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Review

Fresh Produce: A Growing Cause of Outbreaks of Foodborne Illness in the United States, 1973 through 1997

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ABSTRACT

Fresh produce is an important part of a healthy diet. During the last three decades, the number of outbreaks caused by foodborne pathogens associated with fresh produce consumption reported to the Centers for Disease Control and Prevention has increased. To identify trends, we analyzed data for 1973 through 1997 from the Foodborne Outbreak Surveillance System. We defined a produce-associated outbreak as the occurrence of two or more cases of the same illness in which epidemiologic investigation implicated the same uncooked fruit, vegetable, salad, or juice. A total of 190 produce-associated outbreaks were reported, associated with 16,058 illnesses, 598 hospitalizations, and eight deaths. Produce-associated outbreaks accounted for an increasing proportion of all reported foodborne outbreaks with a known food item, rising from 0.7% in the 1970s to 6% in the 1990s. Among produce-associated outbreaks, the food items most frequently implicated included salad, lettuce, juice, melon, sprouts, and berries. Among 103 (54%) produce-associated outbreaks with a known pathogen, 62 (60%) were caused by bacterial pathogens, of which 30 (48%) were caused by *Salmonella*. During the study period, *Cyclospora* and *Escherichia coli* O157:H7 were newly recognized as causes of foodborne illness. Foodborne outbreaks associated with fresh produce in the United States have increased in absolute numbers and as a proportion of all reported foodborne outbreaks. Fruit and vegetables are major components of a healthy diet, but eating fresh uncooked produce is not risk free. Further efforts are needed to better understand the complex interactions between microbes and produce and the mechanisms by which contamination occurs from farm to table.

During the last three decades, consumption of fresh fruits and vegetables in the United States has increased *(80)*. Concomitantly, an increasing number of outbreaks caused by foodborne pathogens that were reported to the Centers for Disease Control and Prevention (CDC) has been associated with fresh produce consumption. This increase in outbreaks caused by produce consumption represents a shift from the vehicles traditionally associated with outbreaks of foodborne illness, generally foods of animal origin, such as eggs, meat, and dairy products *(36)*.

In this review, we describe the epidemiology of produce-associated outbreaks of foodborne disease in the United States that were reported to CDC from 1973 through 1997. These epidemiologic data, while limited because of the passive nature of surveillance and the inconsistent reporting of factors contributing to outbreaks, suggest that additional control measures are needed to increase the safety of fruits and vegetables.

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METHODS

Data sources: the Foodborne Outbreak Surveillance System. Since 1966, the Foodborne and Diarrheal Diseases Branch at CDC has collected data on outbreaks of foodborne disease. State and local health departments reported outbreaks to CDC with a standard reporting form (CDC Form 52.13) *(62)*. Reported data include the number of persons affected, the pathogen or toxin identified, the characteristics of illness, the month of illness onset, the implicated food items, and the locally identified factors causing contamination of produce. The details of food preparation and the source of implicated food items were not systematically reported. The surveillance data have been computerized since 1973 and are periodically summarized and reported *(62)*. Beginning in 1998, both the reporting form and the procedures for reporting were changed substantially; therefore, this analysis is restricted to data from 1973 through 1997 to avoid artifacts of changed surveillance. Data on etiology and food vehicle were reviewed at CDC as they were received; the data have been more consistent since 1980.

Definitions. A produce-associated outbreak was defined as two or more cases of the same illness in which epidemiologic investigation implicated the same uncooked produce item, such as fruit, vegetable (including fresh herbs), salad, or juice. If several outbreaks occurred in different areas of the country but were epidemiologically linked to a single food item, they were defined as parts of a single outbreak.

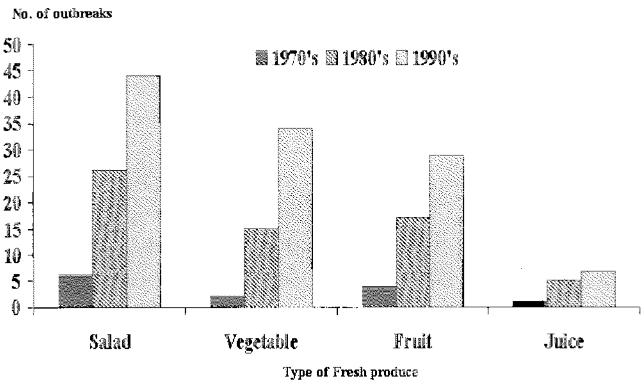

FIGURE 1. *Number of produce-associated outbreaks by specific vehicle* (n *= 190), 1973 through 1997.*

Some epidemiologic outbreak investigations implicated more than one produce item. Therefore, two or more fruits (e.g., "fruit salad" or "watermelon and strawberry") implicated in an outbreak were classified as "mixed fruit," and two or more vegetables (e.g., "vegetable platter" or "lettuce and tomato") were classified as "mixed vegetable." We excluded produce items that were cooked or canned; salads made with eggs, cheese, dairy, seafood, or meat products; and juice made from powder or frozen concentrate. Otherwise, reports implicating "salad" were simply classified as "salad" with exceptions as outlined above.

Data analysis. We divided the data into three time periods: 1973 through 1979 was referred to as the 1970s, 1980 through 1989 was referred to as the 1980s, and 1990 through 1997 was referred to as the 1990s. We conducted our analysis using Epi Info software (version 6.04, CDC, Stone Mountain, Ga.). We also summarized certain categories of produce-associated outbreaks for which (i) the food item was implicated in multiple outbreaks, (ii) the outbreak investigation revealed novel mechanisms of contamination, and (iii) the pathogen was newly recognized as being foodborne. Information on traceback or environmental investigations was extracted from published reports of those outbreaks rather than from the Foodborne Outbreak Surveillance System because this information was not consistently available through the latter.

