Foodborne outbreaks associated with fresh fruits and vegetables have been increasing in occurrence worldwide. Canada has one of the highest per capita consumption rates of fresh fruits and vegetables in the world. In this article, we review the foodborne disease outbreaks linked to produce consumption in Canada from 2001 through 2009. The 27 produce-related outbreaks included an estimated 1,549 cases of illness. Bacterial infection outbreaks represented 66% of the total. Among these, *Salmonella* was the most frequent agent (50% of outbreaks) followed by *Escherichia coli* (33%) and *Shigella* (17%). *Cyclospora cayetanensis* was the only parasite detected and was associated with seven outbreaks. Among the foodborne viruses, only hepatitis A was implicated in two outbreaks. The food vehicles most commonly implicated in outbreaks were leafy greens and herbs (26% of outbreaks), followed by seed sprouts (11%). Contamination sources and issues related to the future control of fresh produce–related foodborne disease outbreaks also are discussed.

A wide variety of fresh fruits and vegetables are currently available on the Canadian market. Today’s consumer is exposed to more kinds of fresh produce than might have been available a few decades ago. One of the best known education tools designed to help people follow a healthy diet is Canada’s Food Guide (26), which recommends eating 4 to 10 servings of fruits and vegetables per day. The healthy eating campaigns appear to be having some impact; Canadians now consume an average of 6 to 7 servings of fruits and vegetables per day compared with 3.6 servings per day consumed in the United States (6).

Canada has one of the highest per capita consumption rates for fresh fruits and vegetables in the world (62), and the consumption of fresh produce has been steadily rising since the 1990s. In 2007, Canadians consumed 10.9% more vegetables than they did 20 years before, and there is a trend of increased consumption of a greater variety of vegetables. Canadians also reached a new record for consumption of fresh fruit at 38.2 kg per person, representing a 16.5% increase over 20 years (54). To meet demand, the Canadian greenhouse industry has been growing steadily over the past few decades, with greenhouse vegetable production reaching $1.2 billion in sales in 2006 (39). To supply produce during the winter months and throughout the year, Canada imports approximately 86% of the fruit and 41% of the vegetables consumed by the population (53).

Because of the convenience of prewashed ready-to-eat (RTE) fresh fruits and vegetables, fresh-cut produce has become a mainstay in many Canadian households. Convenience, however, has a price: cutting, slicing, peeling, and shredding can remove or damage the protective surface of the plant or fruit and could allow microbiological contamination and growth. Exposure of vegetable surfaces by cutting can increase microbial levels six- to sevenfold (19), and prewashing can spread microbiological contamination to other surfaces of the product (19).

In Canada, food safety is a responsibility shared at all levels of government. Health Canada establishes policies, sets standards, and provides advice and information on the safety and nutritional value of food. The Canadian Food Inspection Agency (CFIA) provides federal inspection services related to food and enforces the food safety and nutritional quality standards established by Health Canada (11, 27).

