

BACILLUS CEREUS

THE ORGANISM/TOXIN

Bacillus cereus is a spore-forming organism which occurs naturally in most foods. It causes two different forms of food poisoning: an emetic illness and a diarrhoeal illness. The emetic illness is mediated by a highly stable toxin that survives high temperatures and exposure to trypsin, pepsin and pH extremes. The diarrhoeal illness is mediated by a heat- and acid-labile enterotoxin.

GROWTH AND ITS CONTROL

Growth:

Temperature: Optimum 30-37°C. Some strains can grow up to 55°C while others can grow as low as 4-5°C. Many strains from dairy products are able to grow at low temperatures.

pH: The minimum pH for growth is 4.3, maximum pH around 9.3.

Growth is inhibited in the presence of 0.1% acetic acid (pH 5.1).

Atmosphere: Growth is best in the presence of oxygen. Grows well anaerobically. Toxin production is lower under anaerobic conditions.

Water activity: Minimum range of water activity for vegetative growth is 0.912-0.950.

Survival:

Temperature: *Vegetative cells* are readily killed by heat but spores are moderately heat resistant. Heat resistance is increased in high-fat and oily foods (in soybean oil, the D time at 121°C is 30 min). Higher heat resistances also occur in foods with low water activity.

Spores are more resistant to dry heat than moist heat. *Emetic toxins* are extremely resistant to heat (can survive 90 min at 126°C).

Diarrhoeal toxins are inactivated at 56°C in 5 min.

pH: *B. cereus* organisms die suddenly in yoghurt when the pH reaches 4.5.

Emetic toxin survives extremes of pH (2-11)

Water Activity: Spores survive for long periods in dried foods.

Inactivation (CCPs and Hurdles):

Temperature: *For spores:* D₈₅ = 33.8-106 min. D₉₅ ranged from 1.5-36.2 min in distilled water and 1.8-19.1 min in milk. Considerable variation was observed between different strains.

pH: Inactivated by 0.1 M acetic, formic and lactic acids in nutrient broth.

Water activity: 7.5% NaCl inhibits growth.

Preservatives: (NB: Some of the preservatives discussed here may not be permitted in New Zealand). Growth is inhibited by 0.26% sorbic acid

at pH 5.5 and 0.39% potassium sorbate at pH 6.6.

The addition of 0.2% calcium propionate prevents germination of *B. cereus* in bread.

Nisin is commonly used to inhibit germination and spore growth in processed cheese, dairy desserts, canned foods, cured meats and high moisture baked products such as crumpets and pikelets. A level of 3.75 µg/g of nisin in crumpet batter was effective.

Other antimicrobials which have an effect on *B. cereus* include benzoate, sorbate, ethylenediaminetetraacetic acid (EDTA) and polyphosphates.

Preserving foods in modified atmospheres has been shown to control the growth of *B. cereus*.

Preservatives can be applied at reduced levels to inhibit the growth of *B. cereus* when used in combination (hurdle effect).

Sanitisers/Disinfectants: Most chemical sanitisers used routinely in the food industry will destroy *B. cereus* on surfaces.

Radiation: Spores are more resistant to radiation than vegetative cells. Spores are more sensitive to heat after preirradiation at 4kGy before heating at 90°C.

THE ILLNESS

B. cereus-associated foodborne illness occurs as 2 distinct syndromes: emetic and diarrhoeal.

Incubation: *Emetic*; 1-6 hours after eating contaminated food.

Diarrhoeal; 10-12 hours.

Symptoms: The symptoms of the emetic syndrome result from ingestion of pre-formed toxin: nausea and vomiting, occasionally followed by diarrhoea (similar to *S. aureus*).

Diarrhoeal symptoms result from ingestion of vegetative organisms or spores and their subsequent multiplication and toxin production within the intestinal tract: abdominal pain, watery diarrhoea and occasional nausea (similar to *C. perfringens*).

Recovery is rapid for both syndromes, usually within 12-24 hours. Very few fatalities have been reported.

Condition: Gastroenteritis.

At Risk Groups: All people are believed to be susceptible to intoxication and infection but the intensity of symptoms may vary between individuals.

Long Term Effects: None

Dose: Large numbers, >10⁵ /g of food, are required to produce toxin or cause infection. No food containing >10⁴ *B. cereus* /g can be considered safe for consumption. Small numbers of *B. cereus* in food are not a direct hazard to health.

