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Derivation of performance objectives for *Campylobacter* in broiler carcasses taking into account impact of selected factors on pathogen prevalence and counts

A. De Cesare [a], A. Valero [b, *], F. Pérez-Rodríguez [b], M. Chemaly [c], Gerardo Manfreda [a]

[a] Department of Agriculture and Food Sciences, Alma Mater Studiorum, University of Bologna, Via del Florio 2, 40064 Ozzano dell'Emilia (BO), Italy
[b] Department of Food Science and Technology, University of Cordoba, Campus de Rabanales, Edificio Darwin, 14014 Córdoba, Spain
[c] Anses, Ploufragan/Plouzané Laboratory, Hygiene and Quality of Poultry and Pork Products Unit, BP 53, Ploufragan F-22440, France

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ABSTRACT

Food safety standards in the European Union include microbiological criteria and targets in primary production. The current paper provides a strategy to elucidate risk-based metrics such a potential Food Safety Objective for *Campylobacter* used as benchmark to derive possible Performance Objectives for the pathogen in broiler carcasses tested after chilling. The Performance Objectives were developed using the EFSA data collected on broiler carcasses during the monitoring study performed in 2008 in the European Union according to the evaluation of the different risk factors included in the survey. The FSO for *Campylobacter* was set at −1.2 $\log_{10}$ cfu/g (~6 cfu/100 g). The *Campylobacter* concentrations after chilling resulting in a final concentration equal or below this proposed FSO were suggested as possible POs. The results obtained indicated that batches originating from previously thinned flocks can be more at risk of being colonized with *Campylobacter*. In fact, the estimated mean concentrations of *Campylobacter* on carcasses were 1.05 and 2.38 $\log_{10}$ cfu/g for non thinned and thinned flocks, respectively. Further, the impact of high *Campylobacter* contamination on carcasses (>2.5 $\log_{10}$ cfu/g) was shown since for those carcasses a reduction in PO values higher than 1.5 $\log_{10}$ cfu/g is needed to meet the FSO. In contrast no significant differences for PO values estimated were found between slaughterhouses with different capacity and for carcasses tested at different times from collection. This study provides a validated methodology for the estimation of risk-based metrics based on a quantitative approach allowing food safety authorities to develop specific microbiological criteria.

1. Introduction

Campylobacteriosis is the most common recognized bacterial zoonosis in the European Union and United States (Havelaar, Ivarsson, Lofdahl, & Nauta, 2012). Campylobacteriosis in humans is mainly caused by *Campylobacter jejuni* and, to a lesser extent, by *Campylobacter coli*. Other *Campylobacter* species (e.g. *Campylobacter lari*, *Campylobacter upsaliensis*, *Campylobacter fetus*) are also reported to cause disease in humans, but the reported number of these non-*jejuni/coli* infections worldwide is a small fraction of all *Campylobacter* infections (Wagenaar, French, & Havelaar, 2013).

Depending on severity of the infection, Campylobacteriosis in the acute phase is characterized by diarrhea with abdominal cramps, nausea, fever, and bloody stools. The disease is usually self-limiting, and antimicrobial treatment is only indicated in severe cases. In rare cases, *C. jejuni/coli* can cause a bloodstream infection (Humphrey, O'Brien, & Madsen, 2007). In addition, *C. jejuni* has been identified as an important infectious trigger for Guillain-Barré syndrome, the most common cause of acute flaccid paralysis in polio-free regions (WHO, 2013).

Campylobacter can be isolated from the faeces of healthy food-producing animals (eg, poultry, pigs, cattle, sheep), wild animals (eg, birds), and companion animals (eg, dogs, cats). Presence of *Campylobacter* in these animals is usually asymptomatic, although in cattle and sheep *C. jejuni* has been reported to cause sporadic abortions. The pathogenesis of *C. jejuni* disease in humans and the absence of clinical manifestations in most species is still unexplained (Wagenaar et al., 2013). Manure from animals may contaminate surface water through runoff from pasture, presenting a risk for humans when consumed as (untreated) drinking water.

* Corresponding author. Tel.: +34 957 218516; fax: +34 957 212000.
E-mail address: bt2vadia@uco.es (A. Valero).

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Furthermore, humans can be exposed to surface water through direct contact (swimming) or indirect contact (consumption of raw products irrigated with surface water) (Wagenaar et al., 2013).

A total of 220,209 human cases of Campylobacteriosis were reported in the EU27 in 2011, being the most frequently reported zoonosis (EFSA, 2013). Human exposure from animal reservoirs is possible via multiple pathways including foods, the environment, and direct animal contact. Poultry meat is a major source of infection. It can infect people through cross-contamination to ready-to-eat foods and direct hand-to-mouth transfer through food preparation, and to a lesser extent from the consumption of undercooked poultry meat. Overall, handling, preparation and consumption of broiler meat may account for 20–30% of human cases of Campylobacteriosis reported in 2011 (EFSA, 2013).

