Preventing Foodborne Illness: *Bacillus cereus*[1]

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This is one in a series of facts sheets discussing common foodborne pathogens of interest to food handlers, processors, and retailers.

What is ?

Bacillus cereus is a Gram positive, facultative anaerobic bacterium characterized by large rod-shaped cells and an ability to form heat-resistant endospores. Since this bacterium is commonly widespread in the environment and is often found in soil, it is naturally present in a wide range of food products of both plant and animal origin. *B. cereus* grows best in a temperature range of 39°F (4°C) to 118°F (48°C). Optimal growth occurs within the narrower temperature range of 82°F (28°C) to 95°F (35°C) and a pH range of 4.9 to 9.3 (FDA 2012b).

While there are numerous known species in the genus *Bacillus*, only two, *B. anthracis* and *B. cereus*, are associated with human diseases. *Bacillus anthracis*, though pathogenic, is rarely linked to foodborne illness. However, *Bacillus cereus* is the known source of two distinct types of foodborne illness. Both illnesses are associated with the ingestion of a distinct toxin produced by the bacteria. The first form is emetic, which is characterized by nausea, vomiting, and abdominal cramps. The emetic form has a short onset time of about 1 to 6 hours after consumption of contaminated foods and is caused by the ingestion of a pre-formed toxin that contaminates food prior to eating. The temperature for emetic toxin (cereulide) production ranges from 77°F (25°C) to 86°F (30°F) (FDA 2013a). The second form causes diarrhea and has a longer onset time of about 6 to 15 hours and can last approximately 24 hours. This form of the illness is caused by enterotoxins (toxins that specifically affect the intestinal mucosa) produced by *B. cereus* inside the host after ingestion (FSANZ 2013; Naranjo et al. 2011).

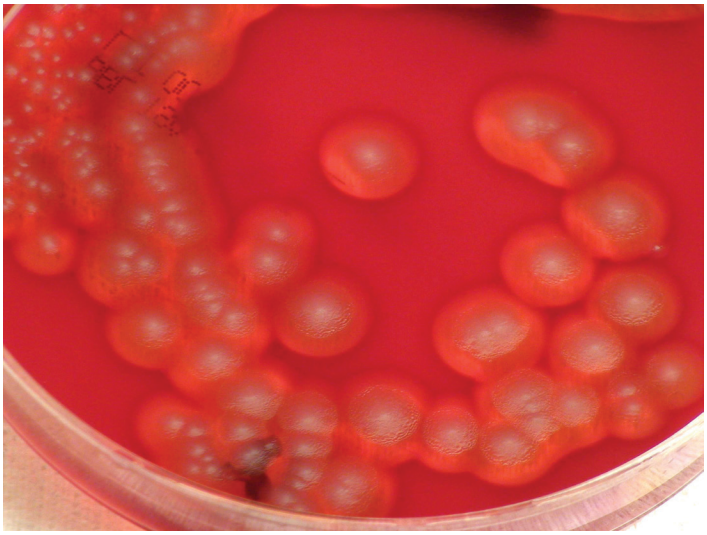

Figure 1. A colony of *Bacillus cereus*.
Credits: CDC/ Amanda Moore, MT; Todd Parker, PhD; Audra Marsh

Transmission of Foodborne Illness

Due to its ubiquity in the environment, *B. cereus* is easily spread to many types of fresh and processed food products. It is found in the environment and on many foods, including meat, cereal dishes, vegetables, milk, products,

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puddings, and soups, but it does not usually pose a health risk. Illness usually occurs when food is improperly cooked and stored in the danger zone (41°F to 135°F) (FDA 2013a) for an extended period of time (Marriot and Gravani 2006).

Transmission of the diarrheal form of the illness is caused by ingestion of viable cells or spores. These cells grow in the body and secrete toxins (whereas the emetic form produces a toxin on the food and is ingested preformed) (Bottone 2010). The diarrheal form typically requires a concentration of 100,000 cells/g or greater to cause illness (FDA 2012). In most instances, illnesses associated with *B. cereus* are almost exclusively the result of improper food handling, storage, and cooling that allow for growth of *B. cereus* and/or production of emetic toxins.

