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Salmonella and broiler processing in the United States: Relationship to foodborne salmonellosis

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ABSTRACT

Salmonella is one of the leading causes of foodborne illness worldwide, with over 40,000 cases reported each year in the United States alone. *Salmonella* is often associated with foods of animal origin, with chicken and dishes containing chicken often thought to be the most likely source. The Food Safety Inspection Service of the United States Department of Agriculture keeps data on the serotypes of *Salmonella* isolated from Hazard Analysis Critical Control Point verification samples obtained each year. The Centers for Disease Control and Prevention (CDC) publishes the most common *Salmonella* serotypes isolated from human disease each year. In addition, CDC maintains records of all reported foodborne outbreaks and the vehicle of illness, when determined. This review examines the overall prevalence of *Salmonella* serotypes isolated from broilers, the serotypes most commonly associated with human illness, and serotypes most commonly found in foodborne salmonellosis associated with chicken or chicken containing products.

1. Introduction

Salmonellosis is a serious public health concern with over 40,000 cases reported each year in the United States alone (CDC, 2009a). In 2009 the Foodborne Diseases Active Surveillance Network (FoodNet) recorded an average incidence of non-typhoid salmonellosis of 15.2 infections per 100,000 persons per year (CDC, 2009a).Studies have shown that, despite variation in *Salmonella* serotypes isolated across these FoodNet sites, the overall incidence of salmonellosis was found to be similar (Voetsch et al., 2004). FoodNet was established in 1995 as a collaborative effort among federal, state, and local government agencies to conduct active surveillance of the incidence of foodborne illness (Kennedy et al., 2004). Currently, there are 10 participating states and/or counties within states: California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, and Tennessee (CDC, 2009a).As of the 2004 addition of Tennessee to the pool, the population of the FoodNet surveillance area was 44.5 million persons, or 15.1% of the United States population. FoodNet is also an "active" surveillance method, as it does not rely on state health departments to report illnesses to the CDC. Instead, FoodNet officials contact laboratory directors on a routine basis to find new cases of foodborne illness. A case report form is generated for each case, which includes information on demographics, clinical outcomes, and the pathogen. All rates are calculated using population estimates for the appropriate years. FoodNet monitoring of laboratories allows more accurate and precise estimates and interpretation of the burden of foodborne diseases over time. On the theory that most foodborne infections cause diarrheal illness, the focus of FoodNet efforts is on persons who have a diarrheal illness.

Salmonellosis is the result of ingestion of bacteria of the genus *Salmonella*. Symptoms of salmonellosis include diarrhea, fever, and abdominal cramps occurring 12 to 72 h after consumption of food containing the *Salmonella* organism. Illness is usually self-limiting, lasts less than a week and does not require treatment (CDC, 2010a). In some instances, chiefly in the elderly, infants and persons with compromised immune systems, the diarrhea becomes so severe that hospitalization is required in 27% of the cases as determined by FoodNet analyses (CDC, 2009b). Poultry, especially chicken, has often been associated with salmonellosis (Mead et al., 2010). In recognition of this association, the Food Safety Inspection Service (FSIS) of the United States Department of Agriculture (USDA) has made reduction of *Salmonella* spp. in various classes of meat and poultry products, especially broilers, a priority (USDA/FSIS, 2008). The questions to be addressed in this paper are as follows: is the overall prevalence of *Salmonella* spp. on broiler carcasses a good indicator of propensity to cause illness, and are the serotypes commonly identified in broiler processing the same as those commonly associated with human illness?

2. Infectious dose of *Salmonella* for humans

The term infectious dose is commonly understood to mean the number of organisms needed to cause disease (Johnson, 2003). Some

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organisms may have relatively low infectious doses (500 or less) while others may require 100,000 or more organisms to cause infection (Todd, Greig, Bartleson, & Michaels, 2008). Information from outbreaks suggests the infectious dose for salmonellosis is low, but there is considerable variability. Capsules containing 4.6 log CFU of *S.* Cubana contaminated carmine dye infected 71% of the susceptible patients who received the capsules (Lang, Kunz, Martin, Schroeder, & Thomson, 1967). Likewise, an outbreak of *S.* Typhimurium was linked to artificial ice cream containing about 4 log CFU, and had an attack rate of 55% (Armstrong et al., 1970). Outbreaks associated with high fat products have been shown to cause disease with much lower levels of organism, for instance, chocolate bars with less than 10 CFU of *S. napoli* per gram (Greenwood & Hooper, 1983) and hamburger with as low as 6 CFU per gram (Fontaine et al., 1978). The infectious dose likely also varies with patient age and health as well as the composition of the food with which the pathogen is associated. Children less than age 4 and persons over the age of 50 constituted the largest groups of laboratory confirmed cases of salmonellosis in the ten FoodNet sites in 2009, each group accounting for 25% of the cases (CDC, 2009b). In addition, 45% of those over the age of 50 were hospitalized and 88% of all deaths where *Salmonella* was listed as the cause of death were in that age group (CDC, 2009b).

Mead et al. (1999) estimated that 95% of cases of salmonellosis are foodborne in origin. Regardless of the point of consumption (e.g. restaurant, institutional, special event, or home) the majority of foodborne salmonellosis infections likely result from improper food handling or some type of cross-contamination event (ICMSF, 1996). Furthermore, these infections are caused by various *Salmonella* serotypes. Serotyping is a useful classification method that allows for trends of *Salmonella* data to be analyzed over time (Brenner, Villar, Angulo, Tauxe, & Swaminathan, 2000). *Salmonella* serotyping could provide a link between the patient and the source of infection.

