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Preventing Foodborne Illness: *Bacillus cereus* and *Bacillus anthracis*[1]

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What causes a foodborne illness?

Bacillus species are Gram positive, aerobic heterotrophs, ubiquitous bacteria, characterized by their ability to form resistant spore coats. There are about 48 known species in the genus *Bacillus* but only *B. anthracis* and *B. cereus* are associated with human disease. *Bacillus* species are mesophilic bacteria that produce heat-resistant endosopores with a growth range of 10°C to 48°C, with optimal growth at 28°C to 35°C. In addition, they can grow in a broad pH range of 4.9 to 9.3.

Bacillus anthracis is responsible for causing the disease anthrax in humans and animals, via direct contact with infected carriers or inhalation of endospores. In rare instances, the consumption of contaminated meats has led to foodborne illnesses associated with *B. anthracis*. Conversely, *B. cereus* is responsible for the majority of foodborne illnesses attributed to *Bacillus*. Although the incidence of naturally acquired anthrax is extremely rare in the United States, the Centers for Disease Control and Prevention estimated that in the year 2001, there were 22 cases. During 1993-1997, *B. cereus* was linked to 14 outbreaks and caused 691 reported cases of foodborne illness in the United States.

Due to recent acts and threats of bioterrorism, *B. anthracis* remains an organism for which control mechanisms are necessary. While the most efficient method of delivering this biological weapon would be via an airborne route, the contamination of foodstuffs and water sources could be possible. With the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 and as the government continually prepares and responds to the threat of bioterrorism, clinical microbiological laboratories could play a key role in the detection, identification, and control of *B. anthracis*.

What are *Bacillus cereus* and *Bacillus anthracis*?

Bacillus cereus

Bacillus cereus is a spore-forming, Gram positive, facultative anaerobic bacterium associated with food poisoning in humans. The food poisoning is a result of ingesting heat-stable enterotoxins

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produced by the bacteria: either a thermostable emetic enterotoxin or a thermosensitive diarrhoegenic enterotoxin. *B. cereus* is widespread in the soil and the food industry, in such foods as herbs, spices, milk and vegetables. Transmission of this disease results not only from contaminated foods, but improper food handling/storage and improper cooling of cooked foodstuffs.

Bacillus anthracis

Bacillus anthracis is a Gram positive, non-motile, aerobic, encapsulated spore-forming bacterial rod that produces exotoxins. Although anthrax is a disease that primarily affects herbivorous animals such as cattle, sheep and horses, recently it has become a concern regarding humans. Infections associated with anthrax are transmitted to humans either by direct contact with an infected animal or person, by consumption of contaminated animal products, or by the inhalation of the exotoxins and the capsule, produced by the spores. The three exotoxins, required for virulence are the edema toxin, lethal toxin, and the protective antigen factor. These toxins can lead to serious health related problems such as edema, necrosis, and hemorrhages. Sources of infection can be classified in three types: cutaneous infections, inhalation anthrax, and gastrointestinal anthrax. Oropharyngeal anthrax and intestinal anthrax may occur if contaminated food or drink is ingested, such as infected meat or milk. Transmission may occur through infected livestock, or contaminated animal products. Although person-to-person transmission is rare, it may occur if infectious discharges, associated with cutaneous infection are spread.

What are the symptoms associated with *Bacillus cereus* and *Bacillus nathracis*?

Bacillus cereus

There are two types of illnesses associated with *B. cereus*. The most common is a diarrheal illness caused by a heat-labile toxin, accompanied with abdominal pain. An incubation period of 4-16 hours is followed by symptoms lasting 12-24 hours. The second type of disease state is an emetic illness caused by a heat-stable toxin, often associated with ingestion of rice that is not properly refrigerated after cooking. This illness is characterized by vomiting and nausea that usually occur within 1-5 hours upon ingestion of the contaminated food. This is sometimes referred to as an intoxication.

