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Research Paper

Prevalence of *Salmonella* in 11 Spices Offered for Sale from Retail Establishments and in Imported Shipments Offered for Entry to the United States

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ABSTRACT

The U.S. Food and Drug Administration conducted a survey to evaluate *Salmonella* prevalence and aerobic plate counts in packaged (dried) spices offered for sale at retail establishments in the United States. The study included 7,250 retail samples of 11 spice types that were collected during November 2013 to September 2014 and October 2014 to March 2015. No *Salmonella*-positive samples (based on analysis of 125 g) were found among retail samples of cumin seed (whole or ground), sesame seed (whole, not roasted or toasted, and not black), and white pepper (ground or cracked), for prevalence estimates of 0.00% with 95% Clopper and Pearson's confidence intervals of 0.00 to 0.67%, 0.00 to 0.70%, and 0.00 to 0.63%, respectively. *Salmonella* prevalence estimates (confidence intervals) for the other eight spice types were 0.19% (0.0048 to 1.1%) for basil leaf (whole, ground, crushed, or flakes), 0.24% (0.049 to 0.69%) for black pepper (whole, ground, or cracked), 0.56% (0.11 to 1.6%) for coriander seed (ground), 0.19% (0.0049 to 1.1%) for curry powder (ground mixture of spices), 0.49% (0.10 to 1.4%) for dehydrated garlic (powder, granules, or flakes), 0.15% (0.0038 to 0.83%) for oregano leaf (whole, ground, crushed, or flakes), 0.25% (0.03 to 0.88%) for paprika (ground or cracked), and 0.64% (0.17 to 1.6%) for red pepper (hot red pepper, e.g., chili, cayenne; ground, cracked, crushed, or flakes). *Salmonella* isolates were serotyped, and genomes were sequenced. Samples of these same 11 spice types were also examined from shipments of imported spices offered for entry to the United States from 1 October 2011 to 30 September 2015. *Salmonella* prevalence estimates (based on analysis of two 375-g composite samples) for shipments of imported spices were 1.7 to 18%. The *Salmonella* prevalence estimates for spices offered for sale at retail establishments for all of the spice types except dehydrated garlic and basil were significantly lower than estimates for shipments of imported spice offered for entry.

Key words: Import; Prevalence; Retail; *Salmonella*; Serotype; Spice

In 1989, the U.S. Food and Drug Administration (FDA) documented the presence of *Salmonella* in samples of whole black pepper offered for import to the United States, finding four different serotypes in the pathogen-positive samples *(21)*. In 2006, Vij et al. *(37)* reported that *Salmonella* contamination of spices was the cause of 95% of the U.S. food recalls associated with spices in 1969 to 2003. From 2007 to 2010, several foodborne outbreaks in the United States were attributed to consumption of *Salmonella*-contaminated spices and seasonings and led to 457 laboratory-confirmed cases of salmonellosis *(9, 12, 15, 22, 36)*. These outbreaks were associated with consumption of black pepper and red pepper (*Salmonella* serotypes Montevideo and Senftenberg), white pepper (*Salmonella* Rissen), and a seasoning mix consisting of broccoli powder, parsley powder, and other spices (*Salmonella* serotypes Wandsworth and Typhimurium). Since 2010, *Salmonella*-contaminated spices have been continued to be reported to the FDA Reportable Food Registry *(31)*. In 2013, the FDA issued a risk profile on pathogens and filth in spices *(29)* that addressed four objectives: (i) to describe the nature and extent of the public health risk posed by consumption of spices in the United States by identifying the most commonly occurring microbial hazards and filth in spices; (ii) to describe and evaluate current mitigation and control options designed to reduce the public health risk posed by consumption of contaminated spices in the United States; (iii) to identify potential additional mitigation or control options designed to reduce the public health risk posed by the consumption of contaminated spices in the United States; and (iv) to identify data gaps and research needs. This risk profile revealed that *Salmonella* is the pathogen most commonly associated with human illness attributed to consumption of contaminated spices and that the presence of *Salmonella* is a systemic challenge in the spice supply

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TABLE 1. *Estimated* Salmonella *prevalence in 125 g of spices offered for sale at retail establishments*

Spice type[a]	Total no. of samples tested	No. of samples positive for *Salmonella*	*Salmonella* prevalence (%)	Clopper and Pearson's 95% confidence interval (%)
Basil	529	1	0.19	0.0048–1.1
Black pepper	1,264	3	0.24	0.049–0.69
Coriander, grd	543	3	0.56	0.11–1.6
Cumin	549	0	0.00	0.00–0.67
Curry powder, grd	518	1	0.19	0.0049–1.1
Dehydrated garlic, grd	615	3	0.49	0.10–1.4
Oregano	669	1	0.15	0.0038–0.83
Paprika, grd	816	2	0.25	0.030–0.88
Red pepper, grd	633	4	0.64	0.17–1.6
Sesame seed, whole	526	0	0.00	0.00–0.70
White pepper, grd	588	0	0.00	0.00–0.63

[a] grd, spice sample was crushed, cracked, granules, flakes, or powder (i.e., not whole). When no form designation is listed, both whole and ground samples were examined.

system. An important data gap identified was the lack of information regarding the prevalence of *Salmonella* contamination among spice types offered for sale to consumers, either in prepared or manufactured foods or in packages at retail establishments sold for use by the consumer in food preparation. Also missing was an estimate of the percentage of spices consumed that had undergone a pathogen reduction treatment, which would reduce or eliminate any *Salmonella* contamination present.

The objective of the present study was to begin to fill these data gaps by conducting a survey of *Salmonella* prevalence in packaged spices offered for sale at retail establishments throughout the United States *(25)* and providing companion data for samples from shipments of imported spices offered for entry to the United States *(2)*. The retail data provide new information about the potential for exposure of U.S. consumers to *Salmonella* through consumption of spices and, when compared with data for shipments of spice offered for entry to the United States, provide information about the efficacy of postimport hazard controls for spices primarily sourced outside the United States. Aerobic plate counts (APC) were determined for packaged spices offered for sale at retail establishments. These data were examined for any correlation between APC and *Salmonella* detection and to determine whether these data provide additional insight into the processing history of these spices.

MATERIALS AND METHODS

Sample collection from retail establishments. A total of 7,250 (dried) spice samples (at least 175 g each) were collected from retail establishments in the United States to allow for both *Salmonella* evaluation and APC, which require 125 and 50 g, respectively. Testing was done at a commercial testing laboratory under contract with the FDA. Spices included in the survey were basil leaf (whole, ground, crushed, or flakes), black pepper (whole, ground, or cracked), coriander seed (ground), cumin seed (whole or ground), curry powder (ground mixture of spices), dehydrated garlic (powder, granules, or flakes), oregano leaf (whole, ground, crushed, or flakes), paprika (ground; this spice is sold only in the ground form), red pepper (hot red pepper, e.g., chili and cayenne; ground, cracked, crushed, or flakes), sesame seed (whole, not roasted or toasted, and not black), and white pepper (ground or cracked). Basil, black pepper, oregano, paprika, and red pepper samples were collected from November 2013 to September 2014. Coriander, cumin, curry powder, garlic, sesame seed, and white pepper samples were collected from October 2014 to March 2015. All retail samples were collected and analyzed for *Salmonella* and APC (Table 1).

Sample collection sites were selected to be geographically representative of U.S. retail markets to the extent possible. For basil, black pepper, oregano, paprika, and red pepper, samples were collected from eight geographic locations (California, Colorado, Connecticut, Georgia, Maryland, Minnesota, Texas, Washington) and from online establishments. The first six states are FoodNet sites, and the distribution of sites spans nearly the full spectrum of U.S. Census Bureau designated divisions *(23)*. For white pepper, cumin, coriander, curry, garlic, and sesame seeds, sampling sites were selected from the same eight states and online plus three additional geographic locations (North Carolina, Vermont, and Illinois). This expanded geographic distribution of collection sites included at least one site in each of the U.S. Census Bureau designated divisions for these spices: California, West Region, Pacific Division; Colorado, West Region, Mountain Division; Connecticut, Northeast Region, New England Division; Georgia, South Region, South Atlantic Division; Maryland, South Region, South Atlantic Division; Minnesota, Midwest Region, West North Central Division; Texas, South Region, West South Central Division; Washington, West Region, Pacific Division; Illinois, Midwest Region, East North Central Division; North Carolina, South Region, South Atlantic Division; and Vermont, Northeast Region, New England Division.

