Case Study: Pathogens and spices

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About case studies

The Environmental and Occupational Health team provides scientific and technical advice and support to the health care system and the Government of Ontario. We have created the case study series to share the diverse environmental health issues we have encountered and encourage dialogue in these areas.

This response was originally produced on July 2015. The specifics about the location and requestor have been removed.

The following was selected as a case study because spices and dried herbs are important food commodities, and are used as an ingredient in a variety of food items. They are classified as low-moisture and ambient-stable, and are perceived to be low-risk foods. However, there have been a number of recalls for spices and dried herbs in the past few years due to contamination with pathogens. Does this food group present a potential hazard for public health?

Background

Spices and dried herbs are important food commodities; they are used all over the world in food preparation, usually in small amounts, to flavour foods. Spices and dried herbs are a group of agricultural commodities that can be fruit or seed-based (such as paprika), bark or flower based (such as cinnamon), root or rhizomes based (such as turmeric and ginger) and leaf based (such as oregano).[1,2] Spices and dried herbs are classified as low-moisture foods (LMFs). Low-moisture foods are defined as food items that have water activity of less than 0.85.[1] Generally, the minimum available water (a_w) required to facilitate growth of most bacteria is 0.87; although under optimal conditions, bacteria such as *Staphylococcus aureus* can grow at a_w of 0.83.[3] As LMFs are generally ambient-stable and assumed to be low-risk, they are considered to be an unlikely source to be implicated for foodborne illness.[4]

However, in recent years, there has been an increased number of recalls for dried herbs and spices due to contamination by pathogens. Based on a review of documented recalls, *Salmonella* is the principal food pathogen associated with dried herbs and spices. Between 1970 and 2003, there were 21 recalls of 12 spice types in the United States (US). Of the 21 recalls, *Salmonella* accounted for 95% (20/21) of documented US recalls.[5] Between January 2008 and August 2011, the Rapid Alert System for Food and Feed (Food and Feed Safety Alerts) of the European Commission reported 22 alerts for herbs, spices and pepper. Of the 22 alerts, *Salmonella* was identified in 21 alerts and *E. coli* was identified in one alert.[3] In Canada, the Canadian Food Inspection Agency (CFIA) recalled a number of spices and dried herb products in 2014. These included paprika powder, spice products, white pepper powder, black peppercorn, flax seed powder, carob powder, rosemary leaves and dried oregano leaves. The pathogen involved in all of these recalls was *Salmonella.*[6] As of June 2015, CFIA has recalled garlic powder, kalonji, and chicken broth powder due to contamination with *Salmonella.*[7]

This document will review the literature on the presence of pathogens in spices and dried herbs at the point-of-sale, the evidence of foodborne illness outbreaks associated with LMFs, the factors that contribute to contamination of these products, and the mechanisms of survival for microorganisms in these products. It will answer the following three questions:

1. What are the microbial qualities of spice/dried herbs products at point-of-sale?
2. Have low-moisture foods such as spices been associated with outbreaks of foodborne illnesses? What are the pathogens associated with these outbreaks?
3. What are the contributing factors for contamination of low-moisture foods (specifically spices and dried herbs), and how can microorganisms survive in low-moisture foods?

Method

A literature search was performed by Public Health Ontario's (PHO) Library Services on March 31st, 2015 in the following databases: Ovid MEDLINE, and Embase, EBSCOhost Food Science, BIOSIS, and Scopus. Search results were limited to English language articles only published from January 1, 2005 –March 31, 2015. Search terms included: "microbial growth, bacterial growth or development, microbial viability counts, spice, relevant spices, nuts or dried herbs, low moisture, low water activity, low Aw, relevant pathogens and foodborne disease, illness or poisoning outbreak." Additional information was identified through cited reference searching of full-text articles.

To review the evidence of outbreaks associated with low-moisture food (LMF), a search was conducted through Public Health Agency of Canada's "Publically Available International Foodborne Outbreak database" (PAIFOD), between January 1, 2005 to April 1, 2015, on documented outbreaks associated with LMF.[8]

The information obtained was evaluated for relevance and 45 records were included in this report.

Microbial quality of spices/dried herbs at point-of-sale

Based on a review of the published literature, a number of studies were identified that examined the microbial quality of different spices and dried herbs at point-of-sale around the globe. *Cronobacter* species, an opportunistic pathogen, has been isolated from a number of LMFs and food ingredients including spices and dry herbs.[9] Similarly, Verotoxigenic *E.coli* (VTEC), *Salmonella, Staphylococcus, Bacillus cereus* (spores), *Clostridium botulinum and Clostridium perfringens* (spores), and *Listeria monocytogenes* have also been isolated from a variety of LMFs.[10]

Spices and spice products that were sampled within these studies had varying degrees of contamination from pathogenic microorganisms. In a study conducted in the United Kingdom, 750 samples of spices and spice ingredients as well as 1,946 samples of ready-to-eat foods where spice had been incorporated were collected to test for a number of pathogens including *Salmonella* spp. *B. cereus* and *Bacillus* spp. (Little et al.). Based on their results, ready-to-eat food samples tested positive for *B. cereus* (17%) and *Bacillus* spp. (17%), Enterobacteriaceae (11%), *E. coli* (4%). In addition, spices and spice ingredients tested positive for *B. cereus* (19%), other *Bacillus* spp. (53%) and *Salmonella* (<1%).[11] A study conducted in Bangladesh examined 42 unopened and opened spice samples of red pepper, turmeric and coriander. From the samples collected, Total Coliform, *E.coli, Staphylococcus*, yeast and mould were identified. The study reported higher levels of contamination in opened spices; although, microbial counts varied by region, year of production and the harvest and storage conditions prior to drying.[2]

In India, Banerjee et al. investigated 154 samples of 27 kinds of spices for microbial contamination. Mould was detected in 97% of the samples with yeast being identified in only one sample. The pathogens that were identified included *B. cereus, C. perfringens, S. aureus, E. coli* and *Salmonella* spp. The non-packaged spices had a higher load of moulds, *B. cereus*, and Enterobacteriaceae than polyethylene-packaged spices.[12]

In a 2007 study conducted in Iran, 351 samples of black pepper, caraway, cinnamon, cow parsnip, curry powder, garlic powder, red pepper, sumac, and turmeric were tested for the presence of a number of aerobic mesophilic bacteria, *E. coli*, and moulds. Based on their results, 63.2% of samples exceeded the standard limits for mesophilic bacteria ($>5x10^5$ CFU/g), 23.4% for *E. coli* (>0.3MPN/g), and 21.9% for moulds ($>5x10^3$ CFU/g).[13] In addition, two studies conducted in Turkey had identified various pathogens (aerobic bacteria, *S. aureus, B. cereus, E. coli,* sulphite reducing bacteria, moulds/yeast, *Salmonella* spp. and *E. coli* 0157 H:7) in sampled spices and dried herbs.[14,15]

Donia et al. performed microbial and aflatoxin analysis on 303 samples of different spices and medicinal dried herbs in Egypt. From their analysis, aerobic bacterial count, spore-forming bacteria, coliform, *E. coli, S. aureus*, yeast and mould were detected. Total viable counts of microorganisms were found in different spices at various levels. For example, *E. coli* was detected in all samples except for tea, black pepper, karakade and saffron, while *S. aureus* was only detected in basil, peppermint and spearmint. The highest and lowest mean counts were found in peppermint and black pepper respectively. All samples tested were free of aflatoxins (B1, B2, G1 and G2).[16] Ahene et al. performed microbial analysis of aniseed, rosemary and several spice products in Ghana. Microorganisms isolated from the spices varied depending on the product tested. For example, aniseed had the highest count of bacterial load, and Royco shrimp cube and Royco beef cube had the least. *Aeromonas salmonicida, Enterobacter cloacae, Enterobacter amnigenus, Enterobacter agglomerans, Enterobacter Sakazakii, Flavobacterium* spp, *Chromobacterium violaceum, Pseudomonas putida, Pseudomonas aeruginosa, Acinetobacter* spp, *Pseudomonas cepacia* and *Serratia plymuthica* were detected in the tested samples.[17] In Brazil, Moreira et al. analysed different spices and dried herbs for the presence of mesophilic bacteria, thermotolerant coliforms, *B. cereus, S. aureus*, and *Salmonella.* Twenty one per cent of all samples tested positive for thermotolerant coliforms, while 5.6% were positive for *Salmonella.* Black pepper had the highest level of contamination; 18.2% of black pepper samples were positive for *Salmonella* spp. and 8.3% of dehydrated green onion samples tested positive for *B. cereus*. No pathogens were detected in samples of bay leaves.[18] Turcovsky et al. tested 602 food items for the presence of *Cronobacter* spp. The highest contamination was observed in foods of plant origin (spices, teas, chocolate, nuts, pastries and vegetables). Sixty two per cent (13/21) of spice samples tested were positive for *Cronobacter* spp.[19]

