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RESEARCH ARTICLE

Bacillus cereus in rice: A review on food poisoning, antimicrobial resistance, and control measures

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ABSTRACT

Rice is often associated with *Bacillus cereus* (*B. cereus*) food poisoning. This review aims to explore the food poisoning activity, antimicrobial resistance, and control measures of *B. cereus* in rice from 1974 to October 2023. We searched for eligible studies from the PubMed database based on explicit criteria following the PRISMA checklist. A total of 117 articles were collected, and the final analysis included 29 studies. Quality appraisal was performed using AMSTAR 2, SANRA 2, and Critical Appraisal Tool standards. *B. cereus* can grow and multiply in food to cause emetic vomiting or diarrheal syndrome. The primary etiology of *B. cereus* contamination is improper food handling and storage temperature during the cooking, cooling, and reheating stages of rice. The alarming rise of antimicrobial resistance in *B. cereus* to beta-lactam antibiotics necessitates alternatives from natural antimicrobial preservatives such as carvacrol, chitosan, or trans-cinnamaldehyde to prevent microbial infestation and toxin production. Implementing food safety strategies tailored to specific food settings, such as restaurants and factory-manufactured ready-to-eat rice, is critical for preventing food contamination by *B. cereus*. Given the heat-resistant spores and intoxication properties of *B. cereus*, it is important to develop effective interventions and hygienic protocols from farm to fork.

Keywords: *Bacillus cereus*; rice; food poisoning; antimicrobial resistance; control measure.

INTRODUCTION

Rice (*Oryza sativa*) is a staple food for more than half of the world's population. Rice production and consumption are among the highest in Asian populations, where 50% of them are from China and India (Muthayya *et al*., 2014). Rice can be processed in different ways (cooking, steaming, parboiling, instant, or ground) into fried rice, rice flour, pasta, or cookies. In general, starchy foods such as rice are common vehicles for *B. cereus* food poisoning (Albaridi, 2022). *B. cereus* is the main causative agent of "fried rice syndrome" because once cooked rice is left at room temperature for a few hours, the humidity of the substrate reaches water activity levels suitable for contamination by this foodborne pathogen, causing food poisoning if consumed (Leong *et al*., 2023).

Every year, unsafe food causes 600 million cases of foodborne illness and 420,000 deaths (WHO, 2015; Lee & Yoon, 2021; Dattani *et al*., 2023). *B. cereus* food poisoning has been reported in many countries, including China (Ming *et al*., 2021; Li *et al*., 2023), Singapore (Rusnan *et al*., 2020), France (Glasset *et al*., 2016), Australia (Thirkell *et al*., 2019), and Malaysia (Leong *et al*., 2023). Changes in eating habits, feeding large populations, complex compounds and long-term storage, increased international food exchanges, and inadequate hygiene practices are major risk factors for foodborne contamination (Rahnama *et al*., 2023). The occurrence of *B. cereus* food poisoning incidents offers a complex and diverse dilemma that requires a thorough and all-encompassing examination.

B. cereus is a Gram-positive, aerobic-to-facultative, motile, and spore-forming bacterium that grows at a broad pH range of 4.5 to 9.5, a minimum water activity (a_w) for growth of 0.93, a wide range of temperatures from 4°C to 48°C, and a concentration of NaCl as high as 7% (Rodrigo *et al*., 2021). It is distinguished by large rod-shaped cells capable of forming heat-resistant endospores and producing a variety of toxins to cause two of the most typical gastrointestinal illnesses: emetic (vomiting) syndrome and diarrheal syndrome (Ash *et al*., 1991; Jovanovic *et al*., 2021; Darwish *et al*., 2022). *B. cereus* can colonize the gastrointestinal tracts of both susceptible humans and animals as opportunistic infections such as bacteremia, endophthalmitis, and serious systemic infections (Callegan *et al*., 2006; Jessberger *et al*., 2020).