Cooking contaminated food at recommended temperatures destroys the vegetative cells of *B. cereus*. Heat-resistant endospores of this bacteria are more likely to survive cooking and start growing again (germinate) when the food is cooled gradually over an extended period of time. The emetic toxin (cereulide) is heat stable up to 121°C (250°F) (Rajkovic 2014). If stored at improper temperatures for several hours before serving (> 41°F (5°C) for cold food; < 135°F (57°C) for hot food), hazardous concentrations of bacterial cells or toxins could develop prior to consumption (HPSC 2012). The temperature range between 57°C (135°F) and 5°C (41°F) is known as the danger zone for food storage and thus should be avoided (FDA 2013a).

Additional sources of foodborne illness outbreaks could be improper hygiene during food canning and inadequate re-heating of food in congregate settings, such as restaurants and schools (HPSC 2012).

What foods have been commonly associated with ?

A broad range of foods have been implicated as vehicles of *B. cereus*. These include boiled or fried rice, cooked vegetables and meats, pasta, vanilla sauce, custards, casseroles, pastries, salads, soups, ice cream, and herbs and spices (FDA 2012). The emetic form of illness (vomiting) is most frequently associated with improperly refrigerated starch dishes, such as fried rice; whereas, the diarrheal form of illness is associated with foods containing meat and vegetables (Todar 2012).

There are many examples of outbreaks caused by this organism. In 2014 in China, 139 people reported nausea, vomiting, and diarrhea after consuming fermented black beans. Three strains of *B. cereus* were isolated from the outbreak, including two strains known to produce the emetic toxin and one known to produce the diarrheal enterotoxin (Zhou et al. 2014). Another severe outbreak occurred in 2003, in Leuven, Belgium, where five children in one family became ill after consuming pasta salad that contained the emetic toxin. The pasta was stored in a refrigerator set at 57.2°F (14°C), which is much higher than the proper storage temperature of 41°F (5°C). The youngest child, a 7 year-old girl, died in the hospital only 13 hours after consuming the pasta (Dierick et al. 2005). The Centers for Disease Control and Prevention (CDC) estimates that *B. cereus* was responsible for 63,400 cases of foodborne illness and 20 hospitalizations in the United States each year between 2000 and 2008 (Scallan et al. 2011; CDC 2012a). In addition, a 2012 CDC surveillance annual report reported two outbreaks and 24 illnesses involving *B. cereus* in the United States (CDC 2012b). However, many cases are never reported or diagnosed in a clinical setting because the associated symptoms are usually mild and/or short-lasting in nature. Table 1 outlines recent *B. cereus* foodborne outbreaks.

Preventing Contamination by

Because *B. cereus* endospores are extremely heat resistant, they are likely to survive cooking at temperatures that would otherwise destroy foodborne pathogen cells. Heat resistance increases with increasing salinity (presence of salt) and decreases with increasing acidity. *Bacillus cereus* spores can germinate when exposed to heat or improper handling; therefore, the 2013 Food Code recommends that hot foods be maintained at a temperature of 135°F (57°C) or above and cold foods be maintained at a temperature of 41°F (5°C) or below (FDA 2013a).

According to the National Institutes of Health (NIH), the National Institute of Allergy and Infectious Diseases (NIAID), the National Food Processors Association (NFPA), and the FDA Food Code 2013, the suggestions below are good methods and practices that destroy *B. cereus*:

- Steaming under pressure, roasting, frying, and grilling foods will destroy the vegetative cells and spores if temperatures within foods are ≥ 145°F (63°C).
- Since foods containing the emetic toxin need to be heated to 249°F (121°C) for more than 80 minutes, reheating foods until they are steaming is not enough to inactivate the emetic toxin and efforts should be devoted to prevention (Rajkovic 2014).
- Heating (i.e., cooking) to ≥ 145°F (63°C) and reheating to 165°F (74°C) for 15 seconds will destroy the vegetative

(actively growing) cells. Once cooked, the rapid cooling of the product will prevent any spores present from germinating. However, note that foods cannot be made safe to eat if toxins have already been formed.