Based on FDA sampling and testing data between FY2007 and FY2009, *Salmonella* was detected in 6.6% of imported spices. This is 1.9 times more *Salmonella* contamination than all other imported FDA-regulated foods during this period of time.[20] The 2014 systematic review by the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) identified 77 studies investigating the prevalence and/or concentration of microbial hazards in spices. The report concluded that many spices can be contaminated with various microbial hazards.[1]

The evidence identified by this review suggests that spices and dried herbs available at point-of-sale can be contaminated with pathogens. A number of studies also concluded that spices and dried herbs may be high risk products, and when contaminated, may pose a potential risk to consumers.[2,13–16]

Foodborne illnesses outbreaks associated with spices and dried herbs

This review identified reports of foodborne illness outbreaks associated with spices, dried herbs and other LMFs. In Canada, a 1974 salmonellosis outbreak associated with black pepper resulted in 17 cases.[21] In 1993, Germany experienced the largest spice-associated outbreak of foodborne illness to date. Potato chips, which were seasoned with contaminated paprika, were implicated as the cause of the outbreak, which resulted in 1,000 cases of *Salmonella*. The investigation revealed that paprika was added to the potato chips after the final pathogen reduction step of food manufacturing.[21] A 2007 multistate salmonellosis outbreak in the U.S. resulted in 69 cases, where 93% of cases were children less than 3 years of age. Imported broccoli powder in spice mix used in Veggie Booty (a children's snack) was implicated as the cause of this outbreak.[22] Another multi-state salmonellosis outbreak, which occurred in 2009, resulted in 272 cases in 44 states. It was discovered that imported contaminated black and red pepper was added to ready-to-eat salami products.[23]

Between January, 1, 2005 and April 1, 2015, 23 foodborne outbreaks associated with spices and dried herbs were documented in the Publicly Available International Microbial Food Safety Database (PAIFOD) of the Public Health Agency of Canada (PHAC). The PAIFOD contains information on approximately 9,000 foodborne outbreaks from Canadian and international sources. The information is obtained from peer-reviewed journals, newspapers, list serves, press releases, health units, and the National Laboratory and government websites. *B. cereus, C. perfringens* and *Salmonella* spp. were the pathogens most commonly associated with spice/herb-related outbreaks. Based on data from the PAIFOD, *Salmonella* spp. was the reported causative agent with all four spice-related outbreaks in the U.S.[8] A preliminary report from FAO/WHO on foodborne pathogens of concern with spices and herbs also concluded that although various bacterial hazards have been identified in spices and herbs, only *Salmonella* spp., *B. cereus and C. perfringens* have been reported to be associated with foodborne outbreaks.[24]

Table 1 summarizes foodborne outbreaks in the past 10 years associated with spices and dried herbs. Table 2 summarizes foodborne outbreaks associated with LMFs that were recorded in the PAIFOD[*].

These findings suggest that if spices and/or dried herbs are contaminated with foodborne pathogens, they have the potential to contaminate ready-to-eat foods, which can result in illnesses and/or outbreaks. Specifically, reports of foodborne outbreaks from spices/herbs contaminated with *B. cereus, C. perfringens and Salmonella spp*. have been documented.

Microbial survival in low-moisture food

Some microorganisms can survive in LMFs for a prolonged period of time. Examples include survival of *Cronobacter* spp. in milk powder and *Salmonella* in chocolate, egg powder, animal feed, spices, nuts and nut butters.[3] *Salmonella* Enteritidis, *E.coli* and *K. pneumonia* have been shown to persist in milk powder for up to 15 months, while *E. Sakazakii, E. vulneris* and *K.oxytoca* were still recoverable after two years.[25] *Salmonella* can survive in low-moisture foods for weeks, months and even years.[26] Long-term survival of different strains of *Salmonella* in peanut butter has been reported by many studies.[27–29] Burnett et al. reported that if peanut butter is contaminated with *Salmonella,* it is likely to survive for the duration of its shelf life.[28] In addition, peanut butter with lower a_w can result in greater survival rates for *S.* Tennessee, *S*. Typhimurium and *Enterococcus faecium*.[27]

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[*] It is important to note that foodborne illness is greatly under-reported; the information presented in Tables 1 and 2 does not represent all related outbreaks that have occurred during this time period.

Day et al. demonstrated that *Salmonella* Typhi and *Shigella dysenteriae* can survive in dry infant formula for an extended period of time. Furthermore, it was observed that the presence of nitrogen can enhance the survival of these pathogens.[30]

Survival among different *Salmonella* serotypes in LMFs may vary under different temperatures and a_w. Temperature, a_w, medium composition of food and serotype of bacteria all play an important role in the survival kinetics of *Salmonella* in LMFs.[31,32] *Salmonella* can survive the longest in seeds and nuts at temperatures of around 20°C.[31] Different *Salmonella* strains that were inoculated in dried paper disks within the laboratory environment survived for up to 70 days at holding temperatures of 25°C–35°C, and up to 24 months at a holding temperature of 4°C.[33] *S.* Tennessee is more persistent than *S*. Montevideo and Typhimurium at higher temperatures in low-moisture whey protein powder held at 36°C and 70°C. In comparison, *S*. Agona did not differ significantly in terms of persistence when compared to *S*. Tennessee under different temperatures.[34]

Table 3 summarizes the characteristics of common foodborne pathogens in low-moisture foods.

Table 3
Microbial characteristics in a low moisture environment[3,10]

Pathogen	Aerobic/Anaerobic	Survival in low-moisture foods
Bacillus cereus	Facultative anaerobe	Spores can survive for months or years in dry environment.
Campylobacter species	Microaerophilic	Does not survive in dry environment.
Clostridium botulinum	Anaerobe	Spores survive in dusty and dry environment.
Clostridium perfringens	Anaerobic	Spores can survive in dry environment.
Cronobacter species (formerly *Enterobacter sakazakii)*	Facultative anaerobe	Can survive in dry foods (evidence of survival of bacteria in powdered infant formula for up to two years).
Escherichia coli 0157:H7	Facultative anaerobe	Can survive in dry foods (e.g., dry fermented meats).
Listeria monocytogenes	Facultative anaerobe	Can survive in dry foods (e.g., dry fermented meats and peanut butter).
Salmonella	Facultative anaerobe	Can survive for weeks, months or years in low-moisture foods (up to a_w 0.30).
Staphylococcus aureus	Facultative anaerobe	Can survive for months in dry foods.

The mechanism(s) by which the microorganisms are able to survive in LMF is not fully understood. Survival of microorganisms in dry processing environments and LMF depends on their ability to adapt to high osmotic potentials or dry conditions. [3,10] Osmoregulation refers to the maintenance of an optimal constant osmotic pressure in the body of a living organism. In low-moisture environments/foods, microorganisms adapt by balancing the osmolarity of their internal cell with that of the external environment to avoid water loss. This is done by a number of different cellular mechanisms that include an influx of K^+, followed by a longer-term adaptation such as the uptake of electrically neutral, low molecular weight compatible solutes (e.g., proline, glycine-betaine and ectoine).[26,32]

In a study by Lehner et al., the following factors were identified in facilitating the survival of *Cronobacter* species in low-moisture environments:

- their ability to form biofilms with the production of cellulose (in the extracellular matrix)
- adherence to hydrophilic and hydrophobic surfaces
- the production of extracellular polysaccharides along with cell-to-cell signalling molecules [35]

Kieboom et al. investigated the morphological changes in *Salmonella* Enteritidis after exposure to low-moisture environments. Exposure to low a_w resulted in the formation of filaments and development of elongated *S*. Enteritidis cells. When placed in more favourable conditions, these cells can split and form numerous single cells. Furthermore, cells exposed to low-moisture environments demonstrated a tolerance to hypochlorite.[36] Filamentation occurs when *S. Enteritidis* is exposed to low a_w and osmotic stress due to the production of inhibitors for cell division. It has been suggested that the production of filaments by microorganisms is to gain a further advantage for survival.[32] The filamented cells can lead to increased desiccation tolerance in comparison to non-filamentous cells.[32]

Deng et al. demonstrated that *Salmonella* cells in peanut oil undergo a physiologically dormant state with <5% of its genome transcribed, compared to 78% in Luria-Bertani broth (a rich growth medium).[37] Additionally, when exposed to environmental stresses such as elevated or lowered osmotic concentrations, a viable but non-culturable (VBNC) state has been reported for many bacteria (such as *Salmonella* spp. and *E.coli)*. Bacteria are thought to be able to survive in this dormant stage; as a result, bacteria that enter into this stage are not culturable for a prolonged period of time.[32,38] The exact role of VBNC state in bacteria is not known. However, most investigators believe it is a survival response to certain environmental stressors such as low a_w.[32]

Salmonella is also capable of forming biofilms in low-moisture environments. Curli fimbriae and cellulose production—both components of biofilm formation— are shown to enhance desiccation survival. Hence, it is suspected that biofilm formation may play a role in survival of *Salmonella*; however, it remains to be determined whether biofilm production has a definite integral role in survival in low-moisture environments.[32]

A number of phenotypes are associated with pathogens isolated from low a_w. *Salmonella* cells isolated from low-moisture foods have a lower infectious dose, increased thermal resistance and higher cross-tolerance to multiple stresses such as disinfectants commonly used in the food industry (e.g., sodium hypochlorite, hydrogen peroxide), ethanol, NaCl, and UV irradiation.[26,32,39]

While the exact mechanism of pathogen survival in LMFs is not known, it is well established in the literature that microorganisms, including *Salmonella,* can survive in LMFs for a prolonged period of time. They are also capable of acquiring a number of phenotypes; thus, if LMFs are contaminated, pathogen removal can be more challenging.

