

Incidence of *Salmonella* on Fresh Fruits and Vegetables Affected by Fungal Rots or Physical Injury

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ABSTRACT

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Enriched wash from healthy and decayed portions of 341 fruits and vegetables collected in the marketplace and affected by fungal rots were tested for suspected *Salmonella* appearing as black, hydrogen sulfide-positive colonies on Salmonella-Shigella agar incubated at 37°C. Suspected *Salmonella* occurred in 20.2% of healthy and in 26.4% of decayed portions, two-thirds of which were caused by *Alternaria* and *Botrytis*. In a similar analysis of 121 samples with mechanical injuries, in which two-thirds were gouges, cuts, and bruises, there were no significant differences in *Salmonella* incidence between injured and uninjured portions. Of 332 suspected *Salmonella* randomly isolated from healthy and decayed or injured portions, 17 (5.1%) were confirmed as *Salmonella* by physiological and serological testing. When tomato, potato, and onion tissues were inoculated with *Salmonella typhimurium*, populations of that bacterium increased by one to two logs over a 48-h incubation at room temperature. Coinoculation of tissues with *S. typhimurium* and *Botrytis* or *Rhizopus*, but not *Alternaria* or *Geotrichum*, caused a statistically significant increase in populations of *Salmonella* compared with the controls.

Clinical cases of salmonellosis caused by contaminated fruits and vegetables have been recently documented or reported with increasing frequency (14,21,25). Most of these cases involved, or were suspected of involving, ingestion of improperly stored or handled prepared foods that initially carried the bacteria as surface contamination (9-11,17). The level of *Salmonella* occurring epiphytically on fruits and vegetables retailed in the marketplace is a concern to epidemiologists and to the food industry (7,26). When foods are improperly handled, the level of this background contamination is suspected of being a contributing factor in development of public health problems.

Salmonella bacteria have been isolated from fresh fruits and vegetables in marketplaces in the United States and in other countries. The reported levels of incidence have been generally consistent despite widespread differences in locations, detection protocols, and types of commodities

sampled. Rude et al. (20) reported 8% incidence of confirmed *Salmonella* in vegetables sampled in the midwestern United States. Garcia Villanova-Ruiz et al. (8) reported 7.5% incidence in Spain, and Wells and Butterfield (24) reported 9 to 10% incidence in New Jersey. Ercolani (6) found *Salmonella* on 68% of lettuce and 72% of fennel sampled in Italy; these, however, were unprocessed field samples with some wrapper leaves.

Salmonella that are epiphytic on fruits and vegetables can multiply if certain extrinsic factors are present, such as improper refrigeration during storage and preparation, poor product quality, or the presence of bacterial soft rot (24). The interaction of *Salmonella* with soft-rotting bacteria affecting a commodity raises the possibility of similar interactions with postharvest fungal decays or other disorders.

Fungal rots are the leading cause of postharvest losses of fruits and many vegetables—among others, melons, tomatoes, strawberries, and sweet potatoes (2,3,4,5)—and have been associated with mycotoxin contamination (13). Their possible interaction with *Salmonella* on fruits and vegetables has not been previously investigated. Mechanical injury in the form of bruises, cuts, and punctures and physiological disorders are other important causes of postharvest losses. Injured tissues are open avenues for infection by bacterial soft rot and other pectolytic microorganisms, as well for colonization by human pathogens (15,17,18,23).

The purpose of this study was to determine if the presence of fungal decay or

physical injuries on fresh commodities in the marketplace influenced the incidence of contamination by *Salmonella*.