The following is a review of produce-related foodborne disease outbreaks that occurred in Canada from 2001 through 2009. The data were gathered from outbreak surveillance conducted by federal and provincial departments and from a literature review of published and internal reports. An outbreak was defined as two or more individuals from different households whose illness was associated with the consumption of produce. Produce vehicles were implicated by laboratory evidence and/or results of epidemiological investigation when laboratory data were unavailable (often due to short shelf life of suspect produce). This review is meant to expand on the information
<table>
<thead>
<tr>
<th>Time frame</th>
<th>Organism</th>
<th>Vehicle</th>
<th>Province</th>
<th>Venue</th>
<th>No. of ill persons</th>
<th>Additional outbreak information</th>
<th>Possible corrective action</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 May</td>
<td><em>Cyclospora</em> cayetanensis</td>
<td>Basil (imported from Thailand)</td>
<td>BC</td>
<td>Various</td>
<td>17</td>
<td>Case study: 11 of 12 affected persons reported eating Thai basil. Traceback identified two suppliers, from a single U.S. state.</td>
<td>Source could not be confirmed due to long incubation period and short shelf life of produce.</td>
<td>29</td>
</tr>
<tr>
<td>2001 May–July</td>
<td><em>Shigella sonnei</em></td>
<td>Spinach</td>
<td>BC</td>
<td>Various</td>
<td>31</td>
<td>CFIA announced a recall of any spinach purchased from the supplier since 1 May 2001. Consumers were advised to discard any spinach originating from this producer.</td>
<td></td>
<td>3, 42</td>
</tr>
<tr>
<td>2001 Feb.–Mar.</td>
<td><em>Salmonella</em> Enteritidis PT913</td>
<td>Mung bean sprouts (suspect)</td>
<td>AB, BC, SK</td>
<td>Various</td>
<td>84</td>
<td>First known occurrence of <em>Salmonella</em> Enteritidis PT913 infection in humans.</td>
<td>CFIA conducted an on-site evaluation of mung bean sprout manufacturing practices and collected 40 food and environmental samples; all produced negative results. A case-control study was performed. Bean sprout samples from this facility analyzed before the outbreak were free of common enteric pathogens, but had elevated levels of coliforms. Source not confirmed.</td>
<td>41</td>
</tr>
<tr>
<td>2002 Oct.</td>
<td><em>Salmonella</em> Newport</td>
<td>Fruit (fruit trays)</td>
<td>ON</td>
<td>Private party</td>
<td>34</td>
<td>Birthday party with purchased fruit trays.</td>
<td>The store voluntarily withdrew the product from the shelves. The action followed an investigation into a number of cases of salmonellosis in the area, all traced back to the fruit packages sold.</td>
<td>44, 47</td>
</tr>
<tr>
<td>2002 Oct.–Nov.</td>
<td><em>E. coli</em> O157:H7</td>
<td>Salad and/or sandwiches</td>
<td>PEI</td>
<td>Long-term care facility</td>
<td>17 (2 deaths)</td>
<td>Irregularities that might have led to cross-contamination or allowed microbes to grow were noted. Kitchen workers and/or improper sanitation techniques may have led to contamination.</td>
<td>Government inspection services found no significant problems in the hospital kitchen. Report included statement that adoption of HACCP systems would reduce the number of irregularities that might lead to contamination.</td>
<td>46</td>
</tr>
<tr>
<td>2002 May</td>
<td><em>S. sonnei</em></td>
<td>Greek pasta salad</td>
<td>ON</td>
<td>Grocery store</td>
<td>Estimated 700+</td>
<td>95% of affected persons recalled eating the specific pasta salad.</td>
<td>An infected produce worker in a grocery store triggered a postexposure prophylaxis vaccination campaign for 19,000 potentially exposed residents.</td>
<td>43</td>
</tr>
<tr>
<td>2002 Aug.</td>
<td>Hepatitis A</td>
<td>Multiple produce</td>
<td>ON</td>
<td>Grocery store</td>
<td>3</td>
<td></td>
<td>The importer voluntarily recalled the implicated Mexican cantaloupe, and the FDA placed the implicated farms on detention. On 28 October 2002, the FDA issued an import alert on cantaloupe from Mexico, detaining all products from entering at all U.S. ports.</td>
<td>13</td>
</tr>
<tr>
<td>2002 Mar.–May</td>
<td><em>Salmonella</em> Poona</td>
<td>Cantaloupe</td>
<td>ON</td>
<td>Various</td>
<td>2</td>
<td>Strains identified in the United States had a PFGE pattern indistinguishable from that of the strain identified in Ontario.</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>2003 July</td>
<td><em>C. cayetanensis</em></td>
<td>Cilantro (suspect)</td>
<td>BC</td>
<td>Community</td>
<td>11</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Time frame</td>
<td>Organism</td>
<td>Vehicle</td>
<td>Province</td>
<td>Venue</td>
<td>No. of ill persons</td>
<td>Additional outbreak information</td>
<td>Possible corrective action</td>
<td>Reference(s)</td>
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<tr>
<td>2004</td>
<td><em>C. cayetanensis</em></td>
<td>Mango or basil (suspect)</td>
<td>BC</td>
<td>Community</td>
<td>17 (9 lab confirmed)</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2004 May–June</td>
<td><em>C. cayetanensis</em></td>
<td>Cilantro (suspect)</td>
<td>BC</td>
<td>Community</td>
<td>8</td>
<td>Suspected, but not confirmed.</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td><em>Salmonella Brandenberg</em></td>
<td>Cucumber</td>
<td>BC</td>
<td>Community</td>
<td>12</td>
<td>Farm as the source.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2004 July</td>
<td><em>Salmonella Javiana</em></td>
<td>Roma tomatoes (suspect)</td>
<td>ON</td>
<td>Restaurant</td>
<td>7</td>
<td>The median age of ill persons was 28 yr (range: 23–36 yr). No deaths, but 14% of ill persons were hospitalized, and all ate at the same restaurant.</td>