Contributing factors for contamination

Once a low-moisture food or the food environment has been contaminated, it is challenging for industry and consumers to address or reduce this contamination. Some of the reasons for this include:

- enhanced resistance of a number of microorganisms to dry rather than wet heat
- challenges for pathogen detection in final product testing (e.g., pathogens are not homogeneously distributed and during enumeration pathogens may be outcompeted by non-pathogenic species)
- longer survival time of microorganisms in low-moisture food
- possibility of spore germination and pathogen growth during rehydration
- public perception that dry foods are sterile, which may lead to careless handling practices.[3,32]

The climate where spices are cultivated and the conditions under which they are cultivated, harvested, processed and stored contribute to the possibility of contamination of spices.[16] Poor collection conditions, unpretentious production processes, use of contaminated water and extended drying time can contribute to microbial contamination of spices.[3,15] Spices are usually cultivated in countries with warm and humid climates. Cosano et al. examined microbial content of saffron produced in different countries; the highest microbial load was detected in samples which were produced in Iran. The authors suspect that this may be due to a warmer climate, although this requires further investigation. In addition, the study could not rule out the possibility that poor harvesting and lack of sanitary practices during storage could be contributing to elevated microbial loads.[40]

Cross contamination and poor sanitation have been related to contamination of low-moisture foods. How and where spices are stored have been related to the level of contamination. Spices held in bulk have higher concentrations of pathogens.[3,12] Unpacked spices, stored in bulk open containers, can be contaminated through dust, waste water and animal/human excreta.[15] Koohy-Kamaly-Dehkoordy et al. suggested that poor microbial quality of the collected spice samples in Iran were a result of environmental or fecal contamination due to unhygienic practices during production.[13]

Other studies have identified poor sanitation, cross contamination, improper maintenance, poor equipment and facility design and lack of proper HACCP system and Good Manufacturing Plan (GMP) as the contributing factors for microbial contamination in LMFs.[26,32]

Summary

Reducing available water is an ancient food preservation technique and helps to minimize microbial growth in LMFs (a_w of less than 0.85). However, if food is contaminated, microorganisms can resist the drying process, and as a result, can survive for a prolonged period of time. It has been documented that vegetative cells and spores of some bacteria are capable of surviving for several months or years in these foods.[1-3,9,11–18,20,41] In the case where pathogens experience rehydration and the food product is temperature abused, there is a possibility for pathogens to multiply, which can result in infection or intoxication.[4] In addition, pathogens isolated from low a_w are also capable of acquiring a number of phenotypes such as a lower infectious dose, increased thermal resistance and higher tolerance to common disinfectants (e.g., sodium hypochlorite).

There are many international studies that have demonstrated the presence of pathogens in spices/dried herbs. Some of the pathogens reported in spices and dried herbs include *E. coli, Salmonella, bacillus* spp. *C. perfringens, Cronobacter* spp., *Shigella,* and *S. aureus.* In Canada, during the period of January 2014 to June 2015, all recalls of spices and dried herbs due to microbial contamination have been associated with the presence of *Salmonella*.[6,7] *Salmonella* was also the main pathogen identified in foodborne illness outbreaks and food recalls associated with spices and dried herbs in the U.S.[20] *B. cereus* and *C. perfringens* have also been associated with reported spice/herb-related outbreaks globally.[8]

In 2014, as a result of a number of outbreaks associated with low moisture foods (LMFs), the Codex Committee on Food Hygiene requested scientific advice from FAO/WHO on LMFs that should be considered high priorities. The FAO and WHO developed and applied a multi-criteria decision analysis approach to rank LMFs that are of greatest concern based on a global microbiological food safety perspective. The microorganisms that were considered for review were *B. cereus, C. botulinum, C. perfringens, Cronobacter* spp., pathogenic *E. coli, Listeria monocytogenes*, *Salmonella* spp., and *S. aureus*. The ranking criteria considered four domains which included international trade, burden of disease, vulnerabilities due to food consumption, and vulnerabilities due to food production. Based on their analysis, spices, dried herbs and tea ranked third with cereals and grains, and dried protein products ranking first and second respectively.[42]

In order to minimize the risk, control measures should be applied to prevent contamination of spice. Examples include implementing preventive measures to reduce the spread of pathogens in a facility, control of raw materials, hygiene practices (control of the movement of personnel and material and hygienic design principles), controlling moisture, validation of control measures and verification of control through environmental monitoring.[43,44,45] Common interventions—for reduction of microbial contamination—applied in the spice industry include heat treatments, chemical treatments and irradiation.[1]

Conclusion

What are the microbial qualities of spice/dried herb products at point-of-sale?

A number of pathogens, including *Salmonella spp*., *Bacillus cereus* and *Bacillus spp*., have been identified in spices and dried herbs at point-of-sale.

Have low-moisture foods such as spices been associated with outbreaks of foodborne illnesses? What are the pathogens associated with these outbreaks?

There have been a number of reports of foodborne illness outbreaks associated with contaminated spices, dried herbs and other low-moisture foods. *Salmonella spp*., *Bacillus cereus* and *Clostridium perfringens* have been linked to foodborne outbreaks associated with spices and dried herbs.

What are the contributing factors for contamination of low-moisture foods (specifically spices and dried herbs) and how can microorganisms survive in low-moisture foods?

Poor sanitation, cross contamination, improper maintenance, poor equipment and facility design, and lack of proper Hazard Analysis Critical Control Point systems and Good Manufacturing Plans can contribute to the contamination of spices and dried herbs.

Survival of microorganisms in dry processing environments and low-moisture foods depend on their ability to adapt to high osmotic potentials or dry environmental conditions.[3,10] While the exact mechanism of pathogen survival in low-moisture foods is not well understood, it is well established in the literature that microorganisms, including *Salmonella*, can survive in low-moisture foods for a prolonged period of time.

The current body of evidence suggests that if pathogenic organisms are present in low-moisture foods, the risk to consumers is possible as indicated by reported outbreaks associated with low-moisture foods.[3]

Appendix 1

Table 1:

Outbreaks associated with spices, dried herbs recorded in publically available international foodborne outbreak database (PAIFOD)[8,21]

