Biomedical Data Science
2025, VOL. 5, NO. 3, 207-211
DOI: 10.47297/wspbdsWSP2752-630543.20250503

Research on the Contamination Status and Control of Bacillus Cereus in Food

Gaoshang Zheng

Food Science and Technology, Jinzhong University, Jinzhong, Shanxi, 030606, China

ABSTRACT
Bacillus cereus is a Gram-positive spore-forming bacterium widely present in the natural environment. The emetic and enterotoxins it produces can easily cause foodborne diseases, posing a serious threat to food safety. This article starts from the biological characteristics of Bacillus cereus, analyzes its contamination status in various foods, explores its pathogenic mechanism and influencing factors, and proposes targeted prevention and control strategies, aiming to provide theoretical references for reducing the contamination risk of Bacillus cereus in food and ensuring public food safety.

KEYWORDS
Bacillus cereus; Food safety; Diarrheal toxin; Emetic toxin

1 Introduction

Bacillus cereus is a conditional pathogen. Its spores have strong resistance to heat, dryness and ultraviolet rays, and are easy to survive during food processing. It is estimated that 1.4% to 12.0% of foodborne diseases worldwide are caused by Bacillus cereus [1]. According to European research, Bacillus cereus is the second leading cause of foodborne disease outbreaks after Staphylococcus aureus [2]. In recent years, with the increase in the consumption of ready-to-eat foods and cold chain foods, the problem of Bacillus cereus contamination has become increasingly prominent and has become an important research object in the field of food safety.

2 The biological characteristics of Bacillus cereus var mycoides

Bacillus cereus is an aerobic or facultative anaerobic Gram-positive bacillus [3]. It is named for the waxy appearance of its colonies, which are rough on the surface and have irregular edges when grown on culture media. Its biological characteristics are mainly reflected in the following aspects:

2.1 Basic characteristics

Bacillus cereus cells are straight rods, approximately (1.0 - 1.2) μm × (3.0 - 5.0) μm in size, mostly existing singly or in short chains [4]. They have peritrichous flagella and are motile, without a capsule. This bacterium readily forms spores in the later stage of growth. The spores are oval or cylindrical, located in the center or sub-terminal of the cell, without swelling the cell. This characteristic makes it highly resistant to adverse environments - spores can withstand boiling at 100° C for several minutes and survive for years in a dry environment. Conventional cooking heating is difficult to completely kill them, which is an important cause of secondary food contamination and foodborne diseases.

In terms of cultivation characteristics, Bacillus cereus grows well on ordinary nutrient agar medium, with the optimal growth temperature ranging from 28 to 35℃ [5], and the suitable pH range being 6.0 to 7.0. After 24 hours of cultivation, colonies with diameters of 2 to 5 mm can be formed. The colony surface is dry and opaque, with wavy or curly edges, and the color is mostly off-white or light gray. On blood agar plates, some strains can produce hemolytic rings, which can be used as a preliminary identification basis.

Bacillus cereus has a strong metabolic capacity and can utilize various carbohydrates as carbon sources and energy. Its biochemical reaction characteristics include: it can ferment glucose, maltose, sucrose, etc. to produce acid but not gas; the VP test (Voges-Proskauer test) is positive [6], which can convert pyruvic acid into acetyl methyl methanol; it does not produce hydrogen sulfide, does not decompose urea, and the catalase test is positive. These biochemical characteristics are key indicators for distinguishing Bacillus cereus from other bacilli (such as Bacillus subtilis) in microbial identification.

2.2 Toxin production characteristics

The pathogenicity of Bacillus cereus is mainly related to the toxins it produces. According to the mechanism of action, these toxins can be classified into two types: emetic toxin (cereulide) and enterotoxin [7].

Vomitoxin is a heat-stable cyclic peptide toxin that is insensitive to changes in temperature and pH. It remains active even after 90 minutes of high-pressure sterilization at 121℃ [8]. It is mainly produced by certain toxigenic strains when they grow and multiply in food (especially at 25-30℃). Once this toxin enters the human body, it can stimulate the nerves of the gastrointestinal tract, causing acute symptoms such as nausea and vomiting. In severe cases, it may even be fatal. The incubation period is relatively short, usually 1-5 hours [9].