<td>14, 48</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td><em>Salmonella Enteritidis PT33</em></td>
<td>Mung bean sprouts</td>
<td>AB</td>
<td>Restaurant</td>
<td>8</td>
<td>Vietnamese restaurants linked to three growers.</td>
<td>40, 49</td>
<td></td>
</tr>
<tr>
<td>2005 May–June</td>
<td>Hepatitis A</td>
<td>RTE leafy greens (suspect)</td>
<td>ON</td>
<td>Restaurant</td>
<td>16</td>
<td>Infected food handler preparing RTE foods, including salad.</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>2005 July</td>
<td><em>C. cayetanensis</em></td>
<td>Basil</td>
<td>QC</td>
<td>Restaurant</td>
<td>200</td>
<td>Individuals became sick after eating a cold plate appetizer containing vinaigrette made with basil.</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>2005 Apr.</td>
<td><em>C. cayetanensis</em></td>
<td>Basil (suspect)</td>
<td>ON</td>
<td>Catered event</td>
<td>44 (16 lab confirmed)</td>
<td>People were exposed at a retreat. Food in common was pasta salad. <em>C. cayetanensis</em> from the environment or a food handler was the likely source of contamination. Because basil has been linked to previous outbreaks of cyclosporiasis, this ingredient in the pasta salad was under greater suspicion as the source of this outbreak.</td>
<td>40, 49</td>
<td></td>
</tr>
<tr>
<td>2006 June–July</td>
<td><em>C. cayetanensis</em></td>
<td>Basil or garlic</td>
<td>BC</td>
<td>Community</td>
<td>28</td>
<td>Inspection of the Canadian plant revealed that it was HACCP compliant. Contamination likely occurred at the plant or earlier in the distribution chain, such as on the farm.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2006 June–Dec.</td>
<td><em>Salmonella Oranienburg</em></td>
<td>Fruit salad</td>
<td>ON</td>
<td>Health care facility</td>
<td>2</td>
<td>Salad produced by one processing plant, but the source was not confirmed. One cluster initially identified; another cluster later identified. PFGE pattern not unique.</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Time frame</td>
<td>Organism</td>
<td>Vehicle</td>
<td>Province(^a)</td>
<td>Venue</td>
<td>No. of ill persons</td>
<td>Additional outbreak information</td>
<td>Possible corrective action</td>
<td>Reference(s)</td>
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</tr>
<tr>
<td>2006 Aug.–Sep.</td>
<td><em>E. coli</em></td>
<td>Spinach</td>
<td>ON</td>
<td></td>
<td>1</td>
<td>Strain from bagged spinach purchased in Canada matched the outbreak strain in the United States (204 cases).</td>
<td>Large spinach recall. The traceback investigation narrowed potential sources to four fields on four ranches. The outbreak <em>E. coli</em> O157:H7 strain from cattle feces was identified on one ranch in California. <em>E. coli</em> indistinguishable from the outbreak strain was found in river water, cattle feces, and wild pig feces on the ranch within 1 mi (1.6 km) of the spinach fields.</td>
<td>30, 63</td>
</tr>
<tr>
<td>2006 Sep.</td>
<td><em>E. coli</em></td>
<td>Lettuce (suspect)</td>
<td>ON</td>
<td></td>
<td>7</td>
<td>Strain PFGE pattern indistinguishable among cases.</td>
<td>Restaurant-associated outbreak; lettuce suspected.</td>
<td>50</td>
</tr>
<tr>
<td>2007 Aug.</td>
<td><em>S. somet</em></td>
<td>Carrots</td>
<td>AB</td>
<td>Grocery store</td>
<td>4</td>
<td></td>
<td>Costco issued a voluntary recall.</td>
<td>7</td>
</tr>
<tr>
<td>2008 Jan.–Apr.</td>
<td><em>Salmonella</em></td>
<td>Cantaloupe</td>
<td>BC, AB, MB, ON, NB</td>
<td></td>
<td>9</td>
<td>Grown and packaged in Honduras and distributed through various stores.</td>
<td>FDA collaborated with Honduran government officials and the company to investigate the source of contamination.</td>
<td>16</td>
</tr>
<tr>
<td>2008 Oct.–Nov.</td>
<td><em>E. coli</em></td>
<td>Lettuce (romaine)</td>
<td>ON</td>
<td>Restaurants (cases in 5 health units)</td>
<td>29</td>
<td>Source not confirmed.</td>
<td>Restaurant was closed and later reopened after food and environmental samples were negative. Leftover food was discarded, and the facility was sanitized. Staff received food handler training from the health unit and were screened for bacteria. The health unit also increased surveillance.</td>
<td>36, 37</td>
</tr>
<tr>
<td>2008 Oct.–Nov.</td>
<td><em>E. coli</em></td>
<td>Spanish onions (suspect)</td>
<td>ON</td>
<td>Restaurant</td>
<td>235</td>
<td>Analytical epidemiological study implicated onions.</td>
<td>Restaurant was closed and later reopened after food and environmental samples were negative. Leftover food was discarded, and the facility was sanitized. Staff received food handler training from the health unit and were screened for bacteria. The health unit also increased surveillance.</td>
<td>36, 37</td>
</tr>
<tr>
<td>2008 Oct.</td>
<td><em>E. coli</em></td>
<td>Iceberg lettuce</td>
<td>ON</td>
<td>Restaurant (jail)</td>
<td>3</td>
<td>Traceback implicated iceberg lettuce from California.</td>
<td>Lettuce from the outbreak was not available for testing because of its perishable nature. Company tested each lot after the outbreak for 30 days. The outbreak in the United States resulted in 47 cases of illness.</td>
<td>9, 35, 40</td>
</tr>
<tr>
<td>2009 July</td>
<td><em>Salmonella</em></td>
<td>Onion sprouts</td>
<td>AB, BC, NS, ON</td>
<td></td>
<td>20</td>
<td>3 PFGE patterns, very similar to one another, were reported.</td>
<td>Outbreak strain was isolated from onion sprout, spent water, interim product, seed, and finished product from an Ontario plant. Contaminated seeds were also found in the Alberta processing plant.</td>
<td>40</td>
</tr>
</tbody>
</table>