- Keep hot foods above 135°F (57°C) and cold foods below 41°F (5°C) to prevent the formation of spores.
- Refrigerate leftovers properly by cooling rapidly to 41°F (5°C) or below. Make sure leftover containers are not stacked close together; this will allow for adequate airflow around the food and ensure rapid cooling.

Good Practices for Food Product Receiving, Handling, Processing, and Storage

The FDA defines current Good Manufacturing Practices (GMPs) in the Code of Federal Regulations, Title 21, Part 117 (FDA 2017). These GMPs outline minimal sanitation requirements in FDA-inspected food handling and processing facilities. It is recommended that more specific and stringent standard operating procedures (SOPs) be developed for individual facilities. In addition, the sanitation recommendations for food service and retail food facilities outlined in the FDA 2009 Food Code were adopted as law by sixteen states, including Florida, as of August 2013 (FDA 2016). The FDA updated the 2009 Food Code with the release of the 2013 Food Code. Since the adoption of the new versions of the Food Code varies by state, it is important that each facility checks with the appropriate state or local regulatory authority to make sure they are using the guidelines required by their jurisdiction. The Florida statues can be found at http://www.leg.state.fl.us/statutes, Title 33: Chapter 509.

In addition to setting and adhering to strict sanitation requirements in the facility, a retail establishment should also develop SOPs for the receiving and storing of food products and ingredients. If food is being processed, appropriate controls and requirements should be established and strictly adhered to. The FDA 2013 Food Code outlines appropriate processing and cooking requirements for food service.

Processing

One of the easiest ways to prevent foodborne illness associated with *B. cereus* is by ensuring that foods are cooked thoroughly and cooled rapidly. One of the leading causes of foodborne infections and intoxications by *B. cereus* is the improper holding of cooked foods. Refer to sections 3-401.11 to 3-401.14 and 3-403.11 of the 2013 Food Code.

- Raw animal meats should be cooked to an internal temperature of 145°F (63°C) or above and be held for a minimum of 15 seconds at that temperature.
- Fruits and vegetables cooked for hot holding should be cooked to an internal temperature of 135°F (57°C).
- Hold all hot food at a temperature of 135°F (57°C) or higher.
- Chill cooked foods promptly. Cooked food should not be left out at room temperature for more than 2 hours, especially meat.
- Reheating previously cooked food so that all parts of the food reach an internal temperature of at least 165°F (74°C) for 15 seconds will kill most harmful bacteria, but may not be adequate to inactivate existing toxins (Rajkovic 2014). (Note: Contaminated food should never knowingly be served, even if reheated properly. If a food is thought to be contaminated, it should be disposed of. When in doubt, throw it out!)

Storage

Once a product has been received or processed, it should be properly displayed or stored. There are some general guidelines governing these practices as well. Refer to sections 3-501.13 and 3-501.14 of the 2013 Food Code.

- Frozen food should remain frozen until used.
- If frozen food is displayed in a refrigerated case and allowed to thaw, the food should remain at 41°F (5°C) or below.
- Frozen food should be thawed at a temperature of 41°F (5°C) or below or under running water at a temperature of 70°F (21°C) or below.
- The product can be thawed as part of the cooking process.
- Food should be cooled from 135°F (57°C) to 70°F (21°C) within a period of two hours.
- Overall, the cooling process from 135°F (57°C) to 41°F (5°C) should take no more than 6 hours.
- Cooked product should be maintained above 135°F (57°C) while displayed and stored at or under 41°F (5°C) for no more than 7 days.
- Properly label all stored food products.
- Always remember, when in doubt, throw it out.

