BACILLUS CEREUS

THE ORGANISM/TOXIN

Bacillus cereus is a spore-forming bacterium that occurs naturally in many kinds of foods and can cause illness in humans. It can form spores that are resistant to heating and dehydration and can therefore survive cooking and dry storage.

When foods containing *B. cereus* spores are in the 'temperature danger zone' the spores may germinate, and the bacteria may grow, produce toxins, and make people sick. Such illness is frequently linked with starchy foods of plant origin such as rice, pasta, potatoes, pastry and noodles.

B. cereus can cause vomiting or diarrhoea and, in some cases, both. This depends on the kinds of toxin it produces.

Enterotoxins produced by *B. cereus* (diarrhoeal toxin) result in the diarrhoeal form of the disease and most often follow ingestion of contaminated food, local bacterial growth and subsequent toxin production in the intestines of the host (Berthold-Pluta *et al*., 2015; Rajkovic, 2014).

Emetic toxin produced by *B. cereus* (cereulide) can result in the vomiting form of the disease following ingestion of food containing pre-formed toxin (Rajkovic, 2014).

Illness from *B. cereus* can be prevented by making certain that hot foods are kept hot and cold foods are stored cold. It is important to remember that re-heating food that has been 'temperature abused' will not make it safe.

GROWTH AND CONTROL

Growth

Temperature

- Optimum 30-37°C
- Range 4-55°C, emetic strains have a minimum of 10°C (Ehling-Schulz et al., 2004)
- Maximum toxin production at 20-25°C, toxin production range 10-40°C
- Psychtrotrophic strains occur, but most are not pathogenic. Those that are tend to have a minimum temperature for growth of around 7°C and cause diarrhoeal disease (Guinebretière et al., 2008).

pH

- Optimum 6-7
- Range 4.5-9.5

Atmosphere

- Facultative anaerobe
- Oxygen required for production of emetic toxin

Minimum Water Activity

- With NaCl >0.93 and <0.95 a_w
- With glycerol 0.93 a_w (ICMSF, 1996)

Survival

Temperature

- Spores more resistant to dry than moist heat, and are also more resistant in oily foods. Cooking at or below 100°C may allow spore survival (van Asselt and Zwietering, 2006)
- Emetic toxins remain stable for 80 minutes at 121°C and 60 minutes at 150°C (pH 9.5) (Rajkovic, 2014).

pH

- Generally vegetative cells decline rapidly in stomach acid, however some may survive depending on food and level of stomach acidity (Clavel *et al.,* 2004)
- Spores are resistant to gastric acidity (between pH 1 and pH 5.2)
- Emetic toxin stable between pH 2 and pH 9

Water Activity

Spores survive long periods in dry foods e.g. population unchanged after 48 weeks in cereal (a_w 0.27-0.28) (Jaquette and Beuchat, 1998)

Inactivation

Temperature

- Vegetative cells destroyed by frying, grilling, roasting and pressure-cooking
- Spores (depends on strain and food):
  - $D_{100°C}$ = 1.2-7.5 minutes in rice
  - $D_{120°C}$ (mean of 465 datapoints) = 2.5 seconds (van Asselt and Zwietering, 2006)
  - $D_{120°C}$ (mean of 19 datapoints in oily foods, e.g. pumpkin pie, soybean oil) = 3.4 min (van Asselt and Zwietering, 2006)
- The emetic toxin is considered stable in foods. There is some laboratory evidence that inactivation can occur under extreme conditions, but these would not occur in foods.
- Diarrhoeal toxin inactivated 5 min at 56°C

pH

- Vegetative cells inactivated in yoghurt (pH 4.5) and fruit juice (pH 3.7, 5-6 $\log_{10}$ reduction within a few hours depending on temperature)
- Diarrhoeal toxins unstable outside range pH 4-11 (Jenson and Moir, 2003)

Water Activity

Vegetative cells inhibited at a_w < 0.91

Preservatives

- Vegetative cell growth inhibited by sorbic acid, benzoate, sorbate, ethylenediaminetetraacetic acid (EDTA) and polyphosphates
- Spore germination and outgrowth inhibited by nisin (NB: Nisin is not sporicidal)

