Microbial Risk Analysis 2–3 (2016) 68–77

Contents lists available at ScienceDirect

Microbial Risk Analysis

journal homepage: www.elsevier.com/locate/mran

The effect of reducing numbers of *Campylobacter* in broiler intestines on human health risk

Maarten J. Nauta[a,*], Gro Johannessen[b], Laura Laureano Adame[c], Nicola Williams[d], Hanne Rosenquist[a]

[a] National Food Institute, Technical University of Denmark, Moerkhoej Bygade 19, DK-2860 Soeborg, Denmark
[b] Norwegian Veterinary Institute, PO Box 750 Sentrum, NO-0106 Oslo, Norway
[c] Nutreco Food Research Center, Casarrubios del Monte, Toledo, Spain
[d] Department of Epidemiology and Population Health, Institute of Infection and Global Health, University of Liverpool, 8 West Derby Street, Liverpool L69 7BE, UK

ARTICLE INFO

Article history:
Received 3 December 2015
Revised 10 February 2016
Accepted 26 February 2016
Available online 2 March 2016

Keywords:
Campylobacter control
Risk assessment
Regression
Colonization level
Europe

ABSTRACT

One option for *Campylobacter* control in broiler chickens is to reduce the concentration in the intestinal content of the birds prior to slaughter, for example by vaccination or phage therapy. It is however unsure how such a reduction in concentration can be translated into a reduction in concentration on the meat and a reduction in the human health risk of campylobacteriosis. In this study, two methods are presented and compared. The first is a linear regression model, based on count data from caecal contents and skin sample data, obtained after processing from the same flocks. Alternatively, a previously published risk assessment model is used, that describes the dynamics of transfer and survival of *Campylobacter* during broiler processing at the slaughterhouse. Data from five European countries are used as inputs for the models. For both approaches the analyses show that a one to two log reduction in concentration in the intestinal content has a large impact on the risk of campylobacteriosis due to the consumption of chicken meat: a relative risk reduction between 44% and 95%. Therefore it seems promising to aim interventions at a reduction of the concentration of *Campylobacter* in the broiler intestines. However, it is not possible to derive a generic rule that can be used to relate a reduction in concentration in broiler intestines into a reduction in human health risk. Regression models based on different data sets predict different relationships between bacterial count data from caeca and skins, whereas the risk assessment model requires data on contamination of the birds' exterior, which is not sufficiently available in combination with caecal concentration data. Simulations performed with the risk assessment model show that it can pretty well adequately describe the observed correlation in the data and the variation in regression lines obtained.

1. Introduction

Thermotolerant *Campylobacter* is a leading cause of zoonotic enteric infections worldwide (WHO, 2012) and the most commonly reported human gastrointestinal bacterial pathogen with more than nine million cases in the European Union (EU) annually (EFSA, 2011; Havelaar et al., 2012). Broiler meat is generally considered to be an important source and therefore *Campylobacter* research and risk analysis have primarily targeted the broiler meat production chain. Control options have been studied by epidemiological risk factor studies, food chain risk assessments and experimental work at farm and during slaughter and processing. Despite these efforts, so far no single intervention has been identified that in practice can be used to substantially reduce the human incidence of campylobacteriosis (EFSA, 2011). In the EU there is, however, consensus that the control of *Campylobacter* at the broiler farm is of utmost importance since the bacteria do not only spread during handling and consumption of broiler meat, but also through the chicken reservoir as a whole (EFSA, 2010a). The project CamCon, under the European Union's Seventh Framework Programme, therefore studied the potential effects of interventions against *Campylobacter* at the farm.

At the farm, *Campylobacter* can be controlled by reducing the prevalence of broiler flocks that become colonized with *Campylobacter* and by reducing the concentrations of *Campylobacter* in the intestinal content of the animals at the point of slaughter. Reduction of the prevalence can be achieved by interventions that

* Corresponding author. Tel.: +4535887085.
E-mail address: maana@food.dtu.dk (M.J. Nauta).

http://dx.doi.org/10.1016/j.mran.2016.02.001
2352-3522/

lower the probability of colonization of flocks, as analyzed in risk factor studies (EFSA, 2011, Newell et al., 2011, Sommer et al., this issue), e.g. strict biosecurity measures. Reduction of concentrations can potentially be achieved by interventions like vaccination or phage therapy (EFSA, 2011). The idea behind these control strategies is that, even though *Campylobacter* may not be eliminated, a reduced concentration in the intestinal content of the birds will lead to a lower number of *Campylobacter* entering the slaughterhouse and consequently lower concentrations of *Campylobacter* on the meat. Risk assessment studies suggest that a reduction of the concentration is an effective means to reduce the human risk for campylobacteriosis (Rosenquist et al., 2003; Nauta et al., 2009a).

