Vital Surveillances

Epidemiological Evaluation of *Bacillus cereus*-Induced Foodborne Outbreaks — China, 2010–2020

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ABSTRACT

Introduction: *Bacillus cereus* (*B. cereus*) is a common gram-positive bacterium that contaminates starch-rich food and can cause outbreaks of foodborne diseases. This study describes the characteristics of outbreaks caused by *B. cereus* in China during 2010–2020 and explore the possible reasons for changes in the number of outbreaks over time. Results of this analysis can efficiently help guide and allocate public resources to prevent *B. cereus*-caused foodborne diseases.

Methods: Descriptive statistical methods were used to analyze the data on *B. cereus* outbreaks in China during this period. The data were identified and reported at all levels in China through National Foodborne Disease Outbreak Surveillance System.

Results: From 2010 to 2020, a total of 419 foodborne outbreaks prompted by *B. cereus* were reported in China, leading to 7,892 cases, 2,786 hospital admissions, and 5 fatalities. The bulk of the outbreaks were recorded in the summer, primarily between May and September. The most recurrent food vehicle was linked with rice or flour-based products, notably those made with rice or fried rice. School canteens bore the brunt of the *B. cereus* outbreaks. In multifactor outbreaks, food contamination was identified as the most common culprit; while in instances where only one factor contributed, improper storage was most frequently implicated.

Conclusion: The prevalence of *B. cereus* outbreaks remained relatively consistent throughout the studied period. Understanding the types of foods, causative factors, and contributing elements leading to *B. cereus* outbreaks can help inform prevention strategies for foodborne illnesses. The majority of outbreaks were associated with rice- or flour-based foods in school canteens, suggesting contamination and improper storage during food preparation. Consequently, it is essential to prioritize continuous education for canteen staff on food safety, efficacious management, and proper practices. The implementation of comprehensive guidelines, encompassing multiple critical aspects, can potentially reduce the occurrence of *B. cereus* outbreaks.

Bacillus cereus (*B. cereus)* frequently contaminates food and functions as an opportunistic pathogen, leading to outbreaks of foodborne diseases (*1*–*2*). Over the past decade in China, it ranks as the fourth leading bacterial pathogen associated with foodborne outbreaks (*3*). *B. cereus* produces a spectrum of toxins that can be primarily classified into vomiting-type and diarrhea-type enterotoxins based on symptoms they cause (*4*–*5*). Its foodborne infections manifest as severe symptoms, such as nausea, vomiting, and diarrhea; in some instances, it can be fatal and typically presents sudden onset (*6*–*8*). Consequently, the results of our analysis can be efficiently utilized to direct and allocate public health resources to mitigate *B. cereus* associated foodborne diseases.

METHODS

Between 2010 and 2020, the National Foodborne Disease Outbreak Surveillance System was used by all sectors of CDC to document incidents of foodborne outbreaks. This study specifically collected data on outbreaks caused by *B. cereus*. Required data for each outbreak comprised of date of occurrence, geographical region, case count, number of hospitalizations and deaths, setting for food preparation, etiologic agents, and implicated food, among other factors. The population statistics were derived from the seventh national census conducted in 2020.

The National Foodborne Disease Outbreaks Surveillance System processed and disseminated all monitoring data. Data cleansing and database creation

were carried out using Microsoft Office (version 2010, Microsoft, Washington, USA), while SPSS (version 16.0, SPSS Inc, Chicago, USA) was employed for the related statistical analysis.

Correlational definitions:

An outbreak of foodborne illness is cited when two or more cases of the disease are documented.

The term "multifactor" is employed to represent the simultaneous presence of two or more elements of food contamination. These elements may include improper storage, contamination or spoilage of ingredients, cross-contamination between raw and cooked foods, and food expiration among others.

RESULTS

Between 2010 and 2020, we documented a total of 419 foodborne outbreaks attributed to *B. cereus*, resulting in 7,892 cases, 2,786 hospital admissions, and 5 fatalities.

Figure 1 illustrates the distribution of outbreak cases over a decade. In 2018, out of all reported outbreaks, 56 instances, constituting 13.37%, were noted, marking the highest count from 2010 to 2020. Notably, the year 2012 reported the most cases, with a sum of 979, constituting 12.40% of all instances. However, the year 2011 recorded the peak for hospitalization rate. The period from 2014 to 2016 experienced five fatalities: one in 2014, two in 2015, and the remaining two in 2016.