A stratified sampling design that included four categories of retail establishments and targeted collection within each establishment was selected to more effectively span the breadth of spice samples available to U.S. consumers. The four retail establishment categories were (i) major chain supermarkets, including national and regional supermarkets; (ii) independent, small chain (<10 stores nationwide), ethnic, or natural foods supermarkets; (iii) discount or variety stores; and (iv) online stores. Only sealed packages or containers of spices were collected (i.e., no spice samples were collected from bulk bins or open containers). Establishments were selected randomly among the population for that establishment category and region. Within each retail establishment, all available varieties of the targeted spice type were collected, each as a unique sample (e.g., store brand whole black pepper, store brand ground black pepper, brand A whole

TABLE 2. *Presence of* Salmonella *in spices offered for sale at retail establishments by store type*[a]

Spice type[b]	Major chain		Independent, small chain, ethnic, natural		Discount or variety		Online		*P* value[c]
	No. sampled	No. positive	No. sampled	No. positive	No. sampled	No. positive	No. sampled	No. positive	
Basil	341	1	37	0	32	0	119	0	NS
Black pepper	907	3	161	0	86	0	110	0	NS
Coriander, grd	277	1	180	1	22	0	64	1	NS
Cumin	289	0	146	0	41	0	73	0	NA
Curry powder, grd	274	0	134	0	30	0	80	1	NS
Dehydrated garlic, grd	400	1	116	0	58	2	41	0	NS
Oregano	456	1	86	0	43	0	84	0	NS
Paprika, grd	495	0	104	1	77	1	140	0	0.049
Red pepper, grd	370	2	120	2	45	0	98	0	NS
Sesame seed, whole	279	0	158	0	22	0	67	0	NA
White pepper, grd	305	0	172	0	30	0	81	0	NA

[a] Summary statistics for total number of samples: 61% of samples were from major chain supermarkets (647 unique addresses); 19% of samples were from independent, small chain (<10 stores nationwide), ethnic, or natural foods supermarkets (245 unique addresses); 7% of samples were from discount or variety stores (111 unique addresses); and 13% of samples were from online stores (105 unique Web sites).

[b] grd, spice sample was crushed, cracked, granules, flakes, or powder (i.e., not whole). When no form designation is listed, both whole and ground samples were examined.

[c] Fisher's exact test. NS, not significant; NA, not applicable (no positive samples were found).

black pepper, brand A ground black pepper, brand B ground black pepper, etc.). We recognized that some varieties of spices are nationally distributed and that it might be possible to purchase the same variety with the same lot number in geographically diverse locations. Care was taken to collect samples with a unique combination of brand, variety, and lot number (or sell-by or use-by date). When collecting samples from a given establishment, when spice package sizes were smaller than the required sample size multiple packages of the same spice type, variety, and lot number (or expiration date, when lot number was not provided) were purchased to make a sufficient sample. In some cases, the store inventory of a given variety was insufficient to collect a complete sample. The numbers of samples collected from each category of retail establishment as a function of spice type are provided in Table 2. Additional information collected for each sample included whether the variety was labeled organic or not organic (i.e., conventional). Numbers of samples of each type of spice labeled organic or conventional are reported in Table 3.

When multiple containers (with the same lot or date) were purchased to form one sample, the containers were placed in a single Ziploc bag. All samples were shipped under ambient temperature conditions by ground transport to analytical laboratories, where bags were stored sealed at 4°C until the microbiological analyses were conducted.

Sample collection from imported shipments of spices offered for entry to the United States. This study also included examination of laboratory results for samples of spices from imported shipments offered for entry to the United States. These samples were collected and analyzed by the FDA as part of its annual fieldwork plan for 1 October 2011 to 30 September 2015 (fiscal year [FY] 2012 to FY2015). This period was selected to include the collection periods for the retail sampling and span sufficient years to ensure enough data were available to allow quantitative comparison of estimated prevalence values for spice samples collected at entry versus retail. The FDA's annual fieldwork plan defines resource allocation, including product categories to be sampled. Selection of food shipments for examination during the annual fieldwork plan are generally based on a number of factors, including the inherent risk of the product, general surveillance activities described in the FDA work plan, FDA work performance goals, and/or congressional work performance goals. All data examined in this study were drawn from reports on surveillance sampling activities rather than compliance activities related to public health emergencies, such as foodborne illness outbreak investigations.

Relevant data from the annual fieldwork plan sampling results were first identified by their product codes *(33),* which generally identify the spice name and form, such as "basil (sweet basil),

TABLE 3. *Presence of* Salmonella *in spices labeled conventional and organic and offered for sale at retail establishments*

Spice type[a]	Conventional		Organic		*P* value[b]
	No. sampled	No. positive	No. sampled	No. positive	
Basil	503	1	26	0	NS
Black pepper	1205	3	59	0	NS
Coriander, grd	442	2	101	1	NS
Cumin	489	0	60	0	NA
Curry powder, grd	443	1	75	0	NS
Dehydrated garlic, grd	548	2	67	1	NS
Oregano	636	1	33	0	NS
Paprika, grd	789	1	27	1	NS
Red pepper, grd	605	4	28	0	NS
Sesame seed, whole	421	0	105	0	NA
White pepper, grd	531	0	57	0	NA

[a] grd, spice sample was crushed, cracked, granules, flakes, or powder (i.e., not whole). When no form designation is listed, both whole and ground samples were examined.

[b] Fisher's exact test. NS, not significant; NA, not applicable (no positive samples were found).

whole," "basil (sweet basil)," or "basil (sweet basil), ground, cracked (spice)." Selected data were further refined using descriptive and additional product code data. For example, descriptive data were used to distinguish samples of oregano from those of marjoram because until 2015 the relevant product code included both spices together as "marjoram, sweet marjoram, oregano." Because oregano is referred to as marjoram in some parts of the world, this procedure may have eliminated oregano samples described solely as "marjoram." Data for ground red pepper were gathered from entries with product code "capsicums (cayenne, chili, hot peppers), ground, cracked (spice)" or "pepper, hot, dried or paste" with appropriate descriptions such as "chili powder." Data for curry powder were gathered from entries with product codes "curry powder, ground, cracked, without salt (spice)" and "curry powder, without salt (spice)" and from product codes for spices "not elsewhere classified" (NEC; "spices, NEC," "spices and seasonings, NEC," or "mixed spices and seasonings, NEC") when accompanied with an appropriate description identifying curry powder. Descriptive data on the spice samples were further reviewed to eliminate as much as possible samples that were mischaracterized, such as samples for which the product codes *(33)* and product descriptions reported did not agree. For example, data for basil, oregano, and coriander, which have both dried and fresh forms, were restricted to those samples for which multiple forms of evidence indicated that the product was dried as provided by the product code and description information. This requirement may have eliminated some spice data but ensured that the data examined referred to only dried products.

Collection and analysis of samples were conducted according to established protocols as described in the FDA *Bacteriological Analytical Manual* (BAM) *(32)*. Generally, 30 subsamples of approximately 160 g each (25 g from each subsample was used in the *Salmonella* presence or absence test) were collected randomly from each shipment. Typically each subsample was collected from a different sack or container of food in the shipment.

