Comprehensive Reviews in Food Science and Food Safety

Chapter III

Outbreaks Associated with Fresh Produce: Incidence, Growth, and Survival of Pathogens in Fresh and Fresh-Cut Produce

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Scope

An important consideration when addressing safety issues is the incidence of pathogens and outbreaks associated with particular food products. This chapter addresses outbreaks that have been associated with the consumption of fresh and fresh-cut produce. In addition, studies that investigate the incidence of pathogens and factors contributing to the survival and growth of pathogens are reviewed. Although they may not be exhaustive, the tables at the end of the chapter include highlights of incidence studies from industry and published literature sources (Tables I1-I7), outbreaks (Tables O1-O10), and growth/survival studies related to fresh produce (Tables G/S1 to G/S8).

1. Foodborne pathogens associated with fresh produce

The minimum processing required for fresh and fresh-cut produce, which omits any effective microbial elimination step, results in food products that naturally would carry microorganisms, some of which may be potentially hazardous to human health. When investigating possible control methods, a vital step is to examine the nature of the human pathogenic microorganisms present in produce throughout the production process. However, incidence studies are time-consuming and expensive. For this reason, sample sizes are often too small to be of statistical relevance, especially if the probability of detection is low. Most researchers do not collect sufficient information regarding the source of the sample other than perhaps the country of origin or sample location (for example, retail outlets, farmers' markets). There has been little consistency in sample collection, treatment, laboratory test methods, or data analysis. Controls are often missing and techniques for isolating pathogens from produce items are often not optimized. In many cases, identification of the pathogen has not been verified. Most published articles stress the detection of pathogens in incidence surveys; negative data may not be reported or their significance is minimized. However, these negative data are important in evaluating the risks associated with consumption of fresh fruits and vegetables and should be considered in risk assessments. Table III-1 outlines some of the factors that should be considered when designing a study to determine the frequency of isolation of pathogens from produce.

Because of the extremely large number of variables that might influence contamination of raw fruits or vegetables, it is difficult to design well-controlled experiments that would address risk factors for contamination. While incidence studies can provide a snapshot assessment of contamination at a particular location on a particular produce item at a particular time of year, they rarely provide information on the source of contamination. For these reasons, caution must be used when interpreting data from these types of studies, and overly broad conclusions should be avoided. Nevertheless, numerous pathogenic microorganisms have been isolated from a wide variety of fresh fruits and vegetables, sometimes at relatively high frequencies (Table I1-I7). Not all of the microorganisms listed in these tables have been linked to produce-associated illnesses. Under the right conditions, however, all of these microorganisms have the potential to cause produce-associated illness. Isolation rates are not consistent. Percentage of samples contaminated ranges from 0 to greater than 50%, depending upon the target pathogen and produce item. Data pro-

Table III-1—Considerations when examining raw fruits and vegetables for the presence and populations of pathogenic microorganisms

Procedure for sampling
Location of source (field, packing shed, processing plant, retail location, food service, home)
Number and size of samples
Distribution of samples in test lot
Protection of samples for transport to laboratory
Handling samples between collection and analysis
Protection against cross-contamination
Temperature between selection and analysis of sample
Time between selection and analysis of samples
Processing samples
Weight or number of pieces to represent samples
Area or portion to be tested (whole piece, skin only, diced, cut)
Selection of wash fluid or diluent
Ratio of produce to wash fluid or diluent
Temperature of produce and wash fluid or diluent
Soaked or not soaked before processing
Type of processing (washing, rubbing, stomaching, homogenizing, macerating, blending)
Time of processing
Culturing techniques
Enrichment and/or direct plating
Composition and volume of enrichment broth
Composition of direct plating medium
Pour-plate or surface plate
Incubation temperature and time
Confirmation procedures

vided by Wells and Butterfield (1997) indicate that *Salmonella* is more readily isolated from decaying fruits and vegetables. Whether this applies to other pathogens is not known.

2. Outbreaks of foodborne illness associated with the consumption of raw fruits and vegetables

The number of foodborne illness outbreaks linked to fresh produce and reported to the United States Centers for Disease Control and Prevention (CDC) has increased in the last years (Bean and Griffin 1990; CDC 1990; CDC 2000). Some of this increase is due to improved surveillance, but other factors may also come into play. A number of reasons have been proposed for this increased association of foodborne illness with fresh produce. Since the early 1970s, a significant increase in the consumption of fresh produce has been observed in the United States, presumably due, in part, to active promotion of fruits and vegetables as an important part of a healthy diet. From 1982 to 1997, per capita consumption of fresh fruits and vegetables increased from 91.6 to 121.1 kg, an increase of 32% (Table III-2). If contamination levels were consistent, increased consumption of these foods should be expected to lead to greater numbers of illnesses over this time. During this same period, there has been a trend toward greater consumption of foods not prepared in the home and an increase in the popularity of salad bars (buffets). Greater volumes of intact and chopped, sliced or prepared fruits and vegetables are being shipped from central locations and distributed over much larger geographical areas to many more people (see Chapter I). This, coupled with increased global trade, potentially increases human exposure to a wide variety of foodborne pathogens and also increases the chances that an outbreak will be detected. Reasons for increases in foodborne illness in the summertime are not fully understood, although abusive temperatures and a higher consumption of fresh produce during the summer months are likely to play a role.

The perishability of produce and a complex distribution system have made it difficult to effectively investigate many produce-related outbreaks. Traceback has been particularly difficult because of the complexity of the distribution system and the practice of comingling produce in packing houses. Epidemiological investigations often take weeks before detecting a link between reported illnesses and a produce item. As a result, there is little or no product available for testing. However, improvements in outbreak investigations and pathogen detection methods have contributed to an increase in documentation of produce-borne illnesses.

Foodborne illness resulting from the consumption of any food is dependent upon a number of factors. The produce must first be contaminated with a pathogen and the pathogen must survive until the time of consumption at levels sufficient to cause illness. The infective dose (minimum numbers of organisms necessary to cause illness) is very low in many cases (Table III-3), which means that the microorganism needs only to contaminate the food to survive without reproducing. For example, pathogenic parasites and viruses are unable to multiply outside of a human or animal host and only need to survive in sufficient numbers to cause illness.

In other cases, however, multiplication of the pathogen is also essential. Some microorganisms cause illness only when ingested in high numbers (for example, *Clostridium perfringens*), while in other cases, the infectious dose is thought to be dependent upon the susceptibility of the individual (most infectious agents). Illness due to *Staphylococcus aureus*, *Bacillus cereus*, or *Clostridium botulinum* is a result of the production of toxins in the food, and it is the toxins that are responsible (sometimes in the absence of viable cells) for symptoms of the disease. These toxins are only produced by multiplying cells. This requires favorable growth conditions. In summary, while enhancing the likelihood of illness, temperature abuse and multiplication of pathogenic bacteria is *not always necessary* for foodborne illness to occur. Although raw produce is often spoiled by other microorganisms prior to detection of toxin, one should not rely on this fact to prevent the development of disease (for example, botulism).

Table III-2—Per capita (kg) consumption of raw fruits and vegetables in the U.S. Source: Fruit and Tree Nut Situation and Outlook Report (USDA 1999)

Year	Fruits	Vegetables
1982	38.7	52.9
1983	41.0	50.9
1984	40.2	55.8
1985	39.3	57.5
1986	42.1	57.0
1987	44.1	60.1
1988	44.1	61.5
1989	43.7	64.7
1990	41.6	60.9
1991	40.7	60.9
1992	44.5	64.2
1993	45.3	66.4
1994	45.6	69.6
1995	44.4	67.7
1996	44.8	70.8
1997	46.7	74.4

A wide variety of bacteria, viruses, and parasites have been linked to outbreaks of illness associated with fresh produce (Table O1 to O10). Although these microorganisms are physiologically diverse, they share some common features (Table III-3). Foodborne pathogens that are frequently associated with fresh produce originate, for the most part, from enteric environments—that is, they are found in the intestinal tract and fecal material of humans or animals. Exceptions include *C. botulinum,* which is usually isolated from soils, water and decaying plant or animal material, and *Listeria monocytogenes*, which can be readily isolated from human and animal feces, as well as from many other environments including soil, agricultural irrigation sources, decaying plant residue on equipment or bins, cull piles, packing sheds and food processing facilities.

Produce can become contaminated with microbial pathogens by a wide variety of mechanisms. Contamination leading to foodborne illness has occurred during production, harvest, processing, and transporting, as well as in retail and foodservice establishments and in the home kitchen (Table III-4). Contamination at any point in the food handling chain can be exacerbated by improper handling and storage of produce prior to consumption (Table 10). The point of contamination is important because control measures will be most effective if geared towards reducing contamination at the source. For example, Good Agricultural Practices will not prevent illness due to postharvest cross-contamination at any point, including foodservice environments or in the home (Table 9).

Contamination of raw fruits and vegetables with pathogenic organisms of human health significance can occur directly or indirectly via animals or insects, soil, water, dirty equipment, and human handling. For example, fruit flies have been shown to transfer *Escherichia coli* O157:H7 to damaged apples under laboratory conditions (Janisiewicz and others 1999). This may have implications during harvesting and in packing sheds or processing facilities, where damaged produce is inevitable and flies may be difficult to control. Humans and animals can shed foodborne pathogens in the absence of signs of illness. While domestic animals may be separated from fruit and vegetable growing operations, wild animals and birds can only be controlled to a limited extent. Human hygiene, including hand washing all along the food

Table III-3—Characteristics of some microbial pathogens that have been linked to outbreaks of produce-associated illness

Microorganism	Typical Incubation Period	Symptoms	Infectious dose (Number of cells)	Source
Bacteria				
Clostridium botulinum	12 to 36 hours	Nausea, vomiting, fatigue, dizziness, dryness of mouth and throat, muscle paralysis, difficulty swallowing, double or blurred vision, drooping eyelids, and breathing difficulties	intoxication growth and toxin production in food	soil, lakes, streams, decaying vegetation, reptiles
Escherichia coli O157:H7	2 to 5 days	Bloody diarrhea, abdominal pain. Can lead to hemolytic uremic syndrome and kidney failure especially in children and the elderly	10 to 1000	animal feces, especially cattle, deer and human; cross contamination from raw meat
Salmonella spp.	18 to 72 hours	Abdominal pain, diarrhea, chills, fever, nausea, vomiting	10 to 100,000	animal and human feces; cross contamination from raw meat, poultry, or eggs
Shigella spp.	1 to 3 days	Abdominal pain, diarrhea, fever, vomiting	About 10	human feces
Listeria monocytogenes	1 day to 5 or more weeks	Febrile gastroenteritis in healthy adults; may lead to spontaneous abortion or stillbirth in pregnant women; severe septicemia and meningitis in neonates and immunocompromised adults; mortality may be 20 to 40%	unknown, dependent uponhealth of individual	soil, food processing environments
Parasites				
Cryptosporidium spp.	1 to 12 days	Profuse watery diarrhea, abdominal pain, anorexia, vomiting	About 30	Animal and human feces
Cyclospora spp.	1 to 11 days	Watery diarrhea, nausea, anorexia, abdominal cramps (duration 7 to 40 days)	unknown, probably low	others? specific environ mental sources unknown at this time
Viruses				
Hepatitis A	25 to 30 days	Fever, malaise, anorexia, nausea, abdominal pain, jaundice, dark urine	10 to 50	human feces and urine
Norwalk/Norwalk-like virus	12 to 48 hours	Vomiting diarrhea, malaise, fever, nausea, abdominal cramps	unknown, probably low	human feces, vomitus

chain, is critical in reducing or eliminating contamination with fecal pathogens.

3. Survival and multiplication of pathogens on raw produce

The survival and/or growth of pathogens on fresh produce is influenced by the organism, produce item, and environmental conditions in the field and thereafter, including storage conditions. In general, pathogens will survive but not grow on the uninjured outer surface of fresh fruits or vegetables, due in part to the protective character of the plant's natural barriers (for example, cell walls and wax layers). In some cases pathogen levels will decline on the outer surface.

In the field, the physical environment of leaf surfaces is considered to be inhospitable for the growth and survival of bacteria (for example, lack of nutrients and free moisture, temperature and humidity fluctuations, and ultraviolet light) (Dickinson 1986). Environmental conditions, however, can greatly influence bacterial populations; the presence of free moisture on leaves from precipitation, dew, or irrigation may promote survival and growth of bacterial populations (Blakeman 1981; Andrews 1992; Beattie and Lindow 1995, 1999). Certain conditions, such as sunlight, particularly the shorter ultraviolet wavelengths, can damage bacterial cells (Webb 1976; Jagger 1981; Sundin and others 1996; Sundin and Jacobs 1999). Consequently, nature may select for bacteria with adaptations to these stressful conditions. Although most of the body of research has been done with stress adaptation of mi-

Table III-4—Sources of pathogenic microorganisms on fresh produce and conditions that influence their survival and growth

Preharvest
Soil
Irrigation water
Green or inadequately composted manure
Air (dust)
Wild and domestic animals
Human handling
Water for other uses (for example, pesticides, foliar treatments, growth hormones)

Postharvest
Human handling (workers, consumers)
Harvesting equipment
Transport containers (field to packing shed)
Wild and domestic animals
Air (dust)
Wash and rinse water
Sorting, packing, cutting and further-processing equipment
Ice
Transport vehicles
Improper storage (temperature, physical environment)
Improper packaging (includes new packaging technologies)
Cross contamination (other foods in storage, preparation and display areas)
Improper display temperature
Improper handling after wholesale or retail purchase
Cooling water (for example, hydrocooling)

croorganisms other than human pathogens (high ultraviolet tolerance in *Pseudomonas syringae* or high osmotic potentials in *Escherichia herbicola)* preliminary results suggest that humans pathogens are less likely to develop stress resistance (O'Brien and Lindow 1988). Many of the human pathogens have an enteric source, and therefore may be unsuccessful as plant colonists relative to the more suited plant microbial populations. The relative fitness of human pathogens and common epiphytes (microbes that grow and persist on plant surfaces) and the interaction between bacterial pathogens and indigenous microflora needs further research.

Similarly, after harvest, pathogens will survive but not grow on the outer surface of fresh fruits and vegetables, especially if the humidity is high. In some cases, pathogen levels will decline on the outer surface. The rate of decline is dependent upon the produce type, humidity, and temperature, as well as the atmosphere and type of packaging used. Growth on intact surfaces is not common because foodborne pathogens do not produce the enzymes necessary to break down the protective outer barriers on most produce. This restricts the availability of nutrients and moisture. One exception is the reported growth of *E. coli* O157:H7 on the surface of watermelon and cantaloupe rinds (Table G/S1).

Survival of foodborne pathogens on produce is significantly enhanced once the protective epidermal barrier has been broken either by physical damage, such as punctures or bruising, or by degradation by plant pathogens (bacteria or fungi). These conditions can also promote the multiplication of pathogens, especially at nonrefrigerated temperatures. Microorganisms often survive at refrigerated temperatures even though these conditions reduce or eliminate the ability of the organisms to multiply. Exceptions to this are the psychrotrophic pathogens including nonproteolytic *C. botulinum*, *L. monocytogenes*, *Y. enterocolitica*, and the presumptive pathogen *Aeromonas hydrophila*. Various enteric pathogens have been shown to multiply on the surface of cut melons, on shredded lettuce, and on chopped parsley and under acidic conditions, such chopped tomatoes and wounded apple tissue (Tables G/S1 – G/S8). Temperature control becomes critical for preventing bacterial reproduction on any cut produce item. Fresh-cut produce, by definition, has been injured through peeling, cutting, slicing, or shredding. These same operations can transfer pathogenic microorganisms, if present, from the surface of the intact fruit or vegetable to the internal tissues. Injured cells and released cell fluids provide a nourishing environment for microbial growth.

A vigorous population of nonpathogenic bacteria is potentially another barrier to reduce the risk of foodborne illness from fresh-cut products. These bacteria do not necessarily prevent the growth of pathogens but they do provide indicators of temperature abuse and age of the produce by causing detectable spoilage. Most pathogens do not cause produce to spoil, even at relatively high populations. In the absence of spoilage, high populations of pathogens may be achieved and the item may be consumed because it is not perceived as spoiled. For this reason, specifications requiring very low microbial counts may, in some cases, compromise produce safety.

Infiltration of wash-water into intact fruit has been demonstrated with several fruits and vegetables, and is thought to have contributed to an outbreak of salmonellosis associated with fresh market tomatoes (Table O8). Wash-water contaminated with microorganisms, including pathogens, can infiltrate the intercellular spaces through pores when conditions are right. Internal gas pressures and surface hydrophobicity usually prevent uptake of water. However, when the produce temperature is much higher than the water temperature, the pressure difference created may be sufficient to draw water into the fruit (Bartz 1999). Adding detergents to the water appears to enhance infiltration, likely due to reduced surface tension. Under some circumstances, wash water may enter an intact fruit through the stem scar or other opening, such as the blossom or stem end of an apple. Conditions that reduce infiltration of plant pathogens should also prevent infiltration of human pathogens.

3.1. Influence of packaging

Fresh produce packaged in gas-permeable films can modify its own atmosphere, thereby creating more favorable conditions for storage. Three mutually interacting processes determine the course of this modification: 1) respiration by the fruit or vegetable, 2) gas diffusion through the produce item, and 3) temperature, and 4) gas transmission through the film. As a result of produce respiration, the oxygen (O_2) concentration in the package is decreased and the carbon dioxide (CO_2) concentration is increased. Growth and toxin production by *C. botulinum* is of particular concern in this instance. This subject has been reviewed in depth (see Chapter IV).

3.2. Specific foods—Examples

3.2.1. Berries. Raw raspberries and possibly blackberries imported from Guatemala have been associated with several large *Cyclospora cayetanensis* outbreaks (Table 9). The natural host for this parasite has not been identified; however, contaminated water used for pesticide application and poor harvester hygiene has been suggested as the most likely routes of contamination. Frozen raspberries or frozen strawberries have been linked to two or three outbreaks of hepatitis A, respectively (Table 9). Hepatitis A, a virus spread by human feces, is thought to have contaminated the berries by contact with infected harvesters or contaminated irrigation water. Frozen raspberries have also been associated with illness due to calicivirus, also spread through human feces.

Raw berries destined for the fresh market are harvested by hand and field packed into retail containers without being washed. Strawberries destined for freezing are destemmed in the field, either using a metal device or a thumbnail. Berries which are to be processed are transported, usually at ambient temperature, to a processing facility where they are washed with potable water or water containing an antimicrobial (for example, chlorine), sometimes sliced, and often mixed with up to 30% sucrose before freezing. The extra human handling during harvesting and comingling in the processing facility may explain the greater association of outbreaks with frozen berries. Also, virus and parasites may actually be preserved by the freezing step.

To date, bacterial foodborne illnesses have not been linked to consumption of berries. However, reservoirs for enteric organisms such as *Salmonella* and *E. coli* O157:H7 are similar to that of hepatitis A virus, suggesting that bacterial pathogens may also be occasional contaminants of berries. A recent FDA survey of imported produce found S*almonella* in one of 143 samples of strawberries (Table I1).

3.2.2. Seed sprouts. Over the past several years, seed sprouts have become a fresh produce item commonly linked to foodborne illness. Seed sprouts are a special problem because bacterial pathogens that may be present at very low levels on sprout seeds at the time of sprouting can multiply to very high levels during the 3 to 10 days sprouting process and can survive through the typical refrigerated shelf life of the products (Table G/S 7). Also, seed sprouts are produced as agricultural commodities, not subject to sanitation requirements because they are not regarded as foods. A wide variety of pathogens have been isolated from sprouted seeds (Table I2). Outbreaks have been associated primarily with *Salmonella* serotypes but have also been attributed to *B. cereus*, *E. coli* O157:H7, and *Y. enterocolitica* (Table 9).

Most sprout outbreaks have been due to seed contaminated with a bacterial pathogen before the sprouting process begins, presumably during production or harvest (Table 9). Many patho-

gens can survive for months under the dry conditions used for seed storage. Populations in the seeds are exceptionally low, making it difficult to detect pathogens in routine seed screening programs (Table I2). Although contaminated alfalfa sprouts have been identified as the source of pathogens in many outbreaks, clover, radish, and mung bean sprouts have also been associated with outbreaks. The association with alfalfa sprouts may be due to the volume consumed, as these are the most popular type of seed sprouts that are commonly eaten raw. Mung bean sprouts, while sold in relatively large quantities are often stir-fried or otherwise heated prior to consumption. This would reduce the risk and likelihood of illness from mung bean sprouts. However, any type of sprout seed may potentially be contaminated with bacterial pathogens before it is sprouted.

3.2.3. Melons. Cut cantaloupe is considered a potentially hazardous food in the FDA Food Code because it is capable of supporting the growth of pathogens due to low acidity (pH 5.2 to 6.7) and high water activity (0.97 to 0.99). The FDA investigated the frequency of *Salmonella* isolated from cantaloupe imported from Mexico (Table I1). In 1990, 11 of 1,440 (0.76%) cantaloupe were positive for eight different *Salmonella* serotypes. In 1991, 24 of 2,220 (1.08%) were positive with 12 different *Salmonella* serotypes isolated. More recently, the FDA isolated *Salmonella* from eight (5.3%) and *Shigella* from three (2.0%) of 151 cantaloupe samples collected from nine countries exporting to the United States (FDA 2001). These results suggest that melons may be naturally contaminated with *Salmonella*.

Outbreaks of salmonellosis have been associated with the consumption of cut cantaloupe and watermelon (Table 9). At least two of these outbreaks have been relatively large and have involved multiple states and/or provinces. For most outbreaks, it has been assumed that *Salmonella* was present on the rind, presumably contaminated in the field or during washing in a packinghouse, and that the edible surface became contaminated during final preparation. Improper storage temperature combined with the favorable conditions for growth on the surface of cut melons were factors that likely contributed to the outbreak (Table 10). Some outbreaks associated with melons have resulted from contamination during final preparation either through an infected food handler (with, for example, Norwalk virus) or cross-contamination from raw beef to the melon (with, for example, *E. coli* O157:H7) via knives, cutting boards, or hands.

Escherichia coli O157:H7 and *Salmonella*, can survive and grow readily on improperly stored (nonrefrigerated) cut melons (Table G/S1). When initial populations were between 2.0 and 3.0 log CFU/g, final levels reached 7.0 or 8.0 log CFU/g after 24 hours at 23 °C (73.4 °F). At 5 °C (41 °F), both *Salmonella* and *E. coli* O157:H7 populations did not increase.

Cut melons are subject to time/temperature requirements of the U.S. FDA model food code criteria for potentially hazardous food. Recommendations made by the FDA to retail establishments that prepare or sell fresh cantaloupe are that melons should be washed before cutting, clean, sanitized utensils and surfaces should be used when preparing cut melons, cut melons should be kept at or below 7 °C (44.6 °F), and they should be displayed for no longer than 4 hours if they are not refrigerated (Golden and others 1993).

3.2.4. Unpasteurized juices. Approximately 2% of all juices sold in the United States are unpasteurized. Parish (1997) provides an excellent review of the safety of unpasteurized fruit juices. Unpasteurized juices are made from fruits and vegetables that are ground and/or pressed or squeezed to extract the juice. Unpasteurized juices are included here because they have not been thermally processed and an evaluation of outbreaks associated with these products might contribute to an understanding of risk factors for contamination of the raw fruits.