MATERIALS AND METHODS

Collection of samples. A total of 341 samples of 27 different fruits and vegetables, listed in Table 1, and affected by different fungal rots, listed in Table 2, were collected in local supermarkets in Somerset and Middlesex counties, New Jersey, approximately twice monthly from 1995 to 1997. Specimens, as they were available, were obtained from displays and each placed in a clean plastic bag. Only those specimens were collected that had lesions caused by a fungus infection in early stages of development and small enough to be trimmed without loss of more than about 10% of the commodity. Samples with lesions with glossy exudation or other symptoms indicating onset of secondary bacterial soft rot were not collected. Lesions were examined microscopically in

Table 1. Incidence of suspected *Salmonella* (black colonies on Salmonella-Shigella agar) on healthy and diseased portions of fruits and vegetables affected by fungal rots

Commodity	Samples tested	Samples positive for black colonies	
		Healthy portion	Decayed portion
Beans, snap	6	0	1
Cantaloupe	9	2	3
Carrot	17	4	4
Cucumber	30	20	22
Eggplant	6	2	1
Lettuce, iceberg	5	0	0
Onion, dry	11	0	0
Parsnip	3	0	0
Pea (pod)	7	0	0
Pepper, bell	57	12	16
Pepper, cubanelle	7	0	0
Pepper, jalapeño	4	0	1
Pepper, longhot	21	2	5
Radish	3	0	0
Squash, summer	2	1	1
Squash, winter	17	4	5
Strawberry	8	0	0
Sweet potato	9	5	5
Tomato	91	15	19
Tomato, plum	15	1	5
Miscellaneous ^a	13	1	2
Totals	341	69	90
Percentage		20.2%	26.4% ^b

^a Basil, cabbage, cauliflower, escarole, Honeydew melon, green onion, and turnip.

^b Percentages are statistically different at the 95% level of probability.

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the laboratory to identify, when possible, the specific fungal disease. In addition, 121 samples of 22 different fruits and vegetables with different types of mechanical (physical) injuries or physiological disorders were collected. Controls were considered to be the healthy portions of the sampled commodities since this was a comparative study of incidence on healthy versus diseased or injured portions. Comparison was also made with controls (i.e., healthy specimens) from a previously published study on commodities infected with bacterial soft rot (24).

Protocol for isolation and detection of *Salmonella*. The infected or injured portion of each sample was trimmed, weighed, and tested as a subsample against the remaining healthy portion. Subsamples were washed with agitation for 1 h in 500 ml of water, then tested for *Salmonella* by a modification of the method of Poelma et al. (19), previously described (24). The method was designed to process a large number of samples, to provide a direct comparison between healthy and affected portions of the commodity, and as a screen for lactose-negative, H₂S bacteria, which would include most *Salmonella* except for *S. paratyphi-A* and some strains of *S. choleraesuis* (1,12). One ml of wash water was diluted 10-fold in selenite cysteine enrichment broth (Difco Laboratories, Detroit, MI) and incubated at 37°C for 24 h, and 10 µl was streaked with a bacteriological loop on a section of a *Salmonella-Shigella* (SS; Difco) agar plate marked into quarters. The loop was then used to sequentially streak each of the remaining sections of the plate in an adaptation of a method described by Krieg (16).

Plates were incubated at 37°C and examined at 24 and 48 h for black or black-centered (i.e., H₂S) colonies. Differences in the incidence of black colonies in healthy and diseased portions were analyzed statistically by the paired *t* test with Statpro statistical software (Wadsworth Professional Software, Inc., Boston, MA).

The reliability of the modified assay for comparing incidence of suspected *Salmonella* on paired samples was confirmed, as described previously (24), by comparisons with the standard isolation protocol of enrichment in two types of broth and streaking on three different types of diagnostic agars, Hektoen Enteric (HE), xylose lysine desoxycholate (XLD), and SS agars (19).

Although the above protocol was designed to detect the incidence of black colonies on SS agar, counts of black colonies on the streaked plates provided a rough estimate of relative concentrations of black colonies in healthy versus diseased samples. An average of total black colonies developing from healthy versus diseased portions was based on positive samples only, i.e., only from plates on which black colonies appeared.