Bacillus anthracis

Cutaneous infection accounts for about 95% of all human cases, followed by inhalation and gastrointestinal anthrax, which are very rare. Cutaneous infections start when the organism enters the body via open skin wounds or abrasions, resulting in skin lesions. The first symptom is a pus filled elevation on the skin, which then turns into an open ulcer. The most severe cases may result in septicemia, invading the bloodstream, and resulting in death.

Symptoms associated with gastrointestinal anthrax include pharyngeal lesions with a sore throat, swelling in the neck, or intestinal infection, resulting in nausea, fever, severe abdominal pain, bloody diarrhea, and hemorrhages, symptoms similar to a *Staphylococcus* infection. There is a 25-50% fatality rate.

Inhalation anthrax is the most severe, and results from inhalation of spores. The spores are small enough to enter the alveoli, germinate, and produce the exotoxins, resulting in infection, and a 90% fatality rate if not treated. Symptoms first resemble those associated with pneumonia; fever, chills, cough, headache, and malaise, followed by more serious symptoms such as hemorrhages and septic shock.

Who is at risk?

Bacillus anthracis and *B. cereus* can infect all persons, since illness may result from ingestion of contaminated foodstuffs. However, the immuno-compromised, followed by the very young and old may suffer from more serious side effects.

Inhalation of *B. anthracis* spores affect those persons who handle contaminated animal products and more recently contaminated mail. Occupational risk groups who work directly with animals, such as

laboratory personnel or veterinarians may be at a higher risk for anthrax.

B. cereus and *B. anthracis* may pose a higher risk for those working in food preparation areas and slaughterhouses. While intact tissues and meat from animals are sterile, once they are slaughtered, they may become contaminated either from the processing plant or from bacteria that grow in the hide and gut.

Generally, gastroenteritis symptoms from *B. cereus* resolve by themselves, but may require medical intervention. Infections of *B. anthracis* require medical attention.

What foods have been commonly associated with *Bacillus cereus* and *Bacillus anthracis*?

Bacillus cereus

Bacillus cereus has a broad range of foods associated with infection including, cooked vegetables and meats, boiled or fried rice, vanilla sauce, custards, soups, ice cream, herbs and spices. Many of these foods may contain *B. cereus* since spores of this organism are heat-resistant and can survive cooking. Studies have shown that *B. cereus* spores can survive even recommended cooking temperatures. Keeping food on warmers may also prove to be ineffective in reducing B. cereus, as spores can still germinate as food is cooled, passing through the "danger zone" of 140^{o}F to 41^{o}F.

Bacillus anthracis

The most common sources of foodborne *B. anthracis* infections are caused by contaminated meat and food products from cattle, sheep, horses, goats and other affected animals. Milk and milk products are also known, albeit rare sources of infection.

What sanitation methods are used to prevent the contamination of foods?

Bacillus cereus

Bacillus cereus spores are extremely heat resistant, so while cooking at proper temperatures would destroy most foodborne pathogens including the vegetative cells of *B. cereus*, it does not destroy the spores. While heat resistance is increased by high salt concentrations and gradual heating, the spores lose their heat resistance in acidic environments. Spores can be activated by heat and or improper handling; therefore the 2001 Food Code recommends that hot foods be maintained at a temperature of 140°F or above.

According to the National Institutes of Health (NIH), the National Institute of Allergy and Infectious Diseases (NIAID), and the National Food Processors Association (NFPA), the suggestions below are good examples of how to destroy *B. cereus*:

- Steaming under pressure, roasting, frying and grilling foods can destroy the vegetative cells and spores.
- Foods infested with the diarrheal toxin can be inactivated by heating for 5 minutes at 133°F.
- Foods infested with the emetic toxin need to be heated to 259°F for more than 90 minutes. Reheating foods until they're steaming is not enough to kill the emetic toxin.

In meat processing facilities, to prevent contamination and toxin formation:

- Assure current Good Manufacturing Practices (cGMP) (21 CFR 110), are being used in the slaughterhouses and processing units.
- Apply approved treatments of carcasses to remove fecal bacteria.
- Use proper cleaning and disinfection of food contact surfaces (FCS) with hypochlorite or other approved sanitizers.
- Utilize a heat process to destroy the vegetative cells and a rapid cooling process to prevent the spores from germinating.
- Keep hot foods above 60°C and cold foods below 4°C to prevent the formation of spores.
- Wash hands, utensils, FCS s with hot soapy water after they touch raw meat or poultry, or before food preparation, and after using the bathroom.