There have been very few surveys of retail juices for the presence of pathogens, probably because of the very low probability of finding pathogens in these products. Sado and others (1998) used rapid test kits to survey retail juices for the presence of *L. monocytogenes*, *E. coli* O157:H7, *Salmonella*, coliforms, and fecal coliforms. Only *L. monocytogenes* was isolated from two of 50 juices, an apple juice (pH 3.78) and an apple raspberry blend (pH 3.75) (Table I1).

Although there is a long history of juice-related outbreaks, they have been relatively infrequent and, until 1995, were generally associated with very small commercial processors or home-prepared products (Table 9). While the acidity of most fruit juices prevents the multiplication of pathogens, survival is much better than has been traditionally assumed (Table G/S 6). Pathogen viability decreases with increasing temperature due to the rapid growth of yeasts and other spoilage organisms at the higher temperatures. This also leads to a decrease in shelf life.

While pathogen contamination routes have not been definitively confirmed in any juice outbreak, the use of dropped fruit, the use of nonpotable water, and the presence of cattle, deer, or, in one case, amphibians, in or near the orchards or groves does appear to be a reoccurring theme. Of five documented outbreaks associated with reconstituted orange juice, three have been the result of contamination by an infected handler preparing the juice (Table 9). In another outbreak the water source used to reconstitute the juice was thought to be a factor.

3.3. Pathogens of concern—Bacteria

3.3.1. *Aeromonas* species. *Aeromonas species* were first recognized as pathogens of cold-blooded animals. The ability of *Aeromonas hydrophila* and *Aeromonas sobria* to cause human infection has not been fully confirmed, however, their potential as infectious agents exists (Wadstrom and Ljungh 1991). The presence of *Aeromonas* in drinking water, fresh and saline waters, brackish water and sewage has been demonstrated on a global scale. Cytotoxic strains have been isolated from a wide range of seafoods, meats and poultry as well as from seed sprouts, lettuce or salad greens, mixed raw vegetables, parsley, and carrots (Table I4, I5, I7); however, outbreaks associated with this organism have not been reported. The pathogen can grow rapidly on raw vegetables and seed sprouts at refrigeration temperature (Tables G/S4 and G/S7). Controlled or modified atmosphere storage does not significantly affect the growth of *A. hydrophila.*

3.3.2. *Campylobacter* species. *Campylobacter jejuni* and *Campylobacter coli* are a leading cause of bacterial enteritis. *Campylobacter* has been isolated from a variety of produce items sampled from farmer's markets in Canada and from mushrooms sampled from retail markets in the United States (Tables I4 and I6). While consumption of contaminated food of animal origin, particularly poultry, is largely responsible for infection, *Campylobacter enteritis* has also been associated with lettuce or salads (Table 9). Cross-contamination during food preparation was thought to be possible or probable, in one case with raw chicken juices (Table 9). Cross-contamination of fresh produce with *Campylobacter* from poultry and other meats is a distinct possibility in delicatessen and other foodservice operations. Therefore, the linkage of *C. enteritis* to uncooked produce should not be viewed as improbable; control should focus on reducing cross-contamination during food storage and preparation. Studies reported by Castillo and Escartin (1994) indicate that *C. jejuni* can survive on sliced watermelon and papaya for sufficient time to be a risk to the consumer (Tables G/S1 and G/S2).

3.3.3. *Escherichia coli.* Enterotoxigenic *E. coli* is a common cause of travelers' diarrhea, an illness sometimes experienced when visiting developing countries. Raw vegetables are thought to be a common cause of travelers' diarrhea. A prospective study of

73 physicians and 48 family members attending a conference in Mexico City in 1974 revealed that enterotoxigenic *E. coli* was the most common cause of illness (Merson and others 1976). Fifty-nine participants became ill from eating salads containing raw vegetables.

Outbreaks of illness determined to be caused by enterotoxigenic *E. coli* in persons who had not traveled outside the United States are not uncommon. In one outbreak, 47 airline passengers suffered from illness strongly associated with eating garden salad made from iceberg and romaine lettuce, endive, and shredded carrots (see Beuchat 1996b). In another outbreak, 78 lodge guests became ill after consuming tossed salad as part of a buffet dinner. The salad contained several ingredients, including onions, carrots, zucchini, peppers, broccoli, mushrooms, and tomatoes (see Beuchat 1996b).

Enterohemorrhagic *E. coli* O157:H7 is recognized as an important foodborne pathogen. The infectious dose is very low and sequelae to gastroenteritis can include bloody diarrhea (hemorrhagic colitis) and hemolytic uremic syndrome. The latter is most common in young children (<5 years) and in the elderly. There have been very few surveys for the presence of the organism in raw produce. Surveys of lettuce or salad mixes in the United Kingdom and United States did not isolate the organism and, although originally included in an FDA imported produce study, it was later deleted because positive samples had not been identified (FDA 2001). However, a single survey in Mexico revealed very high isolation rates (19%) for this organism in mixed vegetables, cilantro, coriander, and celery (Table I5). This single study was published as an abstract in 1995 and, to our knowledge, has not been published as a peer reviewed manuscript. Therefore, we were unable to review their methodology.

Since cattle appear to be a primary reservoir, the vast majority of outbreaks of illness associated with *E. coli* O157:H7 have been associated with consuming undercooked beef and dairy products. However, outbreaks have also been linked to lettuce (Table 10). unpasteurized apple cider (Table 10). cantaloupe (Table 10). and sprouts (Table 9). In outbreaks associated with cantaloupe and in some cases lettuce, contamination, particularly with raw beef juices, occurred during final preparation (Table 9).

Escherichia coli O157:H7 grows rapidly in several types of raw fruits and vegetables, particularly when stored at 12 °C (53.6 °F) or above (Tables G/S1, G/S2, G/S4, G/S5, G/S7). Packaging under modified atmosphere has little or no effect on the survival or growth of *E. coli* O157:H7. In addition, the infection dose of *E. coli* O157:H7 is low and can develop acid-resistance.

3.3.4. *Listeria monocytogenes.* While *L. monocytogenes* causes relatively mild gastroenteritis in healthy adults, the illness can be severe in susceptible individuals including pregnant women, neonates, and immune compromised individuals. The infective dose for this organism has not been clearly established, although it is thought to be relatively low among susceptible individuals. *Listeria monocytogenes* is widely distributed on raw fruits and vegetables (Tables I2 and I4) and on plant material (Beuchat 1996b). However several studies with relatively large sample sizes failed to detect the organism (Table I4). Factors affecting its presence or persistence have yet to be determined. Plants and plant parts used as salad vegetables play a role in disseminating the pathogen from natural habitats to the human food supply. This role may be indirect, for example by contaminating milk via forage or silage, or direct in the form of raw contaminated produce. In 1967, Blenden and Szatalowicz (1967) reported that 731 cases of human listeriosis had been documented between 1933 and 1966 in the United States. They stated that produce such as lettuce or other fresh vegetables contaminated with *L. monocytogenes* may have been responsible for some of these cases. However, documented outbreaks associated with this organism and linked to fresh produce have been limited. Ho and others (1986), (Table 10). reported an outbreak of *L. monocytogenes* infection that involved 23 patients from eight Boston hospitals in 1979. Three foods (tuna fish, chicken salad and cheese) were preferred by case patients more frequently than by control patients. However, the only common foods served with these foods were raw celery, tomatoes, and lettuce. It was concluded that consumption of these vegetables may have caused the listeriosis outbreak. No attempt was made to isolate *L. monocytogenes* from vegetables at the time of the outbreak.

An outbreak of human infection due to *L. monocytogenes* occurred in 1981 in the Maritime provinces (Prince Edward Island, Nova Scotia and New Brunswick) in Canada (Table O8). A case-control survey revealed that cases were more likely than controls to have consumed coleslaw during the three months before onset of illness. Ingestion of radishes was associated with coleslaw consumption but not with illness. Coleslaw obtained from the refrigerator of a patient was positive for *L. monocytogenes* serotype 4b, which was the epidemic strain and the strain isolated from the patient's blood. The coleslaw was commercially prepared with cabbage and carrots obtained from wholesalers and local farmers. Two unopened packages of coleslaw purchased from two different Halifax, Nova Scotia supermarkets yielded *L. monocytogenes* serotype 4b. Both packages of coleslaw were produced by the same processor. An investigation of the sources of cabbage revealed one farmer who, in addition to raising cabbage, maintained a flock of sheep. Two of his sheep had died of listeriosis in 1979 and 1981. The farmer used composted and fresh sheep manure in fields in which cabbage were grown. From the last harvest in October through the winter and early spring, cabbage was kept in a cold-storage shed. A shipment of cabbage from that shed during the period of the outbreak was traced to the implicated coleslaw processor. This information strongly suggests that the vehicle of the 1981 Canadian outbreak of listeriosis was coleslaw.

Listeria monocytogenes can grow on fresh produce stored at refrigerated temperature. Growth on fresh-cut fruit as well as asparagus, broccoli, butternut squash, coleslaw and cauliflower, rutabaga stored at 4 °C (39.2 °F) (Table G/S4), lettuce at 5 °C (41 °F) (Table G/S5) and chicory endive at 6.5 °C (43.7 °F) (Table G/S4) has been reported. Controlled atmosphere storage does not appear to influence growth rates. Carrot juice appears to be inhibitory towards this organism (Beuchat and Brackett 1990a; Nguyen-the and Lund 1991, 1992; Beuchat and others 1994; Beuchat and Doyle 1995). The antimicrobial properties are attributed to phytoalexins naturally present in carrots. The addition of carrot juice as a natural antimicrobial in other food products has been relatively unsuccessful (Beuchat and Doyle 1995).

3.3.5. *Salmonella.* The genus *Salmonella* has over 2700 serotypes. Animals and birds are the natural reservoirs. Surveys of fresh produce have revealed the presence of several *Salmonella* serotypes capable of causing human infection (Table I1-I7).

Poultry and other meat products, eggs and dairy products, are the most commonly implicated sources in salmonellosis outbreaks. Fresh fruits and vegetables are implicated less frequently, although outbreaks have been documented most notably in cantaloupe and sprouts. Several additional large outbreaks of salmonellosis have been attributed to fresh produce. Among them are three multi-state outbreaks traced to the consumption of raw tomatoes; one involved *Salmonella* Javiana in 1992, another involved *Salmonella* Montevideo in 1993, and a third in 2000 involved *Salmonella* Baildon (Table O8). Subsequent laboratory studies revealed that the pathogen can grow in damaged, chopped, or sliced tomatoes (pH 4.1 – 4.5) stored at 20 to 30 °C (68 to 86 °F) (Table G/S3).

3.3.6. *Shigella* species. The genus *Shigella* is composed of four species, *Shigella dysenteriae, Shigella boydii, Shigella sonnei*, and *Shigella flexneri.* All species are pathogenic to humans at a low

dose of infection. Shigellosis is usually transmitted from person-to-person but may also occur by consumption of contaminated water and foods, including foods such as fruits or vegetables that have received little or no heat treatment. Several large outbreaks of shigellosis have been attributed to the consumption of contaminated raw vegetables. A lettuce processing facility was the common source of product responsible for outbreaks caused by *S. sonnei* that occurred simultaneously on two university campuses in Texas (Table 9). Ill students on both campuses had eaten salads from self-serve salad bars. Lettuce was the only produce item used in salads consumed by all students who became ill.

In another outbreak of *S. sonnei* gastroenteritis was associated with eating shredded lettuce (Table 9). All implicated restaurants received shredded lettuce from the same produce facility. An investigation suggested that a worker in the plant was the source of contamination and that the method of processing allowed contamination of the lettuce.

Two Midwestern United States outbreaks of *S. flexneri* infection have been linked to the consumption of fresh green onions (see Beuchat, 1996b). The onions were traced to shippers in California who obtained most of their green onions from a single farm in Mexico. It was concluded that contamination may have occurred in Mexico at harvest or during packing.

Shigella sonnei can survive on lettuce at 5 °C (41 °F) for 3 days without decreasing in number, and increased by more than 1000-fold at 22 °C (71.6 °F) (Table G/S5). *Shigella* can grow in shredded cabbage and chopped parsley stored at 24 °C (75.2 °F) (Table G/S4). Populations of *S. sonnei*, *S. flexneri*, and *S. dysenteriae* inoculated onto the surface of freshly cut cubes of papaya, jicama, and watermelon increased substantially within 4 to 6 hours at 22 – 27 °C (71.6 – 80.6 °F) (Table G/S2, G/S4, and G/S1). The pH values of the three fruits were 5.69, 5.97 and 6.81, respectively.

3.3.7. *Staphylococcus aureus.* *Staphylococcus aureus* has been detected on fresh produce and ready-to-eat vegetable salads (Table I2 and I6), and is known to be carried by food handlers. However, enterotoxigenic *S. aureus* does not compete well with other microorganisms normally present on fresh produce, so incipient spoilage caused by nonpathogenic microbiota would likely precede the development of high populations of this pathogen. An outbreak of staphylococcal foodborne illness was linked to canned mushrooms. Growth and toxin production occurred prior to processing the mushrooms, without significant visual degradation, possibly because the mushrooms were held under ambient conditions in plastic bags and with salt. Conditions within the bags rapidly became anaerobic and the normal spoilage microbiota may have been inhibited and *S. aureus* selected. Because the toxin is heat stable, it survived the thermal process. This suggests that raw produce-associated outbreaks due to *S. aureus* could potentially occur given the right conditions. *S. aureus* has been shown to grow on peeled Hamlin oranges (Table G/S2) stored at 24 °C (75.2 °F) or survived up to 14 days when stored at 4 to 8 °C (39.2 to 46.4 °F).

3.3.8. *Yersinia enterocolitica.* Although animals, particularly swine, are the predominant natural reservoir for *Y. enterocolitica*, the pathogen has also been isolated from several raw vegetables. *Yersinia enterocolitica* infection has been associated with the consumption of mung bean sprouts contaminated with well-water containing the organism (Table 9). Catteau and others (1985) analyzed 58 samples of grated carrots obtained from eating establishments in France and found that 27% were contaminated with *Yersinia*. Seven percent of the samples contained *Y. enterocolitica* serotypes that may be pathogenic to humans. Darbas and others (1985) examined prepared raw vegetables destined for school meals that had been held for up to 5 days in cold storage. Fifty percent of 30 samples of raw vegetables analyzed contained *Yersinia* species. The incidence was higher in root and leafy vegetables than for tomatoes or cucumbers. *Yersinia enterocolitica* was the only species isolated from grated carrots, whereas *Yersinia intermedia* and *Yersinia kristensenii* were mainly isolated from lettuce. Cross-contamination between vegetables was observed in some cases. No pathogenic strains were isolated from raw vegetables analyzed in this study. The pathogen can grow at refrigeration temperatures commonly used during transport and storage of fresh produce.

3.4. Spore-forming pathogenic bacteria

Contamination of vegetables and fruits with spores of pathogenic bacteria such as *B. cereus, C. botulinum,* or *C. perfringens* present in soil is common (Tables I2, I4, I5, and I7). However, only when produce is handled in a manner that enables germination of spores and growth of vegetative cells is there a threat to public health from these spore-forming bacteria. Of particular concern are vegetables packaged under modified atmosphere (see Chapter IV).

Botulism has been linked more to consumption of cooked vegetables than to fresh produce. The organism requires relatively high water activity, a pH of greater than 4.6, relatively warm temperatures, and anaerobic conditions to grow and produce toxin. Growth and toxin production often lag behind spoilage in fresh vegetables. Of greatest concern are those products that will support growth and toxin production prior to visible signs of spoilage.

Outbreaks implicating cabbage and garlic in oil have been documented (Table O8 to 10). The garlic was likely dried and rehydrated prior to mixing with oil, but subsequent studies have shown that the organism will grow in fresh garlic. Botulism has been linked to eating coleslaw prepared from packaged, shredded cabbage mixed with coleslaw dressing (Solomon and others 1990). Since the pH of the dressing was 3.5, *C. botulinum* had apparently grown in the shredded cabbage that was suspected to have been packed in a modified atmosphere. A survey subsequently revealed that 12 of 88 cabbages obtained from supermarkets contained *C. botulinum* spores, and that botulinum toxin can be formed in shredded cabbage when the cabbage is packaged under an atmosphere containing reduced oxygen and stored at 22 to 25 °C (71.7 – 77 °F) for 4 to 6 days. The appearance and color of the stored cabbage was acceptable when toxin was present. Other vegetables that appear to support growth and toxin production of *C. botulinum* before spoilage is detected are cubed butternut squash and sliced onions (Table G/S4).

The high rate of respiration of mushrooms can create an anaerobic environment within film-wrapped packages, thus favoring botulinal toxin production. Botulinal toxin was produced in polyvinyl chloride film-packaged mushrooms held at 20 °C (68 °F) for 3 to 4 days, and the toxic mushrooms appeared to be edible (Sugiyama and Yang 1975). Although placing holes in film reduces the shelf life of mushrooms, this practice is encouraged so as to prevent *C. botulinum* growth. Proteolytic strains of *C. botulinum* grew and produced toxin in vacuum-packaged Enoki mushrooms held at 15 to 27 °C (59 to 80.6 °F), but the mushrooms were visibly spoiled at the time toxin was detected (Malizio and Johnson 1991).

Bacillus cereus has been associated with one outbreak related to the consumption of mixed seed sprouts (Table 9). The organism was subsequently shown to be present at relatively high levels in a variety of seeds sold for sprouting (Table I2). *Clostridium perfringens* was associated with one outbreak epidemiologically linked to the consumption of salad. Illness caused by this organism is usually associated with gravies and meat dishes. Large numbers of the organism are required to cause illness and anaerobic conditions and a nutrient-rich environment are essential for growth of the organism. It is not clear how salad (presumably lettuce salad) would provide these conditions.

3.5. Pathogens of greatest concern—Viruses

Outbreaks caused by hepatitis A virus, calicivirus, and Nor-

walk-like viruses have been associated with the consumption of produce (Table 9). 9). 9). O8). These outbreaks have been associated with frozen raspberries or frozen strawberries, lettuce, melons, salads, watercress, diced tomatoes, and fresh-cut fruit. A number of these outbreaks were the result of contamination via an infected food handler during final preparation (Table 9). Hepatitis A and Norwalk-like viruses are the most commonly documented viral food contaminants. Viruses can be excreted in large numbers by infected individuals and have been isolated from sewage and untreated wastewater used for crop irrigation. Although viruses cannot grow in or on foods, their presence on fresh produce, which may serve as vehicles for infection, is of concern. Of 14 reports of viral gastroenteritis outbreaks cited by Hedberg and Osterholm (1993), a food handler who was ill before or while handling the implicated food was identified as the source of infection in eight outbreaks. Salads were the implicated vehicle in five outbreaks (36%), and cold food items or ice were implicated in all but one outbreak.

The survival of viruses on vegetables has been studied. Several enteroviruses (poliomyelitis, enteroviruses, hepatitis A, rotavirus, and Coxsackie viruses) can survive in a variety of raw vegetables for periods exceeding the normal shelf life of salad vegetables (Table G/S8). Survival appears to be dependent upon the pH, moisture content, and temperature. These observations indicate that salad vegetables can serve as vehicles for the transmission of viral pathogens to humans.

3.6. Pathogens of greatest concern—Protozoan parasites

Reliable and sensitive detection methods for parasites in raw produce are lacking and therefore, incidence studies are not available with the exception of one Costa Rican survey. In Costa Rica, Monge and Chinchilla (1996) surveyed a total of 640 samples from eight different vegetables for the presence of *Cryptosporidium* oocysts, fecal coliforms, and generic *E. coli*. *Escherichia coli* was found at populations of 10^1 (tomato) to $10^5/10^6$ MPN/g (cilantro leaves/cilantro roots). *Cryptosporidium* oocysts were found in at least one of 80 samples of each vegetable except cabbage. Highest isolation rates were seen for cilantro leaves (5 of 80 samples positive) and cilantro roots (7 of 80 samples positive). Highest contamination rates were observed in the rainy season and the probable contamination route was thought to be the use of contaminated irrigation water. No correlation was observed between the presence of *Cryptosporidium* oocysts and populations of fecal coliforms or generic *E. coli*.

3.6.1. *Cryptosporidium parvum*. *Cryptosporidium parvum* is an obligate intracellular parasite. It is currently thought that the form infecting humans is the same species that causes disease in young calves. The forms that infect avian hosts and those that infect mice are not thought capable of infecting humans. *Cryptosporidium* sp. infects many herd animals (cows, goats, and sheep among domesticated animals, and deer and elk among wild animals). The infective stage of the organism is the oocyst. The sporocysts are resistant to most chemical disinfectants, but are susceptible to drying and the ultraviolet portion of sunlight.

Intestinal cryptosporidiosis is characterized by severe watery diarrhea that is particularly severe in immune compromised individuals. Healthy adults may be asymptomatic. The infectious dose is less than 10 organisms and, presumably, one organism can initiate an infection. Oocysts are shed in the infected individual's feces. *Cryptosporidium* sp. could occur, theoretically, on any food touched by a contaminated food handler. The incidence is higher in child day care centers that serve food. Fertilizing salad vegetables with manure is another possible source of human infection. Large outbreaks have been associated with contaminated water supplies suggesting that contaminated irrigation water could be another route of contamination. Produce- and juice-associated outbreaks of cryptosporidiosis have occurred (Table O-5, O-8).

3.6.2. *Cyclospora cayetanensis*. *Cyclospora cayetanensis* is a unicellular parasite previously known as cyanobacterium-like or coccidia-like body (CLB). The first known human cases of illness caused by *Cyclospora* infection (for example, cyclosporiasis) were reported in the medical literature in 1979. Cases have been reported with increased frequency from various countries since the mid 1980s, in part because of the availability of better techniques for detecting the parasite in stool specimens.

Infected persons excrete the oocyst stage of *Cyclospora* in their feces. When excreted, oocysts are not infectious and may require days to weeks to become infectious (for example, to sporulate). Therefore, transmission of *Cyclospora* directly from an infected person to someone else is unlikely. However, indirect transmission can occur if an infected person contaminates the environment and oocysts have sufficient time, under appropriate conditions, to become infectious. For example, *Cyclospora* may be transmitted by ingestion of water or food contaminated with oocysts. Outbreaks linked to contaminated water, as well as outbreaks linked to various types of fresh produce, have been reported in recent years. Raspberries and possibly blackberries imported from Guatemala have been implicated in at least five outbreaks, two involving numerous states and Canadian provinces (Table 9). The route of contamination was not conclusively determined, but was suspected to be related to contaminated water used for irrigation or pesticide application. Berries imported in the spring but not in the fall were associated with illnesses suggesting a seasonality to the illness. In addition, fresh basil and products made from the basil were implicated in an outbreak in 1997 (Table O8). The source of contamination for this outbreak was not determined. How common the various modes of transmission and sources of infection are is not yet known, nor is it known whether animals can be infected and serve as sources of infection for humans. The incubation period between acquisition of infection and onset of symptoms averages 1 week. *Cyclospora* infects the small intestine and typically causes watery diarrhea, with frequent, sometimes explosive, stools. Other symptoms can include loss of appetite, substantial loss of weight, bloating, increased flatus, stomach cramps, nausea, vomiting, muscle aches, low-grade fever, and fatigue. If untreated, illness may last for a few days to a month or longer, and may follow a remitting-relapsing course. Some infected persons are asymptomatic.