Intestinal toxins include heat-stable enterotoxins (HBL) and heat-labile enterotoxins (NHE), among others. The heat-labile enterotoxins are sensitive to temperature and can be inactivated by heating at 60°C for 10 minutes. These toxins mainly cause diarrhea and abdominal pain by destroying the integrity of intestinal epithelial cells and leading to an imbalance in intestinal osmotic pressure. The incubation period is relatively long, usually ranging from 6 to 15 hours.

3 The current situation of bacillus cereus contamination in food

Bacillus cereus is widely distributed in soil, water, air and on the surface of animals and plants. The ways it contaminates food are diverse, and almost all kinds of food may be contaminated, among which grain products, meat, dairy products, vegetables and ready-to-eat foods are more prominently affected [6,10-11].

3.1 Cereals and cereal products

Grains are prone to contact Bacillus cereus in the soil during planting, harvesting and storage, leading to raw material contamination. Studies show that the detection rate of Bacillus cereus in grains such as rice, wheat and corn can reach 30% to 60%, and in some severely contaminated samples in certain areas, the bacterial count can exceed 10^3 CFU/g. Products made from grains, such as rice, noodles, steamed buns and rice noodles, are at risk of becoming the main cause of Bacillus cereus food poisoning if they are not heated thoroughly during processing or if the temperature and storage time are not properly controlled (such as rice left at room temperature for more than 2 hours), which can cause the remaining Bacillus cereus spores to germinate and multiply in large numbers. For example, in a food poisoning incident that occurred in a school in a certain area, it was found through testing that the remaining rice contained a high level of Bacillus cereus, reaching 1.8×107 CFU/g, confirming that the incident was caused by the contamination of this bacterium [12].

3.2 Meat and meat products

Meat is rich in protein and contains micronutrients [13]. During the slaughtering and processing of meat (such as pork, beef, and chicken), it is prone to contamination from the environment (such as knives, cutting boards, and workshop air) or from the operators, with a detection rate usually ranging from 20% to 40%. Some meat products (such as sausages, cured meats, and canned meats) cannot completely kill spores due to processing techniques (such as curing and smoking). If the subsequent storage temperature is not appropriate (such as a refrigeration temperature higher than 4℃), the spores can germinate into vegetative cells and multiply, leading to an excessive bacterial count. Many countries have reported cases of Bacillus cereus poisoning caused by consuming meat products.

3.3 Dairy products and dairy products

The contamination of dairy products (such as milk, yogurt, cheese, etc.) mainly comes from raw milk and the processing stage. The surface of cows' udders and milking equipment may carry Bacillus cereus, leading to the contamination of raw milk. The detection rate of this bacterium in raw milk can reach 15% to 30%. Although pasteurization or ultra-high temperature sterilization can kill most of the vegetative cells, they cannot remove spores [14]. If the hygiene control in the post-sterilization stage (such as filling and storage) is not good, the spores may germinate. In addition, if the fermentation temperature or time of yogurt and other fermented dairy products is not properly controlled, it may also lead to the reproduction of Bacillus cereus. It is also affected by the season. Some studies have pointed out that the incidence rate in spring is higher than that in autumn [15].

3.4 Vegetables and vegetable products

Vegetables come into direct contact with soil during their growth, and the detection rate of Bacillus cereus is relatively high. For leafy vegetables such as spinach and lettuce, the detection rate can reach 40% to 50%. For root and stem vegetables like potatoes and carrots, due to their skin being prone to soil contamination, the detection rate can even exceed 60%. For vegetable products such as cold dishes and pickles, as the processing is mostly cold treatment, it cannot kill spores. Moreover, although the acidic environment of some products like pickles can inhibit some microorganisms, it has limited effect on Bacillus cereus spores. If the storage conditions are improper and the bacteria are exposed to high temperature and high humidity for a long time, it may still lead to an increase in the bacterial count [16]. Studies have shown that the rate of virulence genes carried by fresh vegetables is relatively high [17].

