Estimating *Campylobacter* Burden of Illness from Undercooking Poultry Products in England and Wales

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Abstract: The estimated public health burden of *Campylobacter* infection and illness in England and Wales due to consuming undercooked poultry products is relatively small, ~0.3 percent. The estimated annual number of cases of campylobacteriosis in England and Wales attributed to consumption of chicken is 175,000. Information, on consumer behavior during cooking, heat sensitivity of *Campylobacter*, population data on consumption of poultry products, *Campylobacter* dose response, were used to model, probabilistically, *Campylobacter* infection and illness. The information used in the model was sourced from publicly available databases and from literature. Sensitivity analysis of the model indicates that consumer knowledge of cooking chicken determines risk of *Campylobacter* infection and illness. Model calculations show that it is possible to eliminate this route of infection by consistent monitoring of cooking temperatures and ensuring that a core temperature of 70 degrees C is reached during a cooking process and held for more than 2 minutes. Since 57 percent of meals where chicken is the main ingredient are still prepared at home, targeted information on preparing and cooking chicken in the home will help to decrease the *Campylobacter* burden of illness from undercooking poultry products in England and Wales.

Keyword: *Campylobacter* infection, modeling, undercooking, poultry products.

INTRODUCTION

Campylobacter infection and illness remains the single biggest contributor to foodborne illness in the community in England and Wales. The sources of infection are consumption of undercooked poultry products and cross contamination of ready to eat food by *Campylobacter* spp. (Rosenquist IJFM. 2003) [1]. Poultry products which are undercooked allow for the survival and infection by *Campylobacter* spp. Information on consumption of undercooked poultry products during a consumption event therefore plays a major role in quantification of the risk of *Campylobacter* infection and illness.

Detailed information on the diet of the adult population in Great Britain is available from the National Diet and Nutritional Survey (Ndns NDNS 2001) [2]. This consumption data can be further segmented into the source of a meal i.e. foods consumed and prepared at home, foods consumed and prepared at a retail establishment and consumption of a food manufactured product. The segmentation of the consumption data allows for quantification of the contributions of these sources to the overall risk of *Campylobacter* infection and illness.

We present here an analysis of the contribution of undercooking poultry products to the risk of *Campylobacter* infection and illness in England and Wales by combining information from peer reviewed journals and publicly available databases. Uncertainty in the information on the *Campylobacter* spp. load on chicken carcasses and uncertainty in the cooking process will be translated to the variability of exposure to *Campylobacter* spp. at the point of consumption and subsequent risk of infection and illness.

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MATERIALS AND METHODS

Fig. (**1**) shows the distribution of the logarithm of the concentration, CFU/100 gram, of *Campylobacter* spp. on chilled and frozen chicken samples. This data was retrieved from Jorgensen IJFM 2002 [3] and the transformation from CFU/carcass to CFU/100 gram was obtained by using an average carcass weight of 1500 gram (Defra AUK 2006) [4].

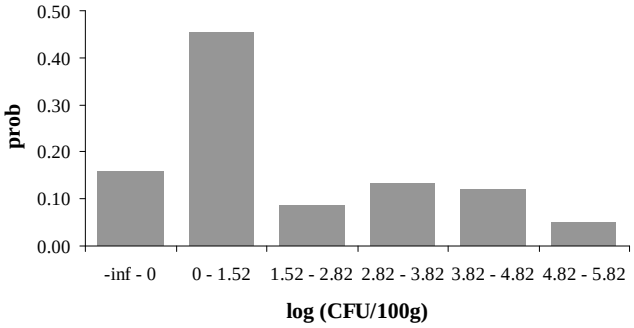

Fig. (1). Distribution of the logarithm of the concentration of *Campylobacter* spp. in 100 gram of uncooked chicken (Jorgensen IJFM 2002) [3].

Information on the load of *Campylobacter* spp. was obtained from samples of chilled and frozen carcasses sold at retail. If the sampling process was repeated the information on the concentration of *Campylobacter* spp. may be different. The variability of the concentration of *Campylobacter* spp. on poultry carcasses can be quantified by a normal distribution of the logarithm of the *Campylobacter* spp. load

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Table 1. Heat Sensitivity of *Campylobacter jejuni* in Ground Chicken Meat (Blankenship AEM 1982) [6]

Temp (˚C)	D-value (min)	No. decimal reduction / min
49	20.50	0.05
51	8.77	0.11
53	4.85	0.21
55	2.12	0.47
57	0.79	1.27

(Uyttendaele IJFM 2006) [5]. The best estimate of the mean of this variability distribution is 1.7 and the best estimate of the standard deviation is 1.7. These parameters were derived from the information obtained from the Jorgensen IJFM 2002 [3] study.