3.6.3. *Giardia lamblia.* Organisms that appear identical to those that cause human illness have been isolated from domestic animals (dogs and cats) and wild animals (beavers and bears). A related but morphologically distinct organism infects rodents, although rodents may be infected with human isolates in the laboratory. Human giardiasis may involve diarrhea within 1 week of ingestion of the cyst, which is the environmental survival form and infective stage of the organism. Normally, illness lasts for 1 to 2 weeks, but there are cases of chronic infections lasting months to years. Chronic cases, both those with defined immune deficiencies and those without, are difficult to treat. Different individuals show various degrees of symptoms when infected with the same strain, and the symptoms of an individual may vary during the course of the disease.

Ingestion of one or more cysts may cause disease. Giardiasis is most frequently associated with the consumption of contaminated water. Cool, moist conditions favor the survival of the organism. Produce-related outbreaks have been linked to lettuce, tomatoes, and onions (Table 9). O8).

4. Conclusions

• Numerous microorganisms, most of them from enteric environments (for example, *Salmonella* spp., *E. coli* O157:H7, *C. jeju-*

ni) but also from other sources (for example, *C. botulinum* and *L. monocytogenes*) have been isolated from a variety of fresh fruits and vegetables.

• Although isolation rates can be high, they are not consistent. The percentage of samples contaminated ranges from 0 to 50%, depending upon the product and target pathogen. Because of differences in their production systems, surface morphology, or other factors, produce items, such as lettuce, berries, seed sprouts, melons, seem to provide conditions for pathogen survival and/or growth.

• The number of foodborne illness outbreaks linked to fresh produce and reported to the United States Centers for Disease Control and Prevention (CDC) has increased in the last years. Some of this increase is due to improved surveillance, but other factors may also come into play, such as increase in consumption, change in consumers' habits, and complex distribution systems.

• Foodborne illness resulting from the consumption of any food is dependant upon a several factors. For example, the produce must be contaminated with a pathogen that survives or grows to infective level doses at the time of consumption. Temperature abuse and growth is not always necessary for foodborne illness to occur.

• Conditions for survival and/or growth of pathogens on fresh produce necessary for illness are influenced by the type of microorganism, produce item, and environmental conditions in the field and subsequent handling and storage. For example, free moisture resulting from condensation rain or irrigation may promote survival and growth of microbial populations in an otherwise inhospitable environment.

• After harvest, pathogens will survive but not grow on the outer surface of most fresh fruits and vegetables, especially if the humidity is high. In some cases, pathogen levels will decline on the outer surface. The rate of decline is dependent upon the produce type, humidity, and temperature, as well as the atmosphere and type of packaging used.

• Survival and multiplication of foodborne pathogens on produce is significantly enhanced once the protective epidermal barrier has been broken either by physical damage, such as punctures or bruising, or by degradation by plant pathogens.

• Physically damage produce and fresh cut produce can promote the multiplication of pathogens, especially at nonrefrigerated temperatures. At refrigerated temperatures the ability of the microorganisms to multiply is reduced with the exceptions of psychrotrophic pathogens (for example, nonproteolytic *C. botulinum*, *L. monocytogenes*, *Y. enterocolitica*).

• Specifications requiring very low microbial counts may, in some cases, compromise produce safety because the population of nonpathogenic bacteria is potentially a barrier that reduces the risk of illness associated with fresh-cut products.

• Under some circumstances (for example, pressure differentials) wash water may enter an intact fruit through the stem scar or other opening, promoting pathogen infiltration. Access to nutrients inside the product may induce pathogen multiplication to hazardous levels. Conditions that reduce infiltration of plant pathogens should also prevent infiltration of human pathogens.

• Packaging of the product under modified atmospheres changes the growth rate of pathogens which may become a concern (for example, growth and toxin production by *C. botulinum*).

5. Research needs

• Continue and increase the number of well-designed incidence studies of pathogens in fresh produce. Isolation studies should be designed considering their statistical relevance, consistency (for example, consistent sample collection, treatment, laboratory test methods, and data analysis) and including testing of control samples. Negative results should also be reported.

• Increase surveillance and investigation of fresh produce related outbreaks.

• Investigate the relative fitness of human pathogens and common epiphytes (microbes that grow and persist on plant surfaces) and the interaction between bacterial pathogens and indigenous microorganisms.

• Determine the effects of various environmental factors (for example, ultraviolet irradiation) on the survival and growth of pathogens of concern.

• Investigate the factors affecting produce infiltration of microorganisms and assess the risk of foodborne disease due to infiltration of pathogen inside produce.

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Table G/S-1—Survival and growth of pathogenic bacteria on raw melons

Pathogen	Melon Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Campylobacter jejuni	Watermelon, cubes	3.0	Spot inoculation, cells suspended in saline. 0.02 ml inoculated per cube.	24 cm^2 cubes with 0.05 ml of lemon juice added per cube. Stored in covered sterile stainless-steel trays.	25-29	2.9	6 h	2	CFU/cube	pH 4.8 after 6 h.	Castillo and Escartin 1994
C. jejuni	Watermelon, cubes	5.5	Spot inoculation, cells suspended in saline. 0.02 ml inoculated per cube.	24 cm^2 cubes without lemon juice. Stored in covered sterile stainless-steel trays.	25-29	2.7	6 h	2.1	CFU/cube	pH 5.5 after 6 h.	Castillo and Escartin 1994
C. jejuni	Watermelon, cubes	5.5	Spot inoculation, cells suspended in saline. 0.02 ml inoculated per cube.	24 cm^2 cubes without lemon juice. Stored in sterile stainless-steel trays with cover.	25-29	2.4	6 h	1.6	CFU/cube	pH 5.5 after 6 h.	Castillo and Escartin 1994
Escherichia coli O157:H7 (4 strains)	Cantaloupe, rind surface	NR[a]	Spot inoculation, cells diluted in 0.1% peptone.	Melons were held in covered covered plastic boxes with 93 ± 5% relative humidity.	25 5	~5.2 ~5.2	21 d 8 d	~7.1 <1.0	CFU/cm^2 CFU/cm^2	—	Del Rosario and Beuchat 1995
E. coli O157:H7 (4 strains)	Cantaloupe, cubes	7.01	Cell suspension diluted in 0.1% peptone and added to sample.	Cubes placed in sealed stomacher bags and incubated.	25 5	3.0 ~3.1	34 h 34 h	~7.0 ~3.1	CFU/g CFU/g	—	Del Rosario and Beuchat 1995
E. coli O157:H7 (4 strains)	Watermelon, cubes	5.56	Cell suspension diluted in 0.1% peptone and added to sample.	Cubes placed in sealed stomacher bags and incubated.	25 5	3.0 3.0	34 h 34 h	~8.7 ~3.0	CFU/g CFU/g	—	Del Rosario and Beuchat 1995
E. coli O157:H7 (4 strains)	Watermelon, rind surface	—	Spot inoculation, cells diluted in 0.1% peptone. relative humidity.	Melons were held in covered plastic boxes with 93 ± 5% relative humidity.	25 5	~5.2 ~5.2	14 d 14 d	~6.4 <1.0	CFU/cm^2 CFU/cm^2	—	Del Rosario and Beuchat 1995
Salmonella (5 serotypes)	Cantaloupe, cubes	6.67	Cell suspension diluted in Butterfield's phosphate buffer,a added to sample.	Cubes placed in open stomacher bags and incubated aerobically.	23 5	2.0 2.0	24 h 24 h	~7.2 ~1.6	CFU/g CFU/g	—	Golden and others 1993
Salmonella (5 serotypes)	Honeydew, cubes	5.95	Cell suspension diluted in Butterfield's phosphate buffer, added to sample.	Cubes placed in open stomacher bags and incubated aerobically.	23 5	2.0 2.0	24 h 24 h	~8.0 ~1.8	CFU/g CFU/g	—	Golden and others 1993
Salmonella (5 serotypes)	Watermelon, cubes	5.90	Cell suspension diluted in Butterfield's phosphate buffer, added to sample.	Cubes placed in open stomacher bags and incubated aerobically.	23 5	2.0 2.0	24 h 24 h	8.6 ~1.9	CFU/g CFU/g	—	Golden and others 1993

Table G/S-1—Survival and growth of pathogenic bacteria on raw melons *(continued form previous page)*

Pathogen	Melon Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Shigella flexneri	Watermelon, cubes	NR	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated and stored in sterile covered glass trays.	22-26	2.8	6 h	4.5	CFU/cm^2	—	Fernandez Escartin and others 1989
S. sonnei whole	Watermelon,	NR	30 ml of inoculum was injected into the whole watermelon through the stem scar.	30 ml of inoculum was injected and incubated.	30 22	2.0 2.0	2 d 4 d	~9.0 ~9.0	CFU/g CFU/g	Inoculated with > 10^2 CFU/g. Melon rotten within 1-2 days at 30 °C and 2-3 days at 22 °C.	Fredlund and others 1987

[a]Not reported

Table G/S-2—Survival and growth of pathogenic bacteria on raw fruit other than melons

Pathogen	Friuit Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Campylobacter jejuni	Papaya, cubes	3.0	Spot inoculation, cells suspended in saline. 0.02 ml inoculated per cube.	24 cm^2 cubes with 0.05 ml of lemon juice added. Stored in sterile stainless-steel trays with cover.	25-29	3.3	6 h	<1.0	CFU/cube	pH 3.6 after 6 h.	Castillo and Escartin 1994
C. jejuni	Papaya, cubes	5.0	Spot inoculation, cells suspended in saline. 0.02 ml inoculated per cube.	24 cm^2 cubes without lemon juice. Stored in sterile stainless-steel trays with cover.	25-29	2.8	6 h	1.7	CFU/cube	pH 5.0 after 6 h.	Castillo and Escartin 1994
Escherichia coli O157:H7	Apple (Golden Delicious, fresh cut tissue)	NR[a]	Spot inoculation, 25 μl inoculated per wound. Inoculum suspended in 0.85% saline.	Apples were wounded (one wound per fruit) aseptically by removing a cyclinder of tissue 3 mm in diameter by 3 mm deep. Stored in plastic boxes on fruit pack trays.	24	2.0 4.0 6.0	48 h 48 h 48 h	~5.5 ~6.0 ~6.5	CFU per wound	—	Janisiewicz and others 1999
E. coli O157:H7 (2 strains)	Apples (Red Delicious, ground)	4.10	Cell suspension in tryptone soy broth, inoculated into sample.	Ground apples were stored in a plastic stomacher bag.	4 10 25	~7.5	18 d 12 d 5 d	~6.8 ~5.8 ~8.5	CFU/ml CFU/ml CFU/ml	Final pH 5.11. At 25 °C no growth within 24 h.	Fisher and Golden 1998
E. coli O157:H7 (2 strains)	Apple (Golden Delicious, ground)	3.84	Cell suspension in tryptone soy broth, inoculated into sample.	Ground apples were stored in a plastic stomacher bag.	4 10 25	~7.5	18 d 12 d 5 d	~7.2 ~6.8 ~8.2	CFU/ml CFU/ml CFU/ml	Final pH 4.95. At 25 °C no growth within 24 h.	Fisher and Golden 1998
E. coli O157:H7 (2 strains)	Apples (Rome, ground)	3.70	Cell suspension in tryptone soy broth, inoculated into sample.	Ground apples were stored in a plastic stomacher bag.	4 10 25	~7.5	18 d 12 d 5 d	~6.8 ~7.0 ~7.5	CFU/ml CFU/ml CFU/ml	Final pH 3.91. At 25 °C no growth within 24 h. Slight growth at 48 h followed by decline.	Fisher and Golden 1998
E. coli O157:H7 (2 strains)	Apples (Winesap, ground)	3.47	Cell suspension in tryptone soy broth, inoculated into sample.	Ground apples were stored in a plastic stomacher bag.	4 10 25	~7.5	18 d 12 d 5 d	~7.0 ~7.0 ~7.0	CFU/ml CFU/ml CFU/ml	Final pH 4.03.	Fisher and Golden 1998
E. coli O157:H7	Apple (5 cultivars, whole)	3.5-4.9	Infected with 0.1 ml of saline suspension of cells, then holes were sealed with tape.	Stored in plastic tub at room temperature.	20-25	5.0-5.2	2 d	4.8 - 8.3	CFU/apple	Survival and growth depended on cultivars and days post harvest. Dropped fruit did not differ from tree-picked fruit in promoting growth.	Dingman 2000
E. coli O157:H7 (2 strains)	Orange (Hamlin, peeled)	6.0-6.5	Spot inoculation, 20 μl inoculated and spread over 1/8 of total suface area. Inoculum suspended in Butterfield's phosphate buffer.	Inoculated fruit were individually packed in perforated plastic containers.	4 8 24	3.5	14 d 14 d 1 d	~3.2 ~2.5 ~7.5	CFU/g CFU/g CFU/g	pH of surface 6.0-6.5. Juice pH 3.8.	Pao and others 1998

Table G/S-2—Survival and growth of pathogenic bacteria on raw fruit other than melons *(continued from previous page)*

Pathogen	Fruit Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Listeria monocytogenes (2 strains)	Orange, (Hamlin, peeled)	6.0-6.5	Spot inoculation, 20 μl inoculated and spread over 1/8 of total suface area. Inoculum suspended in Butterfield's phosphate buffer.	Inoculated fruit were individually packed in perforated plastic containers.	4 8 24	3.9	14 d 14 d 1 d	~4.0 ~3.3 ~5.5	CFU/g CFU/g CFU/g	—	Pao and others 1998
Staphylococcus aureus (2 strains)	Orange, (Hamlin, peeled)	6.0-6.5	Spot inoculation, 20 μl inoculated and spread over 1/8 of total suface area. Inoculum suspended in Butterfield's phosphate buffer.	Inoculated fruit were individually packed in perforated plastic containers.	4 8 24	~2.8	14 d 14 d 1 d	~2.0 ~2.0 ~3.5	CFU/g CFU/g CFU/g	—	Pao and others 1998
Salmonella Chester	Apple (Golden Delicious, disks)	4.1	Dip inoculation, 30 s. Cells suspended in phosphate-buffered saline (pH 7.2).	NR	8	~ 5.5	66 h	~ 5.3	CFU/disk	Acidity did not markedly affect viability	Liao and Sapers 2000
S. Chester	Apple (Golden Delicious, disks)	4.1	Dip inoculation, 30 s. Cells suspended in phosphate-buffered saline (pH 7.2).	NR	20	~ 5.5	66 h	~ 10.4	CFU/disk	Increased to ca. 10.2 log_{10} CFU/ disk within 18 h	Liao and Sapers 2000
S. Typhi	Papaya, cubes	5.69	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated, and stored in covered glass trays.	25-27	2.9	6 h	4.3	CFU/cube	—	Fernandez Escartin and others 1989
S. Typhi	Papaya, cubes	3.59	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, 0.05 ml lemon juice added, inoculated, and stored in covered glass trays.	25-27	3.0	6 h	3.8	CFU/cube	—	Fernandez Escartin and others 1989
Salmonella (2 serotypes)	Orange, (Hamlin, peeled)	6.0-6.5	Spot inoculation, 20 μl inoculated and spread over 1/8 of total suface area. Inoculum suspended in Butterfield's phosphate buffer.	Inoculated fruit were individually packed in perforated plastic containers.	4 8 24	4.4	14 d 14 d 1 d	~3.5 ~2.5 ~7.6	CFU/g CFU/g CFU/g	—	Pao and others 1998
Shigella (3 species)	Papaya, cubes	5.69	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated and stored in covered glass trays.	25-27	2.0-2.4	6 h	3.8-4.2	CFU/cube	*S. sonnei, S. flexneri, S. dysenteriae*	Fernandez Escartin and others 1989

[a]Not reported

Table G/S-3—Survival and growth of pathogenic bacteria on raw tomatoes

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Listeria monocytogenes (2 strains)	Tomato (chopped)	4.1	Cells suspended in 0.1 M phosphate buffer, 10 mL mixed in 1000 g of tomatoes.	Stored in sealed bags with 3% O_2 and 97% N_2 or ambient air. Tomatoes either unwashed or washed in 210 to 280 ppm chlorine prior to chopping.	10	4.5-4.8	10 days	~3.5 to 4.2	CFU/g	Subjectively judged to be inedible after 10 days due to deterioration.	Beuchat and Brackett 1991
L. monocytogenes (2 strains)	Tomato (chopped)	4.1	Cell suspension in 0.1 M phosphate buffer, 10 mL mixed in 1000 g of tomatoes.	Stored in sealed bags with3% O_2 and 97% N_2 or ambient air. Tomatoes either unwashed or washed in 210 to 280 ppm chlorine prior to chopping.	21	5	8 days	1.0 to 3.5	CFU/g	Survival slightly better in chlorine treated samples.	Beuchat and Brackett 1991
L. monocytogenes (2 strains)	Tomato (whole, cherry)	Nra	Dip inoculation, noculum isuspended in 0.1 M phosphate buffer.	Stored in sealed bags with 3% O_2 and 97% N_2 or ambient air. Tomatoes either not washed or washed in 210 to 280 ppm chlorine.	10	3.5 to 3.7	20 days	3.5 to 5.0	CFU/g	Significant growth observed only for Scott A inoculated onto chlorine treated tomatoes stored in air. Little difference between strains, tomato treatments, or storage conditions.	Beuchat and Brackett 1991
L. monocytogenes (2 strains)	Tomato (whole, cherry)	NR	Dip inoculation, inoculum suspended in 0.1 M phosphate buffer.	Stored in sealed bags with 3% O_2 and 97% N_2 or ambient air. Tomatoes either not washed or washed in 210 to 280 ppm chlorine.	21	3.4 to 3.6	2 to 8 days	4.8 to 5.5	CFU/g	Significant growth observed only for Scott A inoculated onto chlorine treated tomatoes stored in air. Little difference between strains, tomato treatments, or storage conditions.	Beuchat and Brackett 1991
Salmonella Baildon	Tomato (diced)	4.50 to 4.52	Cells suspended in deionized water; 30 mL mixed with 2270 g of tomatoes.	Tomatoes (450 g) were sealed in plastic bags. Stored for up to 12 days.	4	0.4	12 days	<1.0	CFU/g	Not detected in 6 enriched 25-g samples analyzed each day (0, 2, 5, 8, 12 days).	Weissinger and others 2000
S. Baildon	Tomato (diced)	4.50 to 4.52	Cells suspended in deionized water; 30 mL mixed with 2270 g of tomatoes.	Tomatoes (450 g) were sealed in plastic bags. Stored for up to 12 days.	4	3.4	12 days	1.8	CFU/g	Counts were reduced by 0.40, 0.67. and 0.75 log_{10} CFU/g after 2, 5, and 8 days, respectively.	Weissinger and others 2000
S. Baildon	Tomato (diced)	4.39 to 4.41	Cell suspended in deionized water; 20 mL mixed with 600 g of tomatoes.	Tomatoes (100 g) were sealed in plastic bags. Stored for up to 72 hours.	21	0.79	72 hours	8.1	CFU/g	Counts were 5.32 and 7.60 log_{10} CFU/g after 24 and 48 hours, respectively.	Weissinger and others 2000
S. Baildon	(diced)	4.39 to 4.41	Cells suspended in deionized water; 20 mL mixed with 600 g of	Tomatoes (100 g) were sealed in plastic bags. Stored for up to 72 hours.	30	0.79	72 hours	7.94	CFU/g	Counts were 7.30 and 7.90 log_{10} CFU/g after 24 and 48 hours, respectively. Tomato	Weissinger and others 2000 tomatoes.

(continued on next page)

Table G/S-3—Survival and growth of pathogenic bacteria on raw tomatoes *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
S. Montevideo	Tomato (cut slices)	4.31 to 4.52	Spot inoculation, inoculum suspended in distilled water. 25µl inoculated onto each slice.	Tomato sliced into quarters.	25	3.4 4.4 7.4	12 hours 12 hours 12 hours	~7.5 ~8.0	CFU/slice	—	Wei and others 1995
S. Montevideo	Tomato (fully ripe, wounded)	4.20 to 4.39	Spot inoculation, noculum suspended in distilled water. 25 µL inoculated onto each wounded area.	Tomatoes were punctured to a depth of 2-mm and 0.6-cm in diameter in eight separate areas.	25	3.0 4.0 7.0	24 hours	~5.0 ~4.8 ~7.1	CFU per wounded area	—	Wei and others 1995
S. Montevideo	Tomato (mature green, wounded)	4.33 to 4.52	Spot inoculation, inoculum suspended in distilled water. 25 µL inoculated onto each wounded area.	Tomatoes were punctured to a depth of 1-mm and 0.6-cm in diameter in eight separate areas.	25	3.0 4.0 7.0	24 hours	~4.8 ~5.5 ~7.0	CFU per wounded area	—	Wei and others 1995
S. Montevideo	Tomato (ripe, chopped)	4.1	Cell suspension in 0.05 M potassium phosphate buffer. 1ml inoculated into 50 g sample.	1-cm cubes. Stored in stomacher bags	5 20 30	4.4	96 hours 22 hours 22 hours	~4.2 ~6.0 ~7.0	CFU/g CFU/g CFU/g	Tomatoes inedible after 22 hours at 20 or 30 °C and after 96 hours at 5 °C.	Zhuang and others 1995
S. Montevideo	Tomato (stem scar)	NR	Spot inoculation, inoculum suspended in distilled water. 25 µL inoculated onto stem scar.	—	20 25	8.0 8.0	7 days 7 days	6.5 5.8	CFU/ stem scar	—	Wei and others 1995
S. Montevideo	Tomato (stem scar)	NR	Spot inoculation, inoculum suspended in TSB. 25 mL inoculated onto stem scar.	—	20 25	7.2 7.2	7 days 7 days	4.6 6.3	CFU/ stem scar	—	Wei and others 1995
S. Montevideo	Tomato (whole, mature green)	NR	Dip inoculation, inoculum suspended in 0.1 M phosphate buffer.	Stored individually in open plastic bags with relative humidity between 45 and 60%.	10 20 30	~1.4	1 to 18 days 7 days 2 days	~ 2.2 ~4.0 ~5.0	CFU/cm^2	Populations declined at 20 and 30 °C after day 7.	Zhuang and others 1995
S. Montevideo	Tomato, skin	NR	Spot inoculation, cells suspended in distilled water. Sterile filter discs submerged in inoculum and placed on tomatoes.	Filter discs were dried at room temperature for 2 hours and removed from tomatoes. Tomatoes were stored at 83% (20 °C) or 72% (25 °C) relative humidity.	20 25	5.8 5.8	5 days 3 days	<1 <1	CFU/ area inoculated	—	Wei and others 1995
S. Montevideo	Tomato, skin	NR	Spot inoculation, cells suspended in TSB. Sterile filter discs submerged in inoculum and placed on tomatoes.	Filter discs were dried at room temperature for 2 hours and removed from tomatoes. Tomatoes were stored at 83% (20 °C) or 72% (25 °C) relative humidity.	20 25	5.5 5.5	7 days 7 days	2.6 4.1	CFU/ area inoculated	—	Wei and others 1995
Salmonella (3 serotypes)	Tomato (cut, small pieces)	4.0 to 4.40	Cell suspension in saline, 0.1 mL inoculated into 20 g of sample.	Inoculated samples sealed in polyethylene plastic bags.	22 30	1.1	24 hours	6.3 to 6.9 7.2 to 8.4	CFU/g CFU/g	Final pH 3.90 to 4.36. *S.* Enteriditis, *S.* Infantis, and *S.* Typhimurium.	Asplund and Nurmi 1991