3.5 Ready-to-eat food

Ready-to-eat foods (such as boxed meals, sushi, sandwiches, etc.) have a relatively high risk of contamination as they do not require reheating before consumption and usually undergo multiple processing steps. If such foods are not refrigerated promptly within 2 hours after preparation (or kept above 60℃), Bacillus cereus can multiply rapidly at 25-37℃ (with a generation time of approximately 20-30 minutes), and the bacterial count can reach a pathogenic level within a short period (it is generally considered that there is a risk of poisoning when the count exceeds 10^5 CFU/g).

Therefore, refrigeration plays a certain protective role for pre-packaged foods [18].

4 Pathogenic mechanism and influencing factors of bacillus cereus contamination in food

4.1 Pathogenic mechanism

The core mechanism by which Bacillus cereus causes foodborne diseases is the damage it inflicts on the human gastrointestinal tract through the toxins it produces, which can be specifically classified into two types: "emetic" and "diarrheal".

Vomiting-type poisoning: It is mainly caused by emetic toxin. When Bacillus cereus proliferates in contaminated food (usually with a count exceeding 10^5CFU/g), the emetic toxin produced enters the human body along with the food. It stimulates the vomiting center in the medulla oblongata within approximately 1 to 5 hours, causing symptoms such as nausea and vomiting. Some patients may also experience dizziness and fatigue. The course of the disease is relatively short (usually it can be relieved on its own within 1 to 6 hours).

Diarrheal type poisoning: It is mainly caused by enterotoxins (such as HBL, NHE, etc.). After the enterotoxins enter the human body (8-16 hours) [19], they bind to surface receptors, destroy the integrity of the cell membrane, cause an imbalance of water and electrolytes in the intestinal tract, and lead to diarrhea and abdominal pain. Some patients may have a low fever, and the course of the disease is relatively long (usually relieved within 12-24 hours).

It should be noted that not all Bacillus cereus strains can produce toxins; only some "toxigenic strains" are pathogenic. Therefore, the detection of Bacillus cereus in food does not necessarily mean that it will cause poisoning. A comprehensive judgment should be made based on the bacterial count and the strain's toxigenic ability [20].

4.2 Factors affecting pollution and pathogenicity

The degree of contamination of Bacillus cereus in food and whether it causes disease are influenced by multiple factors, mainly including:

Temperature: Temperature is a key factor influencing the growth and reproduction of Bacillus cereus. This bacterium can grow within the range of 10-48℃, with the optimal growth temperature being 25-37℃. At this temperature range, spores can rapidly germinate into vegetative cells and multiply in large numbers (for instance, at 30℃, the bacterial count can increase from 10^3 CFU/g to 10^6 CFU/g within 10 hours). However, when the temperature is below 4℃ or above 60℃, its growth is significantly inhibited (spores can survive but do not reproduce). Therefore, the prolonged storage of food at room temperature, especially during summer and autumn, is the main reason for the massive reproduction of this bacterium. Studies have shown that UHT heat treatment in dairy products can eliminate most Bacillus cereus, but it still cannot completely eradicate it [21]. Thus, it can be seen that Bacillus cereus has excellent heat resistance.

• pH Value: Bacillus cereus thrives in a neutral environment (pH 6.0-7.0). Its growth is inhibited when the pH is below 4.5 or above 9.0. Therefore, the risk of contamination by this bacterium in acidic foods (such as pickled foods in vinegar and citrus products) is relatively low. However, some weakly acidic foods (such as tomato products, with a pH of 4.5-5.5) may still be contaminated. pH and other factors also have a significant impact on Bacillus cereus in the aquatic field [22].

• Water activity (Aw): Water activity is an indicator of the available water in food. Bacillus cereus grows rapidly when Aw is above 0.85 [23], and its growth stops when Aw is below 0.93. Therefore, the risk of contamination by this bacterium in dry foods (such as biscuits and milk powder, where Aw is usually below 0.7) is relatively low, but high-moisture foods (such as rice and meat, where Aw is ⩾ 0.95) are more prone to contamination.

• The longer food is stored, the more opportunities for Bacillus cereus to multiply [24]. For instance, if rice is left at room temperature for 2 hours, the bacterial count may increase tenfold; if it is left for 4 hours, the count can increase by more than 100 times, reaching a pathogenic level.