Heat sensitivity of foodborne pathogens is quantified using the concept of thermal death time. Thermal death time is defined as the time necessary to reduce a population of microorganisms or spores by 90 percent at a specified temperature. One widely used translation of this concept is the decimal reduction time, abbreviated as the D value. Comparatively *Campylobacter* spp. are heat sensitive (Blankenship AEM 1982) [6]. Table **1** shows the range of D values for *Campylobacter jejuni* for a series of temperature and the calculated number of decimal reductions if these temperatures were held constant for one minute.

A study on consumer food safety behaviour in the home in the United Kingdom (Worsford BFJ 1997) [7] revealed that 15 percent of respondents did not cook food to an internal temperature of at least 70 degrees C for 2 minutes, as is recommended by the Food Standards Agency, FSA, in the United Kingdom. The survey indicates that food can be subjected to a range of cooking temperatures at home. Uncertainty in cooking temperatures results in the uncertainty in D values and therefore to the survivability of *Campylobacter* spp. cells in the food.

We quantify the uncertainty in the cooking process by assuming that the logarithm of the number of decimal reductions of *Campylobacter* spp. log(R), is normally distributed or alternatively the number of decimal reduction, R, is lognormally distributed. We belief the number of decimal reductions, R, is lognormally distributed (Limpert BS 2001) [8] as the factors or processes which contribute to the reduction of *Campylobacter* spp. during cooking is multiplicative. These factors include the geometry of the chicken, the amount of fat in the chicken and the heat penetration in the chicken.

In the model domain, the mean of log(R) is 2.6 and was estimated from the FSA recommended cooking time and temperature and from extrapolating the D values in Table **1**. The standard deviation of log(R) was 0.4 and estimated from the study of Worsford BFJ 1997 [7]. We assume that 15 percent of consumers did not allow the internal cooking temperature to reach 70 degrees C for one minute. In this representation we belief the standard deviation of log(R) quantifies lack of knowledge of the cooking process. A high standard deviation represents our belief for increased chances of undercooking. We further assume that the source of the chicken meal is correlated to the standard deviation of log(R).

We have segmented the source of the chicken meal into three categories i.e., food prepared at home, food prepared at a retail establishment and a food manufactured product. We believe that the control of cooking processes is not optimal in the home, better at a retail establishment and optimal in food manufacturing. We have reduced the standard deviation of log(R) by 50 percent, 0.2, for a food manufactured product. This standard deviation of 0.2 translates to very high probability that an initial population of *Campylobacter* has declined by more than 12 decimal reductions after cooking. We have decreased the standard deviation to 0.3 for foods prepared at retail establishments to account for better control of cooking processes at these establishments when compared to food prepared at home.

A comprehensive cross-sectional picture of the dietary habits of the population of Great Britain is captured in the National Diet and Nutrition Survey. In this paper, we will be using information from the NDNS survey of adults aged 19 to 64 years of age. The survey records essentially the type, amount and source of food eaten by the respondent over a seven day period. Additionally the time of a consumption event is also recorded.

Foods are categorized into food types which are then subdivided into food groups and finally into individual foods. Each individual food is identified using a four digit code. The food type and food group used in the model domain are meat and meat products and chicken and turkey dishes. In this paper we assume each consumption event can lead to an infection.

Fig. (**2a**) shows the distribution of the number of times a meal consisting of cooked chicken is eaten in a week and Fig. (**2b**) shows the probability density of portion sizes per consumption event from the survey. The NDNS survey also includes a code for source of the food. These codes categorize for where the food is eaten e.g. food derived and eaten at home, food obtained from, and eaten at commercial catering establishments.

We have used these codes to recategorize foods into three groups i.e. food prepared at home (57%), food prepared at a retail establishment (25%) and food manufactured products (18%). Foods included in the group, food manufactured products, were derived from the food name or food description because the NDNS survey does not code for these products.