Microbiological assay. A 125-g sample was used for testing the presence or absence of *Salmonella* in retail spices. Two 375-g samples were evaluated for spices from imported shipments offered for entry; each of the two 375-g unique composite samples were derived from the collected subsamples (i.e., each composite sample was derived from 25 g from each of 15 subsamples) according to the BAM *(28)*. Ratios of spice to preenrichment broth for all samples (retail and entry) were kept at 1:9 except for samples of oregano, for which the ratio was 1:100 to ensure *Salmonella* detection for this spice. Detection, isolation, and confirmation of *Salmonella* isolates from spices were performed according to the BAM *(32)*.

Total APC in 50-g spice samples for sale at retail establishments were determined as described in the BAM *(30)*. APC were not determined for samples collected from shipments of spice offered for entry to the United States.

Serotyping *Salmonella*. *Salmonella* isolates from spices were serotyped using the Luminex xMAP *Salmonella* serotyping assay *(16)*. Isolates that were untypeable by the Luminex assay were serotyped using the Kauffman-White antigenic formulae scheme *(10, 32)*.

PFGE. Pulsed-field gel electrophoresis (PFGE) laboratory analysis was conducted using the official Centers for Disease Control and Prevention (CDC) PulseNet protocol *(7)*. *Xba*I was the primary restriction enzyme and *Bln*I was the secondary restriction enzyme. The PFGE profile data were analyzed using Bionumerics v. 7.6 (Applied Maths, Austin, TX).

Genome sequencing. Isolates from spice samples were grown in tryptic soy broth (Difco, BD, Franklin Lakes, NJ) overnight at 37°C, and genomic DNA was extracted using the DNeasy Blood & Tissue kit (Qiagen, Valencia, CA). DNA concentrations were measured with a Qubit fluorometer (Life Technologies, Invitrogen, Carlsbad, CA) standardized to 0.2 ng/μL and stored at −20°C until used for library preparation. Libraries were prepared with the Nextera XT DNA sample preparation kit (Illumina, San Diego, CA) according to the manufacturer's instruction. Genomes were sequenced using the MiSeq sequencing technology with 500 cycles (two sets of 250 cycles; Illumina) for the pair-end library with a coverage depth of 30 to 90× at the FDA Center for Food Safety and Applied Nutrition (CFSAN) genomics laboratory. All genomes were submitted as assembled reads to the National Center for Biotechnology Information (NCBI) *(1)*.

Statistical analyses. Standard statistical tests in R *(19)* were used in the analyses. Confidence intervals reported are exact Clopper-Pearson binomial confidence intervals. Differences among pairs or sets of data were determined with Fisher's exact text. The Marascuilo procedure was used to simultaneously test for differences in all pairs of proportions when more than two. The nonparametric Kruskal-Wallis rank test was used to determine whether the APC were comparable for *Salmonella*-positive and *Salmonella*-negative samples. For all statistical analyses in this study, $\alpha = 0.05$.

RESULTS AND DISCUSSION

***Salmonella* prevalence in spices offered for sale at retail establishments.** A summary of the *Salmonella* testing results and prevalence estimates for each spice type is provided in Table 1. For each of the 11 spice types examined, estimated prevalence (based on 125 g of spice analyzed) was less than 1%, with all upper 95% confidence intervals less than 2%. Among the spice types, no positive samples were found for cumin (whole, ground, or cracked), sesame seed (whole), or white pepper (ground). These prevalence estimates are not corrected for the sampling design (not weighted for market share) because the detailed information needed was not available.

Table 2 presents the number of samples examined and number of *Salmonella*-positive samples identified for each spice type as a function of retail establishment type. The *Salmonella*-positive rates by establishment type were compared using Fisher's exact test. Significantly different rates ($P \leq 0.05$) were found for only one spice type, paprika (ground). This result suggests that *Salmonella* prevalence in ground paprika sold in independent, small chain, ethnic, or natural foods stores and discount or variety retail establishments might be larger than that in ground paprika sold in major chain and online retail establishments. The data are insufficient to identify which pairs differed using the Marascuilo procedure. This observation may signify differences in the supply chain among the brands available in these retail establishments.

Some spices offered for sale in retail establishments are labeled organic. Use of the term "organic" on a food label is

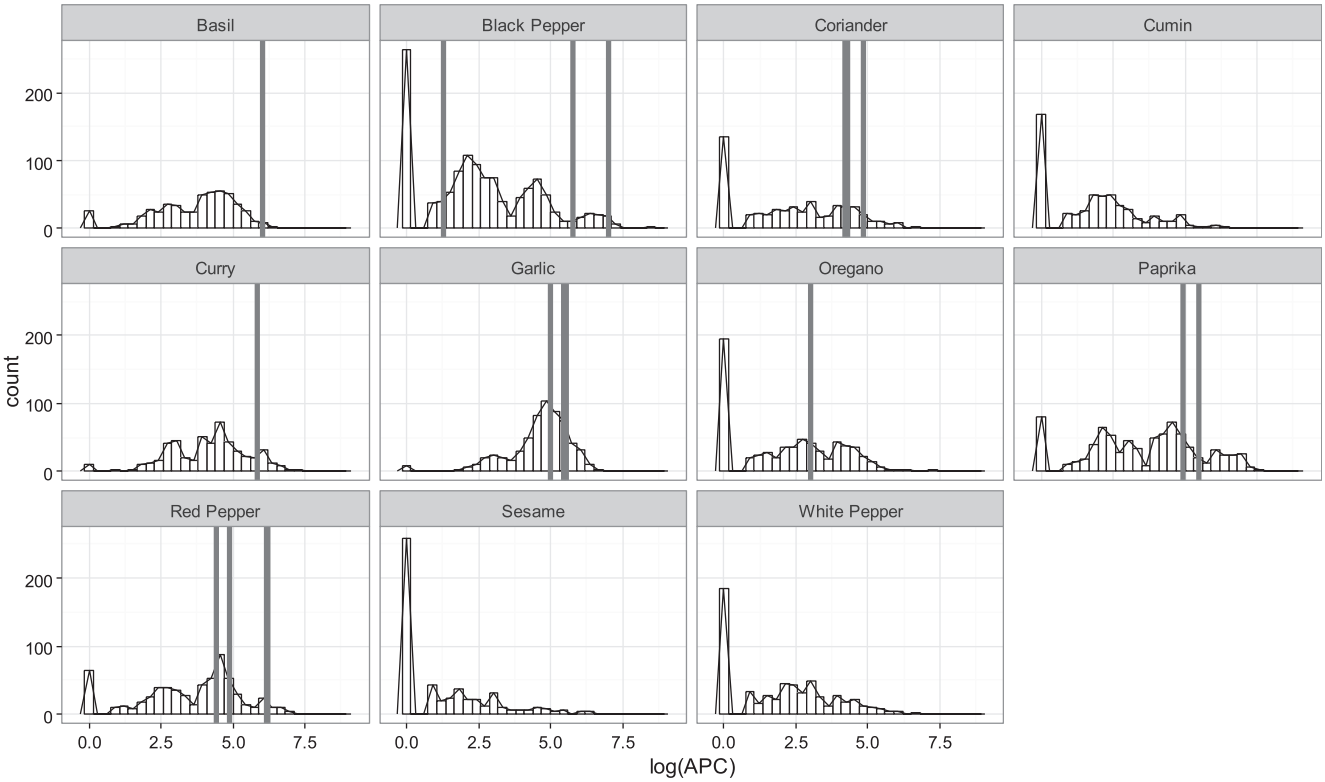

FIGURE 1. *Distribution of log-transformed APC per sample for spices offered for sale at retail establishments. Samples in which no* Salmonella *was detected were estimated to contain <10 CFU/g and were assigned a log APC of 1. Vertical lines indicate* Salmonella*-positive samples.*

overseen by the U.S. Department of Agriculture, National Organic Program. For a spice to be labeled organic, it has to be produced following this program's guidelines. For a multi-ingredient product, for example curry powder, to be labeled organic, at least 95% of the ingredients must be certified as organic *(24)*. Table 3 provides the total number of samples examined and the number of samples positive for *Salmonella* for each spice type. The *Salmonella*-positive rate for spices labeled organic was compared with those labeled conventional. These data indicate that for each spice type for which some positive samples were identified, there was no significant difference in *Salmonella*-positive rates between organic and conventional samples of these spices.