\(^a\) BC, British Columbia; AB, Alberta; SK, Saskatchewan; ON, Ontario; PEI, Prince Edward Island; QC, Quebec; MB, Manitoba; NB, New Brunswick; NS, Nova Scotia.

\(^b\) CFIA, Canadian Food Inspection Agency.

\(^c\) HACCP, hazard analysis critical control point.

\(^d\) PFGE, pulsed-field gel electrophoresis.

\(^e\) FDA, U.S. Food and Drug Administration.

\(^f\) MAPAQ, Quebec Department of Agriculture, Fisheries and Food.
An expanded investigation was previously presented in the 2001 article by Sewell and Farber (52), who described foodborne outbreaks up to 2001. Produce-related outbreaks are very prevalent. The U.S. Centers for Disease Control and Prevention (CDC) (17) indicated that in 2007 (the most recent data available) produce was responsible for 53 outbreaks with 1,106 cases of illness in the United States, second only to the 54 meat-associated outbreaks. For a summary of Canadian produce outbreaks between 2001 and 2009, see Table 1 and Figure 1.

BACTERIAL PATHOGENS: SALMONELLA

Although Salmonella infections are often associated with poultry, recent outbreak surveillance data from the CDC (14) indicate that this bacterial pathogen is the agent most commonly associated with produce-related foodborne outbreaks in the United States. According to the data gathered in Canada from 2001 through 2009, Salmonella was also the pathogen most frequently associated with foodborne illness linked to produce consumption.

In February and March 2001, Salmonella Enteritidis suspected of being associated with mung bean sprouts sickened 84 individuals, of which 6 required hospitalization (41). Phage type 913 was involved; this phage type had not been previously identified in human infections in Canada. The mung bean sprouts were grown in Canada, and the seeds traced to a grower in China with a distributor in the United States. During the outbreak investigation, samples obtained from a single production facility in Alberta were free of common enteric pathogens but had elevated levels of fecal coliforms. Although no gastrointestinal illness was reported among workers, the investigation revealed that plant employees were not disinfecting mung sprouting beans as per the label instructions. It was not clear when the sprouts were contaminated, and it was difficult to determine whether the failure of the sprout grower to chlorinate sprouts contributed to the outbreak. Other possible sources of contamination could have included contaminated seeds, cross-contamination within the sprout production facility, or Salmonella-infected workers (41).

In 2005, another outbreak involving mung bean sprouts occurred in several restaurants in Alberta, resulting in eight cases of salmonellosis (49). The source of the sprout contamination was never identified. An additional sprout-related outbreak occurred in 2009, when Salmonella Cubana was associated with 20 cases of illness in four provinces; the suspect product vehicle was onion sprouts (40).

In September 2002, individuals became ill with salmonellosis after attending two separate parties in Ontario. Epidemiological analysis implicated fruit trays containing cantaloupe, watermelon, blueberries, pineapple, and kiwi (44). In the same year, Salmonella Poona, a serovar seldom isolated from humans, caused two cases of illness in individuals who had consumed contaminated cantaloupes in Ontario (13). The cantaloupes originated from Mexico and were also distributed in the United States, where their consumption resulted in 56 cases of illness and 10 hospitalizations (13). The importer voluntarily recalled the implicated cantaloupe, and the U.S. Food and Drug Administration (FDA) placed the implicated farms on detention. The Salmonella strain involved in this outbreak was indistinguishable by pulsed-field gel electrophoresis (PFGE) from the strain that caused the cantaloupe outbreak in 2000 (13). Although a definite cause of the outbreak was not identified, possible sources of Salmonella included sewage-contaminated water used for irrigation or processing (cleaning and cooling), poor hygienic practices of workers during harvest and processing, pests in packing facilities, and/or inadequate cleaning and sanitizing of equipment (13).

Cantaloupes imported from Honduras were implicated in a 2008 Salmonella Litchfield infection outbreak in Canada. The Canadian and U.S. authorities received reports of 9 cases of illnesses in 5 Canadian provinces and 51 cases of illnesses in 16 U.S. states (16). This Canadian outbreak was linked to that caused by the same organism in the United States (16).

In July 2004, seven cases of salmonellosis due to Salmonella Javiana (all strains with indistinguishable PFGE patterns) occurred in Ontario, all linked to the same restaurant (14). Roma tomatoes were the suspected outbreak vehicle because they were the only common food among all patients (14). Also in 2004, 12 cases of infection with Salmonella Brandenburg, a relatively rare serotype, were investigated in British Columbia, and an epidemiological link to locally grown fresh cucumbers was found (4).

In 2006, a Salmonella Oranienburg infection outbreak resulted in 39 cases of illness in the United States and two cases in Canada (15). The outbreak was associated with fruit salad served in health care facilities in the northeastern United States and in Ontario. The outbreak was identified when U.S. public health laboratories in Massachusetts and New Hampshire subtyped Salmonella Oranienburg isolates by PFGE and submitted their results to PulseNet, the U.S. national molecular subtyping network for foodborne infection surveillance. This allowed identification of matched isolates from different sources and identification of case clusters (15). An expanded investigation was launched by other state health departments, who soon...
confirmed a widespread outbreak. A total of 13 health care facilities had case patients; 10 of these facilities served refrigerated, precut cantaloupe and honeydew melon purchased from the same processing plant in Canada (15). During this time, only 2 of the 13 health care facilities recognized that an outbreak was occurring, probably because most facilities had identified only one or two ill persons (15). The CFIA inspections of the processing plant did not identify any improper practices, and inspectors determined that the plant was in compliance with its hazard analysis and critical control point plan (15). The original source of the cantaloupe and honeydew melons processed in the facility indicated that the melons likely originated from the United States; however, no specific farm was identified (15).

**BACTERIAL PATHOGENS:**
**ESCHERICHIA COLI O157**

Although most cases of illness attributed to *E. coli* O157:H7 infection have traditionally been associated with products of bovine origin, such as ground beef, produce is now recognized as a source of this pathogen (1). During the time period examined (2001 through 2009), six foodborne gastrointestinal disease outbreaks in Canada were associated with *E. coli* O157:H7 and produce.

