Food Control 54 (2015) 353–359

Contents lists available at ScienceDirect

Food Control

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

Comparing foodborne illness risks among meat commodities in the United States

David J. Hsi [a], Eric D. Ebel [b], Michael S. Williams [b, *], Neal J. Golden [b], Wayne D. Schlosser [b]

[a] Office of Field Operations, Food Safety and Inspection Service, USDA, USA
[b] Risk Assessment and Analytics Staff, Office of Public Health Science, Food Safety and Inspection Service, USDA, 2150 Centre Avenue, Building D, Fort Collins, CO 80526, USA

ARTICLE INFO

Article history:
Received 12 December 2014
Received in revised form
9 February 2015
Accepted 12 February 2015
Available online 20 February 2015

Keywords:
Risk assessment
Probability of illness
Risk management

ABSTRACT

Food-safety regulatory agencies are often tasked with oversight of a broad range of food commodities. For these agencies to regulate multiple commodities effectively, they need to develop policies and allocate resources that consider the varying magnitudes of the risk of illness that each of the commodities poses to the broad population of consumers. Process modeling is used in risk assessment to estimate the likelihood of illness by modeling contamination of raw foods, the microbial dynamics of pathogens between production and consumption, and dose–response relationships for the pathogen to estimate the risk and total number of illnesses for a specific commodity. Nevertheless, these models are usually unique to each commodity and constructed using different models and data sources, which can produce estimates that are difficult to compare. An alternative approach is presented that stems primarily from public health data. It uses simple methods to estimate various risk metrics simultaneously for multiple pathogens and commodities. This alternative approach is used to compare multiple risk metrics for beef, lamb, pork, and poultry for both *Salmonella* and *Escherichia coli* O157:H7. The implications of the different risk metrics are discussed with respect to current regulatory efforts in the United States.

1. Introduction

The publication of national burden of foodborne illness estimates (Scallan et al., 2011) and food source attribution estimates (Painter et al., 2013) provide methods for determining annual numbers of foodborne illnesses in the United States associated with broad food categories. For example, combining the Scallan et al. (2011) methods for determining annual *Salmonella* illnesses with the Painter et al. (2013) methods for determining the fraction of *Salmonella* illnesses attributed to a particular food, such as beef, facilitates an estimate of annual *Salmonella* illnesses associated with beef consumption in the United States. Similar approaches for burden of illness and food-source attribution have been applied in Europe (EFSA, 2015; Greig & Ravel, 2009; Havelaar et al., 2012; Pires, Vigre, Makela, & Hald, 2010).

The annual illness burden provides a measure of public health importance of various food–pathogen pairs. The total illnesses from a specific pathogen associated with a food commodity may reflect the amount of the commodity consumed by the U.S. population, the inherent likelihood of illness per food unit consumed, or some combination of these components.

The U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS) has announced that it plans to pursue strategies to reduce the occurrence of *Salmonella* illnesses associated with the meat products it regulates.[1] In addition, FSIS has emphasized control of *Escherichia coli* O157:H7 (STEC O157) in beef products for nearly two decades.

Interest lies in comparing and contrasting the apparent likelihood of *Salmonella* and STEC O157 illnesses per unit of beef, lamb, pork, and poultry consumed in the United States. Comparisons may provide insight to the risks faced by U.S. consumers on an annual basis. In addition, the aggregated risk across a 40-year period, when consumption patterns might be reasonably consistent and representative of the population average (e.g., between the ages of 20 and 60), offers an alternative perspective to the annual risk of illness. Contrasts in risk may suggest approaches for prioritizing the risk management of these food–pathogen pairs.

* Corresponding author. Tel.: +1 970 492 7189.
E-mail address: mike.williams@fsis.usda.gov (M.S. Williams).

[1] *Salmonella* Action Plan http://www.fsis.usda.gov/wps/wcm/connect/aae911af-f918-4fe1-bc42-7b957b2e942a/SAP-120413.pdf?MOD=AJPERES.

http://dx.doi.org/10.1016/j.foodcont.2015.02.018
0956-7135/Published by Elsevier Ltd.

After proposing a simple model that relates annual illness counts to annual consumption amounts, this study uses available data to estimate the likelihood of illness per kilogram, and per serving, of food consumed for each of the target pathogens. The overarching objective of this analysis is to compare the estimated average likelihood of *Salmonella* and STEC O157 illness to the amount of beef, lamb, pork, and poultry consumed annually in the United States. Agreement/disagreement between these estimates will be determined by the degree of overlap in distributions that display uncertainty about these parameters.

2. Methods

2.1. Mathematical modeling

The proposed modeling framework stems from the three primary determinants of adverse human health outcomes from foodborne pathogens: 1) the frequency of exposure to the pathogen; 2) the distribution of pathogens in a random exposure event on a per exposure basis; and 3) the probability that a random exposure event causes the adverse human health outcome (Williams, Ebel, & Vose, 2011).