Confirmation testing of suspected *Salmonella*. A total of 332 well-isolated single black or black-centered colonies on SS agar were subcultured, single-colony cloned, and maintained on *Pseudomonas* Agar F (PAF, Difco), which was used as a general-purpose agar for storage of bacterial cultures. Within 2 months of isolation, strains were subcultured again and tested for negative reactions on urea agar and positive reactions on triple sugar iron (TSI) and lysine iron agar (LIA), as described by Poelma et al. (19) and detailed in a previous report (24). Urease-negative and TSI/LIA-positive strains, presumptive *Salmonella*, were then tested serologically for agglutination with *Salmonella* O antiserum Poly A-1 and Vi, Poly C, D, E, F, or G (Difco) by the procedure previously described (24). Strains causing agglutination were then tested on Roche Enterotube II (Roche Diagnostic Systems, Montclair, NJ) for additional confirmation by the Enterotube II coding and identification system. The chi-square test was used to evaluate the significance of percent differences of confirmed *Salmonella* isolated from healthy versus diseased samples (22).

Coinoculation of tissue disks with *Salmonella* and fungal pathogens. Disks 1 cm in diameter and 4 to 5 mm thick were aseptically cut from tomato, potato, and onion. Three randomly selected disks were placed in 60-mm petri plates and inoculated on the cut surface with 10-µl of a

spore suspension of either *Alternaria tenuis*, *Botrytis cinerea*, *Geotrichum candidum*, or *Rhizopus stolonifer*. Spores were collected from 2-week-old cultures grown on potato dextrose agar (PDA, Difco). Original isolations were from naturally infected tomatoes collected in the marketplace. Plates were flooded with sterile distilled water, harvested by gentle scraping of mycelia with a bacteriological loop, washed once by centrifugation, and resuspended in distilled water. Spore preparations were standardized at 0.3 optical density units at 590 mu, which corresponded to approximately 10⁵ spores per ml. Control disks were given 10 µl of sterile distilled water. Within 1 h of inoculation, disks were coinoculated with 10 µl of a suspension of *Salmonella typhimurium* (ATCC 14028) prepared from a 24-h culture grown on PAF at room temperature, washed once, and standardized at approximately 5 × 10⁶ CFU/ml by optical density measurements also at 590 mu. Control disks were given an additional 10 µl of distilled water, then all disks incubated at 21°C for 48 h.

At 0, 24, and 48 h incubation, three disks per treatment were removed from plates, vigorously agitated for 15 min in 30 ml of sterile distilled water, and 20 µl logarithmically diluted eight times. Each dilution was surface-streaked on SS agar, incubated at 37°C, and examined for black or black-centered (suspected *Salmonella*) col-

Table 2. Types of rots and injuries on commodities associated with suspected *Salmonella*

Decay organism and type of injury	No. of samples tested	No. positive for black colonies	
		Healthy portion	Affected portion
Fungal rots			
<i>Alternaria</i>	115	24	31
<i>Botrytis</i>	119	14	21
<i>Cladosporium</i>	6	0	0
<i>Fusarium</i>	17	7	8
<i>Geotrichum</i>	6	1	1
<i>Pythium</i>	8	6	7
<i>Rhizoctonia</i>	3	2	3
<i>Rhizopus</i>	8	5	5
<i>Sclerotinia</i>	8	1	1
<i>Stemphylium</i>	8	2	2
<i>Thielaviopsis</i>	11	1	2
Unidentified	22	4	6
Miscellaneous ^a	11	2	3
Total	341	69	90
Percentage ^b		20.2%	26.4%*
Injuries			
Broken	4	0	3
Bruises	29	1	2
Cracks	8	3	3
Cuts	19	9	9
Field scars	6	2	1
Gouged	33	10	8
Growth cracks	11	1	1
Insect injury	3	1	1
Pitting ^c	2	1	2
Punctures	6	3	3
Total	121	31	33
Percentage ^b		25.6%	27.3% ns

^a *Colletotrichum*, *Monilia*, *Mycosphaerella*, and *Penicillium*.

^b Difference between percentages significant at the 95% (*) level of probability (*P* = 0.05). ns = not significant.

^c Physiological disorder of peppers (23).

onies at 24 and 48 h. Calculations of viable cells, or CFU per ml, were based on counts from plates containing 30 to 300 colonies per plate (16). Three separate replicated tests were conducted with tomato, potato, and onion tissues. Data were transformed to logs and analyzed for differences by the paired *t* test on Statpro statistical software (Wadsworth).