For more specific recommendations consult the 2013 Food Code: http://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM374510.pdf

References

British Columbia Centre for Disease Control (BCCDC). 2002. "Foodborne Illness Outbreaks: *Bacillus cereus*." *Milk Safety Notes*. Accessed March 6, 2017. http://www.bccdc.ca/NR/rdonlyres/34B36D22-D767-4140-B032-35FE8AAD409F/0/Outbreak_Bacillus_Milk.pdf

Bottone EJ. 2010. "*Bacillus cereus*, a Volatile Human Pathogen." *Clinical Microbiology Reviews*. 23 (2): 382–398.

Centers for Disease Control and Prevention (CDC). 2012a. *Pathogens Causing US Foodborne Illnesses, Hospitalizations, and Deaths, 2000–2008*. Accessed March 6, 2017. http://www.cdc.gov/foodborneburden/PDFs/pathogens-complete-list-01-12.pdf

Centers for Disease Control and Prevention (CDC). 2012b. *Surveillance for Foodborne Disease Outbreaks United States, 2012: Annual Report*. Accessed March 6, 2017. https://www.cdc.gov/foodsafety/pdfs/foodborne-disease-outbreaks-annual-report-2012-508c.pdf

Centers for Disease Control and Prevention (CDC). 1994. "Epidemiologic Notes and Reports: *Bacillus cereus* Food Poisoning Associated with Fried Rice at Two Child Day Care Centers—Virginia, 1993." *Morbidity and Mortality Weekly Report*. 43 (10):177–178. Accessed March 13, 2017. http://www.cdc.gov/mmwr/PDF/wk/mm4310.pdf

Centers for Disease Control and Prevention (CDC). 1986. "*Bacillus cereus* – Maine." *Morbidity and Mortality Weekly Report*. 35 (25): 408–410. Accessed March 13, 2017. https://www.cdc.gov/mmwr/preview/mmwrhtml/00000754.htm

Dierick, K, E Van Coillie, I Swiecicka, G Meyfroidt, H Devlieger, A Meulemans, G Hoedemaekers, L Fourie, M Heyndrickx, and J Mahillon. 2005. "Fatal Family Outbreak of *Bacillus cereus*-Associated Food Poisoning." *Journal of Clinical Microbiology*. 43 (8): 4277–4279.

Delbrassinne, L, N Botteldoorn, M Andjelkovic, K Dierick, and S Denayer. 2015. "An Emetic *Bacillus cereus* Outbreak in a Kindergarten: Detection and Quantification of Critical Levels of Cereulide Toxin." *Foodborne Pathogens and Disease*. 12 (1): 84–87.

Florida Department of Public Health (DOH). 2011. "Outbreak at Okeechobee Correctional Institute." *Food for Thought*. Accessed April 19, 2017 http://www.outbreak-database.com/reports/Florida_Dept._of_health_Publication,_Food_for_Thought,_Issue_1,_February_2011,_See_page_2_.pdf

Food and Drug Administration (FDA). 2017. Code of Federal Regulations Title 21-Part 117—*Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food*. Accessed January 30, 2017: http://www.ecfr.gov/cgi-bin/text-idx?SID=242e99958fe0d430b7ab4c404b393bba&mc=true&node=pt21.2.117&rgn=div5

Food and Drug Administration (FDA). 2016. *Real Progress in Food Code Adoption*. Accessed April 13, 2017. https://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM476819.pdf

Food and Drug Administration (FDA). 2013a. *Food Code 2013*. US Public Health Service. Accessed March 7, 2017. http://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM374510.pdf

Food and Drug Administration (FDA). 2012. Bacillus cereus *and Other* Bacillus *spp. Bad Bug Book: Foodborne Pathogenic Microorganisms and Natural Toxins Handbook*. 92–95. Accessed March 6, 2017. http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/UCM297627.pdf

Food Standards Australia New Zealand (FSANZ). 2013. *Bacillus cereus*. Accessed March 6, 2017. http://www.foodstandards.gov.au/publications/Documents/Bacillus%20cereus.pdf

Health Protection Surveillance Center (HPSC). 2012. "*Bacillus cereus* Food-borne Illness." *Infectious Intestinal Disease: Public Health and Clinical Guidance*. Accessed March 6, 2017. http://www.hpsc.ie/A-Z/Gastroenteric/GastroenteritisorIID/Guidance/File,13492,en.pdf

Marriot, NG and RB Gravani. 2006. *The Relationship of Microorganisms Sanitation. Principles of Food Sanitation* (5th ed.) Springer Science+Business Media, Inc.