[a]Not reported

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Aeromonas hydrophila (2 strains)	Asparagus	NR[a]	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in 6% CO_2, 79% N_2, and 15% O_2 in glass jars.	15 4	4.5 4.5	4 d 14 d	~8.0 ~7.5	CFU/g CFU/g	Asparagus first became unacceptable for consumption on day 6 (15 °C) or day 21 (4 °C).	Berrang and others 1989a
A. hydrophila (2 strains)	Asparagus	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	4.5 4.5	4 d 21 d	~8.0 ~7.5	CFU/g CFU/g	Asparagus first became unacceptable for consumption on day 4 (15 °C) or day 15 (4 °C).	Berrang and others 1989a
A. hydrophila (2 strains)	Broccoli	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in 10% CO_2, 79% N_2, and 11% O_2 in glass jars.	15 4	5.1 4.0	4 d 14 d	~8.2 ~6.0	CFU/g CFU/g	Broccoli first became unacceptable for consumption on day 10 (15 °C) or day 21 (4 °C).	Berrang and others 1989a
A. hydrophila and (2 strains)	Broccoli	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	5.1 4.0	4 d 14 d	~8.2 ~6.0	CFU/g CFU/g	Broccoli first became unacceptable for consumption on day 6 (15 °C) or day 21 (4 °C).	Berrang others 1989a
A. hydrophila (2 strains)	Cauliflower	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	4.0 3.5	4 d 14 d	~8.5 ~5.9	CFU/g CFU/g	Cauliflower first became unacceptable for consumption on day 6 (15 °C) or day 21 (4 °C).	Berrang and others 1989a
A. hydrophila (2 strains)	Cauliflower	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in 3% CO_2, 79% N_2, and 18% O_2 in glass jars.	15 4	4.0 3.5	4 d 14 d	~8.5 ~6.0	CFU/g CFU/g	Cauliflower first became unacceptable for consumption on day 8 (15 °C) or day 21 (4 °C).	Berrang and others 1989a
A. hydrophila (1 strain)	Endive (chicory)	NR	Cell suspension added to samples.	Stored in moderate vacuum packaging containers under moderate vacuum.	6.5	3.2	3-7 d	~7.0	CFU/g	—	Aytac and Gorris1994
A. hydrophila (1 strain)	Endive (chicory)	NR	Cell suspension added to samples.	Stored in moderate vacuum packaging container in ambient air.	6.5	3.2	3 d	6.5	CFU/g	Populations declined to Log 1.0 CFU/g by day 7.	Aytac and Gorris1994

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
A. hydrophila Population at 15 °C	Vegetable Garcia-salads (mixed vegetable)	6.0	Cell suspension, injected through a silicone septum. Cells suspended in brain heart infusion broth.	Samples sealed and stored in polypropylene plastic film.	15	3.0	4 24 h	3.0 ~7.9	9 d	~3.5 steadily declined from 24 h to 6 d.	CFU/g Gimeno and others 1996
Clostridium botulinum (10 strains)	Broccoli spores/g6/6 samples	6.9	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples loosely packaged and stored in sealed polyethylene bags.	Larson and			21	2.0	3 d toxic. Spoilage observed.	NR others 1997
C. botulinum (10 strains)	Broccoli	6.9	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples loosely packaged and stored in sealed polyethylene bags.	12	2.0	9 d	NR	spores/g	3/6 samples toxic. Gross spoilage observed.	Larson and others 1997
C. botulinum (10 strains)	Broccoli	6.9	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples loosely packaged and stored in sealed polyethylene bags.	4	2.0	30 d	NR	spores/g	0/6 samples toxic. Gross spoilage observed.	Larson and others 1997
C. botulinum nonproteolytic (8 strains)	Butternut squash	NR	Spore suspension (2.5 ml) added to 500 g sample.	1-inch cubes, inoculated and sealed in a polystyrene tray.	10 5	3.0 3.0	7 d 21 d	NR	spores/g	Toxin detected at 7 d (10 °C) or 21 d (5 °C). No change in appearance. Final pH 6.4 (5 °C), 6.7 (10 °C).	Austin and others 1998
C. botulinum proteolytic (10 strains)	Butternut squash	NR	Spore suspension (2.5 ml) added to 500 g sample.	1-inch cubes, inoculated and sealed in a polystyrene tray.	15 25	2.0 2.0	14 d 3 d	NR	spores/g	Toxin detected at 14 d (15 °C) or 3 d (25 °C). 15 °C samples dry and moldy. Swelling of packaged observed in 25 °C samples. Final pH 6.5 (15 °C), 6.2 (25 °C).	Austin and others 1998
C. botulinum No toxin detected	Cabbage Petran and	NR	Spore suspension	Samples were sealed in				4.4	2.1	28 d	2.2MPN

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
(12 strains)	(shredded)		(1 ml), heat shocked, sprayed onto sample. Spores were suspended in gel-phosphate buffer.	3-qt pouches and stored vented or not vented. Vented bags were placed with space between samples so that air could circulate.	12.7 21	2.1 2.1	28 d 28 d	2.0 ND[b]	spores/g	in samples stored at 4.4 °C or 12.7 °C. Toxin detected in non-vented samples stored at 21 °C after 7 d. Samples were judged to be inedible prior to toxin detection.	others 1995
C. botulinum (10 strains 5 type A and 5 type B)	Cabbage (shredded)	6.2	Spore suspended in water, 1 ml heat shocked suspension added to sample.	Stored in ethylene vinyl alcohol bags. Sealed in MAP of 70% CO_2 and 30% N_2.	22-25	0.8-1.8	6 d	NR	spores/g	No toxin detected.	Solomon and, others 1990
C. botulinum (10 strains, 5 type A and 5 type B)	Cabbage (shredded)	6.2	Spore suspended in water, 1 ml heat shocked suspension added to sample.	Stored in ethylene vinyl alcohol bags. Sealed in MAP of 70% CO_2 and 30% N_2.	22-25	2-2.3	4 d	NR	spores/g	5/6 bags toxic. Cabbage acceptable. Only type A grew and produced toxin.	Solomon and others 1990
C. botulinum toxic. (10 strains, 5 type A and 5 type B)	Cabbage (shredded)	6.2 Solomon and	Spore suspended in water, 1 ml heat shocked suspension added to sample.	Stored in ethylene vinyl alcohol bags. Sealed in MAP of 70% CO_2 and 30% N_2.		22-25	2.9	4 d	NR	spores/g Cabbage acceptable. Only type A grew and produced toxin.	2/2 bags others 1990
C. botulinum Solomon and (5 strains, type A)	Cabbage (shredded)	6.2	Spore suspended in water, 1 ml heat shocked suspension added to sample.	Stored in ethylene vinyl alcohol bags. Sealed in MAP of 70% CO_2 and 30% N_2.		22-25	1.6-2.1	6 d	NR	spores/g detected.	No toxin others 1990
C. botulinum NR (5 strains, type A)	Cabbage spores/g (shredded)	6.2 5/10 bags toxic	Spore suspended in water, 1 ml heat shocked suspension added to sample.	Stored in ethylene vinyl alcohol bags. Sealed in MAP of 70% CO_2 and 30% N_2. Solomon and				22-25	2.5-3.0	4 d at 4 d, 8/10 bags toxic at 5 d, and 9/10 bags toxic at 6 d. Cabbage acceptable.	5 d6 d others 1990
C. botulinum (10 strains)	Cabbage (shredded)	6.4	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples stored in polyethylene bags and vacuum sealed.	4 12 21	2.0	37 8 4	NR	spores/g	0/6 samples were toxic at end of storage for all three temperatures. Gross spoilage was observed.	Larson and others 1997

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads ***(continued from previous page)***

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
C. botulinum (10 strains)	Carrot (sliced)	6.3	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples stored in polyethylene bags and vacuum sealed.	4 12 21	2.0	78 d 14 d 4 d	NR	spores/g	0/6 samples were toxic at end of storage for all three temperatures. Gross spoilage was observed.	Larson and others 1997
C. botulinum nonproteolytic (8 strains)	Coleslaw	NR	Spore suspension (1 ml) injected through gas-tight septum.	Samples in original package.	5 10	3.0	21 d	NR	spores/g	No toxin detected after 21 d. No change in appearance.	Austin and others 1998
C. botulinum proteolytic (10 strains)	Coleslaw	NR	Spore suspension (1 ml) injected through gas-tight septum.	Samples in original package.	15 25	2.0	21 d	NR	spores/g	No toxin detected after 21 d. No change in appearance.	Austin and others 1998
C. botulinum (10 strains)	Green beans	6.3	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples loosely packaged and stored in sealed polyethylene bags.	4 12 21	2.0	35 9 7	NR	spores/g	0/6 samples toxic at end of storage for all three temperatures. Gross spoilage observed.	Larson and others 1997
C. botulinum proteolytic (10 strains)	Mushroom (enoki)	NR	Spores suspended in trypticase peptone glucose yeast extract, 0.1ml inoculated per package.	Stored under anaerobic conditions in sealed bags.	6 15 15 27	3.0	21 d 7 d 14 d 2 d	No toxin No toxin Toxin Toxin	spores/ package	Spoilage evident when toxin detected.	Malizio and Johnson 1991
C. botulinum proteolytic (10 strains)	Mushroom (enoki)	NR	Spores suspended in trypticase peptone glucose yeast extract, 0.1ml inoculated per package.	Stored under anaerobic conditions in sealed bags.	15 27 27	2.0	14 d 2 d 4 d	Toxin No toxin Toxin	spores/ package	Spoilage evident when toxin detected.	Malizio and Johnson 1991
C. botulinum proteolytic (10 strains)	Mushroom (enoki)	NR	Spores suspended in trypticase peptone glucose yeast extract, 0.1ml inoculated per package.	Stored under anaerobic conditions in sealed bags.	15 21 27 27	1.0	14 d 21 d 2 d 4 d	No toxin Toxin No toxin Toxin	spores/ package	Spoilage evident when toxin detected.	Malizio and Johnson 1991
C. botulinum detected at proteolytic (10 strains)	Onion Austin and	NR	Spore suspension (2.5 ml) added to 500 g sample.	5-mm slices, inoculated and sealed in polystyrene trays.		25	3.0	6 d	—	spores/g 6 d. Swelling of package observed but no change in appearance of onions.	Toxin others 1998

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
C. botulinum detected nonproteolytic (8 strains)	Rutabaga Austin and	NR	Spore suspension (2.5 ml) added to 500 g sample.	1-inch cubes, inoculated and sealed in polystyrene trays.	10	5 3.0	3.0	21 d	NR	spores/g after 21 d. No change in appearance.	No toxin others 1998
C. botulinum detected proteolytic (10 strains)	Rutabaga Austin and	NR	Spore suspension (2.5 ml) added to 500 g sample.	1-inch cubes, inoculated and sealed in polystyrene trays.	25	15 2.0	2.0	21 d	NR	spores/g after 21 d (15 °C). No change in appearance. At 25 °C toxin detected at 7 d. Decay evident. Final pH 5.9.	No toxin others 1998
C. botulinum detected nonproteolytic (8 strains)	Stir fry vegetables	NR Austin and	Spore suspension (1 ml) injected into sealed bags through gas-tight septum.	Stored in plastic film.	5 10	3.0	3.0 3.3	21 d	3.0	CFU/g after 21 d. No change in appearance.	No toxin others 1998
C. botulinum detected proteolytic (10 strains)	Stir fry Austin and vegetables	NR	Spore suspension (1 ml) injected into sealed bags through gas-tight septum.	Stored in plastic film.	15		2.0	21 d	2.8	CFU/g at 21 d. No change in appearance.	No toxin others 1998
C. botulinum detected at proteolytic (10 strains)	Stir fry Austin and vegetables	NR	Spore suspension (1 ml) injected into sealed bags through gas-tight septum.	Stored in plastic film.	25		2.0	11 d	>4.5	CFU/g 11 d. Soft appearance. Final pH 4.2.	Toxin others 1998
Escherichia coli O157:H7 (5 strains)	Carrot (shredded)	7.1	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in polyolefin L-bags consisting 3% O_2 and 97% N_2.	5 12 21	2.5	3 d 3 d 7 d	<1 <1 4.2	CFU/g	Samples held at 5 °C and 12 °C were positive upon enrichment through day 14.	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Carrot (shredded)	7.1	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in air in polyolefin L-bags.	5 12 21	5.3	3 d 14 d 7 d	4.6 6.3 6.0	CFU/g	Samples held at 5 °C were positive upon enrichment through day 14.	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Carrot (shredded)	7.1	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in air in polyolefin L-bags.	5 12 21	2.5	3 d 3 d 7 d	<1 <1 3.8	CFU/g	Samples held at 5 °C and 12 °C were positive upon enrichment through day 14.	Abdul-Raouf and others 1993

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
E. coli O157:H7 (5 strains) (shredded)	Carrot	7.1	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in polyolefin L-bags consisting 3% O_2 and 97% N_2.	5 12 21	5.3	3 d 14 d 7 d	4.1 6.6 6.5	CFU/g	Samples held at 5 °C were positive upon enrichment through day 14.	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Cucumber (sliced)	7.3	Dip inoculation, 1 min. Cells suspended in deionized water.	5-mm discs, stored in 3% O_2 and 97% N_2 in polyolefin L-bags.	5 12 21	5.1	10 d 10 d 7 d	2.3 5.4 4.6	CFU/g	—	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Cucumber (sliced)	7.3	Dip inoculation, 1 min. Cells suspended in deionized water.	5-mm discs, stored in 3% O_2 and 97% N_2 in polyolefin L-bags.	5 12 21	2.3	3 d 3 d 7 d	<1 <1 2.6	CFU/g	Samples stored at 5 and 12 °C were positive upon enrichment through day 3 and day 7, respectively.	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Cucumber (sliced)	7.3	Dip inoculation, 1 min. Cells suspended in deionized water.	5-mm discs, stored in air in polyolefin L-bags.	5 12 21	5.1	10 d 10 d 7 d	3.4 5.7 2.6	CFU/g	—	Abdul-Raouf and others 1993
E. coli O157:H7 (5 strains)	Cucumber (sliced)	7.3	Dip inoculation, 1 min. Cells suspended in deionized water.	5-mm discs, stored in air in polyolefin L-bags.	5 12 21	2.3	3 d 3 d 7 d	<1 <1 3.1	CFU/g	Samples stored at 5 and 12 °C were positive upon enrichment through day 3 and day 10, respectively.	Abdul-Raouf and others 1993
Listeria monocytogenes (1 strain)	Asparagus	NR	Cells injected into samples.	Stored in hemetically sealed bags.	2 4 8 12 20	5.0 5.0 5.0 5.0 5.0	6-24 d 6-24 d 3-24 d 3-15 d 3-6 d	4.5 5.0 7.0 9.0 9.0	CFU/g CFU/g CFU/g CFU/g CFU/g	Approximately 1 log increase at 2 and 4 °C within 3 d followed by decrease.	Castillejo and Rodriguez others 2000
L. monocytogenes (2 strains)	Asparagus	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in 6% CO_2, 79% N_2, and 15% O_2 in glass jars.	15 4	4.0/4.8 4.2/4.8	6 d 21 d	~7.3 ~5.8/6.5	CFU/g CFU/g	Asparagus first became unacceptable for consumption on day 6 (15 °C) or day 21 (4 °C).	Berrang and others 1989b
L. monocytogenes (2 strains)	Asparagus	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	4.0/4.8 4.2/4.8	4 d 14 d	~7.0 ~5.0/5.5	CFU/g CFU/g	Asparagus first became unacceptable for consumption on day 4 (15 °C) or day 14 (4 °C).	Berrang and others 1989b

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads ***(continued from previous page)***

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
L. monocytogenes (2 strains)	Broccoli	NR	Dip inoculation, 1 min. Cells suspended in 0.1M potassium phosphate buffer.	Samples stored in 10% CO_2, 79% N_2, and 11% O_2 in glass jars.	15 4	5.0/5.5 4.0	10 d 21 d	~8.8 ~4.0/4.5	CFU/g CFU/g	Broccoli first became unacceptable for consumption on day 10 (15 °C) or day 21 (4 °C).	Berrang and others 1989b
L. monocytogenes (2 strains)	Broccoli	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	5.6 4.0	10 d 21 d	~8.7 ~3.8/4.0	CFU/g CFU/g	Broccoli first became unacceptable for consumption on day 6 (15 °C) or day 14 (4 °C).	Berrang and others 1989b
L. monocytogenes (5 strains)	Butternut squash	6.3	Cell suspension, 10 ml of cells added to sample. Cells suspended in 0.1% peptone.	2.5-cm cubes, inoculated, and transferred to a foam tray. Sealed and stored in a bag.	4 10	3.0	9 d	~6.5 ~8.5	CFU/g	—	Farber and others 1998
L. monocytogenes (1 strain)	Cabbage (shredded)	NR	Cells suspended in Butterfield's phosphate buffer, 1 ml added to sample.	Samples in stored gas impermeable plastic bags and sealed in ambient atmosphere.	5	3.6	13 d/17 d	4.6/2.1	CFU/g	—	Kallander and others 1991
L. monocytogenes (1 strain)	Cabbage (shredded)	NR	Cells suspended in Butterfield's phosphate buffer, 1 ml added to sample.	Samples in stored gas 30% impermeable plastic bags and sealed in 70% CO_2 and N2. Held refrigerated for first 24 h.	5	3.0	17 d	~4.9	CFU/g	—	Kallander and others 1991
L. monocytogenes (1 strain)	Cabbage (shredded)	6.32 (day 1)	Cells suspended in Butterfield's phosphate buffer, 1 ml added to sample.	Samples in stored gas impermeable plastic bags and sealed in ambient atmosphere. Held refrigerated for first 24 h.	25	4.1	2 d/6-9 d	~6.0/<1.3	CFU/g	—	Kallander and others 1991
L. monocytogenes (1 strain)	Cabbage (shredded)	6.32 (day 1)	Cells suspended in Butterfield's phosphate buffer, 1 ml added to sample.	Samples stored in gas impermeable plastic bags and sealed in 70% CO_2 and 30% N_2.	25	4.0	2 d/6-9 d	~4.5/<1.3	CFU/g	—	Kallander and others 1991
L. monocytogenes (1 strain)	Cabbage (shredded)	NR	Cells suspended in 0.1M potassium phosphate buffer and added to sample.	Samples were mixed, drained and adjusted to incubation temperature within 3 h.	5	4.0	25-64 d	~8.0	CFU/g	—	Beuchat and others 1986
L. monocytogenes (5 strains)	Carrot	NR	Cell suspension, 1 to1.6 ml of inoculum injected through a gas-tight septum. Cells suspended in 0.1% peptone.	Samples purchased from the store. Stored in original packaging.	4 10	2.3 2.3	9 d 9 d	1.0 <1.0	CFU/g	—	Farber and others 1998

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads ***(continued from previous page)***

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
L. monocytogenes (2 strains)	Carrot (shredded)	—	Dip inoculation, cells suspended in 0.1 M potassium phosphate buffer.	Carrots washed or unwashed in 200-250 ppm prior to shredding. Stored in ambient air or in 3% O_2 and 97% N_2.	5 15	1.1-2.6 <1.0	24 d 7 d	3.8-4.6 3.4-5.8	CFU/g	Similar results obtained for unwashed carrots stored at 5 °C. Population declined to <1 log CFU/g (day 7) in unwashed carrots stored at 15 °C.	Beuchat and Brackett 1990a
L. monocytogenes (2 strains)	Carrot (whole)	—	Dip inoculation, cells suspended in 0.1 M potassium phosphate buffer.	Carrots washed or unwashed in 200-250 ppm. Stored in ambient air or in 3% O_2 and 97% N_2.	5 15	1.8-2.4 2.5-3.0	18 d 7 d	<1.0 <1.0	CFU/g	—	Beuchat and Brackett 1990a
L. monocytogenes (2 strains)	Cauliflower	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M potassium phosphate buffer.	Samples stored in 3% CO_2, 79% N_2, and 18% O_2 in glass jars.	15 4	3.4/4.0 2.8/ 3.0	8 d 21 d	~6.8/7.1 ~3.0/3.6	CFU/g CFU/g	Cauliflower first became unacceptable for consumption on day 8 (15 °C) or day 21 (4 °C).	Berrang and others 1989b
L. monocytogenes (2 strains)	Cauliflower	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M potassium phosphate buffer.	Samples stored in ambient air in glass jars.	15 4	3.4/4.0 2.8/ 3.0	8 d 14 d	~6.2/6.8 ~2.3/3.6	CFU/g CFU/g	Cauliflower first became unacceptable for consumption on day 6 (15 °C) or day 14 (4 °C).	Berrang and others 1989b
L. monocytogenes (5 strains)	Coleslaw	6.6	Cell suspension, 1 to1.6 ml of inoculum injected through a gas-tight septum. Cells suspended in 0.1% peptone.	Samples were purchased from the store. Stored in original packaging.	4 10	2.5 2.5	9 d	~4.0 ~5.0	CFU/g	—	Farber and others 1998
L. monocytogenes (1 strain)	Endive (chicory)	NR	Cell suspension added to samples.	Stored in moderate vacuum packaging containers under moderate vacuum.	6.5	3.3	7 d	~2.5	CFU/g	—	Aytac and Gorris1994
L. monocytogenes (1 strain)	Endive (chicory)	NR	Cell suspension added to samples.	Stored in moderate vacuum packaging container in ambient air.	6.5	3.3	7 d	~5.2	CFU/g	—	Aytac and Gorris1994
L. monocytogenes (1 strain)	Endive (broad leaved)	—	Dip inoculation, 10 min. Cells suspended in sterile distilled water.	Samples were inoculated, drained, sealed, and stored in polypropylene pouches.	10	4.5	7 d	5.2	CFU/g	—	Carlin and Nguyen-the 1994
L. monocytogenes (1 strain)	Endive (curly leaved)	—	Dip inoculation, 10 min. Cells suspended in sterile distilled water.	Samples were inoculated, drained, sealed, and stored in polypropylene pouches.	10	4.2	7 d	4.5	CFU/g	—	Carlin and Nguyen-the 1994

