

Challenges in data needs for assessment of food product risk and attribution of foodborne illnesses to food products in the United States

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Abstract

This paper presents discussions on data needs for assessment of food product risk and attribution of foodborne illnesses to food products. Working with the Foodborne Diseases Active Surveillance Network (FoodNet), Food Safety and Inspection Service (FSIS) adapted a Bayesian statistical model to quantify attribution of meat, poultry, and eggs as sources of human salmonellosis in the United States. The model was fitted to the observed number of domestic and sporadic salmonellosis cases using Markov Chain Monte Carlo simulation to estimate the joint posterior distribution.

Our study shows that to adequately assess food product risk and attribute illnesses to food products, we need to obtain data concerning pathogen prevalence and distribution in a wide variety of potential food vehicles and for other important sources of human exposure, such as indirect sources of contamination and non-food sources. Another challenge we encountered is the need to ensure that existing data sources continue to adequately represent the burden of foodborne illnesses in the U.S. population and the distribution of the associated pathogen in food vehicles and exposure sources of interest. Additionally, we need to refine existing data so that the comparisons between data from various sources are based on similar units of observation at the necessary levels of discrimination for defined points along the farm-to-table continuum.

Assessment of food product safety and attribution of foodborne illnesses require extensive data originating from various sources. However, currently available data sources suffer from methodological limitations and the unavailability of certain types of data often result in critical data gaps. An expert elicitation conducted by FSIS shows that when epidemiologic data are lacking, are sparse, or are highly uncertain, data from expert elicitation are useful to fill the critical gaps in food safety studies.

Introduction

In the United States, the authority for food safety oversight is divided between the U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS) and the U.S. Department of Health and Human Services' Food and Drug Administration (FDA). FSIS regulates the production of meat, poultry, and egg products under the authority of the Meat Inspection Act, the Poultry Products Inspection Act, and the Egg Products Inspection Act. FDA regulates other foods under the authority of the Federal Food, Drug, and Cosmetics Act.

Foodborne microbiologic hazards may be responsible for as many as 76 million cases of illness in the United States each year and are thus an important food safety challenge (1). Attributing the burden of foodborne illness to specific food commodities can assist risk managers and policy makers to formulate public health goals, prioritize interventions, and document the effectiveness of prevention efforts for reducing illness and improving public health (2). Food safety requires a farm to fork approach. Attributing illness to foods at different points throughout the food production chain – the reservoir level (cattle, for instance), the production level (ground beef), or the retail level (hamburger patties) – also provides insight into the processes at which food safety mitigations should be applied.

This paper discusses data needs for assessment of food product risk and attribution of foodborne illnesses to food products. Working with the Foodborne Diseases Active Surveillance Network (FoodNet), FSIS adapted a Bayesian statistical model (3) to quantify attribution of meat, poultry, and eggs as sources of human salmonellosis in the United States. The model was fitted to the observed number of domestic and sporadic salmonellosis cases using Markov Chain Monte Carlo (MCMC) simulation to estimate the joint posterior distribution. Assessment of food product safety and attribution of foodborne illnesses require extensive data originating from various sources.

When available data sources suffer from methodological limitations and the unavailability of certain types of data, it often results in critical data gaps. An expert elicitation recently conducted by FSIS and RTI International shows that when epidemiologic data are lacking, are sparse, or are highly uncertain, data from expert elicitation are useful to fill the critical gaps in food safety studies. It ranks the public health risks posed by bacterial hazards in processed meat and poultry products and

attributes foodborne illnesses to specific pathogens as a result of consuming or handling processed meat and poultry products.