The frequency of reported outbreaks varied on a monthly basis (Figure 2), predominantly occurring between May and September. In June, 73 outbreaks were noted, comprising 17.42% of the total outbreaks. The peak in the number of cases was observed in September, with 1,975 cases recorded, affecting the greatest number of individuals (25.01%). The month of May reported the highest rate of hospitalizations (51.04%). Mortalities were relatively low, with two reported in February and one each in April, July, and August.

The data highlighted notable differences in the proportion of outbreak cases attributed to various food sources (Table 1). Foods derived from rice or flour were identified as the primary cause of most outbreaks (46.30%) and associated cases (40.81%). Bakery products were responsible for the highest hospitalization rate (67.78%). Furthermore, five mortalities were chiefly associated with rice or flour-based products and complex foods.

Upon conducting further analysis of each category of rice or flour products implicated in foodborne outbreaks associated with *B. cereus*, it was found that rice and rice products accounted for a higher number of outbreaks (158 outbreaks), compared to flour and flour products (36 outbreaks).

The number of outbreak instances was subject to variation based on the location of food preparation, as outlined in Figure 3. The primary source of these outbreaks, as well as the related cases, was found to be school cafeterias. In fact, 26.25% of outbreaks could be traced back to food prepared in these school canteens, accounting for 48.34% of cases associated with such

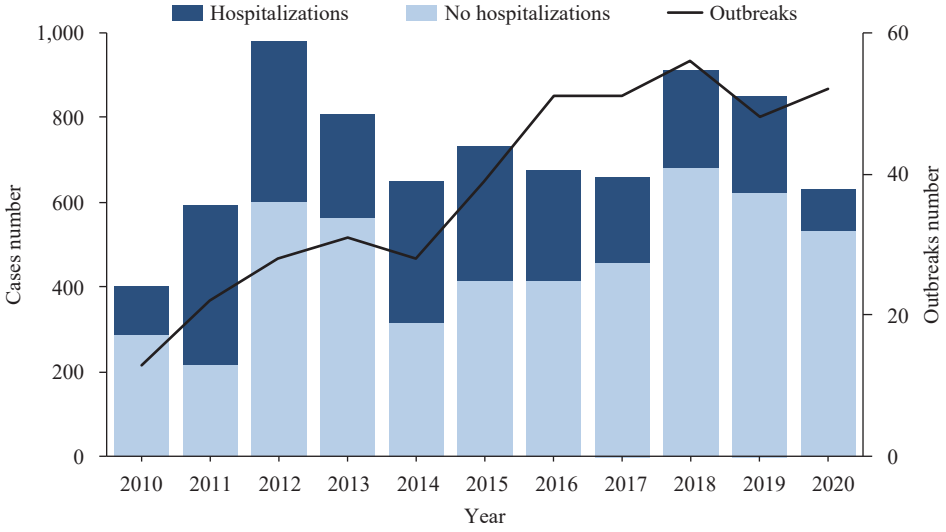

FIGURE 1. Annual distribution of foodborne outbreaks, instances, and hospitalizations attributed to *B. cereus* in China from 2010 to 2020.

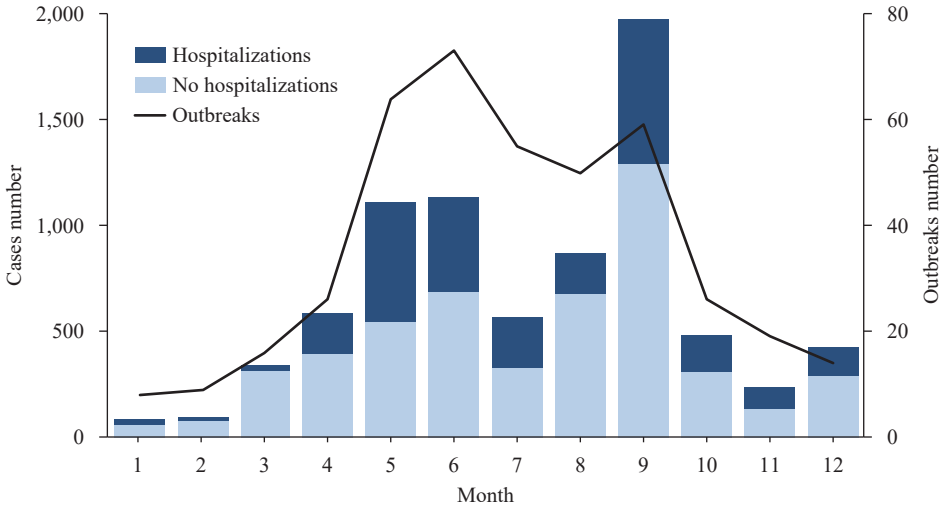

FIGURE 2. Monthly distribution of foodborne outbreaks, cases, and hospitalizations resulting from *B. cereus* in China from 2010 to 2020.