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
L. monocytogenes (3 strains)	Endive (broad leaved)	NR	Dip inoculation, 10 min. Cells suspended in sterile distilled water. Strains inoculated independently.	Samples were inoculated, drained, sealed, and stored in polypropylene pouches.	10	4.1-4.8	7 d	6.1-7.0	CFU/g	When lower inoculation levels were used, populations increased faster during initial storage but final populations were lower.	Carlin and others 1995
L. monocytogenes (3 strains)	Endive (broad leaved)	NR	Dip inoculation, 10 min. Cells suspended in sterile distilled water.	Stored in 90-mm diameter petri dishes and placed in plastic boxes. Boxes contained wet absorbent paper. Stored in modified atmosphere of 10% CO_2, 10% O_2.	3 10	~3.9-4.0 ~4.1-4.2	10 d 8 d	~3.5-4.5 ~6.2-6.7	CFU/g	Higher initial CO_2 levels caused significant spoilage.	Carlin and others 1996
L. monocytogenes (3 strains)	Endive (broad leaved)	NR	Dip inoculation, 10 min. Cells suspended in sterile distilled water.	Stored in 90-mm diameter petri dishes and placed in plastic boxes. Boxes contained wet absorbent paper. Stored in ambient air.	3 10	~3.6-3.9 ~4.1-4.2	10 d 8 d	~4.0-5.0 ~6.2-6.7	CFU/g	—	Carlin and others 1996
L. monocytogenes (5 strains)	Onion	5.8	Cell suspension, 10 ml of cells added to sample. Cells suspended in 0.1% peptone.	1-cm slices, inoculated, and transferred to foam trays. Sealed and stored in bags.	4 10	4.0 3.5	9 d	~3.0 ~4.8	CFU/g	—	Farber and others 1998
L. monocytogenes (5 strains)	Rutabaga	6.3	Cell suspension, 10 ml of cells added to sample. Cells suspended in 0.1% peptone.	0.5 by 0.5 by 7.5cm sticks, inoculated, and transferred to foam trays. Stored and sealed in bags.	4 10	3.0 3.0	9 d	~4.0 ~6.0	CFU/g	—	Farber and others 1998
L. monocytogenes (5 strains)	Stir fry vegetables	6.8	Cell suspension, 1-1.6 ml of inoculum injected through a gas-tight septum. Cells suspended in 0.1% peptone.	Samples purchased from the store. Stored in original packaging.	4 10	2.5 2.5	9 d	~3.0 ~5.5	CFU/g	—	Farber and others 1998
Samonella Typhi	Jicama (cubes)	3.30	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, 0.05 ml lemon juice added, inoculated, and stored in covered glass trays.	25-27	3.1	6 h	3.4	CFU/cube	—	Fernandez Escartin and others 1989
S. Typhi	Jicama (cubes)	5.97	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated, and stored in covered glass trays.	25-27	3.2	6 h	4.7	CFU/cube	—	Fernandez Escartin and others 1989

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Shigella *dysenteriae* and (1 strain) 1989	Jicama (cubes)	5.97	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated and stored in covered glass trays.	25-27	1.5	6 h	2.2	CFU/cm^2	—	Fernandez Escartin and others
S. flexneri (1 strain)	Carrot salad	NR	Cells suspended in water and added to sample.	Samples stored in 50 ml polypropylene centrifuge tubes.	5	~6.7	11 d	~2.5	CFU/g	—	Rafii and Lunsford 1997
S. flexneri (1 strain)	Green pepper (chopped)	NR	Cells suspended in water and added directly to sample.	Samples stored in 50 ml polypropylene centrifuge tubes.	4	6.7	12 d	4.3	CFU/g	—	Rafii and Lunsford 1997
S. flexneri (1 strain)	Coleslaw	NR	Cells suspended in water and added directly to sample.	Samples stored in 50 ml polypropylene centrifuge tubes.	4	~5.1	16 d	~4.3	CFU/g	—	Rafii and Lunsford 1997
S. flexneri (1 strain)	Cabbage (chopped)	NR	Cells suspended in water, added directly to sample.	Samples stored in 50 ml polypropylene centrifuge tubes.	4	6.5	26 d	3.1	CFU/g	—	Rafii and Lunsford 1997
S. flexneri (1 strain)	Onion (chopped)	NR	Cells suspended in water and added to sample.	Samples stored in 50 ml polypropylene centrifuge tubes.	4	6.7	12 d	5.3	CFU/g	—	Rafii and Lunsford 1997
S. sonnei 2000	Parsley (chopped leaves)	NR	Parsley was immersed in suspension of cells in 0.05 M potassium phosphate buffer (pH 6.8) for 1 min while being agitated, then dried at 21 °C for 1 h.	Leaves (300 g) placed in 9-liter pans.	21	3.5	1 d	6.2	CFU/g	Subjective examination revealed that parsley was edible.	Wu and others

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads ***(continued from previous page)***

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
S. sonnei (whole leaves)	Parsley	NR	Parsley was immersed in suspension of cells in 0.05 M potassium phosphate buffer (pH 6.8) for 1 min while being agitated, then dried at 21 °C for 1 h.	Leaves (300 g) placed in 9-liter pans.	21	3.2	7 d	3.8	CFU/g	Subjective examination revealed that parsley was edible.	Wu and others 2000
S. sonnei (whole or chopped leaves)	Parsley	NR	Parsley was immersed in suspension of cells in 0.05 M potassium phosphate buffer (pH 6.8) for 1 min while being agitated, then dried at 21 °C for 1 h.	Leaves (300 g) placed in 9-liter pans.	4	3.2-3.5	14 d	0.4-0.8	CFU/g	Subjective examination revealed that parsley was edible.	Wu and others 2000
S. sonnei (3 strains)	Parsley (chopped)	—	Dip inoculation, cells suspended in 0.05 M potassium phosphate-buffered saline. 1200 g sample inoculated and dried. Chopped after drying.	Stored in 9-liter plastic pans.	4 21	6.48/3.49	2 d	~9.2/~6.3	CFU/g	The pathogen grew to 9.2 and 6.3 log CFU/g within 2 d at 21 °C, followed by a decline. Inoculated chopped parsley stored at 4 °C declined throughout a 14 d storage period.	Wu and others 2000
S. sonnei (3 strains)	Parsley (whole, leaves)	—	Dip inoculation, cells suspended in 0.05 M potassium phosphate-buffered saline. 1200 g sample inoculated and dried.	Stored in 9-liter plastic pans.	21	3.23/6.19	7 d/7 d	~3.0/~6.5	CFU/g	An increase of <1 log within 1 day at 21 °C, followed by a decline in population after 2 d. Inoculated parsley stored at 4 °C declined thoroughout the 14 d storage period.	Wu and others 2000
S. sonnei (1 strain)	Cabbage (shredded)	6.8	Dip inoculation, cells suspended in Butterfield's phosphate buffer.	Stored under vacuum in gas impermeable bags.	24±2 0-6	3.2 3.5	1 d/7 d 7 d	7.0/ < –0.52 3.5	MPN/g	—	Satchell and others 1990
S. sonnei (1 strain)	Cabbage (shredded)	6.8	Dip inoculation, cells suspended in Butterfield's phosphate buffer.	Stored in modified atmosphere (30% N_2, 70% CO_2) in gas impermeable bags.	24±2 0-6	3.4 2.6	1 d/7 d 7 d	7.0/3.7 2.5	MPN/g	—	Satchell and others 1990

Table G/S-4—Survival and growth of pathogenic bacteria on raw vegetables other than tomatoes, sprouts, lettuce, and salads *(continued from previous page)*

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
S. sonnei (1 strain)	Cabbage (shredded)	6.8	Dip inoculation, cells suspended in Butterfield's phosphate buffer.	Stored anaerobically in gas impermeable bags.	24± 2 0-6	3.6 3.8	2 d/7 d 7 d	7.0/4.4 –0.081	MPN/g	—	Satchell and others 1990
Shigella (3 species)	Jicama (cubes)	5.97	Spot inoculation, cells suspended in saline. 1 drop (Pasteur pipette) inoculated per cube.	12 cm^2 cubes, inoculated and stored in covered glass trays.	25-27	2.5-2.6	6 h	3.3-4.0	CFU/cm^2	*S. sonnei, S. flexneri, S. dysenteriae*	Fernandez Escartin and others 1989

[a]Not reported

Table G/S-5—Survival and growth of pathogenic bacteria on raw lettuce and salads

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Clostridium botulinum (10 strains)	Lettuce (intact)	6.2	Spot inoculation, spores prepared in broth, heat shocked, and diluted in distilled water.	Samples stored in polyethylene bags and vacuum sealed.	4 12 21	2.0	50 d 13 d 6 d	NR	NR	At 4 °C, 0/6 toxic. At 12 °C, 0/6 toxic. At 21 °C, 2/6 toxic. Gross spoilage observed when toxin detected.	Larson and others 1997
C. botulinum nonproteolytic (8 strains)	Mixed salad	NR[a]	Spore suspension, 1 ml injected through gas-tight septum.	Samples in original package.	5 10 15 25	3.0	21 d 21 d 14 d 4 d	3.7 3.7 >4.5 >4.4	spores/g	No toxin at 5 or 10 °C. Toxin detected at 14 d (15 °C) and 4 d (25 °C). Moderate browning at time of toxin detection. Final pH 5.3-5.9.	Austin and others 1998
C. botulinun proteolytic (10 strains)	Mixed salad	NR	Spore suspension, 1 ml injected through gas-tight septum.	Samples in original package.	15 15 25	1.0 2.0	21 d 21 d 7 d	NR NR >4.5	spores/g	No toxin at 15 °C. Extensive decay observed when toxin detected (7 d at 25 °C).	Austin and others 1998
C. botulinum (12 strains)	Romaine lettuce (shredded)	NR	Spore suspension (1 ml), heat shocked, sprayed onto sample. Spores were suspended in gel-phosphate buffer.	Samples were sealed in 3-qt pouches and stored vented or not vented. Vented bags were placed with space between samples so that air could circulate.	4.4 12.7 21	2.0 2.0 2.0	28 d 28 d 28 d	2.0 2.1 ND[b]	MPN spores/g	No toxin detected in samples stored at 4.4 °C or 12.7 °C.Toxin detected in non-vented samples stored at 21 °C after 14 d and in vented samples after 21 d. Samples were judged to be inedible prior to toxin detection.	Petran and others 1995
C. botulinum nonproteolytic (8 strains)	Romaine lettuce	NR	Spore suspension, 1 ml injected through gas-tight septum.	Samples in original package.	5 10	3.0	21 d	NR	spores/g	Toxin not detected. No change in appearance.	Austin and others 1998
C. botulinun proteolytic (10 strains)	Romaine lettuce	NR	Spore suspension, 1 ml injected through gas-tight septum.	Samples packaged in film.	15 15 25	1.0 2.0	21 d 21 d 9 d	NR NR >4.5	spores/g	Toxin not detected at 15 °C. No change in appearance. Extensive decay observed when toxin detected at 25 °C.	Austin and others 1998
Escherichia coli O157:H7	Lettuce (shredded)	~7.4	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in polyolefin consisting 3% O_2 L-bags and 97% N_2.	5 12 21	5.3	14 d 3 d/14 d 3 d/7 d	3.1 7.0/8.0 8.5/8.7	CFU/g	—	Abdul-Raouf and others 1993

Table G/S-5—Survival and growth of pathogenic bacteria on raw lettuce and salads

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
E. coli O157:H7	Lettuce (shredded)	~7.4	Dip inoculation, 1 min. Cells suspended in deionized water.	Stored in air in polyolefin L-bags.	5 12 21	5.3	14 d 3 d/14 d 3 d/7 d	4.2 6.8/7.5 8.5/8.8	CFU/g	—	Abdul-Raouf and others 1993
E. coli O157:H7	Iceberg lettuce (shredded)	NR	Dip inoculation (1 min) in 0.1 M phosphate buffer (pH 7.0) suspension before mild heat treatment (50 °C, 90 s).	Stored in plastic bags for up to 18 d.	5	3.4	18 d	2.9	CFU/g	Counts on heated lettuce were similar to counts on unheated lettuce.	Li and others 2001
E. coli O157:H7	Iceberg lettuce (shredded)	NR	Dip inoculation (1 min) in 0.1 M phosphate buffer (pH 7.0) suspension before mild heat treatment (50 °C, 90 s).	Stored in plastic bags for up to 7 d.	15	3.4	7 d	7.6	CFU/g	Counts on heated lettuce were significantly higher than counts on unheated lettuce stored for 4 and 7 d.	Li and others 2001
E. coli O157:H7	Iceberg lettuce (pieces)		Dip inoculation, 30 s. Cells suspended in trypticase soy broth.	Stored in sealed plastic bags.	4	~3.9	4	~3.7	CFU/g	—	Lin and others 2000
Listeria monocytogenes (1 strain)	Butterhead lettuce	NR	Dip inoculation, 10 mins. Cells suspended in sterile distilled water.	Samples were drained on absorbent paper, sealed, and stored in polypropylene pouches.	10	4.4	7 d	5.3	CFU/g	—	Carlin and Nguyen-the 1994
L. monocytogenes (5 strains)	Ceasar salad	6.3	Cells suspended in 0.1% peptone, 1-1.6 ml injected through a gas-tight septum.	Samples purchased from store, inoculated, and stored in original packaging.	4 10	~3.0 ~3.0	9 d	~3.0 ~6.0	CFU/g	—	Farber and others 1998
L. monocytogenes (1 strain)	Lettuce (pieces)	NR	Inoculated with contaminated gloved hands. Inoculum diluted in sterile water.	Stored in sealed plastic bags.	5 12 25	5.4 3.8 4.6	14 d 14 d 14 d	6.5 6.9 5.9	CFU/g	Levels of *L. monocytogenes* estimated by randomly selecting 5 colonies from plate count agar and streaking onto McBride Listeria Agar.	Steinbruegge and others 1988
L. monocytogenes (2 strains)	Lettuce (shredded)	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M phosphate buffer.	Produce washed in 200-250ppm chlorine and stored in Cryovac L-bags in 3% O_2 and 97% N_2.	5 10	4.1 4.2	15 d 10 d	~5.0 ~8.0	CFU/g	—	Beuchat and Brackett 1990b

Table G/S-5—Survival and growth of pathogenic bacteria on raw lettuce and salads

Pathogen	Produce Type	pH	Method of Inoculation	Storage Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
L. monocytogenes (2 strains)	Lettuce (shredded)	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M phosphate buffer.	Produce not washed and stored in Cryvovac L-bags in 3% O_2 and 97% N_2.	5 10	4.8 4.8	15 d 10 d	~4.8 ~7.7	CFU/g	—	Beuchat and Brackett 1990b
L. monocytogenes (2 strains)	Lettuce, whole leaves	NR	Dip inoculation, 1 min. Cells suspended in 0.1 M phosphate buffer.	Produce not washed and stored in Cryvovac L-bags in 3% O_2 and 97% N_2.	5 10	4.6 4.7	15 d 10 d	5.4 6.8	CFU/g	—	Beuchat and Brackett 1990b
L. monocytogenes (2 strains)	Lettuce, whole leaves	NR	Dip inoculation, 1 min. Cells suspended in 0.1M phosphate buffer.	Produce washed in 200-250ppm chlorine and stored in Cryvovac L-bags in 3% O_2 and 97% N_2.	5 10	4.3 4.7	15 d 10 d	4.9 6.8	CFU/g	—	Beuchat and Brackett 1990b
L. monocytogenes (1 strain)	Lamb's lettuce	NR	Dip inoculation, 10 mins. Cells suspended in sterile distilled water.	Samples were drained on absorbent paper, sealed, and stored in polypropylene pouches.	10	4.1	7 d	4.0	CFU/g	—	Carlin and Nguyen-the 1994
L. monocytogenes	Iceberg lettuce (pieces)		Dip inoculation, 30 s. Cells suspended in trypticase soy broth.	Stored in sealed plastic bags.	4	~4.1	4	~4.4	CFU/g	—	Lin and others 2000
Salmonella Baildon	Iceberg lettuce (shredded)	6.06-7.00	Cells suspended in deionized water, 30 ml mixed with 2270 g of lettuce.	Lettuce (450g) was sealed in plastic bags. Stored for up to 12 d.	4	0.3	12 d	<1.0	CFU/g	Detected in 6 of 6 enriched samples (25 g) after 2, 5, and 8 d, and 1 of 6 samples after 12 d.	Weissinger and others 2000
S. Baildon	Iceberg lettuce (shredded)	6.06-7.00	Cells suspended in deionized water; 30 ml mixed with 2270 g of lettuce.	Lettuce (450g) was sealed in plastic bags. Stored for up to 12 d.	4	3.3	12 d	1.8	CFU/g	Counts were 3.24, 3.07, and 2.69 log_{10} CFU/g after 2, 5, and 8 d, respectively.	Weissinger and others 2000
S. Montevideo	Iceberg lettuce (pieces)		Dip inoculation 30 s. Cells suspended in trypticase soy broth.	Stored in sealed plastic bags.	4	~4.1	4	~4.4	CFU/g	—	Lin and others 2000
Shigella sonnei	Lettuce (shredded)	NR	Spot inoculated.	Strain isolated from outbreak and inoculated onto lettuce.	5	NR	7 d	1 log decrease	CFU/g	—	Davis and others 1988
S. sonnei	Lettuce (shredded)	NR	Spot inoculated.	Strain isolated from outbreak and inoculated onto lettuce.	15	3.1	—	—	CFU/g	5 h generation time.	Davis and others 1988
S. sonnei (1 strain)	Lettuce (shredded)	NR	Spot inoculated.	Strain isolated from outbreak and inoculated onto lettuce.	22	3.1	12 h	6.3	CFU/g	*S. sonnei* survived but did not grow at 5 and 15 °C.	Davis and others 1988

[a]Not reported
[b]Not determined

Table G/S-6—Survival and growth of pathogenic bacteria in unpasteurized juice

Pathogen	Juice Type	pH	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Escherichia coli O157:H7 (1 strain)	Apple, cider	3.7	Cells suspended in 0.85% NaCl solution, 1 ml added to 100 ml sample.	Full strength apple cider. Stored in flask on a shaker at 150 rpm.	26	6	6 d	4.5	CFU/ml	—	Janisiewicz and others 1999
E. coli O157:H7	Apple, cider	3.6-4.0	Cells suspended in 0.1 M phosphate buffered saline, 0.5 ml added to sample.	6 different lots of apple cider used.	8	5.0	15-34 d	<1.0	CFU/ml	Populations initially increased slightly, remained stable through day 12 then decreased to undetectable levels. Growth was questioned by authors. Addition of sodium benzoate (0.1%) resulted in more rapid decline (undetectable between day 3-15).	Zhao and others 1993
E. coli O157:H7	Apple, cider	3.6-4.0	Cells suspended in 0.1 M phosphate buffered saline, 0.5 ml added to sample.	6 different lots of apple cider used.	8	2.0	11-15 d	<1.0	CFU/ml	Steady population decline.	Zhao and others 1993
E. coli O157:H7 (2 strains)	Apple, cider (filter sterilized)	3.5	Culture grown in tryptic soy broth, added to sample.	Inoculum grown in apple juice adjusted to pH 6.5.	21 4	~5.3	7 d 7 d	<1.5 2.2	CFU/ml	—	Uljas and Ingham 1998
E. coli O157:H7	Apple, cider	3.6-4.0	Cells suspended in 0.1 M phosphate buffered saline, 0.5 ml added to sample.	6 different lots of apple cider used.	25	5.0	3-6 d	<1.0	CFU/ml	Initial increase in population 24-48 h followed by decline. Growth was questioned by authors. Higher numbers achieved in higher pH juice. More rapid decline when yeast levels were high.	Zhao and others 1993
E. coli (O157:H7)	Apple, cider	3.6-4.2	NR	Room temperature for up to 11 d.	20-25EC	4.3	7 d	2.5 - 41	CFU/ml	Rate of inactivation in cider from McIntosh apples was more rapid than in cider from Red Delicious, Golden Delicious, or Melrose apples.	Dingman 2000

Table G/S-6—Survival and growth of pathogenic bacteria in unpasteurized juice *(continued from previous page)*

Pathogen	Juice Type	pH	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
E. coli O157:H7	Apple, juice	3.70	Cells suspended in 0.85% NaCl solution, 1 ml added to sample.	Full strength apple juice. Stored in flask on a shaker at 150 rpm.	26	6.0	6 d	5.5	CFU/ml	—	Janisiewicz and others 1999
E. coli O157:H7	Apple, juice	3.62	Cells suspended in 0.85% NaCl solution, 1 ml added to sample.	Juice diluted with 50% water. Stored in flask on a shaker at 150 rpm.	26	6.0	6 d	5.0	CFU/ml	—	Janisiewicz and others 1999
E. coli O157:H7	Apple, juice	3.55	Cells suspended in 0.85% NaCl solution, 1 ml added to sample.	Juice diluted with 75% water. Stored in flask on a shaker at 150 rpm.	26	6.0	6 d	4.5	CFU/ml	—	Janisiewicz and others 1999

Table G/S-7—Survival and growth of pathogenic organism on sprout seeds or raw sprouts

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Aeromonas hydrophila	Sprouts, mung bean	Diluted suspension inoculated onto sprouts.	Stored in rigid plastic containers, 400 mB.	6.5	5.0	5 d	~6.8	CFU/g	Sprouts obtained from local retail market.	Aytac and Gorris 1994
A. hydrophila	Sprouts, mung bean	Diluted suspension i noculated onto sprouts.	Stored in rigid plastic containers.	6.5	5.0	7 d	~9.2	CFU/g	Sprouts obtained from local retail market.	Aytac and Gorris1994
Escherichia coli O157:H7 (5 strains)	Seeds, alfalfa	Dip inoculation 1 min. Cells suspended in deionized water.	Inoculated seeds were dried (5.1-6.2% moisture) before storage in sealed containers.	5	3	54 weeks	<0.3	CFU/g	Counts decreased to 1.5 log_{10} CFU/g within 38 weeks. Detected by enrichment at 54 weeks.	Taormina and Beuchat 1999b
E. coli O157:H7 (5 strains)	Seeds, alfalfa	Dip inoculation, 1 min. Cells suspended in deionized water.	Inoculated seeds were dried (5.1-6.2% moisture) before storage in sealed containers.	25	3	54 weeks	<0.3		Counts decreased to 0.74 and <0.3 log_{10} CFU/g after 8 and 12 weeks, respectively. Detected by enrichment after 38 weeks but not 54 weeks.	Taormina and Beuchat 1999b
E. coli O157:H7 (5 strains)	Seeds, alfalfa	Dip inoculation, 1 min. Cells suspended in deionized water.	Inoculated seeds were dried (5.1-6.2% moisture) before storage in sealed containers.	37	3	54 weeks	<0.3		Counts decreased and <0.3 log_{10} CFU/g within 8 weeks. Detected by enrichment after 38 weeks, but not 54 weeks.	Taormina and Beuchat 1999b
E. coli O157:H7 (5 strains)	Sprouts, alfalfa	Dip inoculation of seeds, 1 min. Cells suspended in Butterfield's phosphate buffer.	Counts were monitored during sprout production in glass jars.	25	NR	5 d	7.1-8.0	CFU/g	Seeds were treated with disinfectants before sprouting.	Lang and others 2000
E. coli O157:H7 (5 strains)	Sprouts, alfalfa	Dip inoculation of seeds, 1 min. Cells suspended in deionized water. Sprouts produced from inoculated, dried seeds.	Counts were monitored during sprout production in plastic boxes.	21	2.3	72 h	7.1	CFU/g	Sprouts contained 7.4 and 7.2 log_{10} CFU/g after 24 and 48 h, respectively.	Taormina and Beuchat 1999a
E. coli O157:H7	Sprouts, alfalfa	Dip inoculation of seeds, 10 min. Cells suspended in 0.1% peptone.	Counts were monitored during sprout production in covered trays.	22	3.1	10 d	5.7	CFU/g	Counts reached ca. 5.8 log_{10} CFU/g within 2 d.	Castro-Rosas and Escartin 2000
E. coli O157:H7 (5 strains)	Sprouts, alfalfa	Sprouts were produced at 21 °C from inoculated seeds containing 2.7 log_{10} CFU/g.	Stored in closed plastic boxes.	9	6.0-6.9	12 d	5.6-6.5	CFU/g	Subjective evaluation revealed sprouts were edible.	Taormina and Beuchat 1999a