1. A statistical model for attributing salmonellosis to meat, poultry, and eggs

1.1 Danish *Salmonella* attribution model

Hald et al. (3) described a statistical model that combines epidemiologic surveillance data, pathogen prevalence data, and food consumption data. The model has been used to attribute cases of human salmonellosis in Denmark to specific food commodities and has led to the implementation of food commodity specific policies that have reduced the incidence of foodborne salmonellosis. Human infections caused by *Salmonella* subtypes found in multiple animal reservoirs are attributed proportionally to the occurrence of the distinctive subtypes. Microbial subtyping provides a link between public health endpoint and source of infection. The Danish *Salmonella* model uses a Bayesian framework which applies Markov Chain Monte Carlo simulation to estimate the expected number of human salmonellosis. The approach quantifies the contribution of each of the major animal-food sources to human salmonellosis.

The Danish *Salmonella* attribution model has proven useful for identifying pathogen reservoirs in animal populations, tracking trends of human salmonellosis, and guiding interventions. In concluding their report, Hald et al. called for other countries to apply their model to *Salmonella* surveillance data to promote integration of quantitative risk assessment and zoonotic disease surveillance. We have done that.

1.2 Attribution model parameters

The key equation used in Danish *Salmonella* attribution model is

$$\lambda_{ij} = p_{ij} M_j a_j q_i$$

where λ_{ij} is the expected number of cases for serotype i and product j , p_{ij} is the prevalence of *Salmonella* serotype i in product j , M_j is the amount of product j available for consumption, a_j is the food product-dependent factor for product j , and q_i is the bacteria-dependent factor for serotype i . Attribution of salmonellosis cases to the specific foods was estimated using data for (i) the number of observed human salmonellosis cases, (ii) the prevalence of *Salmonella* serotypes in 7 food commodities (ground beef, intact beef, chicken, turkey, pork, shell eggs, and egg products), and (iii) human consumption of these food commodities. The probable values of a_j and q_i were determined using Bayesian inference given observational data for the total number of salmonellosis cases of each *Salmonella* serotype and the prevalence of the serotypes in the 7 food commodities.

1.3 Adaptation of the Danish *Salmonella* attribution model to U.S. Data

In the adapted model, as in the original version, the simplistic assumption is made that all of the human cases of salmonellosis addressed by the model are associated with a

defined set of food commodities, either directly by the patient consuming that food or indirectly through the commodity's contamination of other foods. The commodities examined in this model are necessarily those for which *Salmonella* data is available.

The model is also limited serotypes of *Salmonella* that have caused human disease and have also been detected in at least one of the food commodities in question. There are many other cases of human salmonellosis that are not caused by these serotypes, just as there are undoubtedly many cases of salmonellosis caused by these serotypes that were not caused by consumption of these food commodities.

Human salmonellosis cases

The data on human cases used in the adapted model were all cases of salmonellosis reported through the Public Health Laboratory Information System (PHLIS) during the six-year period, 1998-2003. This reporting system covers all of the 50 states of the U.S.

Prevalence of Salmonella, by serotype, for foods

For each of the FSIS-regulated commodities—steers and heifers (i.e., young fed cattle), cows and bulls (i.e., older cattle), ground beef, ground turkey, pork, broiler chickens, and pasteurized egg products—*Salmonella* test results of the Hazard Analysis and Critical Control Point monitoring program were used to estimate the prevalence of *Salmonella*, by serotype, in each of product categories except for shell eggs during the six-year period, 1998-2003. Shell egg data are from the Pennsylvania *Salmonella Enteritidis* Pilot Project, 1993-1995.

Consumption data for the U.S. population

Per capita food consumption data were obtained from the Economic Research Service's Food Consumption Data System (<http://www.ers.usda.gov/Data/FoodConsumption/>). Yearly data for 1998 through 2003 were obtained for each of the 7 food categories included in this study.