TABLE 1. Number and proportion of *B. cereus* foodborne outbreaks, incidents, hospitalization cases, and deaths organized by food category in China from 2010 to 2020.

Food category	Outbreaks		Cases		Hospitalizations		Deaths	
	Number	Proportion (%)[§]	Number	Proportion (%)[¶]	Number	Rate (%)[**]	Number	Fatality rate (%)[††]
Rice or flour	194	46.30	3,221	40.81	1,230	38.19	3	0.09
Complex food*	54	12.89	1,430	18.12	347	24.27	2	0.14
Multiple food[†]	51	12.17	1,174	14.88	353	30.07	0	0.00
Meat	29	6.92	398	5.04	251	63.07	0	0.00
Bean	21	5.01	630	7.98	275	43.65	0	0.00
Vegetable	17	4.06	237	3.00	68	28.69	0	0.00
Pastry	14	3.34	239	3.03	162	67.78	0	0.00
Aquatic animal	8	1.91	125	1.58	44	35.20	0	0.00
Beverage and frozen drink	5	1.19	57	0.72	11	19.30	0	0.00
Dairy	3	0.72	93	1.18	9	9.68	0	0.00
Fruit	2	0.48	26	0.33	0	0.00	0	0.00
Egg	2	0.48	8	0.10	0	0.00	0	0.00
Condiment	2	0.48	6	0.08	3	50.00	0	0.00
Other food	3	0.72	31	0.39	19	61.29	0	0.00
Unknown food	14	3.34	217	2.75	14	6.45	0	0.00
Total	419	100.00	7,892	100.00	2,786	35.30	5	0.06

* Complex food: These are items that contain multiple components, but the specific ingredient causing the outbreak cannot be accurately identified.
[†] Multiple food: The causative agent originates from diverse food categories.
[§] Proportion (%)=Outbreaks number/Total number×100%.
[¶] Proportion (%)=Cases number/Total number×100%.
[**] Rate (%)=Hospitalizations number/Cases number×100%.
[††] Fatality rate(%)=Deaths number/Cases number×100%.

outbreaks. However, the household held the record for the highest hospitalization rate at 53.92%, along with the highest mortality rate at 1.37%.

Multifactor contamination was identified as the cause for 39.14% of outbreaks and 41.02% of associated cases. This was closely followed by improper storage, accounting for 111 outbreaks (26.49%) and 1,981 cases (25.10%). The highest rate of