Table G/S-7—Survival and growth of pathogenic organism on sprout seeds or raw sprouts *(continued from previous page)*

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Salmonella (5 serotypes)	Sprouts, alfalfa	Spot inoculation (0.1 ml) of 10 g of sprouts. Cells were suspended in 0.05 M phosphate buffer (pH 6.8).	Stored in closed clear plastic boxes.	10	7.7	11 d	6.9	CFU/g	Sprouts were subjectively judged to be edible after 11 d.	Weissinger and others 2001
S. Stanley	Seeds, alfalfa	Dip inoculation 1 min. Cells suspended in deionized water.	Inoculated seeds were dried before storage in sealed containers.	8, 21	2.5	9 weeks	1.81	CFU/g	Seeds stored at 8 °C for 9 weeks, then 21 °C for 8 weeks contained 0.92 log_{10} CFU/g.	Jaquette and others 1996
S. Stanley	Alfalfa seeds	Dip inoculation, cells suspended in 30 ml deionized water, seeds added to suspension and mixed for 1 min.	Seeds placed on wire screens, dried under a laminar flow hood for 24 h. Seeds stored in plastic bags at 21 °C for 48 h and then stored at 8 °C.	21	2.5	8 weeks	0.9	CFU/g	—	Jaquette and others 1996
S. Typhi	Sprouts, alfalfa	Dip inoculation of seeds, 10 min. Cells suspended in 0.1% peptone.	Counts were monitored during sprout production in covered trays.	22	2.5	6 d	3.7	CFU/g	Counts increased to ca. 6.1 log_{10} CFU/g within 1 d, then decreased through 6 d.	Castro-Rosas and Escartin 2000
S. Typhi	Sprouts, alfalfa	Dip inoculation of seeds, 10 min. Cells suspended in 0.1% peptone. Sprouts produced at 22 °C for 7 d.	Stored in closed trays.	4-7	4.8	15 d	4.5	CFU/g	Decreases have no practical significance to safety.	Castro-Rosas and Escartin 2000
S. Typhi	Sprouts, alfalfa	Seeds were germinated for 24 h, then inoculated with cells suspended in 0.1% peptone.	Counts were monitored during sprout production in covered trays.	22	3.4	8 d	2.4	CFU/g	Counts decreased by ca. 1 log_{10}, suggesting inability to compete with aerobic microorganisms, which were present at 7.5 log_{10} CFU/g when sprouts were inoculated with *S.* Typhi.	Castro-Rosas and Escartin 2000
Vibrio cholerae	Sprouts, alfalfa	Dip inoculation of seeds, 10 min. Cells suspended in 0.1% peptone.	Counts were monitored during sprout production in covered trays.	22	2.5	6 d	3.7	CFU/g	Counts increased to ca. 5.8 log_{10} CFU/g within 1 d, then decreased through 6 d.	Castro-Rosas and Escartin 2000
V. cholerae	Sprouts, alfalfa	Seeds were germinated for 24 h, then inoculated with cells suspended in 0.1% peptone.	Counts were monitored during sprout production in covered trays.	22	2.5	8 d	0.5	CFU/g	Counts decreased by ca. 2 log_{10}, suggesting inability to compete with aerobic	Castro-Rosas and Escartin 2000

Table G/S-7—Survival and growth of pathogenic organism on sprout seeds or raw sprouts *(continued from previous page)*

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
									microorganisms, which were at 7.5 log_{10} CFU/g when sprouts were inoculated with *V. cholerae.*	
V. cholerae	Sprouts, alfalfa	Dip inoculation of seeds, 10 min. Cells suspended in 0.1% peptone. Sprouts produced at 22 °C for 7 d.	Stored in closed trays.	4-7	3.1	15 d	2.1	CFU/g	Decreases have no practical significance to safety.	Castro-Rosas and Escartin 2000

Table G/S-8—Survival of pathogenic viruses on raw produce

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Coxsackie virus B5	Carrot, whole	0.05 ml spot inoculated onto sample. Virus suspended in water.	Samples were left uncovered.	4	~2.6	1 d 5 d	~1.6 <0.6	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Carrot, whole	0.05 ml spot inoculated onto sample. Virus suspended in dilute feces (1%).	Samples were left uncovered.	4	~2.6	1 d 5 d	~1.7 ~1.2	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Carrot, whole	Spot inoculation, 0.05 ml inoculated onto sample. Virus suspended in undiluted feces.	Samples were left uncovered.	4	~2.6	1 d 5 d	~1.9 ~1.4	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Celery	0.05 ml spot inoculated onto sample. Virus suspended in water or dilute feces (1%).	Samples were enclosed in polyethylene bags which contained a dish of water to maintain humidity.	4	~2.6	8 d	~2.6	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Celery	0.05 ml spot inoculated onto sample. Virus suspended in water or dilute feces (1%).	Samples were left uncovered.	4	~2.6	1 d	~2.0	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975

Table G/S-8—Survival of pathogenic viruses on raw produce *(continued from previous page)*

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Coxsackie virus B5	Lettuce, pieces	Spot inoculation, 0.1 ml inoculated onto each 16-mm disc. Virus grown in Hep-2 cells, diluted in phosphate buffered saline.	Lettuce discs were stored in capped storage flasks with no moisture.	4	2.0	7 d	~1.9	—	—	Konowalchuk and Speirs 1974
Coxsackie virus B5	Lettuce, pieces	Spot inoculation, 0.1ml inoculated onto each 16-mm disc. Virus grown in Hep-2 cells, diluted in phosphate buffered saline.	Lettuce discs were stored in capped storage flasks with low moisture levels.	4	2.0	7 d	~1.6	—	—	Konowalchuk and Speirs 1974
Coxsackie virus B5	Lettuce, pieces	Spot inoculation, 0.1 ml inoculated onto each 16-mm disc. Virus grown in Hep-2 cells, diluted in phosphate buffered saline.	Lettuce discs were stored in capped storage flasks with high moisture levels.	4	2.0	7 d	~1.9	PFU/ sample	—	Konowalchuk and Speirs 1974
Coxsackie virus B5	Radish, whole root	0.05 ml spot inoculated onto sample. Virus suspended in water.	Samples were left uncovered.	4	~2.6	1 d 5 d	~1.6 <0.6	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Radish, whole root	0.05 ml spot inoculated onto sample. Virus suspended in dilute feces (1%).	Samples were left uncovered.	4	~2.6	1 d 5 d	~1.8 ~1.3	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975
Coxsackie virus B5	Radish, whole root	0.05 ml spot inoculated onto sample. Virus suspended in undiluted feces.	Samples were left uncovered.	4	~2.6	1 d 5 d	~2.0 ~1.7	PFU/ sample	Presence of moisture improved survival. Survival significantly better in closed containers with high humidity. Presence of feces improved survival.	Konowalchuk and Speirs 1975

Table G/S-8—Survival of pathogenic viruses on raw produce *(continued from previous page)*

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Enteroviruses (5 strains)	Lettuce	Virus suspended in saline, 1 ml inoculated per 100 g sample.	Samples were kept in 150-200 ml beakers.	3.1	Unknown	11 d	—	TCD_{50}/ml	0.5 log decrease observed.	Bagdasaryan 1964
Enteroviruses (5 strains)	Tomato, whole	Virus suspended in saline, 1 ml inoculated per 100 g sample.	Samples were kept in 150-200 ml beakers.	3-8	Unknown	15 d	—	TCD_{50}/ml	1 log decrease observed.	Bagdasaryan 1964
Enteroviruses (5 strains)	Tomato, whole	Virus suspended in saline, 1 ml inoculated per 100 g sample.	Samples were kept in 150-200 ml beakers.	18-21	Unknown	15 d	—	TCD_{50}/ml	1 to 2.5 log decrease observed.	Bagdasaryan 1964
Hepatitis A virus (strain HM 175)	Lettuce (pieces)	Inoculum contained 5% fetal bovine serum.	Samples were held in loosely covered petri dishes to allow air flow.	4 22	7.3 7.3	12 d 12 d	6.9 3.3	PFU/ml	—	Bidawid and others 2001
Hepatitis A virus (strain HM 175)	Lettuce (pieces)	Inoculum contained 5% fetal bovine serum.	Samples held inside heat sealed plastic bag.	4 22	7.3 7.3	12 d 12 d	7.1 6.1	PFU/ml	—	Bidawid and others 2001
Hepatitis A virus (strain HM 175)	Lettuce (pieces)	Inoculum contained 5% fetal bovine serum.	Samples held in heat sealed plastic bags containing 70% CO_2 and 30% N_2.	4 22	7.3 7.3	12 d 12 d	7.2 6.9	PFU/ml	—	Bidawid and others 2001
Rotavirus SA-11	Carrot, pieces	0.1 ml spot inoculated onto sample. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in uncovered containers.	4 25	4.5 4.5	25 d 15 d	~1.2 ~1.0	PFU/ml	—	Badawy and others 1985
Rotavirus SA-11	Carrot, pieces	Immersion inoculation, 200 ml of 10^5 PFU/ml. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in uncovered containers.	4 25	3.0 2.8	4 d 2 d	<1.0 <1.0	PFU/ml	—	Badawy and others 1985
Rotavirus SA-11	Lettuce, pieces	0.1 ml spot inoculated onto sample. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in uncovered containers.	4 25	4.5	30 d 25 d	2.5 1.1	PFU/ml	—	Badawy and others 1985
Rotavirus SA-11	Lettuce, pieces	Immersion inoculation, 200 ml of 10^5 PFU/ml. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in uncovered containers.	4 25	4.5	25 d 15 d	~1.2 ~1.2	PFU/ml	—	Badawy and others 1985
Rotavirus SA-11	Radish, whole root	0.1 ml spot inoculated onto sample. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in covered containers.	4 25	4.5 4.5	30 d 4 d	~1.5 ~2.5	PFU/ml	—	Badawy and others 1985

Table G/S-8—Survival of pathogenic viruses on raw produce *(continued from previous page)*

Pathogen	Produce Type	Method of Inoculation	Conditions	Temp. (°C)	Initial Counts (log_{10} CFU)	Incubation Time	Final Counts (log_{10} CFU)	Unit	Comments	Reference
Rotavirus SA-11	Radish, whole root	Immersion inoculation, 200 ml of 10^5 PFU/ml. Virus grown on MA-104 cells. Virus suspended in Tris-buffered saline.	Samples stored in uncovered containers.	4 25	3.6 3.6	5 d 4 d	~1.0 ~2.0	PFU/ml	—	Badawy and others 1985

Table I-1—Examination of raw fruits for the presence of pathogens

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
L. monocytogenes	Various juices	U.S.	Retail	2/50	0.04	Various unpasteurized fruit and vegetable juices were sampled. *L. monocytogenes* isolated from apple juice and an apple raspberry blend. Juices were also tested for *E. coli* O157:H7 and *Salmonella*. Sample tested negative for the organisms.	Sado and others 1998
Salmonella	Cantaloupe	Various	NRb	8/151	5.3	Produce imported into the U.S. Samples were collected from 9 countries.	FDA 2001
Salmonella	Orange	U.S.	Various (orchard through juice plant)	0/375	0	Fruit surface and juice were analyzed. 1/3 oranges were graded hulls, 1/3 oranges were washed and graded, and 1/3 oranges were ungraded.	Parish; personal communication; unreferenced
Salmonella	Orange/ tangerine	US	Citrus packinghouses	0/336	0		Pao and Brown 1998
Salmonella	Strawberries	Various	NR	1/143	0.7	Produce imported into the U.S. Samples were collected and analyzed from 5 countries.	FDA 2001
Salmonella (8 serovars)	Cantaloupe	Mexico	—	11/1440	0.76	FDA import study between March and April 1990.	Madden 1992
Salmonella (12 serovars)	Cantaloupe	Mexico	—	24/2220	1.1	FDA import study between November 1990 through January 1991. Melons came from the same harvest area associated with1989-90 outbreak.	Madden 1992
Shigella	Cantaloupe	Various	NR	3/151	2.0	Produce imported into the U.S. Samples were collected from 9 countries.	FDA 2001

[a]Country where produce samples were collected and tested
[b]Not Reported

Table I-2—Examination of seed sprouts for the presence of pathogens

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Bacillus cereus	Alfalfa	US	Health food stores	13/14	92.9	Seeds were sprouted in the lab using a home sprouting kit.	Harmon and others 1987
B. cereus	Mung bean	US	Health food stores	33/40	83	Seeds were sprouted in the lab using a home sprouting kit.	Harmon and others 1987
B. cereus	Mung bean	US	At production	2/16	12	Ten surveys were conducted over a six-month period.	Splittstoesser and others 1983
B. cereus	Wheat	US	Health food stores	15/24	63	Seeds were sprouted in the lab using a home sprouting kit.	Harmon and others 1987
Listeria monocytogenes	Mung bean	France	At production	1/31	3.1		See Nguyen-the and Carlin 2000
L. monocytogenes	Mung bean	France	Retail	19/102	19		See Nguyen-the and Carlin 2000
L. monocytogenes	Mung bean	Malaysia	Retail	6/7	86	Samples were taken from refrigerated supermarkets and open wet markets.	Arumugaswarmy and others 1994
Salmonella	Mung bean	US	At production	0/13	0	Ten surveys were conducted over a six month period.	Splittstoesser and others 1983
Salmonella	Mung bean	Sweden	NR[b]	NR	NR		See Beuchat 1996b
Salmonella	Mung bean	Thailand	Open markets	30/344	8.7	Samples were collected monthly for seven months.	Jerngklinchan and Saitanu 1993
Staphylococcus aureus	Alfalfa	Canada	Retail	4/18	22	Sprouts produced by a single processor. Samples obtained from three retail outlets.	Prokopowich and Blank 1991
S. aureus	Mixed sprouts	Canada	Retail	5/18	28	Sprouts produced by a single processor. Samples obtained from three retail outlets.	Prokopowich and Blank 1991
S. aureus	Onion	Canada	Retail	4/18	22	Sprouts produced by a single processor. Samples obtained from three retail outlets.	Prokopowich and Blank 1991

[a]Country where produce samples were collected and tested
[b]Not Reported

Table I-3—Examination of unsprouted seeds for the presence of *Salmonella*

Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Alfalfa	US	Production	0/4	0	Seeds obtained from a local processor.	Prokopowich and Blank 1991
Alfalfa	US	Health food stores	1/10	10	Seeds were labelled as organic.	Andrews and others 1979
Mixed seeds	US	Production	0/4	0	Seeds obtained from a local processor.	Prokopowich and Blank 1991
Onion	US	Production	0/4	0	Seeds obtained from a local processor.	Prokopowich and Blank 1991

[a]Country where produce samples were collected and tested

Table I-4—Examination of lettuce or salad greens for the presence of pathogens

Pathogen	Type	Country[a]	Place of sampling	Incidence	Percentage %	Comments	Reference
Aeromonas hydrophila	Chicory salads	Italy	Retail	12/12	100	Presumptive *A. hydrophila.*	Marchetti and others 1992
A. hydrophila or *A. caviae*	Lettuce, cut	Australia	Retail or production	66/120	55	Cut and packaged lettuce samples obtained over an 8-month period.	Szabo and others 2000
A. hydrophila	Salad mix (various)	Italy	Retail	12/12	100	Presumptive *A. hydrophila.*	Marchetti and others 1992
Clostridium botulinum	Salad mix (various)	US	Retail	2/350	0.6	MAP samples were obtained from three different producers.	Lilly and others 1996
Campylobacter	Lettuce	Canada	Outdoor markets and supermarkets	2/165	1.2	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Campylobacter	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
Cryptosporidium	Lettuce	Costa Rica	Open markets	2/80	2.5	Samples were taken from eight open markets during the dry and rainy season.	Monge and Chinchilla 1996
Escherichia coli O157:H7	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
E. coli O157:H7	Salad mix (various)	US	Retail and food	0/63	0	Samples were taken from 31 retail service and food service facilities.	Lin and others 1996
Listeria monocytogenes	Chopped lettuce	Canada	Hospitals	5/39	13	Samples were stored at 4 °C or 10 °C for up to 11 days.	Odumeru and others 1997
L. monocytogenes	Lettuce	Canada	Retail	0/50	0	Samples were either grown in the US or Canada. Outer leaves were tested.	Farber and others 1989.
L. monocytogenes	Lettuce	France	Production	0/35	0	Lettuce samples were from the packing plant before they were cleaned and packaged.	Gras and others 1994
L. monocytogenes	Lettuce	Malaysia	NR[b]	1/28	3.6		Francis and others 1999
L. monocytogenes	Lettuce	Sri Lanka	NR	10/20	50		Francis and others 1999
L. monocytogenes	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
L. monocytogenes	Lettuce	US	Retail	1/92	1.1	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Lettuce, cut	Australia	Retail or production	3/120	2.5	Cut and packaged lettuce samples obtained over an 8-month period.	Szabo and others 2000
L. monocytogenes	Lettuce, iceberg	US	—	1/297	0.3	Sample collection from December 1992 to February 1993.	Industry data, unpublished but reviewed
L. monocytogenes	Lettuce, Romaine	US	—	0/320	0	Sample collection from December 1992 to February 1993.	Industry data, unpublished but reviewed
L. monocytogenes	Prepacked salads	Northern Ireland	From processor	3/40	7.5	Samples were collected from 2 food processors.	Harvey and Gilmore 1993

(Continued on next page)

Table I-4—Examination of lettuce or salad greens for the presence of pathogens *(continued from previous page)*

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
L. monocytogenes	Prepacked salads	UK	Retail	4/60	6.7	*Listeria* was isolated from two salad varieties. Serotype 1/2 (4 isolates) and serotype 4b (1 isolate). Ten salad varieties were sampled.	Sizmur and Walker1988
L. monocytogenes	Salad mix (various)	Germany	NR	6/263	2.3		See Beuchat 1996b
L. monocytogenes	Salad mix (various)	Netherlands	NR	11/25	44		See Francis and others 1999
L. monocytogenes	Salad mix (various)	Northern Ireland	At production	4/45	9.0	Samples were collected from 12 food processors at 6-week intervals.	Harvey and Gilmore 1993
L. monocytogenes	Salad mix (various)	UK	NR	2/108	1.8		Francis and others 1999
L. monocytogenes	Salad mix (various)	Canada	Hospitals	9/39	23	Samples were stored at 4 °C or 10 °C for up to 11 days.	Odumeru and others 1997
L. monocytogenes	Salad mix (various)	US	Retail and food service	1/63	1.6	Samples were taken from 31 retail and food service facilities.	Lin and others 1996
Staphylococcus aureus	Salad greens	UK	NR	13/256	5.1		See Beuchat 1996b
S. aureus	Salad mix (various)	Egypt	Retail/food service	3/36	8.3		Saddik and others 1985
Salmonella	Lettuce	Various	—	1/116	0.9	Produce imported into the US. Samples were collected from 11 countries.	FDA 2001
Salmonella	Lettuce	Italy	Retail	82/120	68	Samples were taken from five retail outlets and sampled at monthly intervals for 1 year.	Ercolani 1976
Salmonella	Lettuce	Netherlands	Various	2/28	7.1	*Salmonella* tested only when *E. coli* present.	Tamminga and others 1978
Salmonella	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
Salmonella	Salad greens	Egypt	Retail/food service	2/57	3.5		Saddik and others 1985
Salmonella	Salad mix (various)	Egypt	Retail/food service	1/159	0.6		Saddik and others 1985
Salmonella	Salad mix (various)	US	Retail and food service	0/63	0	Samples were taken from 31 retail and food service facilities.	Lin and others 1996
Salmonella	Lettuce	Spain	Farms, wholesale markets, and retail	5/80	6.3	Samples were collected during the four seasons and from different sources. Possible use of contaminated irrigation water.	Garcia-Villanova, Cueto, Espinar and others 1987
Shigella	Lettuce	Various	—	1/116	1.0	Produce imported into the US. Samples were collected and analyzed from 11 countries.	FDA 2001
Shigella	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
Shigella	Salad greens	Egypt	Retail/food service	1/57	1.8		Saddik and others 1985
Shigella	Salad mix (various)	Egypt	Retail/food service	3/159	1.9		Saddik and others 1985
Vibrio cholerae	Lettuce	UK	Retail	0/151	0	Imported whole lettuce.	Little and others 1999
Yersinia enterocolitica	Lettuce, cut	Australia	Retail or production	71/120	59	Cut and packaged lettuce samples obtained over an 8-month period.	Szabo and others 2000
Yersinia	Prepacked salads	UK	Retail	3/3	100	Subsamples from same batch. Predominantly environmental strains of *Y. enterocolitica.*	Brocklehurst and others 1987

[a]Country where produce samples were collected and tested
[b]Not Reported

Table I-5—Examination of mixed raw vegetables for the presence of pathogens

Pathogen	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Aeromonas spp.	Brazil	Retail	43/90	48	Samples contained vegetables like lettuce, watercress, and endive.	See Nguyen-the and Carlin 2000
Clostridium botulinum	US	Retail	1/144	0.7	MAP samples were obtained from three different producers.	Lilly and others 1996
C. perfringens	UK	Retail	34/100	34		See Nguyen-the and Carlin 2000
Escherichia coli (enteropathogenic)	US	Retail	0/49	0	Samples were taken from various chain stores. Raw and frozenvegetables.	Hall and others 1967
E. coli O157:H7	Mexico		17/89	19		See Nguyen-the and Carlin 2000
Giardia spp.	Brazil	Gardens	NR[b]	13		See Nguyen-the and Carlin 2000
Listeria monocytogenes	Germany	Retail	2/103	1.9		See Nguyen-the and Carlin 2000
L. monocytogenes	Italy		7/102	6.9		See Beuchat 1996b
L. monocytogenes	Spain	Markets	8/103	7.8	Samples included a variety of vegetables.	de Simon and others 1992
L. monocytogenes	Taiwan	Markets	6/49	12	Organism was isolated from lettuce, onions. Chinese cabbage, and green	Wong and others 1990
L. monocytogenes	UK	Retail	4/64	6.3	Samples were taken year round from 4 supermarkets.	MacGowan and others 1994
L. monocytogenes	UK	Unknown	8/42	19	Prepared mixed vegetables.	See Francis and others 1999
Salmonella	US	Wholesale and retail	4/50	8.0	Samples were obtained over a 2-year survey. Various vegetables were evaluated.	Rude and others 1984
Salmonella	Iraq	Various	3/43	7.0		Al-Hindawi and Rished 1979
Salmonella	Spain	Various	46/849	5.4	Irrigation water samples were also taken. Results indicate a close relationship between isolates obtained from water and produce samples.	Garcia-Villanova, Galvez-Vargas and others 1987
Yersinia enterocolitica	Brazil	Retail	1/30	3.3	Samples included lettuce, spinach, watercress, and chicory.	dos Reis Tassinari and others 1994
Y. enterocolitica	France	NR	4/58	7.0		Catteau and others 1985; See Beuchat 1996b
Y. enterocolitica	France	NR	15/30	50		Darbas and others 1985; See Beuchat 1996b
Y. enterocolitica	Italy	NR	1/102	1.0		See Beuchat 1996b