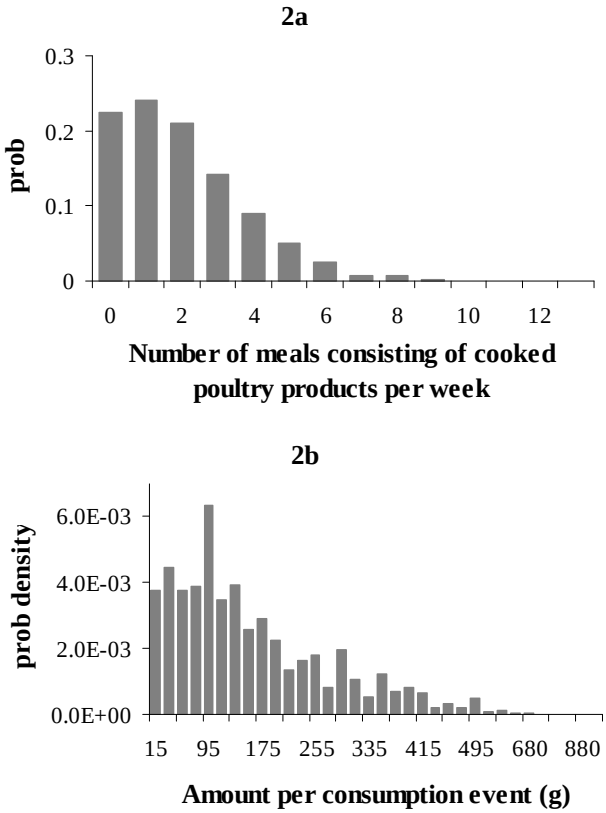

Fig. (2). Consumption of cooked poultry products in the United Kingdom (Ndns NDNS 2001) [3]).

RESULTS AND DISCUSSIONS

Appendix 1 shows the flow chart for calculating the annual *Campylobacter* infection and illness from consumption of undercooked chicken. Uncertain information on initial concentration of *Campylobacter* spp. before cooking, C_p, is translated to uncertain information for the presence of *Campylobacter* spp. post cooking. The number of decimal reduction, R, during cooking is dependent on the source of preparation of the chicken meal. Exposure to *Campylobacter* spp. during a consumption event is obtained by multiplying the concentration post cooking by the portion size. The outcome of the calculation is exposure to *Campylobacter* spp. per consumption event. In this paper, the software tool, HUGIN researcher version 6.9 from HUGIN A/S, Aalborg, Denmark, was used to estimate this exposure. We assume that exposure to one or more *Campylobacter* spp. cells leads to infection and illness. We use this fail safe approximation because information on dose response for *Campylobacter* infection is sparse (Robinson BMJ 1981 [9], Black JID 1988 [10]) and it is generally agreed that the infective dose is very low. The model estimates that the probability of a meal which leads to a *Campylobacter* infection and illness is 10^{-7} given this fail safe assumption.

Sensitivity analysis of the model reveals that the number of decimal reduction, R, during the cooking process is the dominant source of uncertainty. A 10 percent change in the standard deviation of log(R) results in 4 orders of magnitude change in the probability of *Campylobacter* infection and illness. A 10 percent change in the mean of log(R) only results two orders of magnitude change in the probability of *Campylobacter* infection and illness. Comparatively changes in C_p only produced two orders of magnitude change in the probability of *Campylobacter* infection and illness. Therefore consistent monitoring of temperature during cooking of chicken can eliminate this route of infection and illness. This belief is confirmed for food manufactured products where the probability of *Campylobacter* infection and illness is not significant given our belief in better temperature control during manufacturing.

The latest population estimate for England and Wales, excluding children below 4 years old, is 49 million. Therefore the average number of meals containing cooked poultry which is consumed annually in England and Wales is ~5 billion given that the average number of chicken consumption events per week is two. Since the probability of an infected meal is 10^{-7} and we assume that the number of infection and illness follows a binomial process, the annual average number of cases of *Campylobacter* infection and illness due to undercooking poultry products is ~500. Annually 350, 000 cases of *Campylobacter* infection and illness are estimated to occur in England and Wales and approximately fifty percent of these cases can be attributed to consumption of chicken (Adak EID 2005) [11]. The percentage of cases of *Campylobacter* infection and illness in England and Wales due to undercooking poultry is ~ 0.3 percent.

The results confirm expert opinion that other causes of *Campylobacter* infection and illness is the driving force for dominance of this pathogen in the human food chain. Current risk assessments of *Campylobacter* in foods (Rosenquist IJFM 2003 [1], Uyttendaele IJFM 2006 [5]) indicate that cross contamination contributes a major portion of the burden of illness of this pathogen.

CONCLUSION

The estimated public health burden of *Campylobacter* infection and illness in England and Wales, due to consuming undercooked poultry products is relatively small. Even though the data used in the modelling process was sparse and the assumptions used were conservative, the structured probability model reveals that this burden of illness is primarily influenced by food safety behaviour during the cooking process. Since 57 percent of meals where chicken is the main ingredient are still prepared at home, targeted information on preparing and cooking chicken in the home will help to decrease the *Campylobacter* burden of illness from undercooking poultry products in England and Wales.

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APPENDIX 1

Flow chart of the dependency between undercooking and *Campylobacter* infection and illness in England and Wales. The parameters for the Normal distributions are the mean and variance.