• The processing technology: The intensity of heating during food processing directly affects the residual amount of Bacillus cereus. If the heating temperature is insufficient (such as rice not being thoroughly cooked) or the heating time is too short, it is impossible to kill the vegetative cells and spores, and the remaining spores are prone to germinate during subsequent storage; while cross-contamination after processing (such as contact with contaminated tools or containers) may lead to secondary contamination of food.

5 Prevention and control strategies for bacillus cereus in food

In view of the contamination characteristics and pathogenic mechanism of Bacillus cereus, it is necessary to take prevention and control measures throughout the entire chain of food production, processing, storage and consumption to reduce the risk of contamination.

5.1 Prevention and control in the food production process

• Raw material control: Select high-quality raw materials and reduce raw material contamination. Cereals, vegetables and other raw materials should avoid excessive contact with contaminated soil during planting and harvesting, and be dried and cleaned promptly after harvesting; meat raw materials should be purchased from regular channels to ensure that the slaughtering process is hygienic and standardized, and minimize initial contamination.

• Environmental and equipment disinfection: Food production workshops need to be regularly cleaned and disinfected. Surfaces such as the floor, walls, and operation tables can be wiped with chlorine-containing disinfectants (such as 84 disinfectant) to kill Bacillus cereus in the environment. Processing equipment (such as mixers and filling machines) should be thoroughly cleaned before and after use. If necessary, high-temperature sterilization (such as 121℃ high-pressure sterilization for 30 minutes) should be carried out to prevent cross-contamination caused by residual bacteria on the equipment.

• Process optimization: For high-risk foods such as rice and meat, optimize the heating process to ensure thorough heating - rice should be cooked thoroughly (with the core temperature reaching 100℃ and maintained for more than 10 minutes), and meat should be heated to a core temperature of over 70℃ and maintained for several minutes to maximize the elimination of vegetative cells (although spores are difficult to kill, the initial bacterial count can be reduced); for canned and other sealed foods, high-pressure sterilization can be used to completely kill spores.

5.2 Prevention and control in food storage links

• Temperature control: Strictly adhere to the temperature requirements for food storage. High-risk foods (such as rice, boxed meals, and meat products) that cannot be consumed immediately after processing must be refrigerated (temperature ⩽ 4℃) or kept warm (temperature ⩾ 60℃) within 2 hours to avoid being left in the "danger zone" of 10-60℃ for more than 2 hours. For refrigerated foods, maintain a stable temperature in the refrigerator and avoid frequent opening and closing to prevent temperature fluctuations.

• Storage time limit: Clearly define the storage time of food. Ready-to-eat food should not be stored at room temperature for more than 2 hours or in the refrigerator for more than 24 hours. Leftover food should be thoroughly reheated to a core temperature of 70°C and maintained for 2 minutes before consumption, provided it has not gone bad. However, it is not recommended to repeatedly refrigerate and reheat food.

5.3 Prevention and control in the food consumption link

• Household and catering unit precautions: When cooking at home, it is necessary to separate raw and cooked food, avoid using the same knives and cutting boards for raw meat, vegetables and cooked food; leftover food should be refrigerated in time and thoroughly reheated before consumption; when dining out, choose catering units with good hygiene conditions and avoid purchasing ready-to-eat food of unknown origin.

• Enhancing consumer awareness: Through popular science publicity (such as food safety manuals and short videos), raise consumers' understanding of Bacillus cereus, including its contamination risks and prevention methods (such as not consuming food that has been left at room temperature for too long), to reduce poisoning incidents caused by improper consumption habits.

5.4 Prevention and control in the inspection and supervision link

• Establish detection standards: Improve the detection standards for Bacillus cereus in food and clearly define the limit requirements for different foods for instance, as stipulated in GB 29921-2021《the National Food Safety Standard for the Limits of Pathogenic Bacteria in Prepackaged Foods in China》.The limit for Bacillus cereus in ready-to-eat cereal products is n=5, c=2, m=10^3 CFU/g, M=10^4 CFU/g) [25], providing a basis for supervision.