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Spices	*B. cereus*	2007	France	146	Foodborne outbreaks in Europe 2007 - EFSA-ECDC report	Contaminated raw materials -spice blend in couscous dish - laboratory detection of the implicated foodstuff
Spices	*B. cereus*	2009	Belgium	7	The European Union Summary*	Curry - enterotoxin positive strain
Spices	*B. cereus*	2009	Denmark	48	The European Union Summary*	Rose-paprika
Spices	*B. cereus*	2010	Denmark	112	EU 2010 report	White pepper-temperature abuse during food preparation/storage
Spices	*B. cereus*	2011	Finland	4	EU line list 2011	Turmeric / curcuma -temperature abuse
Spices	*B. cereus*	2011	Finland	3	EU line list 2011	Jeera Ground Cumin - temperature abuse
Spices	*B. cereus*	2011	Finland	19	EU line list 2011	Turmeric / curcuma - temperature abuse, Detection of 5000 *B. cereus*/g. in cinnamon - slow cooling
Spices	*B. cereus*	2011	Denmark	30	EU line list 2011	Detection of 5000 *B. cereus*/g. in cinnamon - slow cooling
Spices	*B. cereus*	2011	Denmark	52	EU line list 2011	*B. cereus* detected in pepper - inadequate cooking
Spices	*B. cereus*	2013	Finland	4	Finland Annual Report 2013	Pathogen detected in food or component - symptoms and onset of illness pathognomonic to causative agent; storage time/ temperature abuse, unprocessed contaminated ingredient.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Barbecue spice	*C. perfringens*	2011	Denmark	4	EU line list 2011	Slow cooling – detected in chilled fried chicken and in barbecue spice
Red pepper spice	*C. perfringens*	2011	Denmark	37	EU line list 2011	Slow cooling – detected in red pepper used for stew
Dried chillies	*C. perfringens*	2011	Denmark	3	EU line list 2011	Slow cooling – detected in dried chillies
Pepper	*C. perfringens*	2011	Denmark	10	EU line list 2012	Slow cooling – stew with beef (veal) and pepper; *C. perfringens* 330 ml/g detected in stew and in pepper used for stew
Pepper	*C. perfringens*	2012	Denmark	9	EU line list 2011	Fried pork with parsley sauce. *C. perfringens* detected in pepper used in sauce.
Curry Powder	*S.* Braenderup	2002	United Kingdom	20	Van Doren, 2013	One hospitalization. Spice originated from India.
Spices	*S.* enterica	2013	United Kingdom	413	Public Health England	Inadequate cooking – efforts should be made to raise awareness among importers, exporters and port health authorities concerning the labelling, and in particular the instructions for use, of curry leaves and other herbs.
Spices	*S.* Enteritidis	2012	Hungary	41	EU line list 2011	Six hospitalized: listed as herbs and spices
Black and red pepper	*S.* Montevideo	2009	USA	272	Epidemiol Infect 2012 - Gieraltowski et al	Fifty-two hospitalized: pathogen was identified in ready-to-eat salami from an environmental sample from one manufacturing plant, and sealed containers of black and red pepper at the facility.
Diet supplements	*S.* Montevideo	2010	Germany	31	Eurosurveillance, 2011;16(50)	Herbal food supplement, formulated in capsules, distributed under a Dutch label in Germany.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
White pepper	*S.* Rissen	2008	USA	87	Higa, 2011; Hajmeer and Myers, 2011; Higa, 2012; CDC line list 2008 & Oregon Department of Human Services Public Health Division	Eight hospitalized: Ground white pepper imported from Vietnam. Environmental samples from spice processing facility positive for outbreak strain.
Fennel seed	*S.* Senftenberg	2007	Serbia	14	Emerg Infect Dis. 2010;16(5):893-5	Four hospitalized: "baby" tea containing fennel seed, anise seed, and caraway. Mar 2007-Sep 2008 Microbiological link between spice and illness established. Parents of case-patients reported pouring boiling water over tea leaves during preparation but did not heat tea to boiling 71% of cases of illness in infants <12 months
Black and red pepper	*S.* Senftenberg	2009	USA	11	CDC, 2010; DuVernoy, 2012	Black pepper and red pepper (on Italian-style salami) Jul 2009 – Apr 2010. Microbiological link between spice and illness established. Unopened retail package of salami positive for *S*. senftenberg.
Spices	*S.* Wandsworth & Typhimurium	2007	USA	87	Sotir et al., 2009	Eight hospitalized: seasoning mix and broccoli powder (coating a snack puff) Jan 2007 – Dec 2007. (China for dried broccoli powder; sources of other ingredients in seasoning mix not reported) *S.*Typhimurium, *S.* Kentucky, *Cronobacter sakazakii* from unopened product; *S.* Typhimurium, *S.* Haifa from finished product; *S.* Mbandaka from parsley powder. Microbiological link between spice and illness established. Seasoning mix was applied after final pathogen reduction step.

*The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2009

Table 2:

Outbreaks associated with Low-Moisture Foods Recorded in Publically Available International Foodborne Outbreak database (PAIFOD)[8]

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Rice	*B. cereus*	2005	Belgium	6	European 2005 linelist	
Infant Cereal	*B. cereus*	2005	United Kingdom	2	Int J of Food Micro 2205;102:245-251	
Rice	*B. cereus*	2005	Norway	3	European 2005 linelist	
Spices	*B. cereus*	2007	France	146	Food-borne outbreaks in Europe 2007 - EFSA-ECDC report	Contaminated raw materials -spice blend in couscous dish - laboratory detection of the implicated foodstuff
Spices	*B. cereus*	2009	Belgium	7	The European Union Summary*	Curry - enterotoxin positive strain
Pasta	*B. cereus*	2009	USA	15	CDC line list 2009	
Rice	*B. cereus*	2009	USA	13	CDC line list 2009	White rice
Flour	*B. cereus*	2009	Poland	52	The European Union Summary*	Buckwheat
Rice	*B. cereus*	2009	Netherlands	3	The European Union Summary*	
Rice	*B. cereus*	2009	Netherlands	2	The European Union Summary*	
Rice	*B. cereus*	2009	Netherlands	3	The European Union Summary*	Inadequate hygiene by food handler
Rice	*B. cereus*	2009	Netherlands	3	The European Union Summary*	Prepared too large volumes of food
Spices	*B. cereus*	2009	Denmark	48	The European Union Summary*	Rose paprika
Rice	*B. cereus*	2010	Belgium	9	EU 2010 report	Storage time/temperature abuse
Spices	*B. cereus*	2010	Denmark	112	EU 2010 report	Temperature abuse- white pepper
Rice	*B. cereus*	2010	USA	6	CDC linelist 2010	Rice, white

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Rice	*B. cereus*	2010	USA	22	CDC linelist 2010	Rice, white
Rice	*B. cereus*	2010	USA	2	CDC linelist 2010	White rice pilaf
Rice	*B. cereus*	2010	USA	103	CDC linelist 2010	Rice, white
Rice	*B. cereus*	2010	USA	5	CDC linelist 2010	Beans, unspecified; rice
Grains	*B. cereus*	2010	Finland	8	European line list 2010	Kısır is a traditional Turkish side dish made from fine bulgur, parsley, and tomato paste. Storage time/temperature abuse
Bakery items	*B. cereus*	2011	Belgium	24	EU line list 2011	Disseminated cases
Rice	*B. cereus*	2011	USA	7	CDC line list 2011	White Rice
Rice	*B. cereus*	2011	Sweden	3	EU line list 2011	Storage time - temperature abuse
Pasta	*B. cereus*	2011	Germany	2	EU linelist 2011	Spaetzle (type of South German pasta dish) - *B.* cereus found in spaetzle in a concentration of >3.000.000 cfu/g
Rice	*B. cereus*	2011	Germany	8	EU linelist 2011	Inadequate chilling/slow cooling
Rice	*B. cereus*	2011	Germany	2	EU linelist 2011	Two hospitalized: inadequate chilling, cross-contamination, slow cooling
Grains	*B. cereus*	2011	France	20	EU linelist 2011	Temperature abuse: one hospitalized: Cereal products including rice and seeds/pulses (nuts, almonds)
Grains	*B. cereus*	2011	France	2	EU linelist 2011	One hospitalized: Cereal products including rice and seeds/pulses (nuts, almonds)

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Spices	*B. cereus*	2011	Finland	4	EU line list 2011	Turmeric / curcuma -temperature abuse
Spices	*B. cereus*	2011	Finland	3	EU line list 2011	Jeera Ground Cumin - temperature abuse
Spices	*B. cereus*	2011	Finland	19	EU line list 2011	Turmeric / curcuma - temperature abuse
Grains	*B. cereus*	2011	Denmark	2	EU line list 2011	*B*. cereus detected in bulgur wheat - slow cooling
Grains	*B. cereus*	2011	Denmark	11	EU line list 2011	Bulgur wheat - slow cooling
	B. cereus	2011	Denmark	4	EU line list 2011	*B*. cereus detected in rice - inadequate cooling/slow cooling
Rice	*B. cereus*	2011	Denmark	30	EU line list 2011	Detection of 5000 *B*. cereus/g in cinnamon - slow cooling
Spices	*B. cereus*	2011	Denmark	52	EU line list 2011	*B*. cereus detected in pepper - inadequate cooking
Pasta	*B. cereus*	2012	Belgium	4	EU line list 2012	Pasta may have cross-contaminated fish. *B*. cereus tested positive for enterotoxins. Detected causative agent in food or its component. Symptoms and onset of illness pathognomonic to causative agent
Rice	*B. cereus*	2012	Belgium	20	EU line list 2012	Rice mixed with cucumber
Rice	*B. cereus*	2012	Denmark	4	EU line list 2012	Temperature abuse – inadequate chilling. Detected causative agent in food or its component