In 2002, 81 possible cases, 11 probable cases, and 17 confirmed cases of *E. coli* O157:H7 infection were identified among the staff and patients of six health care facilities on Prince Edward Island (46). Of these, 20 ill persons presented with hemorrhagic colitis, 4 were hospitalized, and 2 died. During this outbreak, most cases occurred in young healthy adults who did not possess particular health risk factors or medical complications. Fresh vegetables were used in the preparation of salads and sandwiches and served to staff and residents. The case-control study revealed that the outbreak cases were 10.4 times more likely than controls to have eaten or prepared the salads (95% confidence interval [CI]: 1.2 to 91.3), and the risk of disease was 5.8 times greater for persons who had prepared or eaten the sandwiches (95% CI: 1.2 to 29.4) (46). All stool isolates of *E. coli* were of phage type 32 and had the same PFGE profile (46). This outbreak was the first time that this *E. coli* PFGE pattern had been identified in Canada. During the investigation, a few irregularities that might have led to cross-contamination or allowed microbial growth were observed. For example, the person responsible for preparing the vegetables continued to work despite having taken two 10-day treatments of antibiotics for diarrhea (46). Sick kitchen workers and improper sanitation techniques may have led to contamination of the produce, resulting in the outbreak.

*E. coli* O157:H7 was once again implicated in a 2006 bagged spinach outbreak in Canada and the United States. Although most of the 204 cases and three deaths occurred in the United States, one case occurred in Canada (30, 63). The source of the outbreak was likely a small cattle ranch in California within 1 mi (1.6 km) of the spinach fields. On this ranch, *E. coli* O157:H7 isolates indistinguishable from the outbreak strain were found in local river water, cattle feces, and wild pig feces. Although a definite conclusion concerning how the spinach became contaminated could not be reached, the investigation revealed risk factors associated with livestock and wild animals living in close proximity to agricultural production (30, 63, 66).

From 2001 through 2009, three *E. coli* O157 infection outbreaks were associated with contaminated lettuce. In 2006, a restaurant-associated outbreak in Ontario resulted in seven confirmed cases of illness, and the presumed causative organisms had indistinguishable PFGE patterns (50). Lettuce was considered a likely source of the outbreak. In 2008, romaine lettuce was the suspected vehicle of *E. coli* O157:H7 infection that resulted in 38 probable and 29 confirmed cases in Ontario (38). Shredded iceberg lettuce was suspected in three *E. coli* O157 illnesses in Ontario that same year (9, 40). The PFGE pattern for the Canadian cases matched that of an *E. coli* O157 strain in the United States that had caused 38 illnesses and resulted in 21 hospitalizations. The lettuce was from California and was sent to a separate company for washing, cutting, and bagging. The source of the lettuce contamination was not determined for either of these outbreaks.

In fall 2008, an *E. coli* O157:H7 infection outbreak involving 235 people was linked to an Ontario restaurant. Approximately 40% of the affected persons reported bloody diarrhea, and 11% were hospitalized; one infected child developed hemolytic uremic syndrome (36, 37). Although the initial source of the outbreak was not identified, the risk of exposure from that site persisted for about 1 week, and the restaurant was closed to prevent further spread of infection. A total of 80 samples of beef from different lots produced on different dates were sampled, and all were negative for *E. coli* O157 (36, 37). The epidemiological investigation and the results of the case-control study indicated that Spanish onions were likely the vehicle of transmission. Improper cleaning of the onion dicer may have propagated the outbreak (37). One of the onion shipments that arrived at the restaurant before the outbreak came from a source other than the usual supplier. Although no other restaurants that had received lots as part of this shipment reported cases of illness, the contamination may have been localized in certain areas of the field or present only in certain bags of onions (36, 37). The on-farm investigation by the CFIA did not find any evidence of environmental contamination. None of the onions from the time of the outbreak were available for sampling, so the source of the contamination could not be definitely determined (36, 37).

**BACTERIAL PATHOGENS:** **SHIGELLA**

In May and June 2001, an outbreak of *Shigella sonnei* infection involving 31 cases occurred in British Columbia. The food vehicle was identified as spinach, which was distributed across British Columbia and Alberta (3, 42). Upon investigation, the CFIA recalled all spinach purchased from the supplier since 1 May 2001. Follow-up inspections revealed that before packaging, the raw spinach had been
washed with irrigation water obtained from a ditch on the property. Shigella was not detected in either the ditch water or the spinach, but E. coli was found, suggesting contamination by sewage from a septic system (3, 5).

Between 11 and 24 May 2002, S. sonnei–contaminated Greek-style pasta salad containing vegetables was the cause of a major foodborne outbreak, with over 700 confirmed and presumptive cases among Ontario residents (47). A total of 426 isolates were characterized, and all had the same PFGE pattern. Further investigation revealed that over 95% of the ill persons reported eating one specific brand of pasta salad, but the specific cause of the outbreak was not confirmed (42, 48). A voluntary recall of the salad was initiated by the company (47).

In August 2007, the CFIA recalled mini-carrots from a U.S. company over concerns that the product was contaminated with Shigella (7). Four confirmed infections were reported in Alberta and British Columbia, all suspected to be associated with these mini-carrots.