APC for samples collected at the retail establishments also were determined. The distribution of APC values by spice type is presented in Figure 1, and summary statistics are presented in Table 4. Among the samples of coriander (ground or cracked) and red pepper (ground, cracked, crushed, or flakes) offered for sale at retail establishments examined in this study, *Salmonella*-positive samples had significantly higher APC than did *Salmonella*-negative samples on average (Kruskal-Wallis test, Table 4). In previous studies, APC for spices differ widely, from <1 to 9 log CFU/g *(3, 5, 11, 18, 21)*. Data for spices that have not undergone a pathogen reduction treatment have a similar trend; APC typically are 2 to 9 log CFU/g, with more specific ranges depending on the spice type *(3, 18)*. Application of pathogen reduction treatments to spices generally reduces APC, although with high variability *(29)*.

TABLE 4. *APC for all samples of a spices offered for sale at retail establishments and for those positive for* Salmonella

Spice type[a]	APC (log CFU/g)		*P* value[b]
	Mean (median) for negative samples[c]	Positive samples[d]	
Basil	3.65 (4.00)	6.00	NA
Black pepper	2.59 (2.40)	1.30, 5.78, 7.00	NS
Coriander, grd	2.40 (2.41)	4.20, 4.30, 4.85	0.04
Cumin	1.84 (1.78)	NA	NA
Curry powder, grd	4.11 (4.30)	5.85	NA
Dehydrated garlic, grd	4.61 (4.78)	5.00, 5.48, 5.56	NS
Oregano	2.26 (2.32)	3.00	NA
Paprika, grd	3.55 (3.90)	4.90, 5.48	NA
Red pepper, grd	3.49 (4.00)	4.40, 4.88, 6.18, 6.20	0.02
Sesame seed, whole	1.25 (1.00)	NA	NA
White pepper, grd	1.98 (2.00)	NA	NA

[a] grd, spice sample was crushed, cracked, granules, flakes, or powder (i.e., not whole). When no form designation is listed, both whole and ground samples were examined.
[b] Kruskal-Wallis rank test was applied to sets of data for which more than two non-zero APC values were obtained. NA, test was not applicable because too few *Salmonella*-positive APC values were available; NS, not significant.
[c] Estimates of <10 CFU/g were set to 1 (i.e., log = 0).
[d] Each value represents an APC for a *Salmonella*-positive sample. NA, not applicable (no positive samples were found).

TABLE 5. *Estimated* Salmonella *prevalence in samples from shipments of imported spices offered for entry to the United States*

Spice type[a]	Total no. of samples tested	No. of positive samples	Prevalence (%)	Clopper and Pearson's 95% confidence interval (%)	Prevalence comparison[b]
Basil	20	1	5.0	0.13–25	NS
Black pepper	223	15	6.7	3.8–11	0.0001
Coriander, grd	92	17	18	11–28	0.0001
Cumin	130	11	8.5	4.3–15	0.0001
Curry powder, grd	177	7	4.0	1.6–8.0	0.0004
Dehydrated garlic, grd	59	1	1.7	0.043–9.1	NS
Oregano	78	8	10	4.5–19	0.0001
Paprika, grd	85	3	3.5	0.73–10	0.007
Red pepper, grd	337	36	11	7.6–14	0.0001
Sesame seed, whole	155	12	7.7	4.1–13	0.0001
White pepper, grd	50	3	6.0	1.3–17	0.0005

[a] grd, spice sample was crushed, cracked, granules, flakes, or powder (i.e., not whole). When no form designation is listed, both whole and ground samples were examined.
[b] Comparison at U.S. entry versus retail, Fisher's exact test. NS, not significant.

The large numbers of retail samples of some spices in the present study in which no aerobic bacteria were detected (APC $<$ 10 CFU/g) (Fig. 1) may indicate that a significant portion of these spices had undergone a pathogen reduction treatment.

***Salmonella* prevalence samples from shipments of imported spices offered for entry to the United States.** *Salmonella* prevalence estimates for spice samples collected from imported shipments offered for entry to the United States for FY2012 to FY2015 were 1.7 to 18% among the 11 spice types examined (based on two 375-g samples analyzed) (Table 5). The *Salmonella* prevalence estimates for 9 of the 11 spice types offered for sale in retail establishments were significantly lower ($P < 0.05$) than the values estimated for the same types of spices from imported shipments (Table 5).

The majority of spices in the United States that are used in food manufacturing and made available for retail sale to consumers are imported, except dehydrated onion and garlic, capsicums (primarily red chili peppers), and mustard seed *(27)*. In 1989, the FDA examined samples of whole black pepper, whole coriander seed, and whole white pepper (two 375-g composite samples of each) from imported shipments of spices offered for entry into the United States *(21)*. Although the number of shipments examined was small (16 for black pepper and 5 each for coriander seed and white pepper), *Salmonella* was found in samples from two shipments of black pepper, for the following *Salmonella* shipment prevalence estimates (95% confidence intervals): 12.5% (1.6 to 38%) for black pepper, 0.00% (0 to 52%) for coriander, and 0.00% (0 to 52%) for white pepper. Since that time, the FDA has reported estimates of *Salmonella* prevalence in a wider diversity of imported spices offered for entry into the United States from FY2007 to FY2009 *(35)*.

Salmonella prevalence estimates for spice samples collected from imported shipments offered for entry to the United States for FY2012 to FY2015 are not significantly different from the estimates determined for shipments for FY2007 to FY2009 *(35),* taking into account differences in the reporting structure, i.e., data for spice types reported separately in the present study were grouped in the previous study (basil with oregano, paprika with hot capsicums), the estimate for shipments of white pepper included whole and ground in the previous study, and an estimate for dehydrated garlic was not provided in the previous study. The *Salmonella* prevalence estimates for shipments of imported black pepper (both ground and whole), ground coriander seed, and ground white pepper reported in Table 5 are also not significantly different from the values reported for shipments of the whole forms of these spices examined in 1989 study *(21),* but the very small numbers of shipments examined during the 1989 study (and consequent large prevalence estimate confidence intervals) reduces the power to discern differences.

Of particular interest in this study was whether the *Salmonella* prevalence estimates for each spice type at the point of entry to the United States were different from those for the same spice type at the point of retail purchase by U.S. consumers, particularly for the spices where the U.S. supply is overwhelmingly imported, as is the case for at least seven of the spices examined in this study: basil, black pepper, coriander, cumin, curry powder, oregano, and white pepper *(25)*. For red pepper, paprika, and sesame seed, imports are also the major source of the U.S. supply, but domestic production is significant: ~35% in 2014 for total capsicum supply and up to 23% based on 2010 data reported by the American Sesame Growers Association *(2)* and 2014 U.S. import data *(25, 26)*.