RESULTS

Verification of methodology. In selecting one of two enrichment media for detecting black H₂S colonies on samples of fruits and vegetables, selenite cysteine broth was a more conservative choice than tetrathionate, as explained in a previous report (24). Although tetrathionate resulted in a greater number of positive samples compared with selenite cysteine, fewer of them were confirmed positive on the other broth. Positive samples produced black colonies on all three diagnostic media tested, but were easiest to visualize on SS agar.

Prevalence of suspected *Salmonella* on fruits and vegetables. A total of 341 samples of fruits and vegetables infected with fungus rots were collected, infected portions trimmed, and healthy and diseased portions analyzed for suspected *Salmonella*. Black or black-centered colonies occurred in 20.2% of the healthy portions and in 26.4% of diseased portions—a 30% increase in incidence of *Salmonella* (*P* = 0.05) (Table 1). The most noticeable difference in incidence occurred with plum

tomatoes, where one healthy and five diseased portions were positive out of 15 tested.

An average of 306 black colonies appeared on plates streaked from diseased portions, compared with 413 from healthy portions (3.1×10^4 and 4.1×10^4 per ml of enriched broth, respectively). Considering that average weights of healthy and diseased portions were 265 and 24 g, respectively, the adjusted estimates for numbers of suspected *Salmonella* on diseased portions were approximately 10 times greater per gram than on the healthy portions.

Alternaria and *Botrytis* were the most frequently encountered fungal pathogens in the market samples (Table 2). Sixty-nine percent of the total diseased samples were caused by these pathogens, which represented over half of the samples positive for *Salmonella* in both healthy and diseased portions. Sixteen percent of healthy and 22% of samples infected with *Alternaria* or *Botrytis* were positive for black colonies—an increase of 37% due to disease.

One hundred twenty-one samples collected had mechanical (physical) injuries (Table 3). Incidence of black colonies was 25.6% in the uninjured (sound) portions of the commodities and 27.2% in the injured portions. Two-thirds of the injuries (67%) were due to gouges, cuts, and bruises (Table 2). Differences in incidence of *Salmonella* between injured and uninjured portions were not statistically significant.

Multiplication of *Salmonella* on fungus-infected tissues. *S. typhimurium* multiplied rapidly at room temperature on inoculated tomato, potato, and onion tissues. After 24 h, populations (CFU concentrations per gram of tissue) increased by one to two log units (Table 4). Coinoculation of the tissues with *Alter-*

naria or *Geotrichum* did not cause additional increases. *Salmonella* increased significantly, however, compared with the controls when tomato tissues were coinoculated with *Botrytis* and when tissues were infected with *Rhizopus*.

Confirmation testing of suspected *Salmonella*. Seventeen of the 332 suspected *Salmonella* isolates, or 5.1%, were confirmed as *Salmonella*. Seven of the strains (2.1% of those sampled) had been isolated from healthy tissues and 10 (3.0% of those sampled) from either fungus-infected or injured commodities, an increase of about 50% (Table 5). No one type of rot predominated among the *Salmonella*-positive samples.

DISCUSSION

Twenty percent of healthy portions of a wide array of fungal-rotted fresh fruits and vegetables yielded suspected *Salmonella*—black, hydrogen sulfide-positive bacterial colonies on SS agar—compared with 26% of infected portions. The increase was statistically significant. Only 5.1% of colonies isolated, however, could be confirmed as *Salmonella*; therefore adjusted values for incidence would be in the range of 1 to 1.3%. Therefore, based on adjusted values for incidence, and assuming the confirmed isolates were representative of the population, diseased tissues carried almost a third more contamination than healthy tissues.