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Grains	*B. cereus*	2012	France	11	EU line list 2012	Temperature abuse - one hospitalized: cereal products including rice and seeds/pulses (nuts, almonds); detected causative agent in food or its component – Symptoms and onset of illness pathognomonic to causative agent
Grains	*B. cereus*	2012	France	5	EU line list 2012	One hospitalized: cereal products including rice and seeds/pulses (nuts, almonds); detected causative agent in food or its component - symptoms and onset of illness pathognomonic to causative agent
Grains	*B. cereus*	2012	Switzerland	8	EU line list 2012	Eight hospitalized: storage time/temperature abuse. Temporary mass catering – camp or picnic. Cereal products including rice and seeds/pulses (nuts, almonds)
Rice	*B. cereus*	2012	Germany	19	EU line list 2012	Inadequate heat treatment, infected food handler. *B*. cereus with cereuildgene found in cooked rice in concentration of 1.6x10E4cfu/g.
Spices	*B. cereus*	2013	Finland	4	Finland Annual Report 2013	Pathogen detected in food or component - symptoms and onset of illness pathognomonic to causative agent; storage time/temperature abuse, unprocessed contaminate ingredient.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Grains	*B. cereus*	2013	Netherlands	2	Netherlands Annual Report 2013	Listed as cereal products including rice and seeds/pulses (nuts, almonds) - pathogen detected in food or component - symptoms and onset of illness pathognomonic to causative agent
Pasta	*B. cereus*	2013	Netherlands	3	Netherlands Annual Report 2013	Chinese noodles- pathogen detected in food or component - symptoms and onset of illness pathognomonic to causative agent
Dry Fish	*C. botulinum*	2005	USA	5	ProMed 2005	Inadequate processing – contamination likely due to storage of uneviserated whitefish with salt in a sealed Ziplock® bag left at room temperature for approximately one month Toxin type E.
Dry Fish	*C. botulinum*	2005	Ukraine	3	Ukrainian News Agency and ProMed	Inadequate processing – three hospitalized: consumption of dried fish
Dry Fish	*C. botulinum*	2005	Russia	0	Regnum.ru & ProMed	Salt omul, prepared in the home
Fish	*C. botulinum*	2005	Norway	3	European 2005 linelist	Three hospitalized: fermented fish (rakfisk)

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Honey	*C. botulinum*	2006	France	2	Eur J Pediatr 2012;171(3):589-91	Two severe cases of infant botulism diagnosed at Grenoble University Hospital, France, in 2006 and 2009. Both cases were characterized by a delay in diagnosis, severe neurological manifestations and extended period of hospitalization in intensive care unit, but a complete recovery.
Honey	*C. botulinum*	2009	United Kingdom	2	Health Protection Report 2009;3(46)	Infant botulism – history of the infants having honey- *C. botulinum* found in honey fed to affected infant before onset of illness, same toxin as infant.
Salmon	*C. botulinum*	2010	USA	2	CDC linelist 2010	One hospitalized: salmon, salted
Honey	*C. botulinum*	2011	Denmark	3	Clinical Microbiology Reference Laboratory a Statens Serum Institut	Infant botulism

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Rice snack	*C. botulinum*	2014	New Zealand	1	ProMED Digest, 32(4) 2015	A spicy rice snack pack – the victim ate a pack of pre-cooked "heat and eat" organic risotto that was probably well past its best-before date. The Ministry for Primary Industries said the rice snack he ate contained no preservatives, and "incorrect handling" was thought to be the cause of his illness. The meal had been made following appropriate regulations, but MPI understood it was not refrigerated. He ate it despite noticing its "blue cheese" smell.
Honey	*C. botulinum*	2013	United Kingdom	2	ProMED Digest, 19(51) 2014	Infant botulism. Three month old given honey, while the five month old had been given a homeopathic treatment that may have contained honey.
Rice	*C. perfringens*	2005	Australia	23	CDI 2006;30(3)	Suspected yellow rice
Pasta	*C. perfringens*	2009	USA	24	CDC line list 2009	Spaghetti
Pasta	*C. perfringens*	2010	USA	250	CDC linelist 2010	Spaghetti
Barbecue spice	*C. perfringens*	2011	Denmark	4	EU line list 2011	Slow cooling – detected in chilled fried chicken and in barbecue spice
Red pepper spice	*C. perfringens*	2011	Denmark	37	EU line list 2011	Slow cooling – detected in red pepper used for stew
Dried chillies	*C. perfringens*	2011	Denmark	3	EU line list 2011	Slow cooling- detected in dried chillies

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Pepper	*C. perfringens*	2011	Denmark	10	EU line list 2012	Slow cooling – stew with beef (veal) and pepper *C. perfringens* 330 ml/g detected in stew and in pepper used for stew
Pepper	*C. perfringens*	2012	Denmark	9	EU line list 2011	Fried pork with parsley sauce. *C.perfringens* detected in pepper used in sauce.
Beef jerky	*E. coli* 0157:H7	2005	USA	3	CDC line list 2005	
Beef jerky	*E. coli* 0157:H7	2007	USA	8	CDC line list	Three hospitalized
Sausage, fermented	*E. coli* 0157:H7	2007	USA	27	CDC line list	Eleven hospitalized: pepperoni
Sausage	*E. coli* 0157:H7	2008	USA	5	CDC line list 2008	Pepperoni
Flour	*E. coli* 0157:H7	2009	USA	80	Clin Infect Dis. (2011) doi: 10.1093/cid/cir831	Thirty-five hospitalized: investigation found no conclusive evidence that contaminated flour was the source of the outbreak, but contaminated flour remains a prime suspect for introducing the pathogen to the product.
Mexican wheat snack	*E. coli* 0157:H7	2010	USA	11	CDC linelist 2010	Four hospitalized: Mexican wheat snack

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Hazelnuts	*E. coli* 0157:H7	2011	USA	8	J Food Prot. 2012;75(2):320–327	Mechanically harvested from the ground. Some may be treated with an antimicrobial wash prior to the drying process. In this instance, it is plausible that feces from wild deer or domestic cattle grazing in the orchards contaminated the surface of the hazelnuts prior to harvesting. Evidence links human cases with isolates that have matching genetic fingerprints to identical isolates from unopened packages of the same lot of product that the cases consumed.
Sausage, fermented	*E. coli* 0157:H7	2011	USA	14	CDC	Three hospitalized: Lebanon bologna is a fermented, semi-dry sausage.
Walnuts	*E. coli* 0157:H7	2011	Canada	14	CFIA	One death, 10 hospitalized: contaminated walnuts – distributed by Quebec-based Amira Enterprises – shelled walnuts from bulk bins.
Flour	*E. coli* O121	2013	USA	35	FSIS, CDC	Seven hospitalized: flour that Rich Products used in its recalled frozen foods in 2013 was likely source.
Salami	*L. monocytogenes*	2010	Canada	2	Ontario Health Officials/ CBC	Linked to recently recalled ham and salami products from Toronto-based company Siena Foods.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Salami	*L. monocytogenes*	2012	New Zealand	4	Hawkes Bay District Health Board	Two deaths: hospital - processed meat such as salami, ham and pepperoni. The DHB confirmed meat had signs of contamination, but won't say whether it was the source of the outbreak.
Powdered infant formula	*Rouxiella chamberiensis*	2013	France	4	Int J Syst Evol Microbiol. 2015 Mar 6. pii: ijs.0.000179. doi: 10.1099/ijs.0.000179.	The new bacterium responsible for the contamination of nutrition solutions involved in the deaths of three very preterm infants and infection of a fourth in Chambery Hospital have been officially recognized by the scientific community, according to the Pasteur Institute. Most likely hypothesis is “an isolated production accident on 28 Nov 2013 at Marette Laboratory", the supplier of the incriminated nutrition pockets.
Anchovy, dried	Salmonella	2005	Canada	2	CFIA	JHC Brand Cooked Seasoning Anchovies - imported from Thailand
Rice	Salmonella	2007	USA	27	CDC line list	None hospitalized: Imperial rice
Almonds	Salmonella	2012	Australia	27	Food Standards Australia New Zealand	Two brands of raw almonds supplied by Select Harvests
Puffed rice cereal	*S.* Agona	2008	USA	35	CDC line list 2008; J Food Prot. 2013(2):192-369, (4):227-230	Twelve hospitalized: associated with nationwide distribution of puffed rice cereal

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Tahini	S. Bovismorbificans	2011	USA	23	MMWR 2012;61(46)	Contaminated tahini (sesame seed paste) used in hummus prepared at a Mediterranean-style restaurant in DC
Snack/Cereal	S. enterica	2007	USA	87	Ped Infect Dis J 2010;29(3):284	Contaminated raw materials: Eight hospitalized: commercial puffed vegetable coated ready-to-eat snack food (OR 23.3, P 0.0001)
Sausage, pork	S. enterica	2010	France	110	Eurosurveillance, 2010;15(24)	Twenty hospitalized: dried pork sausage
Spices	S. enterica	2013	United Kingdom	413	Public Health England	Inadequate cooking – efforts should be made to raise awareness among importers, exporters and port health authorities concerning the labelling, and in particular the instructions for use, of curry leaves and other herbs.
Chocolate	S. Enteritidis	2009	Hungary	35	The European Union Summary[*]	Inadequate cooking – five hospitalized
Chips	S. Enteritidis	2010	USA	7	CDC linelist 2010	Chips, tortilla
Pine nuts	S. Enteritidis	2011	USA	53	CDC Line list 2011	Two hospitalized: Turkish pine nuts purchased from bulk bins at Wegmans grocery stores – imported from Turkey, but may not have originated there.
Chocolate	S. Enteritidis	2011	Poland	9	EU line list 2011	1 hospitalized: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	6	EU line list 2011	2 hospitalized: sweets and chocolate