NZ Incidence: In the Annual Summary of Outbreaks in NZ (1999) 16 outbreaks were attributed to *B. cereus* (45 cases), 6 outbreaks in 1998 (21 cases).

Treatment: Usually no treatment is given. Fluids may be administered when diarrhoea and vomiting are severe.

SOURCES

Human: Humans are not a significant source of food contamination by *B. cereus*. This organism already exists on many foods and can therefore be transiently carried in the intestine of healthy humans (0-43%).

Animal: Animals can carry *B. cereus* on parts of their body. May occasionally cause mastitis in cows.

Food: Raw foods of plant origin are the major source of *B. cereus*. The widespread distribution of the organism, the ability of spores to survive dried storage and the thermal resistance of spores, means that most ready-to-eat foods will contain *B. cereus* and will require control measures to prevent growth, especially after cooking has eliminated competing flora. Strains producing emetic toxin grow well in rice dishes and other starchy foods, whereas strains producing diarrhoeal toxin grow in a wide variety of foods from vegetables and salads to meat and casseroles. Numerous dried herbs and spices and dehydrated foods have been shown to contain *B. cereus*.

Environment: *B. cereus* is widely distributed in nature and can be found in soil, dust, air, water and decaying matter. Its ability to form spores allows survival through all stages of food-processing, other than retorting.

Transmission Routes: Ingestion of contaminated food.

OUTBREAKS AND INCIDENTS

Outbreaks: Most *B. cereus* food poisoning incidents result from eating cooked foods which are cooled slowly and stored incorrectly. Outbreaks of emetic-type illness generally result from eating rice products or starchy foods such as potato and pasta. Outbreaks of diarrhoeal-type illness result from eating foods in which *B. cereus* organisms have grown to large numbers.

New Zealand examples:

Fried rice, meat stew, vegetables: 30 cases. Control measure failure: possibility of inadequate cooling, prolonged storage at incorrect temperatures.

Chinese takeaway meal: 7 cases. Control measure failure: inadequate cooling and storage of rice.

Pancakes: 5 cases. Control measure failure: prolonged storage of pancake batter at ambient temperature.

Seafood chowder: 2 cases. Control measure failures: inadequate cooling, inadequate reheating.

Overseas studies:

Barbecued pork: 139 cases. Control measure failure: inadequate cooling, prolonged storage at ambient temperature.

Chicken fried rice: 14 cases. Control measure failures: inadequate cooling of cooked rice.

Vanilla sauce: 600 cases. Control measure failure: prolonged storage at ambient temperature.

Meals-on-wheels: 49 cases. Control measure failure: prolonged storage at incorrect temperatures.

OTHER *Bacillus* species

Several *Bacillus* species other than *B. cereus* have been implicated in food poisoning episodes. The species most often implicated are *B. subtilis* and *B. licheniformis*. These organisms can produce a highly heat-stable toxin which appears similar to the emetic type produced by *B. cereus*.

Implicated foods: Meat and vegetable products which are associated with seasonings, flour and pastry, e.g. sausage rolls, meat pies and pastries, curries and various ethnic dishes with rice, and stuffed poultry.

Symptoms: *B. subtilis*: acute onset nausea, vomiting and stomach cramps (median 2-5 hours), often with diarrhoea. *B. licheniformis*: diarrhoea is more common than vomiting (median 8 hours).

ADEQUATE PROCESSING GUIDELINES

N.B. These guidelines have been derived from published information. Industry is advised to ensure that processing steps they are using are adequate to meet their particular food safety objectives.

Cook meats to:	Internal temperature reached	Time
Minced meats (beef, veal, lamb, pork) + pork cuts	71°C	15 sec
Minced poultry	74°C	"
Meat cuts (beef, veal, lamb), fish, seafood	63°C	"
Poultry, breast	77°C	"
Poultry, whole	82°C	"
Cool cooked foods at room temperature until:	≥55°C	
Continuously cool cooked foods under refrigeration to achieve a reduction of:	55°C to 25°C	In less than 5 hrs
Followed by:	25°C to 5°C	In less than 10 hrs
Hold foods at	≤ 5°C or ≥ 60°C	
Reheat cooked foods to	74°C	Instantaneous
Reduce pH of food to ≤ 4.3		
Reduce a _w to 0.912 or add appropriate level of preservative to store foods safely		

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