Outbreak and travel information

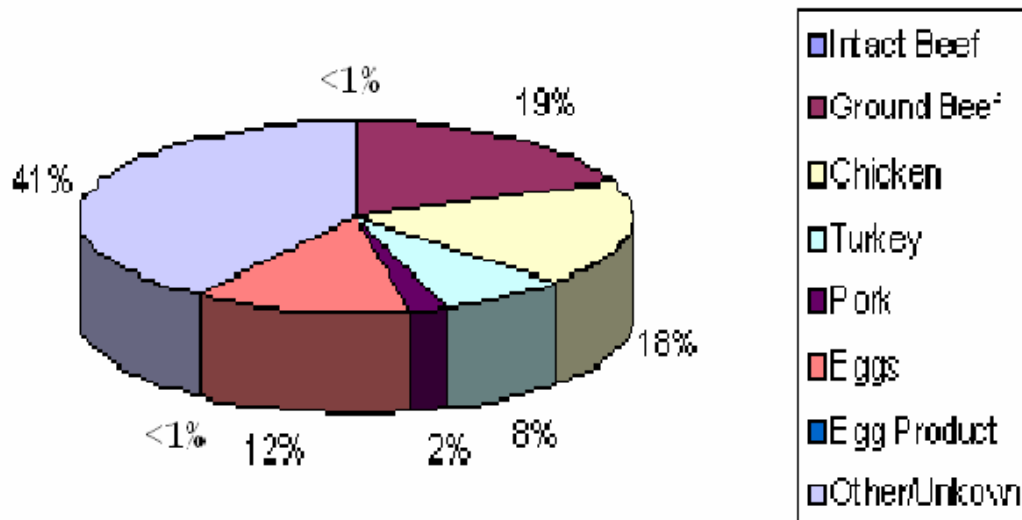
In U.S. data, *Salmonella* serotypes differ in their likelihood of association with outbreaks and with travel. Because this model focused on the attribution of sporadic disease, the initial task was to estimate the number of human cases, by serotype, that were due to domestically acquired sporadic cases.

1.4 Preliminary results

Figure 1 shows the preliminary results from the of relative percentage of estimated culture-confirmed salmonellosis cases from intact beef, ground beef, chicken, turkey, pork, eggs, egg products, and other sources for the period 1998 through 2003 in the U.S. Of all cases of salmonellosis estimated for this period, the largest proportion of cases (19% of all cases) was attributed to ground beef, followed by those attributed to chicken (18% of all cases), eggs (12% of all cases), turkey (8% of all cases), pork (2%

of all cases), intact beef (<1% of all cases), and egg products (<1% of all cases). About 41% of all cases of salmonellosis for this period were not attributed to any of the seven food categories in the model.

Figure 1. Estimated Percentage Distributions of Human Salmonellosis Cases, 1998-2003



1.5 Limitations of the attribution model

A limitation of the model is that it included only those data for *Salmonella* in meat, poultry, and eggs, despite that many other foods, such as produce, milk, and fish are recognized vehicles of salmonellosis (4). It is important, therefore, to obtain robust data for *Salmonella* in these and other food commodities.

Another drawback was that data for shell eggs came from a geographically limited, decade-old study, albeit one with a large sample size (5). The decision to include these data in the model was based on (i) the knowledge that shell eggs have been documented as a source in many salmonellosis outbreaks, especially those of serotype Enteritidis and (ii) the thought that it would be better to present results for shell eggs and let readers determine how to interpret them rather than leave shell eggs out of the model. Regardless, because of the very low incidence of *Salmonella* contamination of eggs (estimates suggest somewhere between 1 in 10,000 to 1 in 20,000 eggs are contaminated (5,6)), it is difficult to generate statistically robust sampling data for *Salmonella* in eggs. Given the importance of eggs as vehicles of salmonellosis, a new, nationally representative survey of *Salmonella* in eggs would help to inform future attribution models.

2. Expert elicitation on the relative risks of meat and poultry products

FSIS recently contracted with RTI International to conduct an expert elicitation to rank the public health risks posed by bacterial hazards and to attribute foodborne illnesses to specific pathogens as a result of consuming or handling processed meat and poultry products. The expert elicitation ranks the public health risks posed by bacterial hazards in each of the 25 categories of processed meat and poultry products for healthy adults and for vulnerable consumers, respectively (7). It also ranks the confidence level on a scale of 1 to 3, with 1 indicating “little or no confidence” and 3 indicating “very confident.”