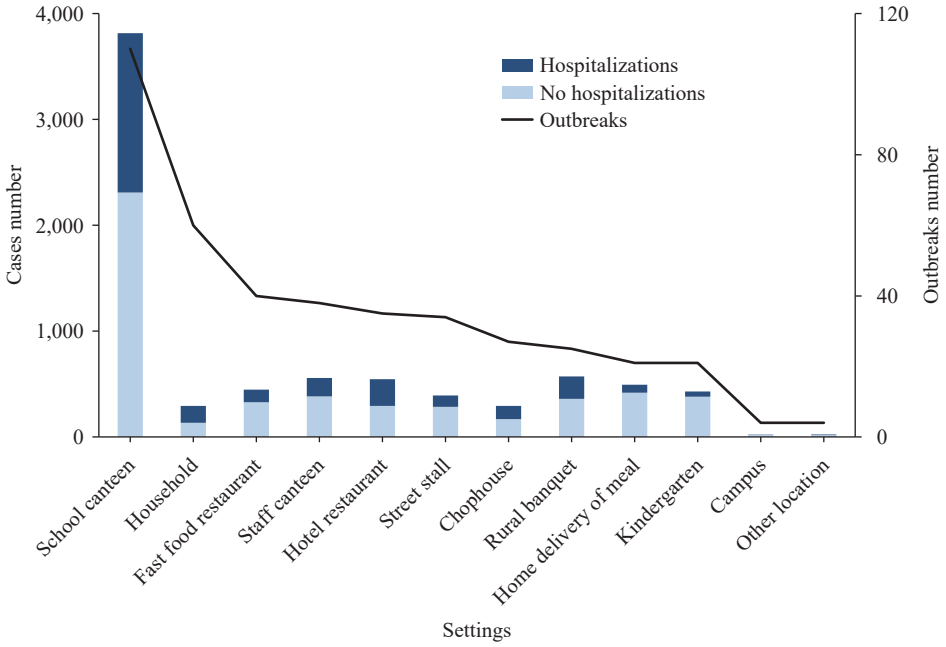

FIGURE 3. Distribution of foodborne outbreaks, cases, and hospitalizations caused by *B. cereus* in various settings in China from 2010–2020.

hospitalization was attributed to food mishandling and ingestion errors, which stood at 71.93%. Moreover, two out of the reported five fatalities were due to undetermined causes.

In the multifactor composition, the occurrence of two factors was most prevalent, accounting for 70.12% of the cases. Conversely, instances involving more than two factors represented 29.88% of the cases. Of the pairings in the two-factor configuration, the most frequent combination, comprising 48.78%, was inadequate storage and inappropriate processing. Meanwhile, the combination of ingredient contamination or spoilage with improper storage made up 9.76%. For configurations involving more than two factors, the most common trio was ingredient contamination or spoilage, inappropriate storage, and improper processing, which accounted for 53.33% of such cases.

DISCUSSION

From 2010 to 2020, microbial agents notably contributed to the incidence of foodborne disease outbreaks in China. These microbial outbreak cases were second only to mushroom poisoning in regards to the number of cases reported. This pattern supports previous studies (*9*), with *B. cereus* ranking fourth among factors associated with microbial foodborne disease outbreaks. However, the fatality rate associated with *B. cereus* was significantly higher compared to other contributing factors. Thus, increased vigilance towards outbreaks of *B. cereus* is highly recommended for relevant departments.

Between 2010 and 2016, China experienced a gradual increase in *B. cereus*-related outbreaks, which subsequently stabilized to approximately 50 outbreaks annually over the subsequent five years. Remarkably, 2018 saw the highest number of these reported outbreaks. The majority of these foodborne diseases related to *B. cereus* typically occurred between May and September, demonstrating a certain level of annual consistency. Notably, the majority of these incidents were reported during the summer, followed by the spring and fall. Attributable to its optimal growth temperature (28–35 °C), *B. cereus* has the potential to proliferate rapidly and generate substantial quantities of toxins, thereby inducing foodborne cases, according to a previous study (*2*). This trend substantiates that the *B. cereus* poisoning peak season is typically the summer. Domestic and international studies (*10*–*11*) further reveal that the most pathogenic food in *B. cereus* outbreaks is primarily rice or flour products, representing nearly half of all categories. Moreover, the proportion of rice and rice products in all types of rice or flour products exceeds 80%. Further breakdown showed that rice and fried rice constituted 36% and 33% within the category of rice and rice products, respectively.

School canteens and households appeared most frequently as sources of food preparation connected to *B. cereus* outbreaks. Nevertheless, the number of instances linked to food prepared in school canteens was markedly greater than those connected to households, constituting nearly half of all affected cases. Given the difficulties students face in discerning food quality and the inherent nature of communal dining in schools, they are at a heightened risk for foodborne disease outbreaks. Therefore, to mitigate the frequency of such outbreaks, supervisory bodies should enhance their oversight and management of food safety in school canteens.

Food contamination is influenced by a myriad of complex factors. Our findings are consistent with prior research (*12*–*13*), revealing that the simultaneous or interactive presence of several factors is most often the cause of food contamination. For instance, improper handling, excessive propagation, and subsequent toxin secretion due to inadequate preservation can result in contamination by *B. cereus*. To mitigate the risk of foodborne outbreaks attributed to *B. cereus*, it is essential to address a multitude of core control and management factors. These include utilizing safe food ingredients, ensuring cleanliness and standardization throughout the food processing procedure, preventing cross-contamination, thoroughly cooking the food, among others. Concurrently, implementing proper preservation to inhibit the growth of *B. cereus* is of great significance.