• Strengthen random inspection and monitoring: Market supervision departments regularly conduct random inspections on high-risk foods (such as boxed meals, rice, and meat products). Foods that are found to exceed standards are promptly removed from shelves and recalled, and the source of contamination is traced. Regular supervision is carried out on food production enterprises to urge them to fulfill their primary responsibility for food safety.

• Research and development of toxigenic strain identification technology: Develop rapid and accurate identification technologies for toxigenic strains of Bacillus cereus (such as PCR technology and immunochromatography), which not only detect the number of bacteria but also determine whether they are toxigenic strains, thereby enhancing the accuracy of risk assessment.

6 Conclusion and outlook

Bacillus cereus, as a common foodborne pathogen, poses a continuous threat to food safety due to its wide distribution, strong spore resistance and toxicity production, especially in grain products and ready-to-eat foods where the contamination risk is relatively high. Its pathogenic mechanism is mainly related to emetic toxins and enterotoxins, and the contamination and pathogenicity are affected by multiple factors such as temperature, pH value and storage time.

At present, through measures such as optimizing processing techniques, strictly controlling storage temperatures, and strengthening inspection and supervision, the risk of contamination can be effectively reduced. However, some challenges still remain: for instance, breakthroughs in spore-killing technology are needed (the current techniques are difficult to completely eliminate spores without affecting food quality), the popularization rate of rapid toxin-producing strain detection technology is relatively low, and consumers' awareness is insufficient.

In the future, it is necessary to further strengthen the basic research on Bacillus cereus (such as the mechanism of spore germination and the regulation of toxin synthesis), develop green and efficient spore-killing technologies (such as pulsed electric field and ultrasonic wave sterilization in combination), enhance the research on the application of gene editing technology in the identification of toxin-producing strains, promote the industrial application of rapid detection technology to achieve on-site rapid screening. At the same time, efforts should be made to increase food safety science popularization, and build a full-chain prevention and control system covering "production - supervision - consumption", so as to more effectively control the contamination of Bacillus cereus in food and ensure public food safety.

References

[1] Wang Y., Qiu J., Wu S., Zhai Y., Zhang J., Zhao R., & Yang D. (2025). Research on the pathogenic mechanism of Bacillus cereus. Journal of Animal Science and Veterinary Medicine, 44(04), 104-109.

[2] Glasset B., Herbin S., Guillier L., Cadel-Six S., Vignaud M. L., Grout J., Pairaud S., Michel V., Hennekinne J. A., Ramarao N., & Brisabois A. (2016). Bacillus cereus-induced food-borne outbreaks in France, 2007 to 2014: epidemiology and genetic characterisation. Euro surveillance.

[3] He Y., Qin Y., Lan C., Zeng C., Zheng Y., & Wu X. (2023). Synergistic inactivation of Bacillus cereus by curcumin and photodynamic therapy and its application in fermented bean curd. Food and Fermentation Industries, 1-8.

[4] Lu X., Cui C., Wang Y., & Zhu W. (2015). Research progress on Bacillus cereus food poisoning. Infectious Diseases Information, 28(4), 251-254.

[5] Fei Y., Li Y., Zhang N., Cui W., Tan Y., & Zhang X. (2025). Current status of Bacillus cereus contamination in food. Chinese Journal of Health Engineering, 24(02), 280-284.

[6] Yang G. (2014). Analysis of detection methods for Bacillus cereus in food. Food Safety Guide, (26), 63-65.

[7] Lu Z., Cui X., Wang D., Zhang Y., Duan J., & Zhao R. (2025). Contamination level and virulence gene distribution of foodborne Bacillus cereus in Beijing from 2021 to 2023. Journal of Hygiene Research, 54(04), 626-630.

[8] Ren F., Liu Y., Wang Y., Yang X., Qiao L., Liu Y., ... & Dong, Q. (2023). Research progress on biofilm formation and cereulide production of Bacillus cereus. Food and Fermentation Industries, 1-9.

[9] Xi S. (2023). Effects of environmental stress factors on the virulence gene expression and pathogenicity of Bacillus cereus from cattle (Master's Thesis, Inner Mongolia Minzu University).