**PROTOZOAN PARASITES: CYCLOSPORA**

Before 1996, cyclosporiasis had been reported only rarely in North America. During that time, most cases were associated with international travel. Cyclosporiasis was not listed as a nationally notifiable disease in Canada until 2000. However, the number of Cyclospora-associated outbreaks has been steadily increasing. This parasite was once thought to be limited to travelers or natives from Cyclospora-endemic areas such as South and Central America, Southeast Asia, the Caribbean, and parts of Eastern Europe (29). Recent foodborne cyclosporiasis outbreaks in North America have changed this perception.

In May 2001, 17 cases of cyclosporiasis in people with no travel history were reported to the British Columbia Centre for Disease Control (BCCDC). Of these 17 people, 12 enrolled in a case-control study (29). Researchers found that 11 of the 12 had been exposed to Thai basil consumed either at a restaurant or at home. This was the first reported outbreak of foodborne cyclosporiasis involving Thai basil. The implicated Thai basil (botanical subtype) had been imported from two distributors in the United States and had been grown within a single state. Further information was not available from the grower; consequently, the precise identity and number of sources of contamination could not be determined (29). Although the specific cause of this outbreak was not confirmed, the suspected source of contamination based on an examination of previous outbreaks was the spread of sporulated oocysts with contaminated irrigation water or during spraying with pesticides (29).

In 2003, cilantro was suspected in a Cyclospora outbreak that sickened 11 people (3). This outbreak was followed by another in 2004 that resulted in eight cases of illness; cilantro was again suspected (48). In general, cilantro may be more exposed to microbial contamination, with total coliform levels increasing during the packaging process (32).

From 2004 to 2006, three major outbreaks of cyclosporiasis occurred in which basil was suspected. In 2004, Cyclospora cayetanensis linked to either mangoes or basil caused 17 (9 laboratory confirmed) cases of illness in British Columbia (3). In one outbreak in 2005, 44 illnesses were attributed to menu items containing fresh basil that had been consumed at a catered retreat in Ontario (49). In June 2005, a larger cyclosporiasis outbreak occurred in Quebec, with an estimated 200 illnesses reported among patrons of a restaurant; basil was suspected (49). In British Columbia in 2006, a Cyclospora infection outbreak with 28 cases was linked epidemiologically to basil or garlic consumption (3).

**FOODBORNE VIRUSES: HEPATITIS A**

From 2001 through 2009, Canada experienced two small hepatitis A outbreaks. In August 2002, Toronto Public Health identified a case of hepatitis A in a food handler who worked in the produce section of a supermarket and was responsible for stocking a number of different produce items (45, 60). The preparation and consumption of these vegetables by consumers exposed them to hepatitis A and resulted in three cases of illness. To contain a possible outbreak situation, the grocery store involved triggered a postexposure prophylaxis vaccination campaign for over 19,000 potentially exposed customers (60).

In 2005, a symptomatic laboratory-confirmed case of acute hepatitis A was reported to health authorities (28). The patient worked as a food handler in a restaurant preparing RTE foods, including leafy greens. In total, 16 laboratory-confirmed cases of hepatitis A were reported among patrons who consumed food at this restaurant.

**DISCUSSION**

An estimated 11 million episodes of foodborne disease occur annually in Canada. For every case of enteric illness reported, 313 to 347 cases go unreported (56). A large socioeconomic cost is associated with acute gastrointestinal illness, e.g., missed paid employment by individuals and their caretakers and the cost of paid sick days associated with sick leave (56). Enteric illnesses are underreported because many patients experiencing only mild illness or discomfort do not visit a primary health care provider, and when they do, stool samples often are not obtained (34). Physicians are less likely to request stool samples from patients with symptoms such as nausea and chills than they are from patients experiencing vomiting (34). Even in cases in which a stool sample is provided, tests for the less commonly known pathogens are not routinely conducted, thus repeating the cycle of underreporting and possibly skewing the reported prevalence of various pathogens in Canada (20). Enteric illness due to contaminated produce can be very difficult to confirm. The short shelf life and rapid distribution of produce makes traceback to the grower challenging. Even when a grower is identified, the harvest is often complete and produce from the relevant time frame is unavailable for testing.

As a result of the continuous demand for produce, Canada must import many of its fruits and vegetables year-round. At least eight of the foods implicated in produce-associated outbreaks from 2001 through 2009 were products...
imported into Canada. As global markets expand, so does the potential of foodborne illness; consequently, extra vigilance is required. Many Canadian producers follow strict produce growing practices and standards; however, information on food safety practices in exporting countries is not always available.

Produce can become contaminated at any point in the farm-to-fork continuum. Because of changes in processing, more precutting and coring of produce may occur in the field during harvest, potentially increasing the probability for contamination (52). As farms become larger, produce fields may be located next to animal production, such as with the *Salmonella* Enteritidis outbreak in mung bean sprouts, where the production facility was located next to a poultry farm, or the *E. coli* spinach outbreak, where wildlife had access to the fields thus bringing wild animals, livestock, and produce closer together. Pathogenic microorganisms present on produce also can originate in the soil in which the food is grown and can be present in fertilizer or untreated sewage.