RESULTS

From 1973 through 1997, 32 states reported 190 produce-associated outbreaks, 16,058 reported illnesses, 598 hospitalizations, and eight deaths. The median number of reported produce-associated outbreaks increased from two outbreaks per year in the 1970s to seven per year in the 1980s to 16 per year in the 1990s, while the total number of foodborne outbreaks with a known food item remained essentially constant over this timespan. This increase was seen for fruit, vegetable, salad, and juice (Fig. 1). The median number of ill persons reported per outbreak increased from 21 in the 1970s to 43 in the 1990s. Produce-associated outbreaks accounted for an increasing proportion of all foodborne outbreaks associated with a specific food, increasing from 0.7% (13 of 1,857 outbreaks) in the 1970s to 6% (114 of 1,788 outbreaks) in the 1990s. They also accounted for an increasing proportion of foodborne outbreak–associated illness among all outbreaks with a reported specific food (including multiple food items), increasing from 1% (708 of 68,712 ill persons) in the 1970s to 12% (8,808 of 74,592 ill persons) in the 1990s. Produce-associated outbreaks occurred throughout the year, with a peak in the spring and a shorter peak in the fall. The seasonal distribution depended on the produce category; outbreaks of illness caused by contaminated fruit peaked in June, whereas those caused by contaminated juice peaked in October.

TABLE 1. *Type of produce items implicated in foodborne outbreaks in the United States, 1973 through 1997*

Produce items	No. of outbreaks
Multiple produce items	105
Salad	76
Mixed fruit	22
Mixed vegetables	7
Single produce items	85
Lettuce	25
Melon	13
Seed sprout	11
Apple or orange juice	11
Berry	9
Tomato	3
Green onion	3
Carrot	2
Apple	1
Pear	1
Pineapple	1
Basil	1
Celery	1
Cucumber	1
Fresh elderberry juice	1
Fresh-squeezed lemonade	1

Twenty-one multistate outbreaks were reported, two each in the 1970s and 1980s, and 17 in the 1990s. The median size of multistate outbreaks was 128 ill persons, compared with 34 for a single-state outbreak. Implicated food items in multistate outbreaks included seed sprouts (five outbreaks), apple cider (two), raspberry (two), cantaloupe (two), frozen strawberry (two); food items implicated only once included basil, carrot, precut celery, green onion, lettuce, lettuce and tomato, tomato, and watermelon.

Types of produce vehicles. The reported produce item was multiple for 105 outbreaks: for 76 outbreaks the implicated vehicle was "salad," for 22 it was "mixed fruit," and for seven it was "mixed vegetables." Among the 85 outbreaks in which a single produce item was implicated, 77 (89%) were associated with eight produce items: lettuce (25 outbreaks), melon (13), seed sprouts (11), apple or orange juice (11), berry (9), tomato (3), green onion (3), and carrot (2). The remaining eight outbreaks were associated with items that were implicated only once (Table 1).

Types of pathogens. A specific etiologic agent was identified for 103 (54%) produce-associated outbreaks that resulted in 11,185 illnesses; 62 (60%) outbreaks were caused by bacteria, 21 (20%) by viruses, 16 (16%) by parasites, and 4 (4%) by chemicals or poisons. *Salmonella* (31,

TABLE 2. *Type of produce items implicated in foodborne outbreaks by pathogen in the United States, 1973 through 1997*

Produce item	No. of outbreaks
Salmonella	30
Salad	7
Seed sprout	7
Melon	6
Apple or orange juice	3
Lettuce	3
Tomato	1
Lettuce and tomato	1
Precut celery	1
Mixed fruit	1
E. coli O157:H7	13
Lettuce	5
Apple cider	4
Salad	2
Cantaloupe	1
Alfalfa sprout	1
Non-O157 *E. coli*	2
Carrot (ETEC O6:NM LT ST)	1
Pineapple (*E. coli* O11:H43)	1
Shigella	10
Salad	6
Lettuce	2
Green onion	1
Mixed vegetables	1
Campylobacter	4
Melon, strawberry	1
Melon	2
Fruit salad	1
Bacillus cereus	1
Sprouts	1
Yersinia enterocolitica	1
Bean sprout	1
Staphylococcus aureus	1
Strawberry	1
Hepatitis A	12
Salad	5
Lettuce	2
Frozen strawberry	2
Green onion	1
Tomato	1
Carrot and celery sticks	1
Norovirus	9
Salad	6
Lettuce	2
Mixed fruit	1
Cyclospora cayetanensis	8
Raspberry	4
Mesclun lettuce	2
Basil	1
Fruit salad	1
Giardia lamblia	5
Fruit salad	2
Iceberg lettuce	1
Salad	1
Mixed vegetables	1
Cryptosporidium parvum	3
Apple cider	2
Green onion	1
Chemical or toxin	4
Poison berries	1
Apple (alkali)	1
Watermelon (aldicarb)	1
Cucumber (aldicarb)	1
Etiologic agent not identified	87
Salad	49
Mixed fruit	15
Lettuce	8
Melon	4
Berries	2
Mixed vegetables	2
Apple	1
Bean sprout	1
Carrot	1
Orange juice	1
Pear	1
Lemonade	1
Tomato	1

48%) was the most common bacterial agent, hepatitis A (12, 57%) the most common viral agent, *Cyclospora cayetanensis* (8, 47%) the most common parasitic agent, and the pesticide aldicarb (2, 50%) the most common chemical agent.

A serotype was reported for all 30 outbreaks of *Salmonella* infection. There were 20 different serotypes identified; those identified more than once included Typhimurium (five outbreaks), Montevideo (four), Javiana (three), Anatum (two), Enteritidis (two), Infantis (two), Newport (two), and Stanley (two).