2.1 Results of 2007 expert elicitation - the likelihood of illness due to consuming or handling meat and poultry products

For both healthy adults and vulnerable consumers, raw ground, comminuted, or otherwise nonintact chicken products were ranked as having the highest risk. In general, results are similar between healthy adult consumers and vulnerable consumers.

Table 1. Top seven product types of the likelihood of illness among healthy adults as a result of consuming or handling finished product types

Finished Product Type	Median Score (1-10)	Level of Confidence (1-3)
Raw ground or otherwise non-intact chicken	10	2.6
Raw ground or otherwise non-intact turkey	9	2.3
Raw ground or otherwise non-intact poultry – no chicken or turkey	8.5	1.8
Raw intact chicken	8	2.6
Raw intact turkey	8	2.5
Raw intact poultry – other than chicken or turkey	8	1.9
Raw ground or otherwise non-intact beef	8	2.5

Table 2. Top seven product categories of the likelihood of illness among vulnerable consumers as a result of consuming or handling finished product types

Finished Product Type	Median Score (1-10)	Level of Confidence (1-3)
Raw ground or otherwise non-intact chicken	10	2.6
Raw ground or otherwise non-intact beef	9.5	2.5

Raw ground or otherwise non-intact turkey	9	2.5
Raw ground or otherwise non-intact poultry – no chicken or turkey	9	2.0
Raw intact chicken	8.5	2.6
Raw intact turkey	8	2.6
Raw intact poultry – other than chicken or turkey	8	2.1

2.2 Results of 2007 expert elicitation - attribution of foodborne illness of *Salmonella* to meat and poultry products

The expert elicitation is also used to attribute foodborne illnesses to handling and consuming foods in 25 processed meat and poultry product categories. Figures 2 and 3 show the attribution results for *Salmonella* (non-typhi) and *Salmonella* (multidrug resistant). The percentages indicate the percentage of illnesses resulting from handling and consuming each category of processed meat and poultry products.

Figure 2. Attribution of Foodborne Illness of *Salmonella* (Non-Typhi) to Meat and Poultry Products