- Cook beef and beef products thoroughly.
- Properly refrigerate leftovers.

Good practices for food product receiving, handling, processing and storage

The FDA defines cGMPs in 21 CRF, Part 110. These cGMPs outline minimally required general 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 2001 Food Code (FDA, 1999 and 2001) have been adopted into many state and local regulations. As there may be some variation in 2001 Food Code adoption, it is important that each facility check with the appropriate state and/or local regulatory authority. 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 receiving and storage of food products and ingredients. If food processing is being performed, appropriate controls and requirements should be established and strictly adhered to. The FDA 2001 Food Code outlines appropriate processing and cooking requirements for many food products processed in a retail facility.

Receiving

Specifications for receiving can be found in section 3-202.11 of the 2001 Food Code http://www.cfsan.fda.gov/~dms/foodcode.html . The following guidelines cover the basic points that should be addressed:

- Potentially Hazardous Food (PHF) should be at a temperature of 41^{o}F or below when received, unless specified by law (e.g., milk, shellfish).
- PHFs that are received hot should be at a temperature of 140^{o}F or above.
- PHFs should be received with no evidence of temperature abuse such as evidence of thawing.

For recommendations that are more specific consult the 1999 or 2001 Food Code http://www.cfsan.fda.gov/~dms/foodcode.html.

Processing

One of the easiest ways to prevent foodborne illness associated with *Bacillus* spp. is by ensuring that foods are cooked thoroughly and cooled rapidly. One of the leading causes of foodborne *Bacillus* infections and intoxications comes from the improper hot holding of prepared food items.

- Cook foods to an internal temperature of 145^{o}F or above for a minimum of 15 seconds (2001 Food Code).
- Hot hold food at a temperature of 140^{o}F or higher.
- Chill.
- Reheating previously cooked material to an internal temperature to 165^{o}F.

For recommendations that are more specific consult the 1999 or 2001 Food Code http://www.cfsan.fda.gov/~dms/foodcode.html.

Storage

Once a product has been received and/or processed, it now will be displayed or stored. There are some general guidelines governing these practices as well.

- Frozen food should remain frozen until it is used.
- If frozen food is displayed in a refrigerated case and allowed to thaw, the food should remain at 41^{o}F or below.
- Frozen food should be thawed at a temperature of 41^{o}F or below or under running water at a temperature of 70^{o}F or below.
- Lastly, the product can be thawed as part of the cooking process.

- Product must be cooled adequately. Refer to sections 3-501.14 and 3-501.15 of the 1999 or 2001 Food Code http://www.cfsan.fda.gov/~dms/foodcode.html
- Cooked product should be maintained above 140^{o}F while displayed and stored at or under 41^{o}F.
- Properly label all stored product.

Personal hygiene

Wash your hands! The major cause of foodborne illness in retail establishments comes from poor personal hygiene, particularly a lack of proper hand washing. Dirty hands can contaminate food. Although hands may look clean, the bacteria that cause illness are too small to be seen. Therefore, whenever you are preparing food and you come in contact with items that are not part of the assembly process, rewash your hands. The same is true even when wearing gloves. THERE IS NO FIVE SECOND RULE WHEN IT COMES TO FOOD SAFETY! Millions of bacteria and other germs can be transferred on contact. Here is a list of times when you should wash your hands:

- before handling, preparing, or serving food
- before handling clean utensils or dishware
- after using the restroom
- after touching your face, cuts, or sores
- after smoking, eating, or drinking
- after handling raw meat - especially poultry
- after touching unclean equipment, working surfaces, soiled clothing, soiled wiping cloths, etc.
- after collecting and taking out the garbage

What is the proper procedure for hand washing?

1. Wet your hands with warm water
2. Apply soap and wash your hands for 20 seconds
3. Rinse and dry with a single-use paper towel
4. Use the paper towel to shut off the water

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