A relevant question is how the effect of an intervention aimed at reducing the concentration of *Campylobacter* in the broiler intestinal content can be translated into a reduction in human health risk. As the effect of cross contamination from colonized flocks to *Campylobacter* negative flocks is generally considered negligible (Johannessen et al., 2007; Callicott et al., 2008; Nauta et al., 2009a), the flock prevalence at slaughter and human health risk of campylobacteriosis consequential to consumption of broiler meat from these flocks are commonly thought to be proportional (EFSA, 2011). However, the relation between the concentration of *Campylobacter* at slaughter and the risk will be different, as cross contamination and inactivation will occur during processing and food handling. Further on, the dose response relation, describing the relation between ingested dose and the probability of infection, is non-linear (Teunis and Havelaar, 2000). Usually, the effects of interventions like vaccination and phage therapy are measured in terms of a reduction in the concentration and/or prevalence in birds intestinal content, for example in the caeca (De Zoete et al., 2007). However, it is not clear what such a result means in terms of reduction of the *Campylobacter* concentration on the processed carcasses, or reduction of human exposure. Bridging that gap requires a risk assessment model that covers the processing steps at the slaughterhouse. Several of these models have been developed, but as these models apply different transmission dynamics, different data and different assumptions, they have not resulted in a clear answer to the question how a reduction of the *Campylobacter* concentration in the broilers intestinal content before slaughter can be translated into a reduction of the concentration on the meat or a reduction in human health risk (Nauta et al., 2009a; EFSA, 2011).

Alternatively, it may be an option to use a simpler approach and develop a regression model that can describe how, for example, mean caecal concentrations in broiler flocks are related to mean concentrations on skin samples or meat samples of processed broilers. For these points in the broiler meat production chain, several authors performed a simple linear regression on log transformed concentration data. Some studies found a significant correlation between the two (Rosenquist et al., 2006; Reich et al., 2008; Laureano et al., 2013; Boysen et al., this issue), but others did not (Allen et al., 2007; Hansson et al., 2007; Nauta et al., 2009b; Seliwiorstow et al., 2015a). EFSA (2011) used the study of Reich et al. (2008) to evaluate the effect of vaccination and phage therapy on human health risk, using two different risk assessment models to link the predicted concentration on broiler skin to human health risk. However, Reich et al. (2008) did not precisely report the regression line obtained and the analysis of censored data (i.e. values below the limit of detection) in their study may have impacted their results.

In the present study, we aim to compare the two approaches, using a risk assessment model or a simple linear regression model, to evaluate whether they predict similar effects of reducing the concentrations of *Campylobacter* in the intestinal content of broilers on the risk of campylobacteriosis for consumers. More precisely, we use a slightly modified version of the risk assessment model developed in the Netherlands (Nauta et al., 2007) and a regression model based on Danish data from 2013 (Boysen et al., this issue). For both methods, the concentration on the broiler skin samples after the chilling step of industrial processing are used to assess the human health risk by applying the same consumer phase/dose response model (Nauta et al., 2012). If the regression model method, which is the simpler approach, gives similar predictions of effects on human health risk as the risk assessment method, it will be the preferable method, and ideally it could provide a rule of thumb for assessing the impact of reductions of the concentrations of *Campylobacter* in broilers at the farm.

For the analyses of the two approaches, data on *Campylobacter* concentrations in broiler caeca from five different European countries are used. These data were collected in the CamCon project (www.camcon-eu.net) and were applied in this study to investigate the importance of realistic differences in *Campylobacter* concentrations and potential differences between countries.

2. Methods

A list of parameters used in this study is given in Table 1.

2.1. Risk assessment model

A modified version of the risk assessment (RA) model of Nauta et al. (2007) was applied to evaluate the impact of changes in intestinal concentration on the human health risk, expressed as an estimated probability of illness.

This risk assessment model covers the pathway from the entrance of the slaughterhouse to the effect of consumption of a meal with chicken breast fillets. One of the inputs to the model is the distribution of the variation in intestinal concentrations of *Campylobacter* in a batch of broilers entering the slaughterhouse, C_{fec}. In the original model this intestinal concentration is defined as the concentration in the feces leaking from the carcass during processing. Here it is assumed here that data on caecal concentrations can be used to describe this distribution. Other inputs relevant for this study are the distribution of *Campylobacter* concentrations on the carcass exterior after bleeding (N_{ext}) and the within-flock prevalence, which is assumed to be 100% in this study (as in EFSA, 2011). For other inputs, the same values are used as in Nauta et al. (2007).

The last part of the model, the consumer phase model, is modified to allow for comparison with the analysis by regression models. This means that the *Campylobacter* concentration on a chicken breast fillet, N_{fillet} (Nauta et al., 2007), is used as an input in the consumer phase model that was also applied in other studies (EFSA, 2011; Nauta et al., 2012; Nauta et al., 2015). This consumer phase model combines the model of Nauta et al. (2008) with the dose response model described by Teunis and Havelaar (2000).The values for N_{fillet} are used as values for concentration on the chicken meat C_{meat} (as defined by Nauta et al., 2012) by assuming fillets weigh 160 g: $C_{meat}= N_{fillet}/160$ cfu/g.

The model is implemented in @Risk 6.2 (Palisade), using a combination of the spreadsheets applied by Nauta et al. (2007) and Nauta et al. (2015).

2.2. Regression model

In this study, we apply the regression model of Boysen et al. (this issue), based on 15 flocks from three Danish broiler slaughterhouse, describing a linear relation between the log concentration on broiler skin samples taken after processing ($\log C_{skin}$) and the log concentration found in the caeca ($\log C_{fec}$).

$$\log C_{skin} = 0.70 \log C_{fec} - 2.5, \quad (1)$$

with a standard error of the estimate of 0.36.