Salmonella prevalence in all spice types offered for sale in retail establishments and examined in this study (Table 1), except dehydrated garlic and basil, was significantly lower than the estimate for imported shipments (Table 5). The prevalence estimate for black pepper offered for retail sale was also significantly lower than the prevalence estimated for imported black pepper offered for entry in 1989, even though the precision of the shipment prevalence estimate was low *(21)*. The small number of shipments of imported basil examined during the FY2012 to FY2015 study period

TABLE 6. *Serotypes and NCBI accession numbers of* Salmonella enterica *isolates from spices offered for sale at retail establishments*

Sample code	NCBI accession no.[a]	Sampling date	Spice type	Store type	*S. enterica* serotype
1101758-11	SAMN03218226	30 Mar. 2014	Basil	Major chain	Infantis
1101756-09	NA	20 Mar. 2014	Black pepper	Major chain	Bovismorbificans
1101993-03	SAMN02800601	8 May 2014	Black pepper	Major chain	Duisburg
1102601-04	SAMN03083790	21 Aug. 2014	Black pepper	Major chain	Subsp. *arizonae* IIIa 41:z4:–
1105097-03	SAMN03761734	18 May 2015	Coriander	Online	Subsp. *diarizonae* IIIb 61:
1106131-02	SAMN04102310	6 Aug. 2015	Coriander	Major chain	Telhashomer
1106761-03	SAMN04156854	24 Sep. 2015	Coriander, organic	Small chain	Meleagridis
1105097-35	SAMN03742073	18 May 2015	Curry powder	Online	Typhimurium
1105680-19	SAMN03965301	6 July 2015	Garlic	Major chain	Tennessee
1103996-04	SAMN03354386	5 Feb. 2015	Garlic	Discount	Worthington
1103859-19	SAMN03354384	23 Jan. 2015	Garlic, organic	Discount	Potsdam
1102387-12	NA	17 July 2014	Oregano	Major chain	Schleissheim
1102312-07	SAMN02949418	3 July 2014	Paprika	Discount	London
1102479-05	NA	4 Aug. 2014	Paprika, organic	Small chain	Muenchen
1101945-05	SAMN02800600	30 Apr. 2014	Red pepper	Small chain	Bareilly
1101879-12	SAMN02800587	17 Apr. 2014	Red pepper	Small chain	Give
1101785-26	SAMN03218227	28 Mar. 2014	Red pepper	Major chain	Oranienburg
1101785-27	SAMN03218228	28 Mar. 2014	Red pepper	Major chain	Sandiego

[a] Isolate identification number assigned by the National Center for Biotechnology Information (NCBI) in their database. NA, accession number and sequencing data are not available.

severely limited the ability to discern differences in prevalence estimates between samples collected at entry and at retail. Among the spice types for which significant differences in prevalence estimates were found, examination of a smaller sample size (mass) for samples from retail than from point of entry likely contributed to the apparent decrease in prevalence *(11, 34, 38)* but cannot fully explain the observations. Under the assumption of a Poisson distribution of the *Salmonella* in the samples and a perfect sensitivity of the microbiological method, a sample mass of 125 g would allow the detection of samples contaminated at 2.4 cells per 100 g or more with a probability of >95%. Sample mass can have an impact on the probability of detecting a positive sample, especially when the contamination level is low or the contaminant is distributed heterogeneously *(8, 13, 14)*. Under those conditions, doubling of the sample mass can double the apparent prevalence of contaminated products. Our observed prevalence could be an underestimate compared with results of other studies with larger sample masses. Specifically, the estimated prevalence in packages offered for sale at retail establishments could be an underestimate when compared with the observed prevalence in shipments of spice offered for entry to the United States. For practical reasons linked to the availability of these spices in stores, it was not possible to collect a larger mass for each sample in this study.

These results of this study are consistent with the assumption that most (bulk) shipments of spice undergo a pathogen reduction treatment following entry to the United States and prior to being released for retail sale, as recommended in industry guidance such as the "Clean, Safe Spices Guidance Document" by the American Spice Trade Association *(4)*. No *Salmonella*-positive samples were found for cumin, sesame seed, or white pepper, which would be expected if all shipments had undergone a highly efficient pathogen reduction treatment after entry and before being offered for sale at retail establishments. The change in *Salmonella* prevalence between point of U.S. entry and retail sale for the other spice types examined was smaller and ranged from a factor of 0.33 (dehydrated garlic; not significant) to 0.015 (oregano). Assuming the spice sampled at the point of entry to the U.S. and retail sale similarly represented the available supply, these results may indicate that pathogen reduction treatments for some shipments were not effective or not applied *(11, 34, 38)* or that posttreatment contamination had occurred. For red pepper and dehydrated garlic, where the supply for sale is a combination of imported and domestically produced, differences in *Salmonella* prevalence pretreatment may also have affected the results. The decreases observed (except for dehydrated garlic) are consistent with more than 90% of contaminated shipments offered for entry to the United States having been treated with an efficient pathogen reduction method prior to being offered for sale in retail establishments. However, these data cannot be used to provide a reliable estimate of the mean log reduction in these spices because of the uncertainties involved, especially the lack of data on pathogen levels in these contaminated spices at the point of import and at retail. Once purchased from retail, spices may be added to foods as a ready-to-eat ingredient or may be cooked.

Serotypes and PFGE profiles of *Salmonella* isolates from spices. Serotypes of *Salmonella* isolates from spices offered for sale in retail establishments or for entry to the United States as imports were very diverse (Tables 6 and 7). Eighteen different *Salmonella* serotypes were identified from the 18 *Salmonella*-positive samples (one serotype per sample) from packages of spices offered for retail sale. Of these 18 serotypes, 16 were *Salmonella enterica* subsp.

TABLE 7. *Serotypes and NCBI accession numbers of* Salmonella *isolates from samples of imported spices offered for entry to the United States, FY2012 to FY2015*

Sample code	NCBI accession no.[a]	Sampling date	Source	FDA product code description	*S. enterica* serotype[b]
759929	SAMN02709285	11 June 2012	Egypt	Basil (sweet basil), whole (spice)	Anatum
759929	SAMN02345246	11 June 2012	Egypt	Basil (sweet basil), whole (spice)	Anatum
868883	SAMN03018552	25 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	6,7:r:−
868883	SAMN03018553	25 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	6,7:r:−
834757	SAMN02678888	4 Nov. 2013	Peru	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Agona
745560	SAMN02345152	14 Mar. 2012	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Amsterdam
863341	SAMN02919100	21 May 2014	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Anatum
863351	SAMN02919101	21 May 2014	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Anatum
793940	SAMN02350499	30 Jan. 2013	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Bareilly
793940	SAMN02678833	30 Jan. 2013	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Bareilly
874653	SAMN03018570	6 Aug. 2014	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Bareilly
804122	SAMN02678840	28 Mar. 2013	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Cerro
791553	SAMN02678641	16 Jan. 2013	Lebanon	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Chester
805089	SAMN02698306	3 Apr. 2013	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Dortmund
762746	SAMN02345268	2 July 2012	Thailand	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Eastbourne
762746	SAMN02847448	2 July 2012	Thailand	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Eastbourne
877470	SAMN03083836	25 Aug. 2014	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Eastbourne
877470	SAMN03083837	25 Aug. 2014	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Eastbourne
852169	SAMN02800594	13 Mar. 2014	Malaysia	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Give
769391	SAMN02345329	14 Aug. 2012	Vietnam	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
769391	SAMN02345327	14 Aug. 2012	Vietnam	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
769391	SAMN02345328	14 Aug. 2012	Vietnam	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
865189	SAMN02934600	3 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
913751	SAMN03770518	29 May 2015	Thailand	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
913751	SAMN03770519	29 May 2015	Thailand	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Hvittingfoss
736429	SAMN02345104	24 Jan. 2012	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Infantis
865131	SAMN02934587	30 May 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Kentucky
865131	SAMN02874022	30 May 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Kentucky
798460	SAMN02698295	1 Mar. 2013	Bangladesh	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Mbandaka
888512	SAMN03253027	12 Nov. 2014	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Muenchen
796675	SAMN02698294	19 Feb. 2013	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	NA
868882	NA	25 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	NA
909872	NA	4 May 2015	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	NA
748595	SAMN02345175	3 Apr. 2012	Thailand	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Newport
791553	SAMN02678640	16 Jan. 2013	Lebanon	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Newport
870836	SAMN03083825	10 July 2014	Uganda	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Newport
865188	SAMN02900559	3 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Oranienburg
763729	SAMN02345275	9 July 2012	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Orion
859339	SAMN02919079	25 Apr. 2014	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Panama
738146	SAMN02345117	2 Feb. 2012	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Pomona
904406	SAMN03483118	24 Mar. 2015	Nigeria	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Pomona

