsory |          |
|                     | Barn age and condition | | New buildings, scheduled maintenance |          |
| Feeding             | Water treatment and drinker type | Approved substances only and nipple drinkers |          |
|                     | Feed storage | Clean silos (one silo per barn), safe feed | McDowell et al. (2008), Borck Høg et al. (2016) |
| Technology          | Flock age/Removal of dead animals | Slaughter as soon as possible/As required |          |
|                     | Farm and slaughterhouse distance | Proper timing of feed withdrawal |          |
|                     | Thinning | All in/all out, technology design |          |
|                     | Downtime | Optimisation (epidemiology versus finance) |          |
| Other factors       | Seasons/Owner’s level of education | | Not influenceable/Regulated by law | Ansari-Lari et al. (2011) |
|                     | Early use of antibiotics | | Suggested with attention to antimicrobial resistance |          |
| Transport           | Improperly cleaned vehicles and crates | Continuous monitoring, optimised cleaning, training | Bull et al. (2006) |
|                     | Knowledge scarcity, poor personal hygiene | Training, knowledge survey, continuous monitoring |          |
| Food chain position | Cause | Corrective action | Reference |
|---------------------|-------|------------------|-----------|
| Receiving           | Lack of separation of positive and negative flocks | In situ colonisation test, training, production plan reevaluation, communication with suppliers | Miwa et al. (2003) |
| Placement to processing line | Contaminated transport equipment, type of equipment, Hygiene shortcomings | Imposing penalty on suppliers, easy to clean crates, Strict hygiene requirements, training | Seliwiorstow et al. (2016) |
| Stunning            | Faecal material released on carcasses hung by legs during electrical stunning | Hanging by neck or gas stunning | |
| Killing/Bleeding    | Non-compliance with hygiene rules | Strict hygiene requirements, training | FAO/WHO (2009) |
| Scalding            | Low decrease in cell count due to low scalding water temperatures, Contamination due to conventional scalding | Process optimisation, proper water temperature (safety versus quality), Counterflow scalding, technology optimisation | FAO/WHO (2009) |
| De-feathering       | Cross contamination of flocks due to bad scheduling, Faecal contamination and intestine damage due to intense mechanical plucking | Reevaluation of the production plan, Technology optimisation | FAO/WHO (2009), Seliwiorstow et al. (2016) |
| Head pulling        | Hygiene shortcomings, Carcass contamination by crop content due to upward head removal | Strict hygiene requirements, training, Technology optimisation (downward head removal) | FAO/WHO (2009) |
| Evisceration        | Intestine and carcass damage due to improper settings, too long feed withdrawal and the lack of weight uniformity | Technology optimisation, proper grow-out plan and scheduling, compromise with suppliers, carcass classification and equipment adjustment | Berrang et al. (2000) |
| Washing             | Low decrease in cell count due to bad practices | Training | Meredith et al. (2013) |
| Chilling            | Contamination by cooling water, Inappropriate chilling | Technology optimisation | Sukte et al. (2017) |
| Cutting (optional)/Packaging | Hygiene shortcomings | Strict hygiene requirements, training | FAO/WHO (2009) |
| Transport/Commerce  | Failure of cold chain and hygiene shortcomings | Strict hygiene and chilling requirements | EC (2005) |
4. CONCLUSIONS

The applied data organisation and weighting method is suitable for supporting decision making, since it was able to identify in total 6 steps representing “major” or “high” risk, and 7 stages that received “medium” risk score. In line with food chain safety approach, hazards should be targeted as early as possible in the chain. In case of Campylobacter spp. exact point of appearance is still debated, moreover, specific control measures are still not available. Because of this lack of a ‘single best’ solution, the additive effect of different interventions along the production chain should be utilised. This is also underpinned by our findings that values of different severity are located at different points of the food chain, which indicates that Campylobacter control measures must be applied throughout the food chain and continuous monitoring is essential. For further refinement of the method, sensitivity analysis and validation by an extended expert group can be conducted.

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