Produce items that were most frequently implicated in outbreaks of *Salmonella* infection included salad, sprouts, and melons; items frequently implicated in outbreaks of *Escherichia coli* O157:H7 infection were lettuce and apple cider. In addition, a multistate outbreak of infection with a *E. coli* O6 strain that produced the heat-stable and heat-labile toxins (O6:NM LT ST) was associated with carrot consumption in Rhode Island and New Hampshire *(20)*, and an outbreak of *E. coli* O11:H43 infections was associated with pineapple consumption. Outbreaks of shigellosis, hepatitis A, or norovirus infections were most frequently associated with the consumption of salads or lettuce (Table 2).

Parasites were reported as the etiologic agent in 16 outbreaks: *C. cayetanensis* (eight outbreaks), *Giardia lamblia* (five), and *Cryptosporidium parvum* (three). The out-

TABLE 3. *Reported lettuce-associated outbreaks with known pathogen in the United States, 1973 through 1997*

Year	Pathogen	No. of ill persons	Location of outbreak	Lettuce type	Reference[a]
1981	Norwalk	92	Alabama	Lettuce	FOSS
1981	*Giardia*	61	New Jersey	Lettuce	FOSS
1985	*Shigella flexneri* 3	25	Texas	Lettuce	FOSS
1986	*Shigella sonnei*	347	Texas	Shredded lettuce	*28*
1988	Hepatitis A	202	Kentucky	Iceberg lettuce	*72*
1990	Hepatitis A	130	Missouri	Lettuce	*19*
1993	*Salmonella* Heidelberg	18	Minnesota	Lettuce	FOSS
1994	*Salmonella* Thompson	16	Minnesota	Lettuce	FOSS
1994	*Salmonella* Braenderup	30	New York	Lettuce	FOSS
1995	*E. coli* O157:H7	92 (1 HUS[b])	Montana	Leaf lettuce	*1*
1995	Norovirus	76	Florida	Lettuce	FOSS
1995	*E. coli* O157:H7	11	Ohio	Iceberg lettuce	FOSS
1995	*E. coli* O157:H7	30	Maine	Iceberg lettuce	*50*
1996	*E. coli* O157:H7	61 (3 HUS)	Multiple states	Mesclun mix	*40*
1996	*E. coli* O157:H7	54	Michigan	Lettuce	FOSS
1997	*Cyclospora*	29	Florida	Mesclun mix	*37*
1997	*Cyclospora*	12	Florida	Mesclun mix	*37*

[a] For an outbreak reported only in the Foodborne Outbreak Surveillance System (FOSS), no reference is available.
[b] HUS, hemolytic uremic syndrome.

breaks of cyclosporiasis were predominantly associated with consumption of raspberries or mesclun lettuce, whereas outbreaks of cryptosporidiosis were associated with consumption of apple cider. *(21, 52)* Among 87 outbreaks for which no etiologic agent was determined, a majority (56%) was associated with salad consumption (Table 2).

The place of food preparation was reported for 157 outbreaks. Among these, 85 outbreaks were associated with food prepared in restaurants, cafeterias, and catering establishments; 17 were associated with food prepared in private homes; and 13 were associated with food prepared in schools, camps, or churches. Forty-two outbreaks were associated with foods prepared in "other" or multiple locations. Limited information on factors that might have contributed to contamination was reported. At least one of several possible factors was reported in 80 outbreaks. These included poor personal hygiene (50 outbreaks), contaminated equipment (20), improper storage temperature (20), and unsafe sources of food (16). Data on illness of food handlers were not systematically reported.

Lettuce-associated outbreaks. The 25 lettuce-associated outbreaks caused 2,078 reported illnesses, 181 hospitalizations, and six deaths. The median size of lettuce-associated outbreaks was 61 cases (range 3 to 347). The type of lettuce was reported in eight outbreaks: iceberg (four), mesclun (three), and leaf (one). Seventeen outbreaks were reported with an associated pathogen, including *E. coli* O157: H7, *Salmonella, Shigella, Cyclospora,* norovirus, hepatitis A virus, and *Giardia* (Table 3). One outbreak occurred in multiple states (Connecticut, Illinois, and New York) involving *E. coli* O157:H7 infections associated with eating mesclun lettuce *(40)*. A traceback of lettuce to the farm of origin was documented for four outbreaks; three farms were located in the United States *(1, 28, 40)* and one in Peru *(37)*. A traceback to a common lettuce distributor was documented for two outbreaks. *(28, 50)* Apparent modes of contamination of lettuce varied with the outbreak and type of pathogen. Contamination with *E. coli* O157:H7 likely occurred on farms through the use of contaminated irrigation water, contaminated wash water, improperly composted manure, and direct contact with feces of cattle, sheep, and other livestock *(1, 40)*; contamination with *Shigella* occurred in a lettuce shredding plant through an infected food handler and cross-contamination of equipment at the shredding plant *(28)*.

Juice-associated outbreaks. The 13 juice-associated outbreaks caused 686 reported illnesses, 34 hospitalizations and no deaths. The median size of juice-associated outbreaks was 18 cases (range 2 to 298). The types of juice reported in 12 outbreaks included apple juice (nine), orange juice (two), fresh squeezed lemonade (one), and elderberry juice (one). Eleven outbreaks were associated with a pathogen, chemical, or toxin: four were caused by *E. coli* O157: H7, three by *Salmonella,* two by *Cryptosporidium,* one by alkali poisoning, and one by poisonous berries (Table 4). Two multistate juice-associated outbreaks caused *Salmonella* Typhimurium infections and *E. coli* O157:H7 infections—the latter outbreak being international *(14, 26)*. Traceback of implicated juice to a single producer (in each outbreak) receiving fruit from single or multiple farms was documented for six outbreaks, all in the United States *(5, 14, 26, 27, 52)*. Accidental poisoning from elderberry juice was caused by the use of locally gathered poisonous berries to make juice *(16)*. Reported practices that could have increased the risk of producing contaminated juice included using fruit that had dropped from trees to the ground *(5, 14, 26)*, inadequate cleaning of fruit before juicing *(26, 52)*, and inadequate sanitizing of processing equipment *(27, 52)*. Among the nine juice-associated outbreaks for which pas-