Disinfectants / Sanitisers

- Most food industry sanitisers destroy vegetative *B. cereus* cells on surfaces
- Glutaraldehyde, formaldehyde, chlorine, iodine, acids, alkalis, hydrogen peroxide, peroxy acids, ethylene oxide, ß-propionolactone and ozone are all sporicidal at high concentrations with long contact times
- Phenolics, QACs, alcohols, bisguanides, organic acids, esters and mercurials have little sporicidal effect
- Chlorine disinfectants such as household bleach contain 5.25% sodium hypochlorite (52,500 ppm available chlorine) and are effective against vegetative *B. cereus* cells but not spores

CLINICAL PICTURE

B. cereus-associated foodborne illness occurs as two distinct intoxication syndromes: emetic and diarrhoeal. Recovery is rapid for both syndromes, usually within 12-24 hours. There are usually no long-term effects, but severe consequences, including fatalities, can occasionally occur.

Emetic syndrome

Incubation: 0.5-6 hours.
Symptoms: Nausea, vomiting, malaise, occasionally followed by diarrhoea.
Dose: Large numbers in the range of 10^5 to 10^8/g viable cells are required before toxin (cereulide) becomes detectable in the food. Emetic toxin concentration in foods implicated in an outbreak in Japan ranged from 0.01 to 1.28 µg/g (Agata *et al.,* 2002). An intoxication dose of 8 µg kg^{-1} body weight has been suggested (Paananen *et al.,* 2002).

Diarrhoeal syndrome

Incubation: 8-16 hours
Symptoms: Abdominal pain, watery diarrhoea, occasional nausea.
Dose: 10^5-10^7 (total cells). Foods with such high populations of *B. cereus* may not be acceptable to the consumer.
At Risk Groups: All people are susceptible to intoxication, but intensity of symptoms varies between individuals.
Treatment: Treatment is usually not given. Fluids are administered when diarrhoea and vomiting are severe.

SOURCES

B. cereus is a spore former. It is widely distributed in nature and contaminates virtually every agricultural commodity. It has been isolated from soil, dust, cereal crops, vegetation, animal hair, fresh water and sediments, although it is not generally isolated from fish (ICMSF, 1996).

Human: Can be transiently carried in the intestine of healthy humans (14-43%) (Jenson and Moir, 2003). However, no person-to-person transmission has been reported.
Food: Transmission is predominantly foodborne. Most raw foods will contain *B. cereus* spores, as do many dried herbs, spices and dehydrated foods. Emetic illness is frequently linked with raw starchy foods of plant origin (such as rice, pasta, potatoes, pastries and noodles). In 95% of emetic cases, fried or cooked rice is implicated (Jenson and Moir, 2003).

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Diarrhoeal illness is often associated with meat products, soups, vegetables, sauces and milk/milk products. Dairy products may spoil through the growth of spores (including the spores of psychrotrophs) that survive pasteurisation.

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OUTBREAKS AND INCIDENTS

NZ Incidence: *B. cereus* infection is not notifiable in New Zealand, though outbreaks can be recorded. There was one outbreak recorded in 2008, involving three cases (ESR, 2009). There were no outbreaks recorded in 2009 (ESR, 2010).

Most *B. cereus* food poisoning incidents are from cereal-based or protein-based foods, slowly cooled and stored between 10 and 50°C. This allows surviving spores to germinate and reach numbers high enough to cause illness.

New Zealand Outbreaks
Pancakes; (5 cases) Commercial eatery. Temperature abuse and poor storage of pancake batter.
Savoury rice, potato, mashed pumpkin (suspected); (27 cases). Food vehicles not identified.

Overseas Outbreaks
Japan, contaminated milk in school lunch: 1877 cases (emetic).
Norway, fish soup: 20 cases (diarrhoeal). Inadequate cooling.
Denmark, meat with rice: >200 cases (diarrhoeal).
Spain, cooked noodles: 13 cases (diarrhoeal). Inadequate cooling of cooked noodles.
Norway, vanilla sauce: >200 cases (diarrhoeal). Prolonged storage at ambient temperature.

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