A survey conducted in an area of British Columbia after the 2001 *S. sonnei* infection outbreak revealed that the water used for irrigation of RTE produce has been impacted to varying degrees by non–point source pollution (5, 51). The *Shigella* infection outbreak in 2001 was traced to a single farm that had been inspected by public health inspectors to examine the potable water, sewage, and disposal systems after the outbreak (51). The study also revealed instances in which cattle and other domestic animals had access to irrigation water, and contamination of the watershed with fecal matter had occurred. A malfunction in the sewage disposal had caused effluent to leach into a ditch containing water used both for irrigation and occasionally for washing produce, including spinach, before shipment (51).

Many of the outbreaks reported in this review (2001 through 2009) occurred as a result of postharvest contamination during transport, sorting, storage, packing, and cutting and further processing of produce. Fresh-cut produce releases juices that can facilitate the spread of bacteria. The risks presented by RTE fresh-cut produce were recently noted by the FDA and formed the basis for the requirement recommending that cut tomatoes be added to the list of potentially hazardous foods (64).

Postharvest contamination associated with outbreaks, such as the 2002 hepatitis A outbreak in a Toronto grocery store, often is caused by an infected food handler. For this Toronto outbreak, the total direct cost to public health for vaccination was only $35 per person; this number included people who were immunized in a Public Education Program campaign to reach approximately 19,000 potentially exposed individuals (60). Depending on the particular case, Public Education Program interventions triggered by a single infected food handler could be more costly to public health than control of a peak outbreak (60). Worker-related outbreaks have been implicated in a number of incidents involving venues such as food service facilities, catered events, homes, schools, daycare centers, and health care institutions. Contamination most frequently occurs via the fecal-oral route but also can occur through exposure to vomit and skin infections (59). The factors most often associated with illnesses were bare hand contact, failure to properly wash hands, inadequate cleaning of utensils and equipment for food preparation, cross-contamination from raw ingredients, and temperature abuse (57). Other risk factors involved have been workers who were (i) asymptomatic shedders, (ii) caregivers of infected family members, or (iii) individuals who did not use proper hygienic conditions when working (57). Food workers sometimes continue to work in spite of illness or may not seek physician care when symptoms are mild or absent (58).

Parasite-related outbreaks in Canada were less common during the 2001 through 2009 reporting period compared with the previous decade (52). *Cyclospora* was implicated in five outbreaks in Canada from 2001 through 2009; these outbreaks were associated with contaminated cilantro, basil, and possibly garlic. In two of the outbreaks involving basil, the product originated from developing countries.

Cyclosporiasis is especially difficult to diagnose, particularly in countries where it is endemic. Generally, awareness of this disease is poor both in primary care practices and testing laboratories. In Canada, improved laboratory detection and disease surveillance in recent years have helped greatly in tracking outbreaks of both waterborne and foodborne cyclosporiasis (18).

The future success of worldwide efforts to prevent produce-related outbreaks depends on understanding the key contributing factors and maintaining best practices to reduce and eliminate contamination. The quality of the water used for both irrigating produce and washing it after harvest is paramount for preserving hygiene in farming operations. Testing and preventive measures are essential to ensure that water sources are pathogen free. The use of untreated manure as a fertilizer (including human, livestock, and animal waste) on farms can lead to produce contamination when the manure is not treated properly (8). Pathogens such as *E. coli* O157:H7 can survive in bovine feces for up to 18 weeks (21). Where feasible and practical, particular care should be taken to ensure that fresh raw manure and human waste do not come into contact with the crop plants and that livestock and wildlife are prevented from accessing fields.

To control bacterial growth, fresh-cut produce should be stored in the refrigerator or should be refrigerated within 2 h of purchase. Food handlers should be educated about the hygienic conditions under which produce should be handled. Workers should not handle produce when sick, and all personnel should thoroughly wash their hands after using the restroom.

This review covers 27 produce-related outbreaks over a 9-year period, with an estimated 1,549 cases of illness. A previous review (52) included 18 outbreaks, with an estimated 1,648 cases of illness, over a 20-year period. Of the outbreaks for which the month was recorded, 54% occurred in late spring and summer. The relative increase in outbreaks and number of cases in this review may be due to better detection methods that were not previously available, including molecular detection methods such as PFGE.
which can link an outbreak food to cases of illness. Previously obscure pathogens such as *Cyclospora*, which was not found in Canada before 1996, are now regularly isolated through the use of newly developed and less labor-intensive methods (33).

Some pathogens that were addressed in the 2001 review (52), such as *Listeria monocytogenes*, were not associated with any produce-related outbreaks in Canada from 2001 through 2009. Other pathogens continue to be of concern, such as *Salmonella* associated with cantaloupe and other melons. In some of these cases, the source of contamination was not identified, but in the outbreaks previously reported by Sewell and Farber (52), contaminated melon pieces were left at room temperature too long, allowing the pathogen to multiply. *Salmonella Oranienburg* was associated with fruit salad eaten in health care facilities in the United States and Canada. Although *Salmonella Oranienburg* was not identified in any of the fruit salad samples collected, the samples were obtained several weeks after illness onset in case patients (15).