Antimicrobial resistance is a major 21st century global health challenge. It is estimated to kill 10 million people by the year 2050 (O'Neill, 2014; Murray *et al*., 2022). *B. cereus* produces beta-lactamase enzymes which is typically resistant to penicillin (Hill *et al*., 1980; Tooke *et al*., 2019), and has acquired resistance to other commonly used antibiotics such as ciprofloxacin, cloxacillin, erythromycin, tetracycline, and streptomycin (Luna *et al*., 2007). Due to its abundant growth in a wide range of ecological settings and endospore formation, *B. cereus* exhibits a great degree of resilience to unfavorable conditions, including starvation, extreme heat, ionizing radiation, mechanical abrasion, chemical solvents, detergents, desiccation, pH extremes, and hydrolytic enzymes (Nicholson *et al*., 2000). Their ability to form biofilm enables bacterial cells to adhere to stainless steel surfaces and even resistant spores are protected from high-heat food processing methods such as drying, pasteurization, etc. (Chemat *et al*., 2017; Pereira & Sant'Ana, 2018), making it extremely hard to eliminate *B. cereus* contamination in food (Kotiranta *et al*., 2000; Samapundo *et al*., 2011; Smith *et al*., 2004).

As the risk of *B. cereus* in rice is a serious food safety issue, this review aims to investigate the food poisoning activity of *B. cereus* linked to rice, its current antimicrobial resistance, as well as different control measures for *B. cereus* in different food settings.

METHODS

Databases and search strategy

We conducted a comprehensive literature search according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page *et al*., 2021). A comprehensive search was conducted using PubMed between 1974 and October 2023, which focused on the five key concepts including temperature, rice, food poisoning, antimicrobial resistance, and control measures. PubMed Search Builders were created using the Boolean scheme (Table 1). We pooled all keywords using the Boolean term "OR" and combined their corresponding search builders that we obtained from PubMed using MeSH terms. We applied restrictions to MeSH-major topics, by using the Boolean operator "AND" in all concepts and keywords that were merged to create the final search strategy (Table 2). All articles were collected using the software Endnote. Two independent researchers reviewed the articles separately to minimize possible errors.

Inclusion and exclusion criteria

The literature search was conducted to identify relevant studies that examine the food poisoning characteristics and mechanisms, microbial enzyme activities under heat treatment, the standpoint of microbiological risk assessment, antimicrobial resistance, and control measures of *B. cereus*. We excluded studies in languages other than English due to an absence of translational resources. Studies in unpublished literature, irrelevant, non-full-text, case-report, editorials, and non-English reports were excluded.

Screening and quality appraisal

After obtaining the relevant articles from the database, we further screened the articles based on the title, abstract, and full-text articles. We then assessed all short-listed articles for quality and risk of bias using Scale for the Assessment of Narrative Review Articles 2 (SANRA 2) (Baethge *et al*., 2019), Assessing the Methodological Quality of Systematic Reviews (AMSTAR 2) (Pizarro *et al*., 2020), and the Critical Appraisal Tool (Public Health Agency of Canada, 2014), depending on the study type. Each assessment tool had its own criteria with different levels of acceptance scoring.

RESULTS

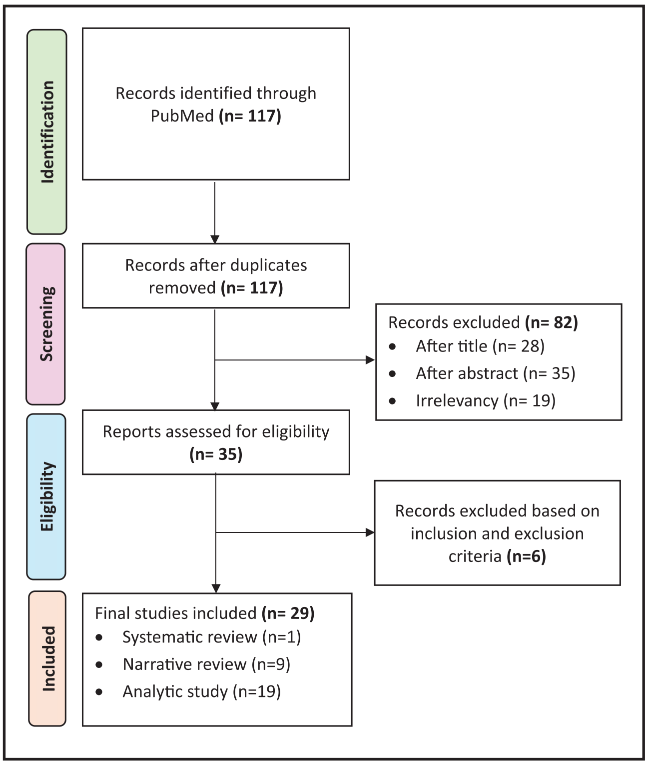
The flowchart illustrates our search strategy and selection process for the final studies (Figure 1). A total of 117 studies were extracted from the database. No duplicate cases were identified before the screening process. We removed 63 articles based on their titles and abstracts. Subsequently, we retrieved 54 articles to assess the full text for relevancy and screened 35 articles for eligibility. Finally, the data included 29 articles for in-depth analysis of quality. Two researchers conducted the data extraction and appraised the studies