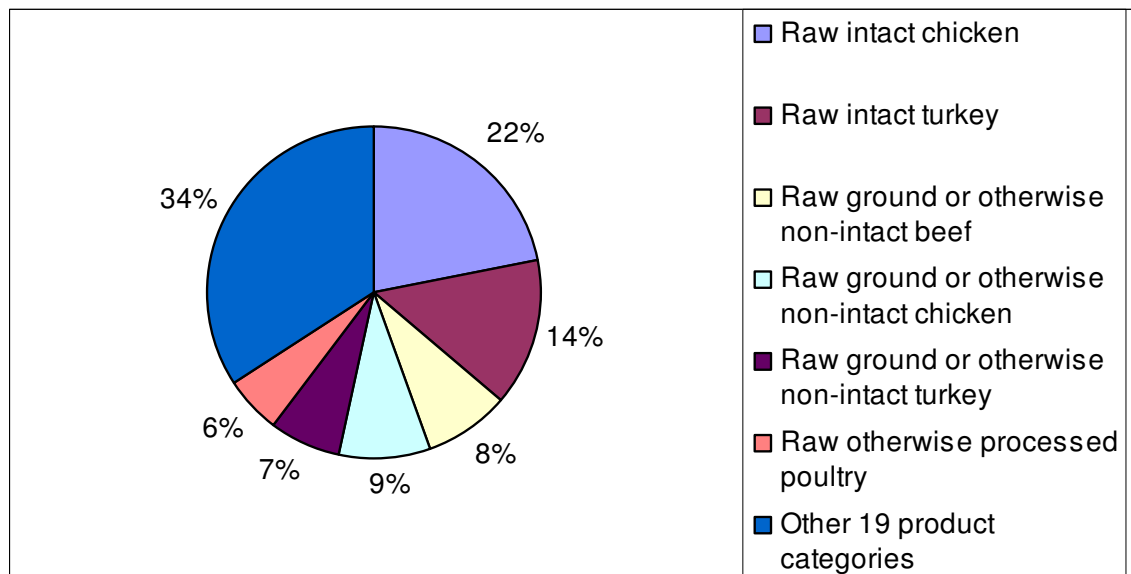
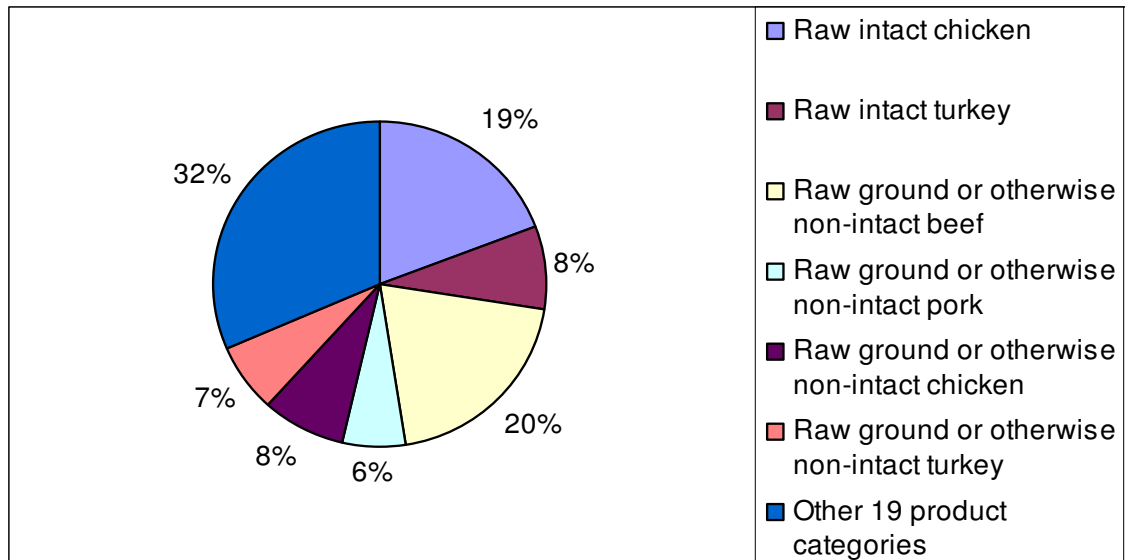


Figure 3. Attribution of Foodborne Illness of *Salmonella* (Multidrug Resistant) to Meat and Poultry Products



3. Challenges in data needs for food safety and attribution

Our study shows that to adequately assess food product risk and attribute illnesses to food products, we need to obtain data concerning pathogen prevalence and distribution in a wide variety of potential food vehicles and other for other important sources of human exposure, such as indirect sources of contamination and non-food sources. When considering the possibility of indirect sources of contamination, non-food animal sources can be parsed into pets, farm animals, and wildlife. Farm animals can be divided by animal species. Pet and animal feeds may also contribute to illness and should be factored into considerations. Contaminated water is a source of illness through direct consumption or indirectly contaminating produce, seafood, etc.

Another challenge we encountered is the need to ensure that existing data sources continue to adequately represent the burden of foodborne illnesses in the U.S. population and the distribution of the associated pathogen in food vehicles and exposure sources of interest. To achieve this goal, it requires the collaboration of various public health, regulatory, and academic organizations. We need a comprehensive approach to ensure that the continued collection of data for attribution efforts which is accurate, consistent, and affordable.

Additionally, we need to refine existing data so that the comparisons between data from various sources are based on similar units of observation at the necessary levels of discrimination for defined points along the farm-to-table continuum. Different food

safety interventions and regulation are necessary for different points in the farm-to-table continuum. As additional data for other food sources are obtained, it will be important that new data collection efforts are consistently implemented at defined points in the farm-to-table continuum.

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