A simplified equation relates total exposures, likelihood of illness (i.e., risk of illness) per exposure $f(ill)$, and total illnesses $I_{food-pathogen}$ for particular food–pathogen pairs:

$$N_{food} \times f(ill)_{food-pathogen} = I_{food-pathogen}.$$

In this equation, N_{food} signifies either the total annual consumption of a food or the total annual number of servings consumed of that food. Interpretation of the risk of illness for a particular food–pathogen pair depends on the units of total annual consumption; it is either the risk of illness per kilogram, or per serving, of food consumed.

2.2. Estimation of N_{food}

As will be discussed, estimates of total annual consumption (N_{food}) can be considered deterministic while estimates of the number of annual illnesses ($I_{food-pathogen}$) incorporate substantial uncertainty. To estimate the risk of illness, the equation above is simply inverted such that $f(ill)_{food-pathogen}=I_{food-pathogen}/N_{food}$.

We examine the risk of illness on both per kilogram and per serving bases. Assuming total annual consumption is the total kilograms of a food consumed in the United States provides a common measure of exposure for comparing likelihood of illness from a particular pathogen among different foods. Alternatively assuming annual consumption represents the total servings of a food consumed in the United States accounts for different serving sizes among the commodities per eating occasion. The likelihood of illness from a particular pathogen per serving of a food is a more common metric for risk assessment because it reflects the risk of illness per actual eating event.

To maintain consistency between available number of servings data, kilograms consumed and reported annual illnesses, consumption estimates are based on the year 2010. Therefore, year-to-year fluctuations in these measures are ignored. In addition, it is assumed that the estimates used are certain values rather than random variables. Given the large magnitudes of estimated kilograms or servings consumed per year, any influence of uncertainty on the final results is expected to be slight.

The U.S. Department of Agriculture, Economic Research Service (USDA-ERS) publishes annual estimates of total disappearance of agriculture commodities (ERS, 2012). For the meat commodities considered here, the estimates use a balance sheet approach to account for the annual supply (beginning stocks, total slaughter of each class of animal, imports) and disappearance (ending stocks, export, or food available for consumption in the United States) of commodities. These estimates convert carcass weight data to boneless, trimmed-weight food availability equivalents and serve as a proxy for actual consumption per annum (Table 1).

The What We Eat in America, National Health and Nutrition Examination Survey (WWEIA/NHANES) is a collaboration between USDA and U.S. Department of Health and Human Services that collects dietary information keyed to United States Department of Agriculture Food Codes (ARS, 2010; CDC, 2012a, 2014). For our purposes, we analyzed consumption of beef, poultry, lamb, and pork commodity classes by only excluding codes in which it was apparent the commodity was not included (e.g., mock chicken or meatless beef). Table 1 presents the total production weight during 2010 of the four commodities available for consumption using the USDA-ERS data, and the total number of servings of each commodity consumed using the WWEIA/NHANES data. Beef servings were tallied across food codes using search terms "Beef," "Hamburger," and "Cheeseburger" (total of 418 different food codes). Lamb servings were tallied across food codes using the search term "Lamb" (total of 49 different food codes). Pork servings were tallied across food codes using search terms "Pork," "Ham," and "Bacon" (total of 298 different food codes). Poultry servings were tallied across food codes using search terms "Chicken," "Turkey," "Poultry," "Duck," and "Goose" (total of 582 different food codes).

Based on the USDA-ERS estimate of the U.S. population in 2010 (309,775,750 persons), the average person consumes 26, 0.3, 20, and 33 kg of beef, lamb, pork, and poultry per year, respectively. Furthermore, the average person consumes 164, 1, 123, and 228 servings of beef, lamb, pork, and poultry per year, respectively.

2.3. Estimation of $I_{food-pathogen}$

The annual number of illnesses reported by a surveillance system for a particular pathogen is $I_{obs-pathogen}$. Most public health surveillance systems are subject to under-reporting bias and can only identify a fraction of the human cases associated with a pathogen. Therefore, for most public health surveillance systems, the number of illnesses reported will differ substantially from the actual number of illnesses caused by a specific pathogen.

Two factors are necessary to expand the observed illnesses to an estimate of the total number of illnesses for a food–pathogen pair, $I_{food-pathogen}$. The first factor is the proportion of illnesses, α, attributed to the food of interest. The second factor describes the proportion of illnesses, ρ, actually reported to the surveillance system. These factors adjust the observed pathogen illness rate parameter to predict the actual number of illnesses whose etiology is the pathogen and a particular food product, so that

$$I_{food-pathogen} = \frac{\alpha_{food} \times I_{obs-pathogen}}{\rho_{pathogen}}.$$

Table 1
Different approaches for total annual consumption (N_{food}) are shown. The total kilograms available for U.S. consumption for the four commodities are derived from USDA-ERS. The total servings consumed in the United States are derived from NHANES.

Commodity	Total kilograms (lbs.) available for consumption, 2010	Total servings consumed, 2010
Beef	8,024,928,682 (17,654,843,100)	50,948,985,332
Lamb	95,170,727 (209,375,600)	442,631,892
Pork	6,321,244,823 (13,906,738,611)	38,143,554,942
Poultry	10,070,042,024 (22,154,092,452)	70,505,613,817