Incidence of suspected *Salmonella* on mechanically injured commodities was essentially the same on injured (26%) and uninjured (27%) portions. Rots caused by *Alternaria* and *Botrytis* and injuries due to gouges, cuts, and bruises constituted over two-thirds of the conditions present in the samples tested. Incidence on affected and unaffected portions among these disease

Table 3. Incidence of suspected *Salmonella* (black colonies on Salmonella-Shigella agar) on fruits and vegetables with mechanical injuries

Commodity	Samples tested	Samples positive for black colonies	
		Sound portion	Injured portion
Bean, snap	4	0	3
Cabbage	3	0	0
Cantaloupe	3	1	0
Carrot	7	0	1
Celery	6	0	0
Cucumber	20	12	8
Fennel	3	0	0
Lettuce ^a	13	1	0
Onion, dry	3	1	0
Pepper ^b	18	5	10
Radish	3	1	0
Squash, summer	21	10	9
Squash, winter	5	0	0
Tomato	5	0	1
Miscellaneous ^c	7	1	1
Totals	121	31	33
Percentage		25.6%	27.2% ^d

^a Includes iceberg, leaf, and romaine.

^b Includes bell and cubanelle.

^c Broccoli, collard greens, escarole, parsnips, and turnips.

^d Percent differences are not statistically significant.

Table 4. CFU of bacteria per gram of host tissue coinoculated with *Salmonella typhimurium* and one of the fungus pathogens

Host ^a	Pathogen	Average CFU/g after hours of incubation ^b		
		0	24	48
Tomato	Uninoculated checks	0	0	0
	<i>Salmonella</i> control	2.4×10^6	5.9×10^8	5.0×10^8
	plus <i>Alternaria</i>		6.2×10^8 ns	1.6×10^9 ns
	plus <i>Botrytis</i>		2.5×10^9 *	3.1×10^9 *
Potato	Uninoculated checks	0	0	0
	<i>Salmonella</i> control	1.7×10^6	6.4×10^7	2.6×10^8
	plus <i>Geotrichum</i>		6.0×10^7 ns	3.0×10^8 ns
	plus <i>Botrytis</i>		2.6×10^8 ns	3.2×10^8 ns
Onion	Uninoculated checks	0	0	0
	<i>Salmonella</i> control	1.6×10^6	9.0×10^7	4.8×10^7
	plus <i>Geotrichum</i>		1.8×10^7 ns	1.2×10^8 ns
	plus <i>Botrytis</i>		9.0×10^7 ns	8.2×10^7 ns
	plus <i>Rhizopus</i>		4.0×10^8 ns	8.3×10^8 *

^a Three disks, 1 cm diameter and 5 mm thick, inoculated with 5×10^4 CFU of *S. typhimurium* ATCC 14028 and 10^3 fungus spores, incubated in a humidity chamber at 25°C, replicated three times.

^b ns = difference between fungus-inoculated and control disks not statistically significant. Asterisk = differences significant at the 95% level (*P* = 0.05).

categories reflected the same differences as in the samples in general.

Unadjusted counts of suspected *Salmonella* colonies on affected and unaffected portions of these commodities were generally the same. However, corrected for relative portion weights (a 1:10 difference), estimated counts on decayed or injured portions were 10 times that of unaffected portions.

Incidence of suspected *Salmonella* on healthy or uninjured portions of fungus-infected samples was 20.4%, and on mechanically injured samples it was 25.6%. In a previously published study on bacterial soft rot, where samples were collected and analyzed by the same techniques, incidence on healthy samples was 33%. The reasons for these variations probably relate to differences in the mixture of commodities represented in the various studies, and to seasonal differences. In the case of fungus-rotted and injured samples in this study, the difference between 20 and 25% may be only apparent since the selection of commodities in the two sets was different. Some commodities tended to have a higher incidence of defects than others. Summer squash, for example, constituted 17% of the samples collected for the injury study but less than 1% of the fungus-infected samples. Tomatoes were two-thirds of the fungus samples but only 4% of the injured ones. In the case of samples affected by bacterial soft rot, the higher incidence was probably due to the spread of bacteria-laden exudate from soft-rotted to healthy tissues. Another possibility is seasonal variations. Fungus-infected samples for the present study were collected throughout the year on a weekly basis, while most (88%) of the healthy samples for the bacterial soft rot study were collected during the warm months of April to October when bacterial counts might be expected to be high.