TABLE 7. *Continued*

Sample code	NCBI accession no.[a]	Sampling date	Source	FDA product code description	*S. enterica* serotype[b]
904406	SAMN03483119	24 Mar. 2015	Nigeria	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Pomona
852686	SAMN02847761	17 Mar. 2014	Peru	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Saintpaul
852686	SAMN02847762	17 Mar. 2014	Peru	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Saintpaul
859617	SAMN02919080	29 Apr. 2014	India	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Saintpaul
888512	SAMN03253028	12 Nov. 2014	Mexico	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Senftenberg
905293	SAMN03573622	1 Apr. 2015	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Sundsvall
865189	SAMN02934598	3 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Telhashomer
865189	SAMN02934599	3 June 2014	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Telhashomer
745560	SAMN02345153	14 Mar. 2012	Pakistan	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Tennessee
819328	SAMN02678863	3 July 2013	Bangladesh	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Virchow
819328	SAMN02678864	3 July 2013	Bangladesh	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Weltevreden
913473	SAMN03780358	27 May 2015	Bangladesh	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Weltevreden
913473	SAMN03780358	27 May 2015	Bangladesh	Capsicums (cayenne chili, hot peppers), ground, cracked (spice)	Weltevreden
768959	SAMN02345330	14 Aug. 2012	Ivory Coast	Pepper, hot, dried, or paste[c]	Aschersleben
768959	SAMN02847515	14 Aug. 2012	Ivory Coast	Pepper, hot, dried, or paste[c]	Aschersleben
812200	SAMN02678815	17 May 2013	India	Coriander, ground, cracked (spice)	47:z4,z23:−
801333	SAMN02678652	15 Mar. 2013	India	Coriander, ground, cracked (spice)	Amsterdam
765279	SAMN02345299	19 July 2012	India	Coriander, ground, cracked (spice)	Bere
770027	SAMN02345333	16 Aug. 2012	India	Coriander, ground, cracked (spice)	Brazzaville
770027	SAMN02847517	16 Aug. 2012	India	Coriander, ground, cracked (spice)	Brazzaville
808487	SAMN02698312	26 Apr. 2013	India	Coriander, ground, cracked (spice)	Cubana
808487	SAMN02847637	26 Apr. 2013	India	Coriander, ground, cracked (spice)	Cubana
790594	SAMN02698283	14 Jan. 2013	India	Coriander, ground, cracked (spice)	Kentucky
801333	SAMN02678653	15 Mar. 2013	India	Coriander, ground, cracked (spice)	Kentucky
736434	SAMN02847397	24 Jan. 2012	India	Coriander, ground, cracked (spice)	Matopeni
736434	SAMN02345105	24 Jan. 2012	India	Coriander, ground, cracked (spice)	Matopeni
853722	SAMN02847766	25 Mar. 2014	India	Coriander, ground, cracked (spice)	Meleagridis
853722	SAMN02847767	25 Mar. 2014	India	Coriander, ground, cracked (spice)	Meleagridis
790332	SAMN02678633	9 Jan. 2013	India	Coriander, ground, cracked (spice)	NA
798462	NA	1 Mar. 2013	Bangladesh	Coriander, ground, cracked (spice)	NA
873148	SAMN03018559	25 July 2014	Pakistan	Coriander, ground, cracked (spice)	NA
873148	SAMN03018560	25 July 2014	Pakistan	Coriander, ground, cracked (spice)	NA
915262	NA	10 June 2015	India	Coriander, ground, cracked (spice)	NA
915262	SAMN03840675	10 June 2015	India	Coriander, ground, cracked (spice)	NA
829491	SAMN02678874	6 Sep. 2013	India	Coriander, ground, cracked (spice)	Reading
829491	SAMN02847676	6 Sep. 2013	India	Coriander, ground, cracked (spice)	Reading
806054	SAMN02678654	2 Apr. 2013	India	Coriander, ground, cracked (spice)	Saintpaul
881877	SAMN03176916	24 Sep. 2014	India	Coriander, ground, cracked (spice)	Stanley
865190	SAMN02934601	3 June 2014	Pakistan	Coriander, ground, cracked (spice)	Weltevreden
865190	SAMN02934602	3 June 2014	Pakistan	Coriander, ground, cracked (spice)	Weltevreden
741814	SAMN02345139	23 Feb. 2012	India	Coriander, ground, cracked (spice)	Westminster

TABLE 7. *Continued*

Sample code	NCBI accession no.[a]	Sampling date	Source	FDA product code description	*S. enterica* serotype[b]
807606	SAMN02698307	18 Apr. 2013	Pakistan	Cumin, ground, cracked (spice)	6,7:r:−
807606	SAMN02847632	18 Apr. 2013	Pakistan	Cumin, ground, cracked (spice)	6,7:r:−
748929	SAMN02847425	3 Apr. 2012	United Kingdom	Cumin, ground, cracked (spice)	Agona
748153	SAMN02345169	29 Mar. 2012	Lebanon	Cumin, ground, cracked (spice)	Caracas
748153	SAMN02345170	29 Mar. 2012	Lebanon	Cumin, ground, cracked (spice)	Caracas
812779	SAMN02678849	17 May 2013	Pakistan	Cumin, ground, cracked (spice)	Enteritidis
812779	SAMN02678850	17 May 2013	Pakistan	Cumin, ground, cracked (spice)	Fischerstrasse
852227	SAMN02847757	12 Mar. 2014	India	Cumin, ground, cracked (spice)	Hvittingfoss
849151	SAMN02847744	21 Feb. 2014	Israel	Cumin, ground, cracked (spice)	Infantis
748929	SAMN02345174	3 Apr. 2012	United Kingdom	Cumin, ground, cracked (spice)	Kentucky
849151	SAMN02847745	21 Feb. 2014	Israel	Cumin, ground, cracked (spice)	Kottbus
852227	SAMN02847758	12 Mar. 2014	India	Cumin, ground, cracked (spice)	Loubomo
834447	SAMN02678886	4 Nov. 2013	Turkey	Cumin, ground, cracked (spice)	Mbandaka
841631	SAMN02698181	19 Dec. 2013	Jordan	Cumin, ground, cracked (spice)	Montevideo
841631	SAMN02847695	19 Dec. 2013	Jordan	Cumin, ground, cracked (spice)	Montevideo
798463	NA	1 Mar. 2013	Bangladesh	Cumin, ground, cracked (spice)	NA
748929	SAMN02345176	3 Apr. 2012	United Kingdom	Cumin, ground, cracked (spice)	Saintpaul
748929	SAMN02345177	3 Apr. 2012	United Kingdom	Cumin, ground, cracked (spice)	Senftenberg
857905	SAMN02847786	15 Apr. 2014	India	Cumin, ground, cracked (spice)	Senftenberg
857905	SAMN02847787	15 Apr. 2014	India	Cumin, ground, cracked (spice)	Senftenberg
808685	NA	29 Apr. 2013	Syrian Arab Republic	Cumin, whole (spice)	NA
735676	SAMN02345099	20 Jan. 2012	India	Curry powder, ground, cracked, without salt	Agoueve
870697	SAMN03018556	9 July 2014	Taiwan	Curry powder, ground, cracked, without salt	Mbandaka
870697	SAMN03018555	9 July 2014	Taiwan	Curry powder, ground, cracked, without salt	Paratyphi B
870697	SAMN03018557	9 July 2014	Taiwan	Curry powder, ground, cracked, without salt	Paratyphi B
830584	SAMN02844919	17 Sep. 2013	India	Curry powder, ground, cracked, without salt	Virchow
812218	SAMN02678816	17 May 2013	India	Curry powder, without salt	Give
779543	SAMN02345509	24 Oct. 2012	India	Curry powder, without salt	Mbandaka
906151	SAMN03577791	7 Apr. 2015	India	Mixed spices and seasoning with salt, NEC[d]	Fresno
745901	SAMN02483553	14 Mar. 2012	India	Spices, ground, cracked, etc., NEC[d]	Larochelle
857370	SAMN02847782	14 Apr. 2014	India	Garlic, ground, cracked (spice)	Agonia
857370	SAMN02847783	14 Apr. 2014	India	Garlic, ground, cracked (spice)	Agonia
851691	SAMN02800590	11 Mar. 2014	Greece	Marjoram, ground, cracked (spice)[e]	Abony
848884	SAMN02847737	21 Feb. 2014	Mexico	Marjoram, ground, cracked (spice)[e]	NA
848884	SAMN02847738	21 Feb. 2014	Mexico	Marjoram, ground, cracked (spice)[e]	NA
763669	NA	9 July 2012	Greece	Marjoram, sweet marjoram, oregano, ground, cracked (spice)[e]	Bousso
818812	SAMN02698333	28 June 2013	Greece	Marjoram, sweet marjoram, oregano, ground, cracked (spice)[e]	Ngozi
800468	SAMN02678439	12 Mar. 2013	Mexico	Marjoram, sweet marjoram, oregano, whole (spice)[e]	Havana
802204	SAMN02678440	19 Mar. 2013	Mexico	Marjoram, sweet marjoram, oregano, whole (spice)[e]	Newport
836059	SAMN02678461	13 Nov. 2013	Mexico	Marjoram, whole (spice)[e]	Sandiego
921262	SAMN03983450	31 July 2015	Mexico	Oregano, whole (spice)	Anatum