Cantaloupes can become cross-contaminated after harvesting (22). One of the postharvest steps involves immersion of the cantaloupes in a water tank for washing. Water can be contaminated by a single contaminated melon, and the pathogen can spread to all melons that are subsequently washed in the same water (23). In general, the contamination of cantaloupes is relatively common. In the United States, 3.3% of cantaloupes in one study were contaminated with *Salmonella Montevideo* (32), an FDA domestic produce survey revealed that 3.0% of cantaloupes were positive for *Salmonella* (61), and other contamination rates also have been reported (12).

Viruses were not implicated in any foodborne outbreaks in the 2001 review, but hepatitis A virus caused two outbreaks during the 2001 through 2009 reporting period. The fact that only one foodborne virus was directly implicated in a foodborne outbreak was somewhat surprising, given the improvements in methodology and heightened awareness in the medical community about the role of viruses in foodborne infections. In the United States, the proportion of confirmed foodborne norovirus outbreaks increased from 1% in 1991 to 12% in 2000. The outbreaks were associated with sandwiches, produce, or salads in 56% of cases in which a source was identified (67).

Sewell and Farber (52) also reviewed five outbreaks involving alfalfa sprouts in which various serotypes of *Salmonella* were implicated. During the 2001 through 2009 current review period, only two sprout-related outbreaks involving mung bean sprouts contaminated with *Salmonella Enteritidis* PT913 were reported. The lack of outbreaks associated with alfalfa sprouts in recent years could be due to increased public awareness that alfalfa sprouts can serve as a vehicle for contamination. The Canadian government also has created sprout initiatives, including Health Canada’s policy on sprouted seeds and beans and the CFIA Code of Practice for the hygienic production of sprouted seeds in Canada, a voluntary guideline for good manufacturing practices (8, 25). Health Canada also has provided recommendations for testing irrigation water and sprouts for pathogens and created educational material for consumers (25, 27). Seed contamination can occur in the field or during harvesting, storage, or transportation. The germination process during sprout production involves keeping seeds at warm temperatures and moist conditions for 4 to 7 days, conditions under which even low levels of microbial contaminants can grow quickly and become a significant risk (8). Mung bean seeds can become contaminated on the farm when grown in fields fertilized with untreated manure. Mung bean sprouts have not been implicated in as many outbreaks as have alfalfa sprouts. No outbreaks involving mung bean sprouts were reported to the CDC before 2000.

As a result of sprout-associated outbreaks, Health Canada in collaboration with the CFIA and the sprout industry developed guidance specifically for managing the health risks associated with sprouted seeds and beans (24). One of the objectives of the Canadian sprout guidance is to inform consumers in general about the potential risks of sprouted seeds and beans, more specifically parents and guardians of young children, the elderly, and people with weakened immune systems, so that these consumers can make informed choices (25). Although the actual source cannot always be determined, previous outbreak investigations have indicated that microorganisms found on sprouts most likely originate from the seeds (8). In Thailand, researchers found that up to 9% of mung bean sprouts were contaminated with *Salmonella* (31). In a survey of California sprout growers, mung bean sprout seeds were not disinfected in accordance with the guidelines set out by the FDA (55). This finding is of concern because *Salmonella* can survive for months on seeds and can grow during the sprouting process; thus, even a low level of seed contamination can be considered a risk (25).

Sewell and Farber (52) discussed four outbreaks of *Cyclospora* infection, all of which were associated with Guatemalan raspberries. These outbreaks spurred the adoption of measures to help control contamination of the Guatemalan berry crop and place restrictions on importation, e.g., only products from low-risk farms were allowed to enter Canada. On 15 March and 4 April 2000, the CFIA introduced import restrictions on Guatemalan fresh raspberries and blackberries, respectively (10). With assistance from Canadian and U.S. officials, the Guatemalan berry commission began to develop a more comprehensive plan for reducing the risk of *Cyclospora* contamination of raspberries. In December 2000, Health Canada recommended the importation of Guatemalan cultivated fresh raspberries and blackberries into Canada only from 15 August to 14 March of each year (10). This decision was based on a Health Canada qualitative risk assessment, recommended risk management options, and the fact that no cyclosporiasis outbreaks had been reported during that time period in Canada, the United States, or other countries (10). Sewell and Farber (52) mentioned that for *Cyclospora*, improved methods of identification (including molecular typing), mandatory reporting of cases, and continued international cooperation will occur. Furthermore, awareness that vehicles other than berries can also lead to infection has increased. Since 2001, seven outbreaks of
Cyclospora infection have been reported, all of which involved basil or cilantro, but not berries.

Because of the apparent increase in foodborne outbreaks related to the consumption of produce, continued and increased cooperation among regulatory health authorities is needed. Improved sampling and testing methodologies, especially for protozoan parasites and foodborne viruses, are also needed. Active surveillance and monitoring programs for produce-related sporadic cases and/or outbreaks should be increased. Programs such as the California Leafy Green Marketing Agreement are important initiatives that can serve as models for improving the microbial safety of produce and increasing consumer protection. New regulations to address some of the on-farm issues may be needed in the future. The United States government recently passed the Food Safety Modernization Act, which shifts the focus to preventing food safety problems rather than simply reacting when they occur. The FDA now has new enforcement authorities designed to reach new compliance rates with prevention and risk-based food safety standards to better respond and contain problems (65). Public awareness of the fact that fresh produce can cause foodborne illness must also be increased.

REFERENCES

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