TABLE 4. *Reported juice-associated outbreaks with known pathogen in the United States, 1973 through 1997*

Year	Pathogen/chemical	No. of ill persons	Location of outbreak	Juice type	Likely mode of contamination	Pasteurized	Reference[a]
1974	*Salmonella* Typhimurium	298	New Jersey New York	Apple	Used dropped apples	No	*14*
1985	*Salmonella* Berta	3	Pennsylvania	Apple	Unknown	Unknown	FOSS
1991	*E. coli* O157:H7	23 (3 HUS[b])	Massachusetts	Apple	Used dropped apples	No	*5*
1993	*Cryptosporidium parvum*	160	Maine	Apple	Used dropped apples	No	*52*
1995	*Salmonella* Hartford, *Salmonella* Gaminara	62	Florida	Orange	Used dropped oranges, improper sanitation of processing equipment	No	*27*
1996	*C. parvum*	31	New York	Apple	Farm near cattle pasture	No	*21*
1996	*E. coli* O157:H7	12 (3 HUS)	Connecticut	Apple	Used dropped apples	No	*21*
1996	*E. coli* O157:H7	6	Washington	Apple	Unknown	No	FOSS
1996	*E. coli* O157:H7	56 (14 HUS; 1 death)	Multiple states, Canada	Apple	Unknown	No	*26*
1997	Poisonous berries	11	California	Elderberry	Used poisonous berries	No	*16*
1997	Alkali	4	New York	Apple	Processing plant	Unknown	FOSS

[a] For an outbreak reported only in the Foodborne Outbreak Surveillance System (FOSS), no reference is available.
[b] HUS, hemolytic uremic syndrome.

teurization information was available, all juices implicated were reported as unpasteurized *(5, 14, 21, 26, 27, 52).*

Melon-associated outbreaks. The 13 melon-associated outbreaks caused 841 reported illnesses, 33 hospitalizations, and no deaths. The median size of melon-associated outbreaks was 27 cases (range 16 to 295). The type of melon reported in 13 outbreaks included cantaloupe (six outbreaks), watermelon (six), and a combination of musk and honeydew melons (one). Nine outbreaks were associated with a pathogen or chemical, including six outbreaks caused by *Salmonella* are one each by *E. coli* O157: H7, *Campylobacter jejuni,* and aldicarb (Table 5). Among the three multistate outbreaks of *Salmonella* infections, two were associated with cantaloupe consumption and one with watermelon consumption *(17, 18, 71).* Traceback investigations identifying the source farm were documented for three outbreaks, all located in Mexico *(18, 56, 71).* Agricultural or preparation practices that could have increased the risk of contaminated melons included surface contamination because melons are normally grown on the ground *(18),* misapplication of insecticide on melons *(17),* failing to wash melon rinds before cutting *(56),* and holding cut melons at room temperatures *(15, 18).*

Sprout-associated outbreaks. The 11 sprout-associated outbreaks caused 1,071 reported illnesses, 97 hospitalizations and one death. The median size of sprout-associated outbreaks was 60 cases (range 4 to 500). The type of sprouts reported in 11 outbreaks included alfalfa (7 outbreaks); bean (2); alfalfa and clover (1); and soybean, cress, and mustard (1). Ten outbreaks were associated with a pathogen: seven with *Salmonella* and one each with *E. coli* O157: H7, *Bacillus cereus,* and *Yersinia enterocolitica* (Table 6). Six sprout-associated outbreaks were multistate outbreaks *(11, 34, 49, 55, 58)*; two outbreaks of *Salmonella* infections were international *(49, 81).*

Traceback investigations in five outbreaks led to multiple sprouters who received seeds from a single distributor or shipper who, in turn, received seeds from multiple domestic or international farms *(11, 49, 55, 58, 67, 81).* Use of seeds that were contaminated through contact with animal feces during storage or the sprouting process was the most likely mode of contamination. The environmental conditions necessary for successful growth of sprouts are also an efficient amplification step for bacterial pathogens present on the seed. Other possible mechanisms of contamination included the use of uncomposted chicken manure as fertilizer, irrigation with contaminated canal water, direct contact of fields with wildlife feces, and runoff from livestock feces *(11, 55).*

Berry-associated outbreaks The nine reported berry-associated outbreaks caused 1,815 reported illnesses, 24 hospitalizations, and no deaths. The median size of berry-associated outbreaks was 38 cases (range 14 to 755). The types of berry reported in nine outbreaks included raspberry (four outbreaks), strawberry (four), and blackberry (one). Seven outbreaks were associated with a pathogen, four with *Cyclospora,* two with hepatitis A virus, and one with *Staph-*

TABLE 5. *Reported melon-associated outbreaks with known pathogens in the United States, 1973 through 1997*

Year	Pathogen/chemical	No. of ill persons	Location of outbreak	Melon type	Reference[a]
1979	*Salmonella* Oranienburg	18	Illinois	Watermelon	*15*
1985	*Campylobacter jejuni*	16	Wisconsin	Cantaloupe	FOSS
1985	Aldicarb	53	Multiple states	Watermelon	*17*
1989	*Salmonella* Chester	295	Multiple states	Cantaloupe	*71*
1991	*Salmonella* Javiana	39	Michigan	Watermelon	*10*
1991	*Salmonella* Poona	143	Multiple states	Cantaloupe	*18*
1993	*Salmonella* Javiana	27	Wisconsin	Watermelon	FOSS
1993	*E. coli* O157:H7	34	Oregon	Cantaloupe	FOSS
1997	*Salmonella* Saphra	24	California	Cantaloupe	*56*

[a] For an outbreak reported only in the Foodborne Outbreak Surveillance System (FOSS), no reference is available.

ylococcus aureus (Table 7). Four berry-associated outbreaks were multistate: two caused by *Cyclospora* and two by hepatitis A virus.