[a]Country where produce samples were collected and tested
[b]Not Reported

Table I-6—Examination of raw herbs or spices for the presence of pathogens

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Campylobacter	Parsley	Canada	Outdoor markets and supermarkets	1/177	0.6	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Cryptosporidium	Cilantro (leaves)	Costa Rica	Open markets	4/80	5.0	Samples were obtained from eight open markets during the rainy and dry season.	Monge and Chinchilla 1996
Cryptosporidium	Cilantro (roots)	Costa Rica	Open markets	7/80	8.7	Samples were obtained from eight open markets during the rainy and dry season.	Monge and Chinchilla 1996
Escherichia coli O157:H7	Cilantro	Mexico	NR[b]	8/41	20		See Beuchat 1996b
E. coli O157:H7	Coriander	Mexico	NR	2/10	20		See Beuchat 1996b
Salmonella	Parsley	Spain	Farm, wholesale, and retail	1/23	4.3	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia- Cueto Villanova, Espinar, and others 1987
Salmonella	Chili	Netherlands	Various	5/16	31		Tamminga and others 1978
Salmonella	Chili	Surinam	NR	5/16	31		Tauxe and others 1997
Salmonella	Cilantro	Various	Various	16/177	9.0	Produce imported into the US. Samples were collected from 6 countries.	FDA 2001
Salmonella	Culantro	Various	Various	6/12	50	Produce imported into the US. Samples were collected from 2 countries.	FDA 2001
Salmonella	Parsley	Various	Various	1/84	1.2	Produce imported into the US. Samples were collected from 7 countries.	FDA 2001
Shigella	Cilantro	Various	Various	0/177	0	Produce imported into the US. Samples were collected from 6 countries.	FDA 2001
Shigella	Culantro	Various	Various	0/12	0	Produce imported into the US. Samples were collected from 7 countries.	FDA 2001
Shigella	Parsley	Various	Various	1/84	1.2	Produce imported into the US. Samples were collected from 6 countries.	FDA 2001
Staphylococcus	Parsley	Lebanon	NR	NR	7.7		See Beuchat 1996b

[a]Country where produce samples were collected and tested
[b]Not Reported

Table I-7—Examination of raw vegetables other than lettuce and salad greens for the presence of pathogens

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Aeromonas hydrophila	Carrots	Italy	Retail	12/12	100	Presumptive *A. hydrophila.*	Marchetti and others 1992
Clostridium botulinum	Cabbage	US	Retail	1/337	0.3	MAP[b] samples of shredded cabbage were obtained from three different companies.	Lilly and others 1996
C. botulinum	Coleslaw	US	Retail	0/72	0	MAP[b] samples of shredded cabbage were obtained from three different companies.	Lilly and others 1996
C. botulinum	Green pepper	US	Retail	1/201	0.5	MAP[b] samples of shredded cabbage were obtained from three different companies.	Lilly and others 1996
C. botulinum	Mushrooms	Netherlands	Farm auctions	0/5	0	Samples were obtained from 5 different auctions. At least 10 different production farms were sampled from each auction.	Notermans and others 1989
Campylobacter jejuni	Mushrooms	US	Retail	3/200	1.5	Samples were obtained from local grocery stores between March and August 1985.	Doyle and Schoeni 1986
Campylobacter	Cabbage	Canada	Outdoor markets and supermarkets	0/130	0		Park and Sanders 1992
Campylobacter	Carrots	Canada	Outdoor markets and supermarkets	0/149	0		Park and Sanders 1992
Campylobacter	Celery	Canada	Outdoor markets and supermarkets	0/150	0		Park and Sanders 1992
Campylobacter	Cucumber	Canada	Outdoor markets and supermarkets	0/123	0		Park and Sanders 1992
Campylobacter	Green onion	Canada	Outdoor markets and supermarkets	1/180	0.6	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Campylobacter	Potatoes	Canada	Outdoor markets and supermarkets	1/153	0.7	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Campylobacter	Spinach	Canada	Outdoor markets and supermarkets	2/183	1.1	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Campylobacter	Radish	Canada	Outdoor markets and supermarkets	2/174	1.1	Samples from farmers markets and supermarkets. Positives only from farmers markets.	Park and Sanders 1992
Cryptosporidium	Cabbage	Costa Rica	Open markets	0/80	0	Samples were obtained from eight open markets during the rainy and dry season.	Monge and Chinchilla 1996
Cryptosporidium	Carrots	Costa Rica	Open markets	1/80	1.3	Samples were obtained from eight open markets during the rainy and dry season.	Monge and Chinchilla 1996

Table I-7—Examination of raw vegetables other than lettuce and salad greens for the presence of pathogens *(continued from previous page)*

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Cryptosporidium	Cucumber	Costa Rica	Open markets	1/80	1.3	Samples were obtained from eight open markets during the rainiy and dry season.	Monge and Chinchilla 1996
Cryptosporidium	Radish	Costa Rica	Open markets	1/80	1.3	Samples were obtained from eight open markets during the rainy and dry season.	Monge and Chinchilla 1996
Cryptosporidium	Tomato	Costa Rica	Open markets	1/80	1.3	Samples were obtained from eight open markets during the dry and rainy season.	Monge and Chinchilla 1996
E. coli O157:H7	Celery	Mexico	NR[c]	6/34	18		See Beuchat 1996b
Listeria monocytogenes	Broccoli	Canada	Hospital	2/35	5.7	Samples were stored at 10 °C prior to testing.	Odumeru and others 1997
L. monocytogenes	Broccoli	US	Retail	0/92	0	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Cabbage	US	Retail	1/92	1.1	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Cabbage, green	US	Processing facility	73/1016	7.2	Samples collected between December 1992 and February 1993.	Industry data, unpublished but reviewed; unreferenced
L. monocytogenes	Cabbage, red	US	Processing facility	10/399	2.5	Samples collected between December 1992 and February 1993.	Industry data, unpublished but reviewed; unreferenced
L. monocytogenes	Carrots	Canada	Hospital	0/35	0	Samples were stored at 10 °C prior to testing.	Odumeru and others 1997
L. monocytogenes	Carrots	US	Retail	1/92	0	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Cauliflower	Canada	Hospital	0/39	0	Samples were stored at 10 °C prior to testing.	Odumeru and others 1997
L. monocytogenes	Cauliflower	US	Retail	0/92	0	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Celery	Canada	Retail	0/30	0	Produce were grown either in the U.S. or Canada.	Farber and others 1989
L. monocytogenes	Celery	Canada	Hospital	0/39	0	Samples were stored at 10 °C prior to testing.	Odumeru and others 1997
L. monocytogenes	Coleslaw	Canada	Hospital	1/35	2.9	Samples were obtained from stored conditions of 10 °C.	Odumeru and others 1997
L. monocytogenes	Coleslaw	Singapore	NR	2/50	4.0		See Francis and others 1999
L. monocytogenes	Coleslaw	UK	Retail	3/39	7.7	Samples were taken year round from four supermarkets.	MacGowan and others 1994
L. monocytogenes	Cucumber	Malaysia	Restaurants	4/5	80	Samples taken from street vendors. Samples were sliced.	Arumugaswarmy and others 1994
L. monocytogenes	Cucumber	Pakistan	Retail	1/15	6.7		See Beuchat 1996b
L. monocytogenes	Cucumber	US	Retail	2/92	2.2	Samples were obtained from two supermarkets.	Heisick and others 1989

Table I-7—Examination of raw vegetables other than lettuce and salad greens for the presence of pathogens *(continued from previous page)*

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
L. monocytogenes	Green pepper	Canada	Hospital	1/35	2.9	Samples were stored at 10 °C prior to testing.	Odumeru and others 1997
L. monocytogenes	Leafy vegetables	Malaysia	Retail	5/22	23	Samples were taken from refrigerated supermarkets and open wet markets.	Arumugaswarmy and others 1994
L. monocytogenes	Mushrooms	US	Retail	10/92	11	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Potatoes	US	Retail	21/132	16	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Raddiccio	US	Processing facility	0/180	0	Samples collected between December 1992 and February 1993.	Industry data, unpublished but reviewed; unreferencd
L. monocytogenes	Radish	Canada	Retail	0/10	0	Produce were grown either in the U.S. or Canada.	Farber and others 1989
L. monocytogenes	Radish	US	Retail	19/132	14	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Tomato	Canada	Retail	0/20	0	Produce were grown either in the U.S. or Canada.	Farber and others 1989
L. monocytogenes	Tomato	Pakistan	NR	2/15	13		See Beuchat 1996a
L. monocytogenes	Tomato	US	Retail	0/92	0	Samples were obtained from two supermarkets.	Heisick and others 1989
L. monocytogenes	Unspecified vegetables	UK	Retail	5/90	5.6	Samples were taken year round from four supermarkets.	MacGowan and others 1994
Salmonella	Artichoke	Spain	Farm, wholesale, and retail	3/25	12	Samples were collected all seasons at four different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Cabbage	Netherlands	Various	0/18	0		Tamminga and others 1978
Salmonella	Cabbage	Spain	Various	7/41	17	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Cardoon	Spain	Farm, wholesale, and retail	1/4	20	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Cauliflower	Netherlands	Various	1/13	7.7	*Salmonella* tested only when *E. coli* present.	Tamminga and others 1978
Salmonella	Cauliflower	Spain	Farm, wholesale, and retail	1/23	4.3	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Celery	Netherlands	Various	0/20	0		Tamminga and others 1978
Salmonella	Celery	Various	Various	1/84	1.2	Produce imported into the U.S. Samples were collected from 2 countries.	FDA 2001

Table I-7—Examination of raw vegetables other than lettuce and salad greens for the presence of pathogens *(continued from previous page)*

Pathogen	Type	Country[a]	Place of Sampling	Incidence	Percentage %	Comments	Reference
Salmonella	Eggplant	Netherlands	Various	2/13	1.5	*Salmonella* tested only when *E. coli* present.	Tamminga and others 1978
Salmonella	Endive	Netherlands	Various	2/26	7.7	Samples were either locally grown or imported from Italy.	Tamminga and others 1978
Salmonella	Fennel	Italy	Retail	64/89	72	Samples were taken from five retail outlets and sampled monthly for 1 year.	Ercolani 1976
Salmonella	Fennel	Netherlands	Various	0/15	0	Samples were either locally grown or imported from Italy.	Tamminga and others 1978
Salmonella	Green onion	Various	Various	1/180	0.6	Produce imported into the U.S. Samples were collected from 5 countries.	FDA 2001
Salmonella	Pepper	Netherlands	Various	0/20	0		Tamminga and others 1978
Salmonella	Spinach	Spain	Various	2/38	5.2	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Zuchini	Netherlands	Various	0/11	0		Tamminga and others 1978
Salmonella	Beet leaves	Spain	Various	4/52	7.7	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Salmonella	Celery	Spain	Farm, wholesale, and retail	2/26	7.7	Samples were collected all four seasons at different sources. Possible contamination from contaminated irrigation water.	Garcia-Villanova, Galvez Vargas, and others 1987
Shigella	Celery	Various	Various	2/84	2.4	Produce imported into the U.S. Samples were collected from 2 countries.	FDA 2001
Shigella	Green onion	Various	Various	2/180	1.1	Produce imported into the U.S. Samples were collected from 5 countries.	FDA 2001
Staphylococcus	Carrots	Lebanon	NR	NR	14		See Beuchat 1996b
Staphylococcus	Radish	Lebanon	NR	NR	6.3		See Beuchat 1996b
Yersinia enterolitica	Watercress	Brazil	Retail	1/5	20		Tassinari and others 1994

[a]Country where produce samples were collected and tested
[b]Modified atmosphere packaging
[c]Not Reported

Table O-1—Examples of reported outbreaks of foodborne disease associated with melons

Pathogen	Year	Location	Produce Source	Venue	Type of Melon	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Escherichia coli O157:H7	1993	Oregon	NR[a]	Restaurant	Cantaloupe	9	0	NR	Possible contamination of cantaloupe with organism from raw beef.	See Del Rosario and Beuchat 1995; Anonymous 1993
Norwalk virus	1987	United Kingdom	NR	NR	Melon	206	0	NR	Infected food handler.	See Lund and Snowdon 2000
Salmonella Chester	1989-90	Multistate, U.S.	Mexico and Central America	Unknown	Cantaloupe	<245 (25,000 estimated)	2	No	Cut cantaloupe from salad bars.	see CDC 1991; see Lund and Snowdon 2000
S. Javiana	1991	Michigan	NA	Indoor picnic and in-school party	Watermelon	26 primary 0 13 secondary	Yes		Melon not washed prior to cutting. Suspected contamination from melon rind. Melon served over 3 hour period at room temperature. Leftovers served the next day.	Blostein 1993
S. Miami	1954	Massachusetts	Florida	Supermarket	Watermelon	17	1	Yes	Laboratory demonstration of contamination of internal flesh during slicing with either contaminated melon surface or contaminated knife. Organism recovered from shelf where knife was kept but not from knife used to cut melons. Organism was isolated from home samples but not from supermarket samples. Melons were from Florida where *S.* Maimi is common.	Gayler and others 1955
S. Oranienburg	1979	Illinois	Illonois	Supermarket	Watermelon	18	0	No	Damaged fruits were cut, covered with plastic film, and displayed, sometimes without refrigeration until sold.	CDC 1979
S. Oranienburg	1998	Ontario, Canada	U.S., Mexico, or Central America	Various	Cantaloupe	22	0	No	Possible contamination with organism from surface when slicing. Cut fruit was probably left sitting at room temperature for several hours before consumption.	Deeks and others 1998
S. Poona	1991	Multistate, U.S. and Canada	Texas or Mexico	Unknown	Cantaloupe	>400 confirmed U.S., 72 Canada	0	NR	Fruit salads containing sliced cantaloupes.	CDC 1991
S. Poona	2000	Multistate, U.S. (8 states)	Mexico	Various	Cantaloupe				Case control study clearly implicated.	Farrar; pers comm; unreferenced
S. Saphra	1997	California	Mexico	Home, grocery stores, and restaurants	Cantaloupe	24	0	NR	Multiple purchase sites suggest at retail contamination during production or harvest. Lack of refrigeration may have contributed to outbreak.	Mohle-Boetani and others 1999; Farrar, pers comm; unreferenced
Salmonella	1950	Minnesota	NA	Roadside stand Watermelon		6	0	Yes	Prepared cut melon. *S.* Bareilly isolated from melon. Melon kept at ambient temperature.	See Blostein 1993
Shigella sonnei	1987	Sweden	Morocco	Dinner party Suspect watermelon		15	0	No	Melon consumed immediately after slicing. Possible contamination of melon from injected water.	Fredlund and others 1987

[a] NR, not reported

Table O-2—Examples of reported outbreaks of foodborne parasitic disease associated with raw berries

Pathogen	Year	Location	Produce Source	Venue	Type of Berry	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Cyclospora cayetanensis	1995	Florida	Guatemala likely	Two social events	Raspberries likely	87	0	No	Raspberries from both events were purchased from separate sources. Two clusters reported.	Koumans and others 1998
C. cayetanensis	1996	20 U.S. states and 2 Canadian provinces	Guatemala	Various	Raspberries	1465	0	No	Possible contamination due to fruit spraying with insecticides and fungicides mixed with contaminated water.	Herwaldt and Ackers 1997; Fleming and others 1998
C. cayetanensis	1997	Multistate, U.S. and Ontario, Canada	Guatemala	Various	Raspberries	1012	0	No	Source of contamination unknown.	Herwaldt and Beach 1999; CDC 1997b
C. cayetanensis	1998	Ontario, Canada	Guatemala	Various	Raspberries	315	0	No	Source of contamination unknown.	CDC 1998c; Herwaldt 2000
C. cayetanensis	1999	Ontario, Canada	Guatamala likely	Banquet hall	Blackberries suspected	104	0	NR[a]	Source of contamination unknown.	Herwaldt 2000

[a] NR, not reported

Table O-3—Examples of reported outbreaks of foodborne viral disease associated with contaminated frozen berries

Pathogen	Year	Location	Produce Source	Venue	Type of Berry	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Calicivirus	1997	Quebec, Canada	Bosnia	2 separate events	Raspberries (frozen)	>200	0	NR[a]	Likely contamination occurred before shipping from Bosnia.	Gaulin and others 1999
Calicivirus	1998	Finland	Imported	Unknown	Raspberries (frozen)	>500	0	NR	Source of contamination unknown.	See Lund and Snowdon 2000
Hepatitis A	1983	Scotland	Scotland	Hotel	Raspberries (frozen)	24	0	No	Suspected raspberry mousse prepared from frozen raspberries. Suggested contamination by infected picker(s).	Reid and Robinson 1987
Hepatitis A	1988	Scotland	Scotland	Home	Raspberries (frozen)	5	0	No	Raspberries from a small farm were frozen at home. Several pickers at the farm had symptoms of hepatitis A.	Ramsay and Upton 1989
Hepatitis A	1990	Georgia Montana	California (1988)	School Institution for disabled	Strawberries (frozen)	15 (Georgia) 13 (Missouri) +29 secondary	0	No	Frozen strawberries used to make dessert. Empty strawberry containers with same lot number obtained from both locations implicated same source. Suspected contamination by infected picker(s). Strawberries picked and stems removed in field. Fruits washed in 3 ppm chlorine prior to slicing and freezing.	Niu and others 1992
Hepatitis A	1997	Multistate U.S.	Mexico	Schools	Strawberries (frozen)	242 + 14 suspect	0	No	Frozen strawberries and strawberry shortcake were implicated in the outbreak. Possible contamination during harvesting. Handwashing in field limited. Stems removed with fingernails. Evidence suggested low levels of nonuniform contamination.	Hutin and others 1999; CDC 1997a

[a] NR, not reported

Table O-4—Examples of reported outbreaks of foodborne disease associated with seed sprouts

Pathogen	Year	Location	Seed Source	Type of Sprout	No. of Cases	No. of Deaths	Isolated from Sprouts/ Seeds	Comments	Reference
Bacillus cereus	1973	Texas	Uganda (soy), Holland (cress), and Denmark (mustard)	Soy, mustard, and cress	4	0	Yes/Yes	Sprouted from a home seed sprouting kit.	Portnoy and others 1976
Escherichia coli O157:H7	1996	Japan	NR[a]	Radish	6561 (101 with HUS[b]), 160 secondary cases	2	No/No	Contamination route unknown.	WHO, Weekly Epidemiological Record 1996a, 1996b
E. coli O157:H7	1997	Japan	NR	Radish	126	0	Yes/No	The pathogen was isolated from leftover sprouts in the refrigerator but not the seeds from the same seed lots.	See Feng 1997; Taormina and others 1999
E. coli O157:H7	1997	Michigan and Virginia	NR	Alfalfa	108	0	NR/NR	Sprouts were sprouted from same seed lot in both states.	CDC 1997d
E. coli O157:NM	1998	California	California and Nevada	Clover/ Alfalfa	8	0	Yes/No	Sprouts were traced to a single sprouter. Contaminated seeds suspected (same sprouter as 1997-98 *S.*Senftenberg outbreak).	Farrar; pers comm; unreferenced; Taormina and others 1999
Salmonella Bovismorbificans	1994	Sweden and Finland	Australia	Alfalfa	595	0	Yes/No	Contaminated seeds came from the same seed lot and importer.	Ponka and others 1995
S. Enteriditis	2000	Alberta and Saskatchewan, Canada	China	Alfalfa	8	0	NR/NR	Outbreaks occurred at 5 Vietnamese restaurants. Sprouts came from 2 seeds imported from China.	Farber 2000; personal communication; unreferenced growers who received
S. Enteriditis	2000	California	China	Mung	45	0	No/No	Cluster of illness linked to 3 Vietnamese restaurants. *S.* Enteriditis isolated from environment at sprouter.	California Dept. Health Services 2000; Farrar; pers comm; unreferenced
S. Gold-Coast	1989	U.K.	The Netherlands	Cress	31	0	Yes/No	Contaminated seed and/or sprouter.	Feng 1997; Taormina and others 1999
S. Havana	1998	California and Arizona	NR	Alfalfa	14 (California) 4 (Arizona)	1	No/Yes	Sprouts were traced to a single producer. Seeds obtained from the same lot yielded sprouts from which *S.* Havana was cultured.	Backer and others 2000
S. Havana/ Cubana/ Tennessee	1998	California	California	Alfalfa	34	0	Yes/Yes	Contaminated seeds were suspected.	Farrar; pers comm; unreferencd; Taormina and others 1999
S. Infantis and *S.* Anatum	1997	Kansas and Missouri	Unknown	Alfalfa	109	0	NR/NR	Seeds were believed to be contaminated.	Feng 1997; Taormina and others 1999
S. Mbandaka	1999	Oregon, California, Idaho, and Washington	California	Alfalfa	Appx. 68	0	Yes/Yes	Seeds were believed to come from the same lot and distributed to various growers in California, Florida, and Washington. No cases in Florida	Farrar; personal communication; unreferenced

Table O-4—Examples of reported outbreaks of foodborne disease associated with seed sprouts *(continued from previous page)*

Pathogen	Year	Location	Seed Source	Type of Sprout	No. of Cases	No. of Deaths	Isolated from Sprouts/ Seeds	Comments	Reference
S. Meleagridis	1997	Canada	Unknown	Alfalfa	124	0	NR/NR	Sprouts were organically grown with no chlorine pre-soak.	See Feng 1997; Farber 2000; pers comm; unreferenced
S. Montevideo and S. Meleagridis	1996	California	California	Alfalfa	>500	1	Yes/No	The sprouts were traced to a specific sprouter. Seeds traced to single California seed grower. Contaminated seeds suspected.	Taormina and others 1999; Farrar; pers comm;
S. Newport	1995	Denmark (probably U.S. and Canada)	The Netherlands	Alfalfa	154	0	Yes/Yes	Seeds came from the same shipper as U.S./Canada outbreak (see below). Source of contamination unknown.	See Feng 1997; Farber 2000; pers comm; unreferenced
S. Newport	1995-96	British Columbia, Oregon Canada, (probably Georgia and Vermont) and Denmark	The Netherlands	Alfalfa	133	0	Yes/Yes	Organism isolated were indistinguishable from the Denmark outbreak (see above).	See Feng 1997; Taormina and others 1999
S. Paratyphi Java B var.	1999	Alberta, British Columbia, and Saskatchewan, Canada	Unknown	Alfalfa	46	0	NR/NR	Spouts were from the same brand or common seed source.	Farber 2000; pers comm; unreferenced
S. Saint-Paul	1988	U.K.	Thailand and Australia	Mung	143	0	Yes/Yes	Multiple serovars isolated from bean spouts, seeds, and environmental samples (from producer waste materials).	O'Mahony and others 1990
S. Saint-Paul S. Havana S. Muenchen	1988	Sweden	NR	Mung	148	0	Yes/NR	Probably same seeds as UK outbreak. *S.* Havana and *S.* Muenchen but not S. Saint-Paul isolated from sprouts.	See Nguyen-the and Carlin 2000; See O'Mahony and others 1990
S. Senftenberg	1997-98	California	5 U.S. states	Alfalfa and clover sprouts	52	0	Yes/No	Sprouts were traced to a specific sprouter. Contaminated seeds suspected. Same sprouter as 1998 *E. coli* O157:N.M. outbreak.	Jeff Farrar; pers comm; unreferenced; Taormina and others 1999
S. Stanley	1995	Multistate, U.S, Canada and Finland	The Netherlands	Alfalfa	>272	0	No/No	Seeds came from the same sprouter. At least 4 seed lots involved. Possible contamination occurred prior to shipping.	Mahon and others 1997
S. Virchow	1988	U.K.	Thailand and Australia	Mung	7	0	Yes/NR	Probably from the same outbreak as *S.* Saint-Paul in UK.	O'Mahony and others 1990
Yersinia enterolitica	1982	Pennsylvania	Unknown	Bean sprouts	16	0	NR/NR	Bean sprouts were immersed at home in well water contaminated with *Yersinia*.	See Cover and Aber 1989

