Enumeration of *Salmonella* in Ground Meat and Poultry as a Means to Protect Public Health

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BACKGROUND

Non-typhoidal *Salmonella* is the most common cause of foodborne illness in the United States. In 2011, the incidence rate based on actual cases reported to FoodNet was 16.47 illnesses per 100,000 individuals (CDC 2013). CDC also estimates that for every 1 *Salmonella* case reported, an additional 29 cases go undiagnosed due to the self-limiting nature of most cases of illness. Thus the actual incidence is higher, with an estimated 1.2 million cases occurring annually, making Salmonellosis the most common cause of hospitalization and death associated with foodborne illnesses (Scallan et al. 2011).

The food safety and public health communities continue to examine how food is exposed to *Salmonella*, how those exposures translate to human illness, and the factors that can drive the severity of foodborne illness. Clearly, reducing the frequency of exposure to levels of *Salmonella* that cause illness is critical to protect public health. This paper proposes that meaningful gains in public health will be achieved by:

- Enumerating samples to establish how widely the levels of *Salmonella* in ground meat and poultry products vary;
- Examining the range of distribution (e.g., frequency of finding "low" vs. "high" levels of *Salmonella*);
- Understanding the factors that result in the high levels of *Salmonella* in the product;
- Enabling the industry to make better decisions regarding processing based on enumeration data; and,
- Understanding and characterizing treatments that result in the elimination or significant reduction of *Salmonella* in ground meat and poultry products.

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HYPOTHESIS

The risk of foodborne illness is influenced by the concept of infectious dose; that is, the consumption of different levels of *Salmonella* is correlated with different probabilities of illness. Reducing the actual levels of *Salmonella* in ground meat and poultry will reduce the number of illnesses associated with these products irrespective of serovar. A heightened focus on enumerating samples of ground meat and poultry and ascertaining the *number of Salmonella* that are present in a given sample, versus relying solely on the qualitative approach of prevalence, will allow for a food safety system more capable of ensuring food related illness, and provide for better public health protection.

SALMONELLOSIS IN THE UNITED STATES

There has not been a decline in overall incidence rate of *Salmonella* infections in 15 years and in 2011 the incidence rate was three times higher than the 2010 National Health Objectives Target. However, a recent Center for Science in the Public Interest (CSPI; DeWaal & Glassman 2013) analysis of outbreak data covering a ten year period (2001-2010) shows that the number of outbreaks of foodborne illness related to meat and poultry has actually decreased.

While reductions in *Salmonella* related illness associated with animal protein are promising, poultry and beef continue to be considered important vectors for *Salmonella* infection because of the organism's ability to colonize within the digestive tract of both poultry and livestock. *Salmonella* can easily enter the bovine lymphatic system, and infect the ovarian tissue of hens, contaminating eggs before being laid (World Health Organization and Food Agriculutral Organizations of the United Nations 2002; Arthur et al. 2008). Given the natural association between *Salmonella* and animal products, it is unrealistic to think that the industry will be successful in eradicating *Salmonella* in animal protein in the near term.

REGULATORY STANDARDS AND INDUSTRY PRACTICES

While food attribution is challenging, it is clear that meat and poultry processors must remain vigilant in continuing to address *Salmonella* and other pathogens. USDA FSIS has established performance standards for *Salmonella* that specify the number of samples within a sample set that can test positive for generic *Salmonella* after enrichment (*Salmonella* prevalence; Table 1). The current percent positives for all meat and poultry categories are well below the performance standards. However, the performance standards do not address the *enumeration* of *Salmonella* in a given positive sample (*Salmonella* level). The continued trend in Salmonellosis is driving regulators to put more focus on *Salmonella* prevention strategies and regulatory actions.

Currently, the industry utilizes a variety of measures—both on farm, and during processing, to control *Salmonella*. In many cases, it is the cumulative effect of the measures that result in pathogen control. The establishment of a baseline of prevalence and the requirement to do "better" than the moving baseline is logical. However, it has become apparent that performance standards based on prevalence are not enough, and don't provide a full picture of the efficacy of control measures. A "positive" result does not provide information on whether that positive was due to 1 *Salmonella* or 10 million.

The distinction between "high" and "low" and the quantification of "more protection" is certainly debatable. Industry-wide quantification (enumeration) will provide much-needed data to help define "high" and "low". Similar to the approach used by FSIS in the initial establishment of the baseline for performance standards, gaining a better understanding of the spectrum of "positive"—understanding how often ground product contains 10^6 vs. 10^4 vs. 10^1 vs. 10^{-1} cfu/g —will allow the industry to focus resources on the products (and practices) that are most likely to result in human illness. As discussed in the section on level of *Salmonella*, the consumption of different amounts of *Salmonella* are associated with different probabilities of illness. We are in *no way* suggesting that processors should be complacent in producing product with any number of *Salmonella*, since there can always be some probability of illness associated with the pathogen. However, data suggest that the probability of illness is increased as exposure to greater numbers of *Salmonella* increases. It is clear that the exact number of *Salmonella* needed to cause illness is dependent on a number of factors (including host susceptibility and serovar) and can be quite variable. However, we maintain that pathogen reduction efforts should focus on reducing the probability of illness. If we operate under the premise that "more is worse", we believe that we can achieve the Healthy People 2020 goals more readily by reducing the prevalence of product in the marketplace that is *most* likely to cause illness.