Multiplication of *Salmonella* did occur on fungus-infected tissues, particularly if

there was some liquefaction and pectolytic degradation. On tissues coinfecting with *Rhizopus* or *Botrytis*, organisms in which pathogenesis is associated with pectolytic degradation, multiplication did occur. In relatively dry infections, such as *Alternaria* rot, such increase was not detected.

In conclusion, the incidence of suspected *Salmonella* on diseased portions of fruits and vegetables infected with fungal rots is slightly higher than that in healthy portions. No such trend was noted on damaged versus undamaged portions of mechanically injured commodities. These observations are different from those seen in our previous study (24) on soft-rotted commodities, where both healthy and diseased portions contained higher incidence of suspected *Salmonella*, and where diseased portions had twice the incidence of healthy portions. Regarding the percentage of confirmed *Salmonella*, since it was not possible to test every H₂S-positive colony, a representative sampling indicated that the percentage was the same in both diseased and healthy portions. The essential difference, therefore, between fungus-infected and healthy portions was an increased incidence rather than increased concentration of *Salmonella*. Based on these data, it would appear that, unlike bacterial soft-rotted commodities, those infected with fungal rots or those that are mechanically damaged carry little or no greater than average risk of *Salmonella* contamination.

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LITERATURE CITED

- Brenner, D. J. 1984. Family I. *Enterobacteriaceae*. Pages 408-516 in: Bergey's Manual of Systemic Bacteriology, Vol. 1. N. R. Krieg, and J. G. Holt, eds. William & Wilkins, Baltimore, MD.
- Ceponis, M. J., and Butterfield, J. E. 1974. Retail and consumer losses in sweet potatoes

marketed in metropolitan New York. HortScience 9:393-394.

- Ceponis, M. J., Cappellini, R. A., and Lightner, G. W. 1986. Disorders in tomato shipments to the New York market, 1972-1984. Plant Dis. 70:261-265.
- Ceponis, M. J., Cappellini, R. A., and Lightner, G. W. 1986. Disorders in muskmelon shipments to the New York market, 1972-1984. Plant Dis. 70:605-607.
- Ceponis, M. J., Cappellini, R. A., and Lightner, G. W. 1987. Disorders in sweet cherry and strawberry shipments to the New York market, 1972-1984. Plant Dis. 71:472-475.
- Ercolani, G. L. 1976. Bacteriological quality assessment of fresh marketed lettuce and fennel. Appl. Environ. Microbiol. 31:847-852.
- Fairchild, C. 1990. *Salmonella* outbreak source sought. The Packer. Vol. XCVII, No. 33, Aug. 18, 1990. pp. 1A and 7A.
- Garcia Villanova-Ruiz, B., Galvez-Vargas, R., and Garcia-Villanova, R. 1987. Contamination of fresh vegetables during cultivation and marketing. Int. J. Food Microbiol. 4:285-291.
- Geldreich, E. E., and Bordner, R. H. 1970. Fecal contamination of fruits and vegetables during cultivation and processing for market. A review. J. Milk Food Technol. 34:184-195.
- Golden, D. A., Rhodehamel, E. J., and Kauter, D. A. 1993. Growth of *Salmonella* spp. in cantaloupe, watermelon and Honeydew melons. J. Food Prot. 56:194-196.
- Gould, W. A. 1973. Micro-contamination of horticultural products. HortScience 8:116-119.
- Guthrie, R. K. 1992. *Salmonella*. CRC Press, Boca Raton, FL.
- Harwig, J., Scott, P. M., Stolts, D. R., and Blanchfield, B. J. 1979. Toxins of molds from decaying tomato fruit. Appl. Environ. Microbiol. 38:267-274.
- Hedberg, C. W., MacDonald, K. L., and Osterholm, M. T. 1994. Changing epidemiology of food-borne disease: A Minnesota perspective. Clin. Infect. Dis. 18:671-682.
- Janisiewicz, W. J., Conway, W. S., Brown, M. W., Sapers, G. M., Fratamico, P., and Buchanan, R. L. 1999. Fate of *Escherichia coli* O157:H7 on fresh-cut apple tissue and its potential for transmission by fruit flies. Appl. Environ. Microbiol. 65:1-5.
- Krieg, N. R. 1981. Enrichment and isolation. Pages 112-142 in: Manual of Methods for General Bacteriology. P. Gerhardt, ed. American Society for Microbiology, Washington, DC.
- Lin, C.-M., and Wei, C.-I. 1997. Transfer of *Salmonella montevideo* onto the interior surfaces of tomatoes by cutting. J. Food Prot. 60:858-863.
- Lund, B. M. 1983. Bacterial spoilage. Pages 219-257 in: Postharvest Pathology of Fruits and Vegetables. C. Dennis, ed. Academic Press, London.
- Poelma, P. L., Andrew, W. H., and Silliker, J. H. 1984. *Salmonella*. Pages 286-326 in: Compendium of Methods for the Microbiological Examination of Foods. M. L. Speck, ed. American Public Health Association, Washington, DC.
- Rude, R. A., Jackson, G. L., Bier, J. W., Sawyer, T. K., and Risty, N. G. 1984. Survey of fresh vegetables for nematodes, amoebae and *Salmonella*. J. Assoc. Off. Anal. Chem. 67:613-615.
- Schwartz, S. 1995. *Salmonella* poisoning: Sprouts are suspect in outbreak. The Packer. Vol. CLL, No. 27, Jul. 3, 1995. p. 6A.
- Snedecor, G. W., and Cochran, W. G. 1980. Statistical Methods. 7th ed. Iowa State University, Ames.
- Snowdon, A. L. 1990. A color atlas of post-harvest diseases of fruits and vegetables. Vol.