Table 1. Bibliographic search strategy

Concept	Keywords	PubMed search builder
Inherent behavior of *Bacillus cereus*	*Bacillus cereus*, sporulation, temperature, storage temperature, reheating temperature, germination	Bacillus cereus/sporulation [MeSH Terms]) OR (Bacillus cereus/temperature [MeSH Terms])) OR (Bacillus cereus/storage temperature [MeSH Terms])) OR (Bacillus cereus/reheating temperature [MeSH Terms])) OR (Bacillus cereus/germination [MeSH Terms])
Food source of *Bacillus cereus*	*Bacillus cereus*, food, rice	(Bacillus cereus/food [MeSH Terms]) OR (Bacillus cereus/rice [MeSH Terms]))
Bacterial food poisoning	*Bacillus cereus*, food poisoning, infection, toxicoinfection, emetic, diarrheal, syndrome	(Bacillus cereus/food poisoning [MeSH Terms]) OR (Bacillus cereus/infection [MeSH Terms])) OR (Bacillus cereus/toxicoinfection [MeSH Terms])) OR (Bacillus cereus/emetic [MeSH Terms])) OR (Bacillus cereus/diarrheal [MeSH Terms])) OR (Bacillus cereus/syndrome [MeSH Terms])
Antimicrobial resistance and control measure	*Bacillus cereus*, antimicrobial resistance, analysis, drug effects, prevention and control, therapy	(Antimicrobial resistance/analysis [MeSH Terms]) OR (Antimicrobial resistance/drug effects [MeSH Terms])) OR (Antimicrobial resistance/prevention and control [MeSH Terms])) OR (Antimicrobial resistance/therapy [MeSH Terms])) OR (Antimicrobial resistance/Bacillus cereus [MeSH Terms])

Table 2. MeSH strategy and corresponding filters

Full MeSH strategy	Number of articles
(Bacillus cereus/temperature[MeSH Terms]) OR (Bacillus cereus/storage temperature[MeSH Terms])) OR (Bacillus cereus/reheating temperature[MeSH Terms])) AND (Bacillus cereus/rice[MeSH Terms])) AND ((Bacillus cereus/food poisoning[MeSH Terms]) OR (Bacillus cereus/toxic[MeSH Terms])) OR (Bacillus cereus/ toxicinfection[MeSH Terms])) OR (Bacillus cereus/emetic[MeSH Terms])) OR (Bacillus cereus/diarrheal[MeSH Terms])) OR (Bacillus cereus/syndrome[MeSH Terms]))) AND ((Antimicrobial resistance/analysis[MeSH Terms]) OR (Antimicrobial resistance/drug effects[MeSH Terms])) OR (Antimicrobial resistance/prevention and control[MeSH Terms])) OR (Antimicrobial resistance/therapy[MeSH Terms])) OR (Antimicrobial resistance/Bacillus cereus[MeSH Terms])	117 articles are obtained after applying filters (filters: articles published in the English language and published in free full text)



Figures 1. Flow diagram of the literature search and selection of eligible studies.

independently. Any disagreement was subject to consensus within the group and writing committee.