Traceback of implicated berries to a single farm or processor was reported in 1990, when frozen strawberries implicated in a hepatitis A virus outbreak in Montana and Georgia were traced to a common source. All of the implicated strawberries had the same lot number, indicating that they were processed during the same shift in a California processing plant that obtained berries from its own farm *(60)*. Other traceback investigations led to multiple farms in a single country. For example, consumption of frozen strawberries caused a multistate hepatitis A virus outbreak in 1997, and traceback led to four farms in Mexico and a single processing plant in California where the strawberries were frozen and packaged *(41)*. Traceback of raspberries implicated in *Cyclospora* outbreaks led to farms in Guatemala *(37–39)*.

Possible points of contamination identified in outbreak investigations varied by outbreak and pathogen. Frozen strawberries implicated in two hepatitis A outbreaks were likely contaminated by food handlers, including field workers using bare hands or fingernails to harvest fruit or workers at processing plants *(41, 60)*. Once the fruit is contaminated, the hepatitis A virus remains infectious for prolonged periods, despite freezing *(41)*. Raspberries implicated in several multistate outbreaks of cyclosporiasis were likely contaminated on the farm through the use of inadequately treated water used to mix insecticides and fungicides, which are applied directly onto raspberries *(4, 38)*. Seasonal cyclosporiasis among family members of field workers in Guatemala has been documented *(4)*, and workers could contaminate the fruit directly during harvesting or packing. However, *Cyclospora* oocysts found outside of the human host, such as in water and soil, are more mature (and more infectious) than those found in freshly excreted

TABLE 6. *Reported sprout-associated outbreaks with known pathogen in the United States, 1973 through 1997*

Year	Pathogen	No. of ill persons	Location of outbreak	Sprout type	Souce of contamination	Reference[a]
1973	*Bacillus cereus*	4	Texas	Soy, cress, mustard	Seed	*67*
1982	*Yersinia enterocolitica*	16	Pennsylvania	Bean sprout	Unknown	FOSS
1990	*Salmonella* Anatum	15	Washington	Alfalfa	Unknown	FOSS
1995	*Salmonella* Stanley	128	Multiple states, Finland	Alfalfa	Seed	*49*
1995	*Salmonella* Newport	69[b]	Oregon, Canada, Denmark	Alfalfa	Seed	*81*
1996	*Salmonella* Stanley	30	Virginia	Alfalfa	Unknown	FOSS
1996	*Salmonella* Montevideo and Meleagridis	500	California	Alfalfa	Seed	*58*
1997	*Salmonella* Infantis and Anatum	81	Missouri, Kansas	Alfalfa, mung, other sprouts	Seed	*66*
1997	*E. coli* O157:H7	108 (3 HUS[b])	Michigan, Virginia	Alfalfa	Seed	*11*
1997	*Salmonella* Senftenberg	60	California, Nevada	Alfalfa, clover	Seed and/or sprouter	*55*

[a] For an outbreak reported only in the Foodborne Outbreak Surveillance System (FOSS), no reference is available.
[b] HUS, hemolytic uremic syndrome.

TABLE 7. *Reported berry-associated outbreaks with known pathogen in the United States, 1973 through 1997*

Year	Pathogen	No. of ill persons	Location of outbreak	Berry type	Reference[a]
1985	*Staphylococcus aureus*	14	New York	Strawberry	FOSS
1990	Hepatitis A	51	Multiple states	Frozen strawberry	*50*
1995	*Cyclospora*	38[b]	Florida	Raspberry	*37, 46*
1995	*Cyclospora*	32[b]	New York	Raspberry	*38*
1996	*Cyclospora*	631[c]	Multiple states, Canada	Raspberry[d,e]	*38*
1997	*Cyclospora*	755[f]	Multiple states, Canada	Raspberry[e]	*39*
1997	Hepatitis A	258	Multiple states	Frozen strawberry	*41*

[a] For an outbreak reported only in the Foodborne Outbreak Surveillance System (FOSS), no reference is available.
[b] In retrospect, the outbreaks in Florida and New York in 1995 could have been part of the same outbreak.
[c] This number represents U.S. cases reported in FOSS, which is less than in the published report (1,465 cases) because of differences in case definitions and the passive nature of the FOSS.
[d] Guatemalan blackberries, not raspberries, were served at one event in Quebec, Canada *(39)*.
[e] Blackberries and raspberries were served together at some events involved in these outbreaks; therefore, blackberries could not be ruled out as a suspicious vehicle in the analysis *(39)*.
[f] This number represents cases reported in FOSS, which is less than in the published report (1,012 cases) because of differences in case definitions and the passive nature of the FOSS.

stool. Therefore, direct contamination of berries by uninfectious oocytes from field worker feces is less plausible than contamination by infectious oocysts from water or soil, especially because raspberries are kept cool after they are picked (slowing oocyte maturation) and have a relatively short shelf life *(38)*. No wild or domestic animal reservoir of *C. cayetanensis* has been documented to date, suggesting that oocysts found in water and soil are likely from human fecal shedding *(38)*.