TABLE 7. *Continued*

Sample code	NCBI accession no.[a]	Sampling date	Source	FDA product code description	*S. enterica* serotype[b]
760736	SAMN02844908	18 June 2012	Canada	Paprika, ground, cracked (spice)	Anatum
760736	SAMN02709286	18 June 2012	Canada	Paprika, ground, cracked (spice)	Anatum
834749	SAMN02678887	4 Nov. 2013	Peru	Paprika, ground, cracked (spice)	Carrau
721910	SAMN02847367	25 Oct. 2011	Spain	Paprika, ground, cracked (spice)	Mikawasima
721910	SAMN02345022	25 Oct. 2011	Spain	Paprika, ground, cracked (spice)	Mikawasima
770705	SAMN02345340	24 Aug. 2012	Indonesia	Pepper, black, ground, cracked (spice)	Ball
750383	SAMN02345188	13 Apr. 2012	Indonesia	Pepper, black, ground, cracked (spice)	Kentucky
841737	SAMN02698182	19 Dec. 2013	Ghana	Pepper, black, ground, cracked (spice)	Kingston
769168	SAMN02345332	15 Aug. 2012	Vietnam	Pepper, black, ground, cracked (spice)	Rissen
776593	SAMN02345469	3 Oct. 2012	Sri Lanka	Pepper, black, ground, cracked (spice)	subsp. *houtenae*
776593	SAMN02847536	3 Oct. 2012	Sri Lanka	Pepper, black, ground, cracked (spice)	subsp. *houtenae*
759487	SAMN02345245	8 June 2012	People's Republic of China	Pepper, black, ground, cracked (spice)	Thompson
759487	SAMN02847441	8 June 2012	People's Republic of China	Pepper, black, ground, cracked (spice)	Thompson
733973	SAMN02345092	10 Jan. 2012	Vietnam	Pepper, black, ground, cracked (spice)	Weltevreden
791567	SAMN02678636	16 Jan. 2013	Lebanon	Pepper, black, ground, cracked (spice)	Weltevreden
913912	SAMN03863767	2 June 2015	Belgium	Pepper, black, whole (spice)	Bredeney
913912	SAMN03863768	2 June 2015	Belgium	Pepper, black, whole (spice)	Typhimurium
805156	SAMN02698379	5 Apr. 2013	Vietnam	Pepper, black, whole (spice)	NA
807610	SAMN02698308	19 Apr. 2013	Vietnam	Pepper, black, whole (spice)	NA
781886	SAMN02345534	6 Nov. 2012	Philippines	Pepper, black, whole (spice)	Newport
805156	SAMN02698378	5 Apr. 2013	Vietnam	Pepper, black, whole (spice)	Senftenburg
830366	SAMN02844918	16 Sep. 2013	Hong Kong Special Administrative Region	Pepper, black, whole (spice)	Stanley
854201	SAMN02847769	25 Mar. 2014	Pakistan	Pepper, black, whole (spice)	Ursenback
769919	SAMN02345326	14 Aug. 2012	Philippines	Pepper, black, whole (spice)	Weltevreden
788665	NA	26 Dec. 2012	Taiwan	Pepper, white, ground, cracked (spice)	Enteritidis
908414	SAMN03732551	22 Apr. 2015	People's Republic of China	Pepper, white, ground, cracked (spice)	Infantis
870689	SAMN03018554	9 July 2014	Taiwan	Pepper, white, ground, cracked (spice)	Mbandaka
789923	SAMN02698282	9 Jan. 2013	Thailand	Sesame seed (edible)	47:z4,z23
789923	SAMN02847597	9 Jan. 2013	Thailand	Sesame seed (edible)	47:z4,z23
726616	SAMN02847387	22 Nov. 2011	Thailand	Sesame seed (edible)	Amsterdam
726616	SAMN02345058	22 Nov. 2011	Thailand	Sesame seed (edible)	Amsterdam
878867	NA	3 Sep. 2014	India	Sesame seed (edible)	Amsterdam
730998	SAMN02345079	20 Dec. 2011	India	Sesame seed (edible)	Anatum
746288	SAMN02350498	19 Mar. 2012	India	Sesame seed (edible)	Bareilly
746109	SAMN02345158	19 Mar. 2012	India	Sesame seed (edible)	Charity
851893	SAMN02847754	11 Mar. 2014	India	Sesame seed (edible)	Charity
851893	SAMN02847755	11 Mar. 2014	India	Sesame seed (edible)	Charity
739096	SAMN02847405	7 Feb. 2012	India	Sesame seed (edible)	Cubana
739096	SAMN02345124	7 Feb. 2012	India	Sesame seed (edible)	Cubana
725743	SAMN02847386	16 Nov. 2011	India	Sesame seed (edible)	Gaminara
725743	SAMN02345057	16 Nov. 2011	India	Sesame seed (edible)	Gaminara

TABLE 7. *Continued*

Sample code	NCBI accession no.[a]	Sampling date	Source	FDA product code description	*S. enterica* serotype[b]
905849	SAMN05256161	6 Apr. 2015	People's Republic of China	Sesame seed (edible)	Kentucky
740445	SAMN02345132	15 Feb. 2012	India	Sesame seed (edible)	Tennessee
740445	SAMN02847408	15 Feb. 2012	India	Sesame seed (edible)	Tennessee
740445	SAMN02847409	15 Feb. 2012	India	Sesame seed (edible)	Tennessee
747724	SAMN02345171	29 Mar. 2012	India	Sesame, whole (spice)	Hvittingfoss
747724	SAMN02345172	29 Mar. 2012	India	Sesame, whole (spice)	subsp. *diarizonae*

[a] Isolate identification number assigned by the National Center for Biotechnology Information (NCBI) in their database. NA, accession number and sequencing data not available.
[b] NA, serotype data not available.
[c] Product description identified product as chili powder.
[d] Product description identified product as curry powder (mixture of spices). NEC, not elsewhere classified.
[e] Product description identified product as oregano.

enterica, 1 was *S. enterica* subsp. *diarizonae,* and 1 was *S. enterica* subsp. *arizonae*. From the 114 *Salmonella*-positive shipments of imported spice offered for entry to the United States identified during the FY2012 to FY2015 study period, 170 *Salmonella* isolates were obtained, and serotypes were identified for 155 of these isolates. Of the 68 unique serotypes identified among these isolates, 66 were *S. enterica* subsp. *enterica,* 1 was *S. enterica* subsp. *diarizonae,* and 1 was *S. enterica* subsp. *houtenae*. Multiple serotypes were recovered from a small number of the samples from shipments of imported spice offered for entry to the United States. In other studies, including the two previous FDA reports on *Salmonella* in samples from shipments of imported spice offered for entry to the United States, a wide diversity of serotypes was found in samples of spices, and multiple serotypes were recovered from a single spice sample *(20, 21, 29, 35, 41)*. Such diversity is not unusual for FDA-regulated food products in general *(39, 40)*.