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Chocolate	S. Enteritidis	2011	Poland	21	EU line list 2011	6 hospitalized: sweets and chocolate-inadequate cooking
Chocolate	S. Enteritidis	2011	Poland	6	EU line list 2011	2 hospitalized: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	11	EU line list 2011	2 hospitalized: other Salmonella species as well; sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	3	EU line list 2011	2 hospitalized: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	4	EU line list 2011	2 hospitalized: sweets and chocolate – cross contamination
Chocolate	S. Enteritidis	2011	Poland	9	EU line list 2011	Inadequate cooking
Chocolate	S. Enteritidis	2011	Poland	6	EU line list 2011	Sweets and chocolate - infected food handler
Chocolate	S. Enteritidis	2011	Poland	8	EU line list 2011	Seven hospitalized: inadequate chilling – temperature abuse; sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	14	EU line list 2011	Six hospitalized: storage time – temperature abuse; sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	31	EU line list 2011	Five hospitalized: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	4	EU line list 2011	Three hospitalized: cross-contamination; sweets and chocolate - infected food handler

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Chocolate	S. Enteritidis	2011	Poland	6	EU line list 2011	Two hospitalized: storage time-temperature abuse: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	11	EU line list 2011	Eight hospitalized: sweets and chocolate
Chocolate	S. Enteritidis	2011	Poland	8	EU line list 2011	Two hospitalized: cross contamination
Chocolate	S. Enteritidis	2011	Poland	13	EU line list 2012	Two hospitalized: sweets and chocolate
Spices	S. Enteritidis	2012	Hungary	41	EU line list 2011	Six hospitalized: listed as herbs and spices
Chocolate	S. Enteritidis	2012	Poland	13	EU line list 2012	Sweets and chocolate – temperature abuse- detected causative agent in food or its component-indistinguishable from cases
Chocolate	S. Enteritidis	2012	Poland	15	EU line list 2012	Sweets and chocolate - detected in food or its component - indistinguishable from cases
Chocolate	S. Enteritidis	2012	Poland	17	EU line list 2012	Sweets and chocolate; detected in food or its component - indistinguishable from cases
Chocolate	S. Enteritidis	2012	Poland	23	EU line list 2012	Sweets and chocolate - unprocessed contaminated ingredient
Chocolate	S. Enteritidis	2013	Romania	5	Romanian Annual Report 2013	Five hospitalized: sweets and chocolate; inadequate heat treatment; detected in food - indistinguishable from cases

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Almonds	S. Enteritidis NST3+	2005	Sweden	15	Eurosurveillance Monthly June 2007	Case-control study showed eating almonds was a risk factor for infection with *S.* Enteritidis NST3+ (unmatched OR 45.0, 95% CI: 4.8-421.8). Salmonella not isolated from tested almonds
Pasta	S. Enteritidis pt 4	2005	Austria	2	European 2005 linelist	Two hospitalized: spaghetti
Pasta	S. Enteritidis pt 21	2005	Austria	2	European 2005 linelist	Spaghetti
Spices	S. Heidelberg	2013	United Kingdom	58	UK Annual Report 2013	Green chilli, dried curry leaves, ginger, coconut; detected in food and symptoms and onset of illness pathognomonic to agent, unprocessed contaminated ingredient - cohort study
Salami	S. Infantis	2009	Germany	4	The European Union Summary*	Salami bought in Italy during vacation and brought to Germany by consumer.
Salami	S. Kedougou	2006	Norway	54	Eurosurveillance weekly release 2006;11(7)	One death: S. Kedougou isolated from opened package of a particular brand of Danish-style salami; isolated from an unopened package of the same product from a shop
Salami	S. London	2006	Australia	5	OzFoodNet sites, 1 Jan-31 March 2006	Salami (non-commercial)

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Tahini	S. Mbandaka	2012	New Zealand	3	New Zealand Public Health Surveillance. 2013.	Three cases with PFGE profile indistinguishable from the *S*. Mbandaka isolated from unopened tubs of tahini. The PFGE profile of the *S*. Mbandaka isolated from tahini was distinguishable to bovine and poultry PFGE profiles that had been previously identified in NZ.
Tahini	S. Mbandaka	2013	USA	8	FDA	Tahini sesame paste distributed by Krinos Foods, New York.
Chocolate	S. Montevideo	2006	United Kingdom	180	Health Protection Agency	Three hospitalized: Cadbury detected salmonella at its Marlbrook plant in Herefordshire on January 20. But it was only on June 19, after tests linked the chocolate and the illness, that the company told the FSA about the contamination. Cadbury took two days to comply with the FSA's request to withdraw the seven infected products, including Dairy Milk bars.
Black and red pepper	*S*. Montevideo	2009	USA	272	Epidemiol Infect 2012 - Gieraltowski et al	Fifty-two hospitalized: Pathogen was identified in ready-to-eat salami, from an environmental sample from one manufacturing plant, and sealed containers of black and red pepper at the facility.
Diet supplements	*S*. Montevideo	2010	Germany	31	Eurosurveillance, 2011;16(50)	Herbal food supplement, formulated in capsules, distributed under a Dutch label in Germany.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Tahini	*S.* Montevideo	2012	New Zealand	17	New Zealand Public Health Surveillance. 2013.	Seventeen cases confirmed – 12 with an indistinguishable PFGE "cluster" profile indistinguishable from the S. Montevideo isolated from unopened tubs of tahini (sesame seed paste) sourced from the warehouse of the Auckland distributor.
Chia seeds	*S.* Newport *S.* Hartford *S.* Oranienburg *S.* Saintpaul	2014	Canada	63	PHAC, CFIA; ProMED Digest, 24(70), 2014	Twelve hospitalized - products containing chia seeds and sprouted chia seed powder under the brands Organic Traditions, Back 2 the Garden, Intuitive Path SuperFoods, Harmonic Arts Botanical Dispensary, Naturally Organic, Pete's Gluten Free, Noorish Superfoods, MadeGood, and Dietary Express.
Chia seeds	*S.* Newport *S.* Hartford *S.* Oranienburg	2014	USA	36	30 May 2014, ProMED & CDC	A total of 31 persons infected with the outbreak strains of S. Newport (20 persons), S. Hartford (7 persons), or S. Oranienburg (4 persons) were reported from 16 states. Five hospitalized. Collaborative investigation efforts of state, local, and federal public health and regulatory agencies indicated that organic sprouted chia powder was the likely source of this outbreak. Sprouted chia powder is made from chia seeds that are sprouted, dried, and ground

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Milk, powdered	*S.* Oranienburg	2011	Russia	16	Belgian food safety authority; ProMED Digest 2012 #41	Imported from Belgium - one production lot comprising 19 tons implicated; 16 tons shipped to Russia, and the remaining 3 tons, mixed together with other production lots, were supplied to several developing countries.
Cashew nuts	*S.* Poona	2011	Sweden	16	EU line list 2011	Cashew nuts
White pepper	*S.* Rissen	2008	USA	87	Higa, 2011; Hajmeer and Myers, 2011; Higa, 2012; CDC line list 2008 & Oregon Department of Human Services Public Health Division	Eight hospitalized: Ground white pepper imported from Vietnam. Environmental samples from spice processing facility positive for outbreak strain.
Chocolate	*S.* Schwarzengrund	2007	United Kingdom	90	Harker et al. 2013 Epi & Infect.	Chocolate coated Brazil nuts; PFGE common profile in all cases
Fennel seed	*S.* Senftenberg	2007	Serbia	14	Emerg Infect Dis. 2010;16(5):893-5	Four hospitalized: "baby" tea containing fennel seed, anise seed, and caraway. Mar 2007-Sep 2008 Microbiological link between spice and illness established. Parents of case-patients reported pouring boiling water over tea leaves during preparation but did not heat tea to boiling 71% of cases of illness in infants <12 months
Black and red pepper	*S.* Senftenberg	2009	USA	11	CDC, 2010; DuVernoy, 2012	Black pepper and red pepper (on Italian-style salami) Jul 2009 – Apr 2010 Microbiological link between spice and illness established. Unopened retail package of salami positive for *S.* senftenberg.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Nuts/dry Fruits	*S.* Senftenberg	2013	USA	8	FDA Feb 19, 2014	Six states - January to May 2013. Same strain found in Arya variety pistachios
Salami	*S.* Typhimurium	2005	Sweden	15	Eurosurveillance 2006;11(2)	Imported Italian salami sold in Sweden. *S.* Infantis had been isolated from this salami sample and also *S.* Typhimurium NST.
Cake mix	*S.* Typhimurium	2005	USA	26	J Food Prot. 2007;70(4):997-1001	May- June of 2005- cases ate cake batter ice cream. *S.* Typhimurium isolated from two cake mix samples; food isolates indistinguishable from the outbreak pattern by PFGE.
Salami	*S.* Typhimurium	2006	Italy	12	Eurosurveillance 2006;11(2)	Salami samples - veterinary laboratories isolated two *S.* Typhimurium strains from processed pork meat - identical to outbreak strain.
Almonds	*S.* Typhimurium	2012	Australia	39	Australia's Department of Health and Aging	Seven hospitalized: Consumption of raw almonds supplied by Select Harvests Limited (Thomastown, Victoria).
Rice	*S.* Typhimurium 9	2010	Australia	2	CDI 2011;35(1)	Two hospitalized: Broken rice - cooked rice from fractured rice grains