Tomato-associated outbreaks. The three reported tomato-associated outbreaks caused 234 reported illnesses, 18 hospitalizations, and one death. The median size of tomato-associated outbreaks was 29 cases (range 29 to 176). Two outbreaks were associated with pathogens, *Salmonella* Javiana and hepatitis A virus. Traceback of tomatoes implicated in two multistate outbreaks in 1990 and 1993 led to the same South Carolina tomato packer *(35)*. Contamination is likely to have occurred at the packing shed, where warm tomatoes were placed in a cool, unchlorinated water bath. Under these conditions, gases within the fruit contract during cooling, resulting in an inward hydrostatic force, drawing in water as well as pathogens *(83)*.

DISCUSSION

Between 1973 and 1997, the proportion of reported outbreaks of foodborne illness that were associated with produce increased eightfold while the total number of outbreaks of foodborne disease that were attributable to a known food item was unchanged. The median number of persons ill per produce-associated outbreak increased twofold between 1973 and 1997 and accounted for an increasing proportion of ill persons in all outbreaks of foodborne illness with a known food item. Among produce-associated outbreaks, the food items most frequently implicated included salad, lettuce, juice, melon, and sprouts. A pathogen was reported for 54% of produce-associated outbreak investigations, with *Salmonella* being the most common. During the study period, *Cyclospora* and *E. coli* O157:H7 were newly recognized as causes of foodborne illness. Several food-pathogen combinations were reported, most commonly lettuce or fruit juice associated with *E. coli* O157:H7 infection; melon, sprout, or tomato with *Salmonella* infection; and berry with *Cyclospora* infection. Multistate outbreaks were reported almost exclusively in the 1990s, which might reflect more centralized production and wider distribution of produce as well as improved local and national surveillance systems.

The increase in reports of produce-associated outbreaks over the last three decades might be related to changes in consumer food preference, food production and distribution practices, and to the emergence of new foodborne pathogens. In the last 20 years, the consumption of fruits and vegetables in the United States has increased substantially, with per capita consumption of produce rising 24% from 573 pounds in 1970 to 711 pounds in 1997 *(68)*. This increase could be a result of nutritional guidelines that promote an increased daily intake of fruits and vegetables to improve health *(2)*, the availability of a wider variety of fresh produce such as alfalfa sprouts, and the increasing popularity of salad bars.

Globalization of the food supply has made fruits and vegetables available regardless of season. Improvements in mass production and distribution and changes in trade policy allow highly perishable foods, including most produce, to travel long distances with minimal spoilage. These improvements and changes also facilitate transport of contaminated produce. This means that farming and processing practices in many countries could play a role in produce-associated outbreaks. For example, the 1996 outbreak of cyclosporiasis associated with raspberries followed the introduction of raspberries as a new crop in Guatemala, where on-farm contamination likely occurred *(38)*. In 1998, outbreaks of *Shigella sonnei* and enterotoxigenic *E. coli* infection were associated with eating fresh parsley grown on a farm in Mexico, where water used in a hydrocooler to chill parsley was not continuously monitored for adequate chlorine levels and was recirculated, allowing cross-contamination *(22)*.

Produce can be contaminated at any point during its growth, harvesting, processing, distribution, and final preparation *(7)*. For pathogens with animal reservoirs, contamination in the field can occur if animals or their manure are present in the fields or the irrigation water. The skin of produce grown or harvested from the ground or in contact with improperly composted manure can become contaminated with fecal pathogens such as *E. coli* O157:H7, which can remain viable in bovine feces for up to 70 days *(82)*. Fruit harvested from trees, such as peaches and plums, could be more frequently contaminated with *E. coli* when grown either adjacent to or downwind or crosswind from a dairy operation *(33)*. For pathogens with human reservoirs, produce can become contaminated if water (containing *Cyclospora* oocysts) is used to mix insecticides and other chemicals applied directly to produce and during harvesting by pickers and handlers or children present in the fields, especially in the absence of adequate latrines or hand-washing facilities.

Produce contamination also can occur during postharvest processing, by chilling and washing with contaminated water, for example. Water baths used for processing produce could spread contamination from one harvested item to the next. Unenclosed processing sheds allow animals carrying human pathogens such as *Campylobacter (48)* and *Salmonella (69)* to contaminate processing water. Some pathogens, such as *C. cayetanensis (37)*, hepatitis A *(45)*, and *C. parvum (31)* are moderately or highly resistant to chlorine; therefore, filtering or heating water is a more effective preventive measure against these organisms. Contamination could occur during shipping of produce from farms to distributors or retail stores if trucks previously contaminated by the transport of animals or meat are then used to transport produce without adequate decontamination.

Further processing, such as slicing, shredding, squeezing, and peeling might take place at a distributor, factory, grocery store, restaurant, or consumer's kitchen. During this step, contamination can occur through dirty wash water, by cross-contamination from other food items, or from an infected foodhandler. Food handlers infected with *Cyclospora* are unlikely to contaminate food with this organism because oocyts from freshly excreted stool are not infectious; they require days to weeks in appropriate environmental conditions to become so *(37)*. Amplification of many bacterial pathogens can occur because of time and temperature abuse, such as a lack of refrigeration. These pathogens on produce surfaces can grow more rapidly if the contaminated produce is first chopped, releasing nutrients and water for pathogen growth, and then held at room temperature. In 1999, an investigation of an outbreak of salmonellosis linked to cilantro consumption showed increased growth of *Salmonella* Thompson on chopped cilantro stored at room temperature *(13)* compared with whole cilantro, and this has also has been shown to occur with *Shigella* on other leafy vegetables *(22, 28)*. In contrast to bacteria, viruses such as hepatitis A and parasites such as *C. cayetanensis* and *C. parvum* do not multiply in food or water *(37, 45)*.