3. Food attribution

Attributing salmonellosis microbiologically to a particular food is difficult for many reasons, but largely because the food has been eaten or disposed of, and food recall data are very unreliable (Hoffman, Fishbeck, Krupknik, & McWilliams, 2007). An epidemiologic approach relies on foodborne outbreak data and case control studies. Best estimates can be obtained by a combination of disease expert elicitation, outbreak data, illness case–control studies, risk assessments, and serotype data (Batz et al., 2005).

3.1. Expert elicitation

Expert judgment can be used when scientific or epidemiologic data are lacking or uncertain, but it is limited in value since it is based on perception rather than data. Hoffman et al. (2007) in their expert elicitation attributed 35% of the cases of foodborne salmonellosis to poultry (chicken and turkey products), as well as 35% of hospitalizations and 18% of deaths associated with salmonellosis in the US. The most used statistics are therefore gleaned from foodborne outbreaks.

3.2. Outbreak data

A foodborne outbreak is defined as two or more persons who ate the same contaminated food contracting the same illness (CDC, 2005). Many outbreaks are confined to a small geographic area, although more and more widespread multistate outbreaks are being recognized. For instance in 2008–2009 there was a multistate outbreak of salmonellosis associated with peanut butter and products containing peanut butter. More than 500 persons became ill in 43 states, 116 of whom were hospitalized, and salmonellosis contributed to the death of 8 of the patients (CDC, 2009c).

Line item data on foodborne outbreaks are maintained by CDC in a searchable database that contains data from 1998 through 2008. These items consist of information reported to the CDC by state and local health departments. A search of the CDC database for confirmed cases of *Salmonella* foodborne outbreaks with a known food vehicle was performed by the authors and the data are presented in Table 1. Salmonellosis outbreaks associated with chicken for the entire period constituted 16% of the outbreaks. Starting in 2005 there was a gradual decrease both in the total number of outbreaks per year and also in the number attributed to chicken or dishes containing chicken. A limitation of using outbreak data is that CDC reports that in more than 50% of outbreaks of salmonellosis, no vehicle for the illness is discovered (CDC, 2009d), and it is believed that the incidence of salmonellosis is underreported by as much as 38% (Voetsch et al., 2004; Scallan et al., 2011).

3.3. Case control studies

Salmonellosis associated with an outbreak is a small number when compared to the number of isolated or “sporadic” illnesses that occur each year. For the period 1988 through 1997 CDC had an average annual number of culture-confirmed cases of salmonellosis of over 45,000, but slightly less than 5400 cases annually were associated with outbreaks (CDC, 1996; CDC, 2000). Evaluating risk factors via case control studies of sporadic infections is a valuable tool in identifying food vehicles of importance for particular serotypes.

A population-based case–control study in 5 FoodNet areas in 1996 to 1997 found that eating eggs prepared outside the home was the most significant risk factor for illness for *S.* Heidelberg infections (Hennessy et al., 2004). Kimura et al. (2004) reported on a case control study of sporadic *S.* Enteritidis infections in FoodNet sites. Risk factors identified were international travel, eating undercooked eggs and consuming chicken prepared outside the home. This was the first time that chicken had been identified as a risk factor for *S.* Enteritidis infections. Another population based case control study of *S.* Enteritidis infections in 2002–2003 found that travel outside the US during the 5 days before onset of illness was highly correlated to *S.* Enteritidis infections, followed by eating chicken prepared outside the home and preparing undercooked eggs inside the home, this study also indicated that contact with birds and reptiles was also a risk factor, substantiating that salmonellosis is not 100% foodborne (Marcus et al., 2007).

4. Most commonly isolated serotypes from human disease

The 20 most isolated serotypes of *Salmonella* from human cases are also tabulated annually by the CDC. The information from 1998 through 2006 is presented in Table 2; the top 5 serotypes have not changed from 1998 to 2006. Serotypes *S.* Typhimurium and *S.* Enteritidis are isolated most frequently from human clinical cases. In 1998, the top four serotypes caused almost 62% of human salmonellosis, *S.* Typhimurium (26%), *S.* Enteritidis (17.7%), *S.* Newport (6.7%) and *S.* Heidelberg (5.6%) (CDC, 2010b). It appears, however, that more diversity is occurring in serotypes causing human disease. In 2006, the top four serotypes caused slightly less than 46% of human salmonellosis reported to CDC, with *S.* Typhimurium causing 16.9% of cases and *S.* Enteritidis causing 16.6% of cases. CDC also reports that *S.* Typhimurium isolates from human disease have decreased 28% between 1996 and 2006, while *S.* Enteritidis isolations decreased 30%. In the same time period, isolations of serotype *S.* Tennessee, *S.* Mississippi and serotype *S.* I 4, [5], 12:i:— increased sharply. Serotype *S.* I 4, [5], 12:i:— is closely related to serotype *S.* Typhimurium, and has been found with increasing frequency worldwide as a cause of salmonellosis (Soyer et al., 2009). The CDC data include information not only from foodborne outbreaks, but also from sporadic cases of foodborne salmonellosis as well as salmonellosis contracted from other vectors, such as pets.