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Flour	*S.* Typhimurium 42	2008	New Zealand	39	Foodborne Path and Dis 2013 McCallum et al.	STM42 isolates from a wheat-based poultry feed raw material (broll; i.e., product containing wheat flour and particles of grain) had been identified in the 2 months prior to this cluster. This outbreak associated with consumption of uncooked baking mixture containing flour contaminated with STM42. The implicated flour mill initiated a voluntary withdrawal from sale of all batches of flour thought to be contaminated.
Sausage	*S.* Typhimurium	2008	Australia	2	CDI 33(1) 2009	Cabanossi or pepperoni
Salami	*S.* Typhimurium DT120	2010	Denmark	20	Eurosurveillance, 2010;16(19)	Salami produced in Germany and contained a mix of New Zealand deer and EU pork.
Nuts/dry fruits	*S.* Typhimurium DT 170	2010	Australia	19	CDII 2010;34(3)	Peanut/cashew mixture positive for *S.* Typhimurium MLVA profile 3-9-8-15-523.
Pork salami	*S.* Typhimurium DT 193	2011	Australia	4	CDI 2012;36(3)	One hospitalized: homemade pork salami.
Salami	*S.* Typhimurium pt U302	2005	Canada	47	CCDR 2006;32(7)	Nine hospitalized: mortadella, salami, prosciutto, or capicollo.

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Spices	*S.* Wandsworth	2007	USA	69	Sotir, et al., 2009	Six hospitalized: seasoning mix and broccoli powder (coating a snack puff) Jan 2007 – Dec 2007. (China for dried broccoli powder; sources of other ingredients in seasoning mix not reported) *S.* Typhimurium, *S.* Kentucky, *Cronobacter sakazakii* from unopened product; *S.*Typhimurium, *S.*Haifa from finished product; *S.* Mbandaka from parsley powder Microbiological link between spice and illness established. Seasoning mix applied after final pathogen reduction step.
Milk, powdered	*S.* Worthington	2005	France	49	Eurosurveillance Weekly Report 2005;10(7)	Post pasteurization contaminated powdered milk distributed nationwide for institutional use (hospitals, residential homes, schools and daycare centres) - cases mainly elderly, hospitalized people.
Chocolate	Staphylococcus	2010	Romania	5	European line list 2010	Five hospitalized: inadequate cooking, unprocessed contaminated ingredient
Rice	Staphylococcus	2011	Portugal	50	EU line list 2011	Storage time/infected food handler -temperature abuse; *B.* cereus 1,0E+4 as well

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Grains	Staphylococcus	2011	France	9	EU linelist 2011	One hospitalized: cross contamination-cereal products including rice and seeds/pulses (nuts, almonds)
Diet supplements	Staphylococcus	2015	USA	2	ProMED Digest, 32(4) 2015	Aloha Inc - Premium Protein powder in chocolate and vanilla blends potentially contaminated with *S*. aureus enterotoxin. To date, Aloha has received 17 complaints from customers who have reported transient gastrointestinal symptoms consistent with staphylococcal food poisoning.
Milk, powdered	*S. aureus*	2006	USA	36	Ottawa County (MI) Health Department & CDC line list	Poor hygiene and cleanliness-Ottawa County Adult Correctional Facility
Pasta	*S. aureus*	2008	USA	17	CDC line list 2008	Spaghetti
Cereal	*S. aureus*	2009	France	2	The European Union Summary*	Cereal products including rice and seeds/pulses (nuts, almonds)
Pasta	*S. aureus*	2009	Belgium	10	The European Union Summary*	Inadequate cooking- enterotoxin A detected in spaghetti; outbreak on either an aircraft, ship, train.
Rice noodles	*S. aureus*	2010	Australia	3	CDI 2010;34(4)	Rice noodle; *S. aureus* (>2.5 x 107 org/g)- staphylococcal enterotoxin detected in rice noodle samples from the venue.
Fried rice	*S. aureus*	2012	USA	4	CDC linelist 2012	

Vehicle	Microorganism	Year	Country	Cases	Source	Details
Jam	S. aureus	2013	Canada	223	ProMED Digest, 2013;14(58) & Toronto Public Health	Five hospitalized: temperature abuse-CNE linked to a Toronto bakery's maple bacon jam topping for the cronut burger - inadequate refrigeration of the maple bacon jam at multiple points before serving to the customer -toxin found in jam samples from both LeDolci and Epic Burgers
Pasta	Streptococcus	2012	USA	18	CDC linelist 2012	Group A

*The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2009

References

1. Food and Agriculture Organization of the United Nations; World Health Organization. Preliminary report of FAO/WHO expert consultation on ranking of low moisture foods. Ranking of low moisture foods in support of microbiological risk management: report of an FAO/WHO consultation process [Internet]. Rome: Food and Agriculture Organization of the United Nations; 2014 [cited 2015 Apr 16]. Available from: ftp://ftp.fao.org/codex/meetings/CCFH/CCFH46/LMF%20Part%201-3%2030Oct%202014.pdf

2. Parveen S, Das S, Begum A, Sultana N, Hoque MM, Ahmad I. Microbiological quality assessment of three selected spices in Bangladesh. Int Food Res J. 2014;21(4):1327–30. Available from: http://www.ifrj.upm.edu.my/21%20(04)%202014/9%20IFRJ%2021%20(04)%202014%20Parveen%20674.pdf

3. Beuchat L, Komitopoulou E, Betts R, Beckers H, Bourdichon F, Joosten H, et al. Persistence and survival of pathogens in dry foods and dry food processing environments. Belgium: International Life Science Institute, Europe; 2011. Available from: http://www.ilsi.org/Europe/Documents/Persistence%20and%20survival%20report.pdf

4. University of Warwick. Health, safety, and well-being: high and low risk foods [Internet]. Coventry, UK: University of Warwick; 2011 [cited 2015 May 22]. Available from: http://www2.warwick.ac.uk/services/healthsafetywellbeing/guidance/foodhygieneandsafety/highandlowriskfoods/

5. Vij V, Ailes E, Wolyniak C, Angulo FJ, Klontz KC. Recalls of spices due to bacterial contamination monitored by the U.S. Food and Drug Administration: the predominance of Salmonellae. J Food Prot. 2006;69(1):233–7.

6. Canadian Food Inspection Agency. Complete listing of all recalls and allergy alerts: 2014 [Internet]. Ottawa, ON: Government of Canada; 2013 [cited 2015 May 22]. Available from: http://www.inspection.gc.ca/about-the-cfia/newsroom/food-recall-warnings/complete-listing/eng/1351519587174/1351519588221?ay=2014&fr=0&fc=0&fd=0&ft=1

7. Canadian Food Inspection Agency. Complete listing of all recalls and allergy alerts: 2015 [Internet]. Ottawa, ON: Government of Canada; 2013 [cited 2015 May 22]. Available from: http://www.inspection.gc.ca/about-the-cfia/newsroom/food-recall-warnings/complete-listing/eng/1351519587174/1351519588221?ay=2015&fr=0&fc=0&fd=0&ft=1

8. Greig JD. Outbreaks associated with low moisture foods, recorded in Publically Available International Foodborne Outbreak Database (PAIFOD) [unpublished]. Guelph, ON: Public Health Agency of Canada, National Microbiology Laboratory at Guelph; 2015.

9. Baumgartner A, Grand M, Liniger M, Iversen C. Detection and frequency of Cronobacter spp. (Enterobacter sakazakii) in different categories of ready-to-eat foods other than infant formula. Int J Food Microbiol. 2009;136(2):189–92.

10. Beuchat LR, Komitopoulou E, Beckers H, Betts RP, Bourdichon F, Fanning S, et al. Low-water activity foods: increased concern as vehicles of foodborne pathogens. J Food Prot. 2013;76(1):150–72.

11. Little CL, Omotoye R, Mitchell RT. The microbiological quality of ready-to-eat foods with added spices. Int J Environ Health Res. 2003;13(1):31–42.

12. Banerjee M, Sarkar PK. Microbiological quality of some retail spices in India. Food Res Int. 2003;36(5):469-474. Available from: http://www.sciencedirect.com/science/article/pii/S0963996902001941

13. Koohy-Kamaly-Dehkordy P, Nikoopour H, Siavoshi F, Koushki M, Abadi A. Microbiological quality of retail spices in Tehran, Iran. J Food Prot. 2013;76(5):843–8.

14. Kahraman T, Ozmen G. Quality of selected spices and herbs consumed in Turkey. Arch Für Leb. 2009;60(6):185–91.

15. Hampikyan H, Bingol EB, Colak H, Aydin A. The evaluation of microbiological profile of some spices used in Turkish meat industry. J Food Agric Environ. 2009;7(3&4):111–15.