[a] NR, not reported
[b] Hemolytic uremic syndrome

Table O-5—Examples of reported outbreaks of foodborne disease associated with unpasteurized fruit juice

Pathogen	Year	Location	Fruit Source	Type of Juice	Venue	No. of Cases	No. of Deaths	Isolated from Juice	Comments	Reference
Crytosporidium parvum	1996	New York	New York	Apple	Small cider mill	20 confirmed, 11 suspected	0	NR[a]	No drops used; However, dairy farm across the street. *E. coli* detected in well water samples indicating fecal contamination. Apples were brushed and washed prior to pressing.	CDC 1997c
Cryptosporidium	1993	Maine	Maine	Apple	School 160 primary and 53 secondary		0	Yes	Apples shaken from trees and gathered from ground, cattle grazed on grass beneath trees, oocysts found in calf manure, apples inadequately washed and pressed for juice at an agricultural fair.	Millard and others1994
Escherichia coli O157:H7	1991	Mass.	Mass.	Apple	Small cider mill	23 (4 HUS)	0	No	90% drops used in making juice. Apples were not washed or scrubbed. Cattle raised nearby.	Besser and others 1993
E. coli O157:H7	1996	Conn.	Conn.	Apple	Small cider mill	14 (3 HUS, 1 HUS+TTP[c])	0	No	Some drops used in juice. Apples were brushed and washed in potable water before juiced using a wooden press. Potassium sorbate (0.1%) added as a preservative.	CDC 1997c
E. coli O157:H7	1996	Wash.	Wash.	Apple	Small cider mill	6	0	No	Cider was made for local church event from local orchard. Apples were washed.	See Farber 2000
E. coli O157:H7	1996	British Columbia, Canada, California, Colorado, and Washington	U.S.	Apple	Retail	70 (14 HUS)	1	Yes	Phosphoric acid wash, brushed, and rinsed; However, phosphoric acid based solutions may have been used incorrectly (not intended for produce/ waxed produce) or some times used at low concentrations. Possibly poor quality apples, some dropped apples used, apple orchard near cattle/deer.	CDC 1996b; Cody and others 1999
E. coli O157:H7	1998	Ontario, Canada	Ontario, Canada	Apple	Farm/ Home	14	0	No	Cattle kept in orchard prior to apple harvest. Apples collected from ground if suitable on inspection. Water supply on farm not potable. Apples used without further inspection, brushing or washing.	Tamblyn and others 1999
E. coli O157:H7	1999	Oklahoma	Oklahoma	Apple	—	7	0	NR	Drop apples used. Possible contamination from wild and	See Farber 2000

Table O-6—Examples of Reported Outbreaks of Foodborne Disease Associated with Reconstituted Orange Juice

Pathogen	Year	Location	Produce Source	Type of Juice	Venue	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Hepatitis A	1962	Missouri	Unknown	Orange (reconstituted)	Hospital	24	0	NR	The orange juice was prepared by subclinical hepatitis A handler.	Eisenstein and others 1963
Salmonella Typhi, typhoid fever	1944	Ohio	Unknown	Orange (reconstituted)	Residential hotel	18	1	NR	Juice was handled by an asymptomatic food worker.	Duncan and others 1946
S. Typhi, typhoid fever	1989	New York	Unknown	Orange (reconstituted)	Resort hotel	46 confirmed 24 suspected	0	NR	An asymptomatic food handler prepared the juice at a New York hotel.	Birkhead and others 1993

Table O-5—Examples of reported outbreaks of foodborne disease associated with unpasteurized fruit juice *(continued from previous page)*

Pathogen	Year	Location	Fruit Source	Type of Juice	Venue	No. of Cases	No. of Deaths	Isolated from Juice	Comments	Reference
									Utensils used were difficult to clean. Orange juice distributed near restrooms.	
Unknown	1965	California	Unknown	Orange (reconstituted)	Unknown	563	0	NR[a]	Possible contaminated water source used to reconstitute juice.	Tabershaw and others 1967
[a] NR, not reported									domestic animal manure.	
E. coli O157:H7 suspected	1980	Toronto, Ontario, Canada	Canada	Apple	Local market	14 HUS[b]	1	No	Juice purchased from a local market and fair. Juice tasted "bad" or "different".	Steele and others1982
Enterotoxigenic *E. coli*	1992	India	India	Orange	Roadside vendor	6	0	Yes	Two roadside vendors selling fresh squeezed juice, one was 6 meters away from the garbage heap.	Singh and others 1995
Salmonella Enteriditis	2000	Multistate, U.S.	California	Citrus	Retail and Food Service	14	0	No	Gallon sized containers of citrus juices were implicated in the outbreak.	Butler 2000
S. Gaminera, *S.* Hartford, and *S.* Rubislaw	1995	Florida	Florida	Orange	Retail	62 ill and 7 hospitalized	0	Yes	*S.* Gaminera was isolated from several containers of juice after outbreak. Numerous in-plant sanitation problems found. Surface water was used for orchard irrigation. Drops were used for juice. *Salmonella* was isolated from amphibiams and soil around the processing plant.	CDC 1995; Cook and others 1998
S. Muenchen	1999	U.S. and Canada	Mexico	Orange	Restaurant	207 confirmed, +91 suspected	1	Yes	Multiple strains of *Salmonella* isolated from orange juice collected from producer. Juice squeezed in Mexico and transported to Arizona in tanker trucks where it was bottled. Follow-up investigations revealed that ice was added illegally to juice prior to transport.	CDC 1999a
S. Typhi	1898	France	France	Apple	NR	NR	NR	NR	—	
S. Typhi	1922	France	France	Apple	NR	23	0	NR	Non-potable water was used to wash apples.	Paquet 1923
S. Typhimurium	1974	New Jersey	New Jersey	Apple	Farm and small retail outlets	296	0	Yes	A high proportion of dropped apples used to make the juice. Manure used to fertilize apple trees. Equipment rinsed with cold water, not sanitized. Six of thirty employees were *S.* Typhimurium positive.	CDC 1975
S. Typhimurium	1999	Australia	Australia	Orange	Retail	405	0	Yes	*Salmonella* was isolated from juice. unopened cartons of orange	Survellence Management Section 1999

[a] NR, not reported
[b] Hemolytic uremic syndrome
[c] Thrombotic thrombocytopenic purpura

Table O-6—Examples of reported outbreaks of foodborne disease associated with reconstituted orange juice

Pathogen	Year	Location	Produce Source	Type of Juice	Venue	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Hepatitis A	1962	Missouri	Unknown	Orange (reconstituted)	Hospital	24	0	NR	The orange juice was prepared by subclinical hepatitis A handler.	Eisenstein and others 1963
Salmonella Typhi, typhoid fever	1944	Ohio	Unknown	Orange (reconstituted)	Residential hotel	18	1	NR	Juice was handled by an asymptomatic food worker.	Duncan and others 1946
S. Typhi, typhoid fever	1989	New York	Unknown	Orange (reconstituted)	Resort hotel	46 confirmed 24 suspected	0	NR	An asymptomatic food handler prepared the juice at a New York hotel. Utensils used were difficult to clean. Orange juice distributed near restrooms.	Birkhead and others 1993
Unknown	1965	California	Unknown	Orange (reconstituted)	Unknown	563	0	NR[a]	Possible contaminated water source used to reconstitute juice.	Tabershaw and others 1967

[a] NR, not reported

Table O-7—Examples of reported outbreaks of foodborne disease associated with raw lettuce or salads

Pathogen	Year	Location	Produce Source	Venue	Type of Lettuce or Salad	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Campylobacter jejuni	1984	British Columbia, Canada	NR[a]	University cafeteria	Salad	330	0	No	Possible cross contamination during food preparation and poor food storage practices. Salad appeared to initiate outbreak.	Allen 1985
C. jejuni	1996	Oklahoma	NR	Restaurant	Lettuce	14	0	NR	Probable cross contamination of lettuce with raw chicken juices.	CDC 1998b
Clostridium perfringens	1993	Ontario, Canada	Unknown	Wedding reception	Salad	48	0	No	Salad implicated but epidemiology weak.	Styliadis 1993
Cyclospora cayatenesis	1997	Florida	Possibly Peru	Restaurants cruise ship	Baby lettuce leaves (mesclun)	>91	0	NR	Possibly related outbreaks traced to cruiseship sailing out of Florida and several Florida restaurants. Lettuce originated from Peru and U.S., purchased from the same distributor.	See Herwaldt and Beach 1999
Calicivirus	1992	Ontario, Canada	NR	Catered event	Salad	27	0	NR	Salad served at a potluck. Vegetables may have been improperly washed or cross contaminated by an infected food handler.	Todd 1998
Escherichia coli O157:H7	1995	Idaho	Unknown	Unknown	Lettuce (romaine)	21	0	NR	Possibly infected food handler.	CSPI 2000
E. coli O157:H7	1995	Maine	California	Scout camp	Lettuce (iceberg)	30	0	NR	Cross contamination with raw hamburger juice.	CSPI 2000
*E. coli*O157:H7	1995	Ontario, Canada	NR	Acute care hospital	Iceberg lettuce	23	0	NR	Outbreak occurred in an acute care hospital. Lettuce received was heavily spoiled.	Preston and others 1997
E.coli O157:H7	1995	Alberta, Canada	NR	Restaurant	Caesar salad	37	0	NR	—	Farber; pers comm; unrefcd

Table O-7—Examples of reported outbreaks of foodborne disease associated with raw lettuce or salads (*continued from previous page*)

Pathogen	Year	Location	Produce Source	Venue	Type of Lettuce or Salad	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
E.coli O157:H7	1995	Montana	Montana and Washington	Retail	Lettuce	70	0	No	Possible contamination from irrigation runoff or compost used to fertilize the fields. Cattle had access to the stream above the pond used for irrigation.	Ackers and others 1998
E.coli O157:H7	1996	Connecticut and Illinois	U.S.	Various	Mesclun lettuce	49	0	Yes	The implicated lettuce was traced to a single grower processor. Cattle was found near the lettuce fields.	Hilborn and others 1999; See Tauxe 1997
E.coli O157:H7	1998	California	NR	Restaurant	Salad	2	0	No		Griffin and Tauxe 1999
Giardia	1989	New Mexico	NR	Church dinner	Lettuce and onions	21	0	NR	Possible contamination from potable water used in washing the vegetables. Possible cross contamination from using the same cutting board to cut all vegetables.	CDC 1989
Hepatitis A	1986	Florida	NR	Restaurant	Lettuce salad	103	0	No	The probable source for the outbreak was an infected foodhandler with poor hygiene practices. The lettuce was shredded with hands.	Lowry and others 1989
Hepatitis A	1988	Kentucky	U.S. but possibly Mexico	Restaurants	Iceberg lettuce	202	0	No	Three restaurants received lettuce from the same produce distributor. Contamination suspected to have occurred before distribution.	Rosenblum and others 1990.
Shigella sonnei	1983	Texas	Arizona, California, New Mexico	University cafeteria	Lettuce	140	0	No	Two concurrent outbreaks at separate universities. Both universities purchased lettuce from the same supplier. Supplier purchased lettuce from three states. Farm source could not be determined.	Martin and others 1986
S. sonnei	1986	Texas	Texas	Restaurants	Shredded lettuce	347	0	No	Implicated restaurants received shredded lettuce from one source. Possible contamination from food handler at the shredding facility.	Davis and others 1988
S. sonnei	1994	Norway, Sweden, and UK	Spain	Various	Lettuce (iceberg)	110 (Norway), 8 (Sweden), NR (UK)	0	No	Fecal coliforms and *Salmonella* were detected in iceberg lettuce obtained from patient's homes.	Kapperud and others 1995
Vibrio cholerae	1970	Israel	NR	NR	Mixed vegetables	176	0	NR	Possible contamination from waste water irrigation.	See Nguyen-the and Carlin 2000

[a] NR, not reported

Table O-8—Examples of reported outbreaks of foodborne disease associated with raw produce other than melons, berries, seed sprouts, and lettuce or salads

Pathogen	Year	Location	Produce Source	Venue	Type of Produce	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Clostridium botulinum (type A)	1987	Florida	NR[a]	Home	Cabbage salad	4	0	Yes	Preformed toxin and spores were found in coleslaw dressing which contained cabbage and carrot pieces. Possible growth of *C. botulinum* in the cabbage.	Solomon and others 1990
C. botulinum (type A)	1989	New York	NR	Home	Chopped garlic in oil	3	0	Yes	Product was made from chopped garlic, ice water and olive oil some-time between 1985 and 1987. Chemical or acid additives not used. "Keep refrigerated" in small print. Jar was stored at room temperature for approximately 3 months prior to opening. Refrigerated after opening. Same processor as 1985 outbreak (Solomon and Kautter, 1988).	Morse and others 1990
C. botulinum (type B)	1985	British Columbia, Canada	US	Restaurants	Chopped garlic in oil	37	0	Yes	The product was made from dehydrated and rehydrated and soybean oil. Chemical or acid additives not used. "Keep refrigerated" in small print. Jar was stored at room temperature at the restaurant.	Solomon and Kautter 1988
Cryptosporidium parvum	1997	Washington	US	Restaurants	Green onions (inconclusive association)	54	0	No	Green onions were not washed before delivery to the restaurant and not washed before serving to customers. Possible contamination by a food handler.	CDC 1998a
Cyclospora cayatenansis	1997	Multistate, US	US	Retail/ Catered events	Basil	>308	0	Yes	Suspected fresh basil. Mode of contamination unknown.	CDC 1997b
Escherichia coli (enterotoxigenic)	1993	Rhode Island New Hampshire	US	Airline, hotel	Shredded carrots	47 121	0	NR	Possible contamination of carrots used in salads. Carrots used came from same state.	CDC 1994
E. coli O157:H7 1999	1998	Indianapolis	NR	Restaurant	Coleslaw	33	0	Yes		Griffin and Tauxe
E. coli O157:H7	1998	Wisconsin	NR	Catered event	Fruit salad	47 (3 HUS)	0	No		Griffin and Tauxe 1999
Giardia lamblia	1989	US	NR	NR	Lettuce, tomatoes, onions	21	NR	NR		See Nguyen-the and Carlin 2000
Hepatitis A	1971	Tennessee	Tennessee	Home	Raw watercress	129	0	No	Watercress harvested from small streams near farm. Specimen cultures revealed gross contamination with fecal organisms. Several abandoned septic tanks were seen near the stream.	CDC 1971
Hepatitis A	1994	Arkansas	NR	NR	Diced tomatoes	92	0	NR	Suspected contamination by food handler.	Lund and Snowdon 2000
Listeria monocytogenes	1979	Boston	NR	Hospitals	Raw tomatoes, lettuce and celery suspected	20	5	NR	Multiple hospitals involved. Tuna fish, chicken salad and cheese sandwiches epidemiologically linked to listeriosis. All served with tomatoes, raw vegetables such as celery and lettuce.	Ho and others 1986; Schlech and others 1983

(continued on next page)

Table O-8—Examples of reported outbreaks of foodborne disease associated with raw produce other than melons, berries, seed sprouts, and lettuce or salads *(continued from previous page)*

Pathogen	Year	Location	Produce Source	Venue	Type of Produce	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
L. monocytogenes	1981	Nova Scotia, Canada	Nova Scotia, Canada	Various	Vegetable mix for coleslaw	41	17	Yes	Cabbage was grown on farm where two sheep had died of listeriosis. Raw and composed manure was used to fertilize the fields. Cold storage may have allowed for *Listeria* growth.	Farber 2000; pers comm; unreferenced; Schlech and others 1983
Norwalk virus	1982	Minnesota	NR	Hotel restaurant	Fruit salad, coleslaw, and tossed salad	233	0	NR	Outbreak traced to three separate banquets. Fruit salad and coleslaw prepared by one worker during her acute illness and up to 48 hours following her recovery. A second worker prepared implicated tossed salad 24 hours following her recovery.	White 1986
Norwalk virus	1990	Hawaii	NR	Cruise ship	Fresh cut fruit	>217	0	NR	Possible contamination occurred during preparation. Fresh cut fruits included pineapple, papaya, watermelon, cantaloupe, and honeydew melon.	Herwaldt and others 1994
Salmonella Baildon	1998 to 99 two packers in Florida.	Susman 1999; US	Multistate,	Florida	Various	Tomatoes	85	3	NR Possible field contamination by domesting or wild animals.	Tomates traced to Cummings 1999
S. Javiana	1990	Multistate, US	South Carolina	Various	Tomatoes	174	0	NR	Contamination of water bath used by packer.	See Tauxe 1997; See Beuchat 1996b
S. Montevideo	1993	Multistate, US	South Carolina	Various	Tomatoes	84	0	No	Contamination of water bath used by packer.	See Lund and Snowdon 2000; See Wei and others 1995; Tauxe 1997
S. Typhi mamey. Source of	1998 to 99	See Lund and	US	Brazil	Unknown	Mamey	13	0	Unknown contamination not known.	Imported frozen Snowdon, 2000
Shigella flexneri 6A	1994	Multistate, US	Mexico	Various	Green onions	72	0	ND	Possible contamination during harvest or packaging in Mexico.	Tauxe, 1997
S. sonnei	1998	Multistate, US and Canada	Mexico	Restaurants	Parsley	310	0	No	Municipal water supplied to packing shed was unchlorinated. Water was used in hydrocooler where it was recirculated. Also used to make ice for packing the parsley. Workers had limited hygiene education and sanitary facilities. In restaurants parsley was often chopped and left at room temperature for several hours prior to serving.	CDC, 1999b
Vibrio cholerae	1970	Israel	NR	NR	Various raw vegetables	176	NR	NR	Contamination by irrigation and untreated waste water.	See Nguyen-the and Carlin, 2000
V. cholerae	1991	Peru	Peru	Various	Cabbage	Unknown	71	NR	Several factors were associated with cholera transmission including contaminated drinking water, going to fiestas, and eating raw or lightly cooked cabbage. Farmers in region commonly used untreated sewage to irrigate crops.	Swerdlow and others 1992

[a] NR, not reported

Table O-9—Examples of reported outbreaks of foodborne disease associated with raw produce due to contamination during final preparation

Pathogen	Year	Location	Venue	Type of Produce	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Campylobacter jejuni	1984	British Columbia, Canada	University cafeteria	Salad	330	0	No	Possible cross contamination during food preparation and poor food storage practices. The salad appeared to initiate outbreak.	Allen 1985
C. jejuni	1996	Oklahoma	Restaurant	Lettuce	14	0	NR[a]	Probable cross contamination of lettuce with raw chicken juices.	CDC 1998b
Crytosporidium parvum	1997	Washington	Restaurants	Green onions (inconclusive association)	54	0	No	Green onions were not washed before delivery to the restaurant and not washed before serving to customers. Possible contamination by a food handler.	CDC 1998a
Calicivirus	1992	Ontario, Canada	Catered event	Salad	27	0	NR	Salad served at a potluck. Vegetables may have been improperly washed or cross contaminated by an infected food handler.	Todd 1998
Escherichia coli O157:H7	1993	Oregon	Restaurant	Cantaloupe	9	0	NR	Possible contamination of cantaloupe with organism from raw beef.	See Del Rosario and Beuchat 1995; Anonymous 1993
E. coli O157:H7	1995	Idaho	Unknown	Lettuce (romaine)	21	0	NR	Possibly contaminated by food handler.	CSPI 2000
E. coli O157:H7	1995	Maine	Scout camp	Lettuce (iceberg)	30	0	NR	Cross contamination with raw hamburger juice.	CSPI 2000
Giardia	1989	New Mexico	Church dinner	Lettuce and onions	21	0	NR	Possible contamination from potable water used in washing the vegetables. Possible cross contamination from using the same cutting board to cut all vegetables.	CDC 1989
Hepatitis A	1986	Florida	Restaurant	Lettuce salad	103	0	No	The probable source for the outbreak was an infected food handler with poor hygiene practices. Lettuce was shredded by hand.	Lowry and others 1989
Hepatitis A	1994	Arkansas	Unknown	Diced tomatoes	92	0	Unknown	Suspected contamination by f ood handler.	Lund and Snowdon 2000
Norwalk virus	1987	United Kingdom	NR	Melon	206	0	NR	Infected food handler.	See Lund and Snowdon 2000
Norwalk virus	1990	Hawaii	Cruise ship	Fresh cut fruit	>217	0	NR	Possible contamination occurred during preparation. Fresh cut fruits included pineapple, papaya, watermelon, cantaloupe, and honeydew melon.	Herwaldt and others 1994.

[a] NR, not reported
Note: These outbreaks are also found in Tables 1 to 8.

Table O-10—Examples of reported outbreaks of foodborne disease asociated with temperature abuse

Pathogen	Year	Location	Produce Source	Venue	Type of Produce	No. of Cases	No. of Deaths	Isolated from Produce	Comments	Reference
Clostridium botulinum (type A)	1989	New York	NR[a]	Home	Chopped garlic in oil	3	0	Yes	Product was made from chopped garlic, ice water and olive oil sometime between 1985 and 1987. Chemical or acid additives not used. "Keep refrigerated" in small print. Jar was stored at room temperature or approximately 3 months prior to opening. Refrigerated after opening. Same processor as 1985 outbreak (Solomon and Kautter, 1988).	Morse and others 1990
C. botulinum (type B)	1985	British Columbia, Canada	U.S.	Restaurants	Chopped garlic in oil	37	0	Yes	Product was made from dehydrated and rehydrated and soybean oil. Chemical or acid additives not used. "Keep refrigerated" in small print. Jar was stored at room temperature at the restuarant.	Solomon and Kautter 1988
Salmonella Javiana	1991	Michigan	NA	Indoor picnic and in-school party	Watermelon	26 primary 13 secondary	0	Yes	Melon not washed prior to cutting. Suspected contamination from melon rind. Melon served over 3 hour period at room temperature. Leftovers served the next day.	Blostein 1993
S. Oranienburg	1979	Illinois	Illonois	Supermarket	Watermelon	18	0	No	Damaged fruits were cut, covered with plastic film, and displayed, sometimes without refrigeration until sold.	CDC 1979
S. Oranienburg	1998	Ontario, Canada	U.S., Mexico, or Central America	Various	Cantaloupe	22	0	No	Possible contamination with organism from surface when slicing. The cut fruit was probably left sitting at room temperature for several hours before consumption.	Deeks and others 1998
Salmonella	1950	Minnesota	NR	Roadside stand	Watermelon	6	0	Yes	Prepared cut melon. *S.* Bareilly isolated from melon. Melon kept at ambient temperature.	See Blostein 1993

[a] NR, not reported
Note: These tables are also found in Tables 1 to 8