Table 5. Sources of confirmed *Salmonella* isolates

Strain designation ^a	Date collected	Commodity	Portion	Disorder
123	03/10/95	Pepper	Healthy	
116	03/25/95	Tomato	Healthy	
135	04/18/96	Sweet potato	Healthy	
165	04/29/96	Cucumber	Healthy	
175	04/29/96	Cucumber	Healthy	
180	04/29/96	Cucumber	Healthy	
184	05/06/96	Pepper	Healthy	
113	07/31/95	Tomato	Diseased	Unidentified rot
78	07/31/95	Cantaloupe	Diseased	Fusarium rot
151	08/14/95	Butternut squash	Diseased	Watery soft rot (<i>Sclerotinia</i>)
66	11/13/95	Onion, green	Diseased	Gray mold rot (<i>Botrytis</i>)
252	04/22/96	Carrot	Diseased	Black rot (<i>Thielaviopsis</i>)
253	07/08/96	Tomato	Diseased	<i>Alternaria</i> rot
254	07/08/96	Tomato	Diseased	<i>Alternaria</i> rot
106	10/30/96	Cantaloupe	Diseased	Fusarium rot

^a All strains positive for *Salmonella* by physiological testing and by serological reactions against *Salmonella* O antiserum Poly A-1 and Vi or Poly C, D, E, and F.

- 2: Vegetables. CRC Press, Boca Raton, FL.
24. Wells, J. M., and Butterfield, J. E. 1997. *Salmonella* contamination associated with bacterial soft rot of fresh fruits and vegetables in the marketplace. *Plant Dis.* 81:867-872.
25. Wood, R. C., Hedberg, C., and White, D. 1991. A multi-state outbreak of *Salmonella javiana* infections associated with raw tomatoes. (Abstr.) Page 69 in: *CDC Epidemic Intelligence Serv. Annu. Conf.*, 40th, U.S. Department of Health and Human Services, Public Health Service, Washington, DC.
26. Zhuang, R.-Y., Beuchat, L. R., and Angulo, F. J. 1995. Fate of *Salmonella montevideo* on and in raw tomatoes as affected by temperature and treatment with chlorine. *Appl. Environ. Microbiol.* 61:2127-2131.