By first addressing the "worst offenders"—the product that has very high levels (cfu/g) of *Salmonella*—industry will be better able to investigate the factors that resulted in high loads, enabling the implementation of more effective mitigations.

LEVEL OF *SALMONELLA*

If an enumeration approach is taken, people may ask "what is the acceptable level of *Salmonella?"* Clearly, the industry seeks to reduce *Salmonella* to the lowest possible levels, but still, the issue of infectious dose warrants review. It is worth re-emphasizing that rather than attempt to identify a "safe" level of *Salmonella,* we propose that illnesses will be reduced by addressing product that has the highest levels of the pathogen and is therefore most likely to cause illness.

In 2002, the World Health Organization (WHO) and Food and Agricultural Organization (FAO) of the United Nations, using a working group that included two representatives from USDA FSIS, reviewed multiple dose-response models for *Salmonella* in all food items to determine the risk of illness at different levels of *Salmonella* contamination. Each model, based on either outbreak data, surrogate organisms, or feeding trials, shows that as the dose increases the attack rate increases and there is a greater risk of illness. Using the outbreak model, they

Table 1. USDA FSIS Performance standards and prevalence

Product	Original Salmonella Performance Std	Updated Salmonella Performance Std	% positive: 2010 Data (29,734 samples)[1]
Ground Chicken	44.6%		18.8%
Broilers	20%	9.8%	6.7%
Ground Turkey	49.9%		10.2%
Turkeys	NA	7.1%	4.6%
Ground Beef	7.5%		2.2%
Market Hog	8.7%		2.4%
Cow/bull	2.7%		0.5%
Steer/heifer	1%		0.1%

[1] http://www.fsis.usda.gov/PDF/Serotypes_Profile_Salmonella_2010.pdf#page=98, Table 7 (turkey), table 5 (beef), table 6 (chicken), 2010 data

found that doses greater than or equal to 2 logs are more likely to be associated with illness in both healthy and susceptible populations and is not dependent on the *Salmonella* serovar present. Review of other outbreaks with various strains of *Salmonella* indicated that the probability of illness was greater in outbreaks where the infectious dose ranged from $10^2 – 10^9$ cfu. After reviewing all dose-response models, WHO and FAO concluded that the outbreak model was the best method to determine the probability of illness associated with a given dose of *Salmonella* (World Health Organization and Food Agriculutral Organizations of the United Nations 2002).

Teunis et al. (2010) evaluated non-typhodial *Salmonella* outbreaks to determine a dose-response model that could be utilized when the *Salmonella* dose or the number of exposed was unknown. This study also found that as the dose increased, the probability of illness increased. Doses above 10^2 cfu had probabilities of illness ranging from 0.05 to 1.0, where doses less than 10^2 cfu had probabilities of illness ranging from 0.01 to 0.56 (World Health Organization and Food Agriculutral Organizations of the United Nations 2002 and Teunis et al. 2010). There is too much variability to suggest a definitive cut off point below which *Salmonella* would cause illness. Still, few would argue that higher levels of *Salmonella* are *less* likely to cause illness, thus we propose that resources be focused on enumerating *Salmonella* so that products containing higher levels of the pathogen are identified, enabling industry to investigate the root cause of the high level of contamination. In turn, this will allow the development and evaluation of mitigations to reduce both levels and prevalence of *Salmonella* with a positive public health impact. Additional work is needed to examine the relationship between levels of *Salmonella* and the connection to human illness. In the case of ground meat and poultry, enumeration will allow the industry to identify product that is most likely to cause illness.

SUMMARY

As stated previously, qualitative performance standards provided USDA FSIS, the industry, and public health officials with useful information when they were first implemented. However, to achieve meaningful gains in public health, research is needed in several areas including:

- Enumeration of samples to establish how widely the levels of *Salmonella* in ground meat and poultry products vary;
- Understanding the factors that result in the high levels of *Salmonella* in the product;
- Understanding and characterizing treatments that result in the elimination or significant reduction of *Salmonella* in ground meat and poultry products;
- Increased development of enumeration methods;
- Increased knowledge on infectious dose.

In addition, a transition from focus solely on qualitative performance standards to focus on having data that provide both qualitative and quantitative (enumeration) measures of *Salmonella* can support activities which will reduce the actual levels of *Salmonella* in ground meat and poultry.

Recent *Salmonella* public health evaluations indicate that illnesses due to this organism are not decreasing in the US (CDC 2013 and Scallan et al. 2011). This organism has a high economic burden that will continue to increase without a change in practices and policies that result in a decreased frequency of exposure to foods containing levels of *Salmonella* that result in illness. Research suggests that the likelihood of infection is dependent on dose. While there may be a level of exposure below which illness is unlikely, reducing exposure to high levels of *Salmonella* will undoubtedly reduce the risk of *Salmonella* illnesses, thus improving public health and helping reach the Healthy People 2020 goals.

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