16. Donia AMA. Microbiological quality and aflatoxinogenesis of Egyptian spices and medicinal plants. Glob Vet. 2008;2(4):175–82.

17. Ahene RE, Odamtten GT, Owusu E. Fungal and bacterial contaminants of six spices and spice products in Ghana. Afr J Environ Sci Technol. 2011;5(9):633–40. Available from: http://www.ajol.info/index.php/ajest/article/viewFile/72061/61005

18. Moreira PL, Lourenção TB, Pinto JPAN, Rall VLM. Microbiological quality of spices marketed in the city of Botucatu, São Paulo, Brazil. J Food Prot. 2009;72(2):421–4.

19. Turcovský I, Kuniková K, Drahovská H, Kaclíková E. Biochemical and molecular characterization of Cronobacter spp. (formerly Enterobacter sakazakii) isolated from foods. Antonie Van Leeuwenhoek. 2011;99(2):257–69.

20. Center for Food Safety and Applied Nutrition; Food and Drug Administration, U.S. Department of Health and Human Services. FDA draft risk profile: pathogen and filth in spices [Internet]. Silver Spring, MD: Food and Drug Administration; 2013 [cited 2015 Mar 31]. Available from: http://www.fda.gov/downloads/Food/FoodScienceResearch/RiskSafetyAssessment/UCM367337.pdf

21. Van Doren JM, Neil KP, Parish M, Gieraltowski L, Gould LH, Gombas KL. Foodborne illness outbreaks from microbial contaminants in spices, 1973-2010. Food Microbiol. 2013;36(2):456–64.

22. Sotir MJ, Ewald G, Kimura AC, Higa JI, Sheth A, Troppy S, et al. Outbreak of Salmonella Wandsworth and Typhimurium infections in infants and toddlers traced to a commercial vegetable-coated snack food. Pediatr Infect Dis J. 2009;28(12):1041–6.

23. Gieraltowski L, Julian E, Pringle J, Macdonald K, Quilliam D, Marsden-Haug N, et al. Nationwide outbreak of Salmonella Montevideo infections associated with contaminated imported black and red pepper: warehouse membership cards provide critical clues to identify the source. Epidemiol Infect.

2013;141(6):1244–52. Available from:
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3640547/pdf/S0950268812001859a.pdf

24. Food and Agriculture Organization of the United Nations; World Health Organization. Summary report: joint FAO/WHO expert meeting on microbiological hazards in spice and dried aromatic herbs, 7-10 October 2014. Preliminary report [Internet]. Rome: Food and Agriculture Organization of the United Nations; 2014 [cited 2015 Jul 3]. Available from:
ftp://ftp.fao.org/codex/meetings/ccfh/ccfh46/Report_Spices_Dried_Herbs_Expert%20Meeting.pdf

25. Caubilla Barron J, Forsythe SJ. Dry stress and survival time of Enterobacter sakazakii and other Enterobacteriaceae in dehydrated powdered infant formula. J Food Prot. 2007;70(9):2111–7.

26. Podolak R, Enache E, Stone W, Black DG, Elliott PH. Sources and Risk Factors for Contamination, Survival, Persistence, and Heat Resistance of Salmonella in Low-Moisture Foods. J Food Prot. 2010;73(10):1919–36.

27. Kataoka A, Enache E, Black DG, Elliott PH, Napier CD, Podolak R, et al. Survival of Salmonella Tennessee, Salmonella Typhimurium DT104, and Enterococcus faecium in peanut paste formulations at two different levels of water activity and fat. J Food Prot. 2014;77(8):1252–9.

28. Burnett SL, Gehm ER, Weissinger WR, Beuchat LR. Survival of Salmonella in peanut butter and peanut butter spread. J Appl Microbiol. 2000;89(3):472–7.

29. Mattick KL, Jorgensen F, Legan JD, Lappin-Scott HM, Humphrey TJ. Habituation of Salmonella spp. at reduced water activity and its effect on heat tolerance. Appl Environ Microbiol. 2000;66(11):4921–5. Available from: http://aem.asm.org/content/66/11/4921.full.pdf+html

30. Day JB, Sharma D, Siddique N, Hao Y-YD, Strain EA, Blodgett RJ, et al. Survival of Salmonella Typhi and Shigella dysenteriae in dehydrated infant formula. J Food Sci. 2011;76(6):M324–8.

31. Santillana Farakos SM, Schaffner DW, Frank JF. Predicting survival of Salmonella in low-water activity foods: an analysis of literature data. J Food Prot. 2014;77(9):1448–61.

32. Finn S, Condell O, McClure P, Amézquita A, Fanning S. Mechanisms of survival, responses and sources of Salmonella in low-moisture environments. Front Microbiol. 2013;4:331. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3827549/

33. Hiramatsu R, Matsumoto M, Sakae K, Miyazaki Y. Ability of Shiga toxin-producing Escherichia coli and Salmonella spp. to survive in a desiccation model system and in dry foods. Appl Environ Microbiol. 2005;71(11):6657–63. Available from: http://aem.asm.org/content/71/11/6657.full.pdf+html

34. Farakos SMS, Hicks JW, Frye JG, Frank JF. Relative survival of four serotypes of Salmonella enterica in low-water activity whey protein powder held at 36 and 70°C at various water activity levels. J Food Prot. 2014;77(7):1198–200.

35. Lehner A, Riedel K, Eberl L, Breeuwer P, Diep B, Stephan R. Biofilm formation, extracellular polysaccharide production, and cell-to-cell signaling in various Enterobacter sakazakii strains: aspects

promoting environmental persistence. J Food Prot. 2005;68(11):2287–94.

36. Kieboom J, Kusumaningrum HD, Tempelaars MH, Hazeleger WC, Abee T, Beumer RR. Survival, elongation, and elevated tolerance of Salmonella enterica serovar Enteritidis at reduced water activity. J Food Prot. 2006;69(11):2681–6.

37. Deng X, Li Z, Zhang W. Transcriptome sequencing of Salmonella enterica serovar Enteritidis under desiccation and starvation stress in peanut oil. Food Microbiol. 2012;30(1):311–5.

38. Oliver JD. Recent findings on the viable but nonculturable state in pathogenic bacteria. FEMS Microbiol Rev. 2010;34(4):415–25.

39. Gruzdev N, Pinto R, Sela S. Effect of desiccation on tolerance of salmonella enterica to multiple stresses. Appl Environ Microbiol. 2011;77(5):1667–73. Available from: http://aem.asm.org/cgi/pmidlookup?view=long&pmid=21216905

40. Cosano I, Pintado C, Acevedo O, Novella JL, Alonso GL, Carmona M, et al. Microbiological quality of saffron from the main producer countries. J Food Prot. 2009;72(10):2217–20.

41. Department of Health, State Government of Victoria. Report on a survey of spices for the presence of pathogens: a national survey conducted under the Coordinated Food Survey Plan with participation by food regulatory agencies in Australia [Internet]. Victoria: State of Victoria; 2011 [cited 2015 May 11]. Available from: http://www.health.vic.gov.au/archive/archive2011/foodsafety/archive/downloads/survey_spices.pdf.

42. Food and Agriculture Organization of the United Nations; World Health Organization. Ranking of low moisture foods in support of microbiological risk management: report of an FAO/WHO consultation process [Internet]. Rome: Food and Agriculture Organization of the United Nations; 2014 [cited 2015 Jul 3]. Available from: ftp://ftp.fao.org/codex/meetings/CCFH/CCFH46/FAO_WHO%20Presentation%20on%20LMF%20ranking.pdf.

43. Chen YH, Scott VN, Freier TA, Kuehm J, Moorman M, Meyer J, et al. Control of Salmonella in low-moisture foods II: hygiene practices to minimize Salmonella contamination and growth. Food Prot Trends. 2009;29(7):435–45.

44. Chen YH, Scott VN, Freier TA, Kuehm J, Moorman M, Meyer J, et al. Control of Salmonella in low-moisture foods III: process validation and environmental monitoring - part three of a three-part series. Food Prot Trends. 2009;29(8):493–508.

45. Scott VN, Chen YUH, Freier TA, Kuehm J, Moorman M, Meyer J, et al. Control of Salmonella in low-moisture foods I: Minimizing entry of Salmonella into a processing facility. Food Prot Trends. 2009;29(6):342–53.

Authors

Naghmeh Parto, MSc. CPHI (c), Senior Program Specialist

Reviewers

Ray Copes, MD, Chief, Environmental and Occupational Health

Acknowledgements

Judy D. Greig R.N., BSc., MSc.
Food Safety Microbiologist/Epidemiologist
Public Health Agency of Canada

Andre Laflamme M.Ed., BAA, C.P.H.I. (C)
Manager, Environmental Health
Niagara Region Public Health

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Environmental and Occupational Health
Email: eoh@oahpp.ca

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