To cause disease, pathogens contaminating fruits and vegetables need to survive or reproduce to maintain their minimum infectious dose until consumed by humans. The infectious dose is low for some foodborne pathogens: as few as 800 organisms of *Campylobacter (8)*, fewer than 100 organisms of *Salmonella (9)*, 2 to 45 organisms of *E. coli* O157:H7 *(75)*, nine oocytes of *C. parvum (61)*, and fewer than 100 particles of norovirus virus *(44)* can cause illness. A low pH is inhospitable to the growth or survival of many pathogens; therefore, for many years, foods with pH less than 4.5 were thought to be safe. However, *C. parvum*, *E. coli* O157: H7, and *Salmonella* have caused outbreaks related to consumption of acidic fruit juices *(5, 27, 52)*. One possible explanation is that certain pathogens develop tolerance to acidic environments that might otherwise be unsuitable for survival or growth. The inducible acid tolerance of some organisms under environmental stresses, such as chronic exposure to low pH, results in the expression of acid shock proteins that provide protection to the organism from normally lethal pH levels *(32)*. Laboratory investigations have demonstrated that several serotypes of *Salmonella*, including Hartford and Typhimurium, can survive in orange juice for up to 27 days at pH 3.5 and 60 days at pH 4.1 *(64)*. Refrigeration temperature (4°C) decreases microbial metabolism and therefore reproduction, but lower temperatures might also improve survival of certain organisms exposed to low-pH environments *(47, 53)*. For example, *E. coli* O157: H7 can survive in unpasteurized apple cider at pH less than 4.0 for up to 7 days when stored at room temperature (25°C), but when refrigerated (8°C), it can survive for up to 20 days *(5)*. Because the shelf life of a typical unpasteurized refrigerated juice can vary between 5 and 23 days *(64)*, the consumer could be exposed to a sufficient number of pathogens to cause illness.

Physical barriers such as skin or rind do not necessarily prevent the contamination of produce because bacterial microorganisms from contaminated wash water have been found to enter into fruits and vegetables under certain conditions. For example, when warm produce is immersed in cooler water, a resulting pressure difference between the produce core and the surrounding water allows pathogens in the water to enter the core, generally through the area around the stem *(3, 73)*. Internalization of bacterial pathogens present in processing water has been shown to occur in tomatoes *(83)*, sprouts *(42)*, apples *(12, 32)*, and mangoes *(65)*.

Sprout seeds are a particular challenge *(59)*. Seeds for sprouting are often treated like seeds for agricultural use and therefore might not be afforded any special protection from contamination. Once seeds are contaminated, *Salmonella*, and likely *E. coli* O157:H7, can survive for months under dry storage conditions *(54)*. Because the warm and humid environmental conditions needed for sprouting are also ideal for bacterial growth, these pathogens can amplify 3 to 4 log units during the sprouting process *(42)*. Therefore, even low-level contamination of sprout seeds with

Salmonella can be sufficiently amplified during sprouting to yield an infectious dose *(9)*. Haro-Kudo et al. further demonstrated that when roots of fully developed radish sprouts were immersed in water containing *E. coli* O157:H7, the pathogen was found throughout the edible portion of the sprout, suggesting that water used for sprouting is another source of contamination and that inner tissues of the sprout can become contaminated *(42)*.

Prevention strategies. Preventing contamination of fruits and vegetables is the responsibility of a broad range of government agencies and industries. The U.S. Food and Drug Administration (FDA) has worked with foreign governments and industries that have been implicated in produce-associated outbreak investigations to improve farming and exporting practices for produce. For example, after the raspberry-associated outbreaks of cyclosporiasis in 1996 and 1997, the FDA banned importation of raspberries from Guatemala until farms met minimum standards of water quality, sanitation, and worker hygiene *(37)*. Similarly, following several outbreaks of salmonellosis linked to Mexican cantaloupe between 2000 and 2002, the FDA placed farms implicated in the traceback investigation on detention and conducted sampling surveys of cantaloupe from Mexico that revealed that 5% of 151 cantaloupes sampled were contaminated with *Salmonella*. As a result, since October 2002, the FDA detained whole and precut cantaloupes from Mexico until the grower or producer supplied information demonstrating that their product should be exempt from detention *(25)*. To assist industries in preventing contamination of produce before it reaches the consumer, the FDA and U.S. Department of Agriculture issued the *Guidance for Industry—Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (76)*. This voluntary program is not federally enforceable, although it is adopted by many industries interested in safeguarding their product.

Some food-specific regulatory strategies have also been developed *(7)*. The FDA has adopted a hazard analysis and critical control point (HACCP) safety program to improve the safety of juice products. Following multiple outbreaks of infections with *Salmonella* and *E. coli* O157:H7 linked to orange and apple juice consumption, the juice industry was required to implement a HACCP plan beginning in 2001 *(78)*, which require juice manufacturers to achieve a 100,000-fold (5-log) reduction in the number of harmful pathogens in their finished products compared with levels present in untreated products. However, not all pathogen reduction processes used for juice production provide equal protection. In 1999, 207 cases of *Salmonella* Muenchen infections were reported from 15 U.S. states and two Canadian provinces, and illness was associated with drinking commercially distributed orange juice that had undergone a 5-log reduction process thought to be equivalent to pasteurization *(23)*. In 2000, an outbreak of *Salmonella* Enteritidis infections caused 85 illnesses in 10 states and was associated with drinking unpasteurized, commercial juice that was squeezed after a sanitizer was applied to the skin of the fruit, a process also considered a legitimate 5-log reduction process *(70)*.

The FDA has also developed guidelines for seed sprout producers that include disinfection of seeds with high levels of hypochlorite and testing of spent irrigation water. The most effective treatment available is to soak seeds with 20,000 ppm calcium hypochlorite *(43, 76)*. A chlorine-free alternative for seed disinfection is ionizing radiation, which can kill pathogens in seeds while maintaining seed viability; the FDA recently allowed the use of up to 8 kGy of radiation on sprout seeds for disinfection prior to sprouting (a minimum dose of 5 kGy is required to inactivate *E. coli* O157:H7 and *Salmonella*) *(77)*.