We evaluated one systematic review article (Mengistu *et al*., 2022) using AMSTAR 2 criteria with a passing score of 60% as our cut-off for acceptance (Table 3). We used SANRA 2 criteria to assess the nine narrative review articles with a passing score of 70% were utilized as the cut-off for acceptance (Table 4). A total of 19 analytic articles were assessed by the Critical Appraisal Tool (Table 5). After quality assessment, we summarized these articles, including their titles, author and year, study design, relevancy, and conclusion (Table 6).

DISCUSSION

B. cereus food poisonings were reported in different studies on a wide range of food types, including cooked meat, processed meat products, vegetables, rice, cereals, starchy food, dairy products, ready-to-eat foods, and confections (Rahnama *et al*., 2023). Among all food types, rice and rice products are the main vehicles for *B. cereus* food poisoning (Rodrigo *et al*., 2021; Leong *et al*., 2023; Rahnama *et al*., 2023). Rice is one of the most widely consumed cereals, feeding more than 3.5 billion people worldwide, particularly in Asia, Latin America, and parts of Africa (Albaridi, 2022). Since these regions are considered warmer climates and their room temperature may reach 37°C, inadequate preparation and improper storage temperature of rice, e.g., keeping cooked rice leftovers at room temperature can be very risky for *B. cereus* food poisoning (Memish *et al*., 2014; Albaridi, 2022).

Table 3. Quality assessment of systematic review using AMSTAR 2

	AMSTAR 2 criteria	(Mengistu *et al*., 2022)
1.	Did the research questions and inclusion criteria for the review include the components of PICO?	Yes
2.	Was an "a priori" design implemented?	No
3.	Did the review authors explain their selection of the study designs for inclusion in the review?	Yes
4.	Did the review authors use a comprehensive literature search strategy?	Yes
5.	Did the review authors perform study selection in duplicate?	Yes
6.	Did the review authors perform data extraction in duplicate?	Yes
7.	Did the review authors provide a list of excluded studies and justify the exclusions?	Yes
8.	Did the review authors describe the studies included in adequate detail?	No
9.	Did the review authors use a satisfactory technique for assessing the risk of bias in individual studies that were included in the review?	Yes
10.	Did the review authors report on the sources of funding for the studies included in the review?	Yes
11.	If a meta-analysis was performed, did the authors use appropriate methods to statistically combine results?	Yes
12.	If a meta-analysis was performed, did the review authors assess the potential impact of risk of bias in individual studies on the results of the meta-analysis or other evidence synthesis?	No
13.	Did the review authors account for risk of bias in individual studies when interpreting/discussing the results of the review?	No
14.	Did the review authors provide a satisfactory explanation for and discussion of any heterogeneity observed in the results of the review?	Yes
15.	If they performed quantitative synthesis, did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its impact on the results of the review?	No
16.	Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	Yes
Total score (out of 16)		11 (68.8%)*
Overall methodological quality		Moderate

Yes= 1 point; No= 0 point.
*60% or above cut-off as the threshold for acceptance.

Table 4. Quality assessment of narrative reviews using SANRA2

	Justification of importance for readership	Statement of aims/formulation of questions	Description of literature search	Referencing	Scientific reasoning	Appropriate presentation of data	Total score (out of 12)*
(Bottone, 2010)	2	2	2	1	2	2	11 (91.7%)
(Dietrich *et al*., 2021)	1	1	1	2	2	2	9 (75.0%)
(Jessberger *et al*., 2020)	2	2	2	1	2	2	11 (91.7%)
(Jovanovic *et al*., 2021)	2	2	1	2	2	2	10 (83.3%)
(Rodrigo *et al*., 2021)	2	2	2	2	1	2	11 (91.7%)
(Smelt *et al*., 2002)	2	1	2	1	2	2	10 (83.3%)
(Ceuppens *et al*., 2011)	2	2	1	2	1	2	10 (83.3%)
(Lotte *et al*., 2022)	1	2	1	2	2	2	10 (83.3%)
(Stenfors Arnesen *et al*., 2008)	2	1	2	2	1	2	10 (83.3%)

SANRA2 scoring of 0= low standard; 1= moderate standard; 2= high standard.
*****70% or above cut-off as the threshold for acceptance.