Countries have traditionally attempted to improve food safety by setting microbiological criteria (MC) for raw or finished processed products. The MC define the acceptability of a product or a food lot based on the absence/presence or number of microorganisms, including parasites, and/or quantity of their toxins/metabolites per unit(s) of mass, volume, area or lot (CAC, 1997; ICMSF, 2002). They have been recognized as a valuable tool for validation and verification of HACCP-based processes and procedures. In EU legislation, they are also used as a method of communicating the level of hazard control that should be achieved. However, the MC have been often set without estimating their effect on reducing the risk of foodborne disease. Therefore, new metrics based on the formal risk analysis approach have been proposed by the Codex Alimentarius Commission (CAC, 2004). Such metrics are represented by Food Safety Objectives (FSO) and Performance Objectives (PO).

An FSO is the maximum frequency and/or concentration of a hazard in a food at the time of consumption that provides or contributes to the achievement of what the governments deem as an Appropriate Level Of Protection (ALOP) against that hazard. In relation to *Campylobacter* in the European Union, a possible ALOP might be to obtain e.g. 50% and 90% reductions of the prevalence of human Campylobacteriosis caused by broiler meat consumption or cross-contamination (EFSA 2011). Maximum hazard levels at earlier points along the food chain are called Performance Objectives (POs). POs may be set by both government or industry and should take into consideration the initial level of the hazard before any treatment, as well as the decreases and possible increases of that hazard level, if any, before consumption. Thus, POs and FSOs are targets to be met. In this context, MC based on within-lot testing is meant to provide a statistically designed means for determining whether these targets are being achieved. Therefore, MC will not change with the introduction of FSOs or POs, representing additional tools that the food industry can use to build food safety into their products.

At present, food safety standards in the EU include MC and targets in primary production. Since both these parameters for *Campylobacter* in poultry meat have not been suggested yet and we are moving to the adoption of risk based metrics, the current paper provides a strategy to elucidate a potential Food Safety Objective (FSO) and subsequently derive possible POs for *Campylobacter* carcasses after chilling according the evaluation of different risk factors as assessed in the EFSA monitoring study performed in 2008 in the European Union under decision 2007/516/EC.

2. Materials and methods

2.1. Description of the dataset

The dataset used in this study is part of the anonymized raw dataset of the EU-wide baseline survey performed by EFSA on the prevalence of *Campylobacter* in broiler batches and prevalence and concentration of *Campylobacter* on broiler carcasses in the EU in 2008 (EFSA, 2010a). The data from 10,162 carcasses belonging to 3400 batches sampled in 25 different countries were selected for the analysis. Three countries included in the EFSA survey were excluded from the analysis due to the lack of data (<30). The term "batch" is referred to carcasses originating from one flock, or the part of one flock that is slaughtered and processed at one slaughter plant at the same day.

Although the EFSA survey considered prevalence of *Campylobacter* in broiler faeces, in this study, only data from breast and neck skin of broiler carcasses collected immediately after chilling were analyzed. In fact, the establishment of a PO was assumed to be set for carcasses collected immediately after chilling. Therefore, in this study prevalence data refer to the number of positive breast and neck skin samples obtained by detection, or enumeration, over the total number of tested samples. Concentration data refers to the number of *Campylobacter* ($\log_{10}$ cfu/g) on neck and breast skin samples.

2.2. Estimation of a Food Safety Objective

For the purpose of this study, a deterministic approach was selected to derive a potential FSO (ICMSF, 2002), which was used as benchmark to elucidate POs for *Campylobacter* in carcasses. This approach was selected as a first approximation to derive target values for FSO, as already shown in previous works (Sosa-Mejia, Beumer, & Zwietering, 2011). To this end, the following equation was applied (Pérez-Rodríguez, van Asselt, García, Zurera, & Zwietering, 2007):

$$\text{Cases} = P*D*N*R \quad (1)$$

where *Cases* corresponds to the number of reported cases associated with *Campylobacter* species in the 27 EU member states; P is the prevalence value for the pathogen; D is the ingested dose; N is the number of consumed servings and R corresponds to the probability of illness per ingested cell taken from an exponential dose–response model with the form:

$$\text{P\_ill} = 1 - \exp(-D*R) \quad (2)$$

where *P_ill* represents the probability of becoming ill after ingesting a dose of a certain number of cells (D). Dose is defined as the product between concentration (cfu/g) and serving size (g). Therefore, the equation can be rewritten as:

$$\text{Cases} = P*C*S*N*r \quad (3)$$

where C and S represents concentration at consumption (cfu/g) and serving size (g), respectively and r is derived from in-vivo or in vitro studies or epidemiological data.

To estimate the FSO, the factor P^*C was calculated as a function of the remaining parameters, i.e. *Cases*, N, S and r which were derived by using the total values reported for the 27 EU countries. Thereafter, the estimated value was assumed to be the FSO for *Campylobacter* based on consumption of poultry-based products.

2.3. Selection of datasets of risk factors for the elucidation of Performance Objectives

To provide an illustration of how POs can be derived, representative factors influencing *Campylobacter* counts and prevalence in carcasses (EFSA, 2010b; Habib et al., 2012) were taken into account for the analysis. Factors considered were 'slaughterhouse