Prevention strategies available to the consumer to prevent illness from produce consumption are limited for produce eaten without cooking. Choosing unblemished produce might reduce the risk of internally contaminated fruit. Particular care to avoid cross-contamination of fresh produce in the kitchen by direct or indirect contact with food such as raw meat or eggs is warranted. Once produce is cut, eating or refrigerating it promptly will prevent amplification of bacterial pathogens. Although washing produce with water can effectively eliminate sand and other debris, it can reduce pathogen load by only 1 or 2 log units and does not eliminate it *(6)*. If contamination is limited to the outer surface of a food, then surface treatments, such as washing and scrubbing might be effective, provided that these treatments do not lead to the contamination of the work space or cut surfaces of the produce itself. Certain produce items, such as cantaloupe and raspberries, however, have surfaces that are complex and difficult to clean, and some pathogens might adhere tightly to the surface of these produce items *(63)*. For certain items, contamination can be internal, and surface treatments are essentially ineffective in reducing pathogen burden *(83)*. To reduce the risk of illness, the FDA recommends that consumers wash produce items in cool tap water immediately before eating, scrub firm produce with a brush, and cut away bruised or damaged areas *(79)*. The use of detergents or soap to clean produce in the home is not recommended. Vaccination might prevent some cases of food-associated hepatitis A, although this preventive measure is routinely recommended only for those at increased risk of hepatitis A infection, such as travelers to endemic countries or men who have sex with men *(24)*. If an outbreak of hepatitis A infections is swiftly detected, those exposed might consider using postexposure prophylaxis with immunoglobulins that is more than 85% effective if treatment is administered within 14 days of exposure *(24)*. Persons at high-risk, such as the elderly, young children, or those who are immunocompromised, might want to avoid uncooked produce items that appear to be particularly risky, such as alfalfa sprouts and unpasteurized juices. The use of ionization radiation on certain produce items has been approved by the FDA and is highly effective in killing some microorganisms in food *(57)*. Further efforts are needed to understand the modes of contamination and how they might be prevented. In combination with good agricultural practices and consumer education, pasteurization of some produce items by irradiation or other methods might be the most comprehensive and safe way to reduce the current health risks in eating uncooked fruits, vegetables, and juices.

This review of surveillance data has several important limitations. The number of outbreaks reported likely underestimates the actual number that occurs. The calculation of the proportion of outbreaks due to produce depends on the choice of denominator; had we excluded outbreaks due to mixed food items from the denominator, the percent would likely be higher. The Foodborne Outbreak Surveillance System is passive and relies on voluntary reporting of outbreaks. In addition, the foodborne outbreak reporting form used during this study period did not allow for thorough reporting on factors that might have contributed to the outbreak or on the quality of information available on which conclusions were made about the food vehicle and the pathogen responsible for an outbreak. Changes were made to the foodborne outbreak reporting forms in 1998 to address these shortcomings. The widespread distribution of produce items with low levels of contamination leads to widely dispersed outbreaks with low attack rates that can be difficult to detect without subtype-based laboratory surveillance such as *Salmonella* serotyping or PulseNet (National Molecular Subtyping Network for Foodborne Disease Surveillance) *(74)*. Some pathogens, such as *Cyclospora,* norovirus, and enterotoxigenic *E. coli* are not routinely tested for in clinical diagnostic laboratories, so illnesses and outbreaks they cause are particularly likely to be missed in passive surveillance systems. At the Minnesota Department of Health, foodborne outbreaks of undetermined etiology have been characterized by clinical syndrome and stool specimens obtained during outbreaks have been tested for the presence of calcivirus by PCR since 1996. Data collected in Minnesota from 1981 through 1998 indicated that among the 75 produce-associated outbreaks reported, 59% had a norovirus-like clinical syndrome or were confirmed in the laboratory as norovirus, suggesting an important role of this pathogen in produce-associated outbreaks for which no etiologic agent was identified in the national survey *(30)*. The long incubation periods of pathogens such as *Cyclospora,* hepatitis A, and *Listeria* complicate investigations that depend on recall of specific food exposures weeks before the onset of illness. In addition, consumer recall of exposures can be poor for inconspicuous ingredients in garnishes or sandwiches, like sprouts or parsley, making these foods difficult to implicate. The short shelf life of produce limits microbiological testing of a suspected item because by the time the outbreak is detected, the product is long gone. In many outbreak investigations, specific points of contamination were not determined or reported through the Foodborne Outbreak Surveillance System; therefore, few of the produce items implicated in these outbreaks were traced back to the farm. As a result, we do not have quantitative information about the proportion related to contamination occurring in the field versus processing plants versus place of final preparation, such as a restaurant or home, although the latter appears to be an important place where produce contamination occurs *(29)*. Nor do we have information about the proportion of outbreaks related to consuming organically versus conventionally grown produce or imported versus domestic produce. Anecdotally, in those outbreaks with documented traceback investigations, both domestic and foreign farms or postharvest processing plants have been implicated.

Foodborne outbreaks associated with fresh produce in the United States have increased in absolute numbers and as a proportion of all reported foodborne outbreaks. Fruit and vegetables are major components of a healthy diet, but eating fresh uncooked produce is not risk free. Further efforts are needed to better understand the complex interactions between microbes and produce and the mechanisms by which contamination occurs from field or orchard to table. The intensive outbreak investigation that includes traceback to the farm of origin and investigation of potential points of contamination is a powerful method for determining such mechanisms. Laboratory and field studies of the behavior of microbes in produce as it is grown, harvested, and processed can offer novel and important insights into potential control strategies. New control measures that prevent or reduce contamination of fresh produce are needed. Continued reporting of foodborne disease outbreaks is critical in assessing the success of current and future prevention strategies.

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