This study focuses solely on outbreaks investigated by the China CDC, which may not accurately reflect the true incidence. Monitoring foodborne disease outbreaks is a multifaceted endeavor necessitating government support, swift diagnosis from medical institutions, thorough food hygiene assessments by the Market Supervision and Administration Department, diligent epidemiological inquiry by the CDC, and exact laboratory testing.

Acknowledgements: All members of all participating CDCs.

Conflicts of interest: No conflicts of interest.

Funding: The National Key Research and Development Program of China (2022YFC2602303, 2021YFF0703804, 2017YFC1600100) and the Research Project on Health Policy of Shanghai (2021HP10).

doi: 10.46234/ccdcw2023.140

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Submitted: May 24, 2023; Accepted: August 13, 2023

REFERENCES

1. Zhou GP, Liang TG, Ding SJ. Analysis on 299 *Bacillus cereus* food poisoning cases in 1986–2007. Chin J Food Hyg 2009;21(5):450 – 4. http://dx.doi.org/10.13590/j.cjfh.2009.05.012. (In Chinese).
2. Wang XR, Huang Q. Reseach progress in prediction models and risk assessment of *Bacillus cereus* contamination in food. Chin J Food Hyg 2022;34(6):1366 – 74. http://dx.doi.org/10.13590/j.cjfh.2022.06.040. (In Chinese).
3. Li WW, Pires SM, Liu ZT, Ma XC, Liang JJ, Jiang YY, et al. Surveillance of foodborne disease outbreaks in China, 2003-2017. Food Control 2020;118:107359. http://dx.doi.org/10.1016/j.foodcont.2020.107359.
4. Kobayashi A, Higashi H, Shimada T, Suzuki S. Baseline and seasonal trends of *Bacillus cereus* and *Bacillus subtilis* from clinical samples in Japan. Infect Prev Pract 2023;5(2):100272. http://dx.doi.org/10.1016/j.infpip.2023.100272.
5. Yang S, Wang YT, Liu YT, Jia K, Zhang Z, Dong QL. Cereulide and emetic *Bacillus cereus*: characterizations, impacts and public precautions. Foods 2023;12(4):833. http://dx.doi.org/10.3390/foods12040833.
6. Yu B, Li FL, Zhao TC, Li F, Zhou BQ, Xu HY. Hybridization chain reaction-based flow cytometric bead sensor for the detection of emetic *Bacillus cereus* in milk. Sens Actuators B: Chem 2018;256:624 – 31. http://dx.doi.org/10.1016/j.snb.2017.09.199.
7. Ren BB, Lasam G. A rare case of native mitral valve *Bacillus cereus* endocarditis culminating into a cerebrovascular infarction. Cardiol Res 2018;9(3):173 – 5. http://dx.doi.org/10.14740/cr672w.
8. European Food Safety Authority. Opinion of the scientific panel on biological hazards (BIOHAZ) on *Bacillus cereus* and other *Bacillus* spp in foodstuffs. EFSA J 2005;3(4):175. http://dx.doi.org/10.2903/j.efsa.2005.175.
9. Liu JK, Bai L, Li WW, Han HH, Fu P, Ma XC, et al. Trends of foodborne diseases in China: lessons from laboratory-based surveillance since 2011. Front Med 2018;12(1):48 – 57. http://dx.doi.org/10.1007/s11684-017-0608-6.
10. Wang J. Study on contamination distribution and genetic diversity of *Bacillus cereus* isolated from food in China. Guangzhou: Guangdong University of Technology; 2013. http://dx.doi.org/10.7666/d.Y2305299. (In Chinese).
11. Zheng JH, Li GH, Lu JJ. Investigation on a food poisoning caused by *Bacillus cereus*, Tai'an city, 2021. Prev Med Trib 2022;28(4):305 – 7. http://dx.doi.org/10.16406/j.pmt.issn.1672-9153.2022.04.016. (In Chinese).
12. Ankolekar C, Rahmati T, Labbé RG. Detection of toxigenic *Bacillus cereus* and *Bacillus thuringiensis* spores in U.S. rice. Int J Food Microbiol 2009;128(3):460 – 6. http://dx.doi.org/10.1016/j.ijfoodmicro.2008.10.006.
13. Lu XH, Cui C, Wang YP, Zhu WP. Research progress of *Bacillus cereus* foodborne diseases. Infect Dis Inf 2015;28(4):251 – 4. http://dx.doi.org/10.3969/j.issn.1007-8134.2015.04.017. (In Chinese).