[10] Xian J., & Li L. (2023). Research on the contamination status of Bacillus cereus in three types of traditional fermented foods. China Brewing, 42 (12), 33-37.

[11] Hui Guo, Pengfei Yu, Shubo Yu, Juan Wang, Junhui Zhang, Ying Zhang, Xiyu Liao, Shi Wu, Qinghua Ye, Xiaojuan Yang, Tao Lei, Haiyan Zeng, Rui Pang, Jumei Zhang, Qingping Wu & Yu Ding. (2021). Incidence, toxin gene profiling, antimicrobial susceptibility, and genetic diversity of Bacillus cereus isolated from quick-frozen food in China [J]. LWT, 140: 110824.

[12] Wang Jiyan. (2021). Investigation and Analysis of a Food Poisoning Incident Caused by Bacillus cereus. Journal of Applied Preventive Medicine, 27(03), 211-213.

[13] Ali S., Alsayeqh AF. (2022). Review of Major Meat-Borne Zoonotic Bacterial Pathogens [J]. Frontiers in Public Health, 10: 1045599.

[14] Liu Min, Xue Yanfei, Cao Binglei & Zhang Qun. (2021). Research Progress on Detection Techniques of Bacillus cereus Spores in Dairy Products. China Port Science and Technology, 3(12), 68-72.

[15] Guoping Zhou, Haizhou Liu, Jing He, Yongming Yuan & Zhiming Yuan. (2008). Occurrence of Bacillus cereus, B. thuringiensis and B. mycoides in Chinese Pasteurized Full-Fat Milk [J]. International Journal of Food Microbiology, 121(2): 195-200.

[16] Quan Fei, Fu Shiqi, Kang Ying, Yan Aixia, Wang Yuanyuan, Li Shoufei... & Li Ying. (2024). Detection and Antibiotic Resistance Characteristics of Bacillus cereus in Fresh Vegetables in a District of Beijing from May to September 2021. Chinese Journal of Food Hygiene, 36(01), 15-20.

[17] Qu Yang, Yang Zhengyang, Zhou Changyan, Lin Ting & Suo Yujian. (2024). Distribution of Virulence Genes and MLST Analysis of Bacillus cereus from Fresh Vegetables. Journal of Shanghai Agricultural Sciences, 40(03), 79-85.

[18] Fan Yongxiang & Liu Xiumei. (2006). Control of Foodborne Diseases and Food Safety Management in Catering. Foreign Medical Sciences (Hygiene Section), (03), 170-175.

[19] Kim J. B., Jeong H. R., Park Y. B., Kim J. M., & Oh D. H. (2010). Food poisoning associated with emetic-type of Bacillus cereus in Korea. Foodborne pathogens and disease, 7(5), 555-563.

[20] Zhou Shuang, Yang Ge & Zhang Lei. (2025). Research on the Counting Method of Non-pathogenic Contaminants in Bacillus cereus Tablets. Pharmaceutical and Clinical Research, 33(01), 35-38.

[21] Dalabasmaz S., Dittrich D., Kellner I., Drewello T., & Pischetsrieder M. (2019). Identification of peptides reflecting the storage of UHT milk by MALDI-TOF-MS peptide profiling. Journal of Proteomics, 207, 103444.

[22] Zhang Fuying & Li Xinfu. (1992). Research on the Effects of Low pH on the Embryonic Development of Fish, the Growth of Fry and the Damage to Gill Tissue. Acta Hydrobiologica Sinica, (02), 175-182 + 196.

[23] Xie Xiaoyan. (2024). The Impact of Environmental Factors on the Growth of Pathogenic Bacillus cereus in Food and Toxin Production. Food Industry, (12), 144-146.

[24] Wang Yangrui, Yuan Shuo, Bai Fengling, Tan Xianqian, Cui Fangchao, Lyu Xinran... & Dong Hao. (2025). The Preservative Effect of Bacillus cereus YF-2 on Chilled Salmon. Chinese Journal of Food Science, 25(01), 305-313.

[25] Zhang Weiwei, Lu Fei, Zhang Jinlan, Wang Jianming & Gao Lihua. (2010). Research Progress on Bacillus cereus in Food. China Brewing, (05), 1-4.