Naranjo, M, S Denayer, N Botteldoorn, L Delbrassinne, J Veys, J Waegenaere, N Sirtaine, R Driesen, K Sipido, J Mahillon, and K Dierick. 2011. "Sudden Death of a Young Adult Associated with *Bacillus cereus* Food Poisoning." *Journal of Clinical Microbiology*. 49 (12): 4379–4381.

Ontario Agency for Health Protection and Promotion (OAHPP). 2015. "Case Study: Evidence of Foodborne Outbreaks Associated with Pizza." *Public Health Ontario Partners for Health*. Accessed March 9, 2017. http://www.publichealthontario.ca/en/eRepository/Case_Study_Pizza_2015.pdf

Rajkovic, A. 2014. "Microbial toxins and low level of foodborne exposure." *Trends in Food Science & Technology*. 38 (2): 149–157.

Scallan, E, RB Hoekstra, FJ Angulo, RV Tauxe, MA Widdowson, SL Roy, JL Jones, PM Griffin. 2011. "Foodborne Ilness Acquired in the United States- Major Pathogens." *Emerging Infectious Diseases*. 17(1): 7–15. Accessed March 6, 2017. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3375761/#SD1

Todar, K. 2012. "*Bacillus cereus* Food Poisoning." In *Todar's Online Textbook of Bacteriology*. Accessed March 27, 2017. http://textbookofbacteriology.net/B.cereus.html

Zhou, G, K Bester, B Liao, Z Yang, R Jiang, and NB Hendriksen. 2014. "Characterization of Three *Bacillus cereus* Strains Involved in a Major Outbreak of Food Poisoning After Consumption of Fermented Black Beans (*Douchi*) in Yunan, China." *Foodborne Pathogens and Disease*. 11 (10): 769–774.

Table 1. Significant *Bacillus cereus* Foodborne Outbreaks.[1]

Year	Location	Cases	Deaths	Toxin	Food/Source
1985	US	11	0	ND[2]	Hibachi steak
1988	Canada	37	0	ND	Milkshake
1989	US	55	0	ND	Cornish game hens
1989	Canada	74	0	ND	Milk
1991	US	139	0	Diarrheal	Barbecued pork
1993	US	14	0	Emetic	Fried rice
1998	France	44	3	Diarrheal	Vegetable puree
2000	Italy	173	0	Diarrheal	Cake
2003	Belgium	5	1	Emetic	Pasta salad
2005	US	26	1	ND	Turkey
2006	US	26	0	Emetic	Fried rice
2007	Australia	1	1	ND	Asparagus sauce
2008	Belgium	1	1	Emetic	Spaghetti
2010	US	103	0	Emetic	Rice
2010	US	17	0	ND	Pork/Chicken
2011	US	58	0	ND	ND
2012	Belgium	20	0	Emetic	Rice, cucumber, chicory
2013	UK	93	0	ND	Rice
2014	England	14	1	ND	Intravenous liquid (TPN[3])
2014	Canada	44	0	Emetic	Fried rice
2014	China	139	0	Emetic	Fermented black beans
2015	US	22	0	ND	Enchilada, cheese, salsa
2015	US	3	0	ND	Rice

[1] Delbrassinne et al. 2015; Zhou et al. 2014; FSANZ 2013; DOH 2011; Naranjo et al. 2011; Dierick et al. 2005; BCCDC 2002; CDC 1994; CDC 1986; CDC 2017 (http://wwwn.cdc.gov/foodborneoutbreaks/)
[2] No Data.