Salmonella serotypes Infantis, Muenchen, and Typhimurium, which were found in some samples offered for sale in retail establishments and some samples from shipments of imported spice, are on the CDC top 10 *Salmonella* serotypes causing culture-confirmed infection in 2015 *(6)*. *Salmonella* Enteritidis, *Salmonella* Newport, and *Salmonella* Saintpaul, which are also on the CDC top 10 list, were also found in some samples from shipments of imported spice offered for entry to the United States.

PFGE profiles (Figs. 2 and 3) of retail spices also revealed the presence of very diverse *Salmonella* populations among the contaminated spice samples.

Genomic sequences of *Salmonella* isolates from spices. Sequencing data for most isolates from this project are available from the NCBI database, and accession numbers for these isolates are listed in Tables 6 and 7. The closest relative for each isolate is shown as a single nucleotide polymorphism–based subtree in the NCBI Pathogen Detection database *(17)*.

This results of this study begin to fill some of the data gaps identified in the 2013 FDA risk profile on pathogens and filth in spices *(29)*. Estimates of *Salmonella* prevalence in 11 commonly used spice types offered for sale to consumers in retail establishments in the United States were compared with estimates for the same spice types in shipments of imported spice offered for entry to the United States. However, specific information about *Salmonella* prevalence in postentry spices used in food manufacturing was not available.

Salmonella was not found in any of the more than 500 samples of cumin seed, sesame seed, or white pepper from packages sold in retail establishments across the United States. *Salmonella* was found among samples of the other eight spice types examined: basil leaf, black pepper, coriander, curry powder, dehydrated garlic, oregano, paprika, and red pepper. Among these spice types, *Salmonella* prevalence estimates were 0.15 to 0.64%. The *Salmonella* prevalence estimates for 9 of the 11 spice types offered for sale in retail establishments were significantly lower than the

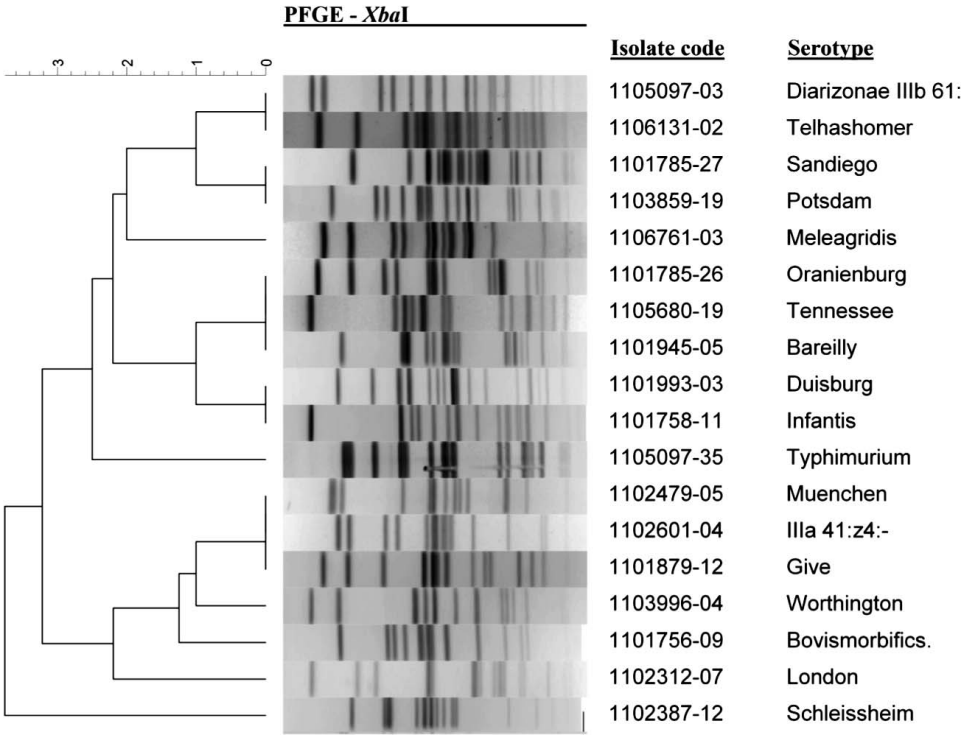

FIGURE 2. *PFGE profiles from restriction enzyme* Xba*I of* Salmonella *isolates from spices offered for sale at retail establishments.*

estimates at the point of entry (Table 5). For the nine spice types primarily sourced outside the United States, these data are consistent with the assumption that a large fraction of imported spice shipments are treated for pathogens after they enter the United States. No significant difference was found between *Salmonella* prevalence estimates for retail and entry (imported) samples for basil and dehydrated garlic; dehydrated garlic is sourced both domestically and abroad. The presence of *Salmonella* in some samples of basil, black pepper, coriander, curry powder, dehydrated garlic, oregano, paprika, and red pepper offered for sale at retail establishments to U.S. consumers for use in home food preparation

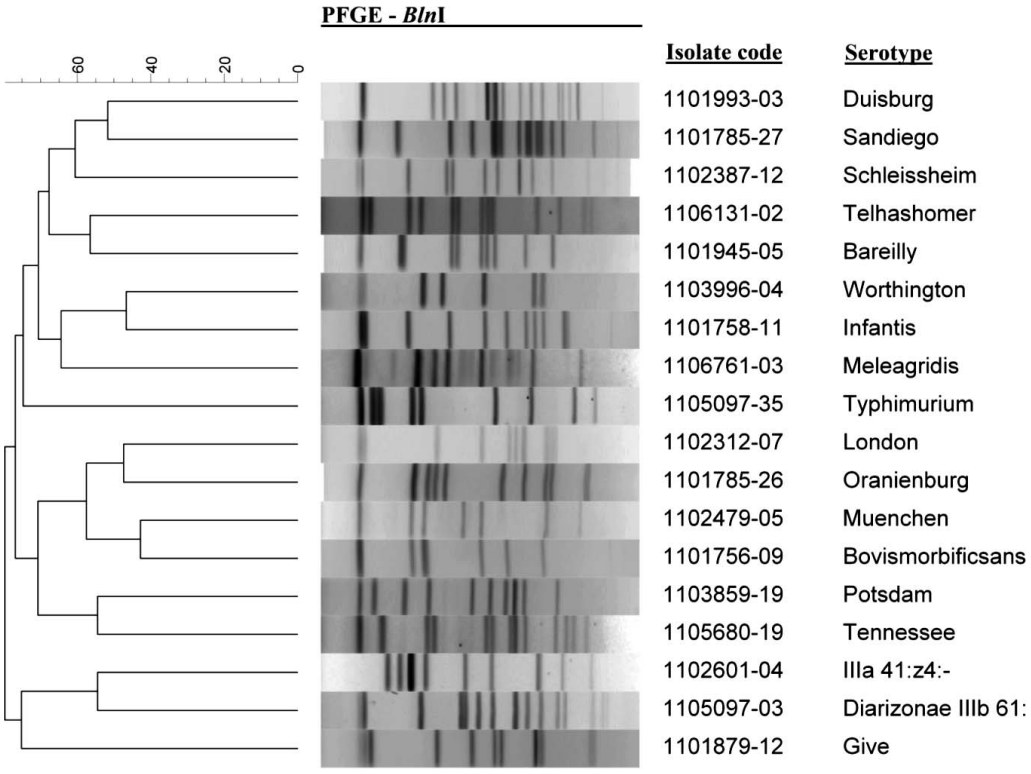

FIGURE 3. *PFGE profiles from restriction enzyme* Bln*I of* Salmonella *isolates from spices offered for sale at retail establishments.*

indicates that for these spice samples and, presumably, the lots from which they arose hazard controls were insufficient to eliminate *Salmonella*.

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