Due to the inherent characteristic of *B. cereus*, the heat-resistant spores can facilitate their survival capability if rice is stored within the temperature-dangerous zones (between 10°C and 60°C) during cooking, cooling, and reheating for several hours, allowing *B. cereus* to reach >10^6 cells/g (Rodrigo *et al*., 2021; Albaridi, 2022; Darwish *et al*., 2022; Griffiths & Schraft, 2017; Owusu *et al*., 2023). As a result, *B. cereus* can contaminate the rice to cause foodborne intoxications and toxicoinfections in a susceptible host (Jovanovic *et al*., 2021; Darwish *et al*., 2022). Foodborne intoxications are diseases caused by the ingestion of preformed toxins in food by microorganisms, whereas foodborne toxicoinfections are another type of food poisoning caused by the ingestion of large numbers of pathogenic bacteria capable of releasing toxins in the gastrointestinal tracts (Darwish *et al*., 2022). Emetic (vomiting) syndrome and diarrheal syndrome are the two most encountered in *B. cereus* foodborne-related illnesses, depending on the context in which it grows (Griffiths & Schraft, 2017; Darwish *et al*., 2022).

The emetic form of *B. cereus* is a type of foodborne intoxication. Its acute attack is characterized by nausea and vomiting with the absence of diarrhea within 1 to 4 hours post-ingestion of contaminated foods when the bacteria reach 10^5 to 10^8 CFU/g (Ehling-Schulz *et al*., 2004; Stenfors Arnesen *et al*., 2008). Starchy foods with improper refrigeration, such as fried rice, pasta, and noodles have the most frequent implications. Cereulide is an emetic toxin produced by *B. cereus* when the pH, water activity, and temperature are optimal. This toxin is highly hydrophobic, so it must either bind to target cells or dissolve in foodborne vehicles to cause food poisoning (Agata *et al*., 1994; Rouzeau-Szynalski *et al*., 2020). Cerulide-induced emetic syndrome is usually self-limiting and has a short duration. However, it can damage the mitochondrial transmembrane potential and ionic cell equilibrium by crossing the blood-brain barrier and causing cell death, which can have an immediate effect on the central nervous system (Bauer *et al*., 2018). The second form of *B. cereus* diarrheal syndrome is a slow-onset foodborne toxicoinfection frequently associated with processed meat, vegetables, soup, and fish (Jessberger *et al*., 2020). It is caused by the consumption of foods containing potentially dangerous levels of *B. cereus* where 10^5 to 10^8 cells multiply and produce various heat-labile enterotoxins in the small intestine (Granum & Lund, 1997). These enterotoxins include cytotoxin K (cytK), non-haemolytic enterotoxin (NHE), and hemolysin BL (HBL) (Granum & Lund, 1997; Moravek *et al*., 2006). When the bacteria reach incubation after 8 to 16 hours, the infected host responds with major abdominal pain and watery diarrhea (Stenfors Arnesen *et al*., 2008).

Antimicrobial resistance of *B. cereus* in rice can have far-reaching consequences for public health, especially when it comes to the consumption of rice and starchy foods (Rodrigo *et al*., 2021). The resistance of *B. cereus* to antimicrobial drugs can complicate the choice of treatment and increase the risk of severe infections. Through horizontal gene transfer between the environment and plant- or human-associated bacteria, drug-resistant *B. cereus* strains can transfer their resistance genes to other pathogens (Larsson & Flach, 2022). This may increase the possibility of treatment failures and the emergence of multidrug-resistant bacteria by facilitating the spread of antibiotic resistance through the food chain. The presence of transposon and plasmid, two mobile genetic elements in *B. cereus*, facilitates the uptake and transfer of resistance genes from the environment, leading to novel resistance phenomena characterized by increased multidrug resistance (Fiedler *et al*., 2019). *Bacillus cereus* group strains are known to be typically resistant to beta-lactam antibiotics as a result of the production of beta-lactamase enzymes. *B. cereus* can produce a variety of beta-lactamases that confer ampicillin resistance by degrading the beta-lactam ring structure of ampicillin and penicillin and rendering them inactive (Hall & Barlow, 2004). This was confirmed in many studies that a significant amount of *B. cereus* (>90%) resistant to ampicillin and penicillin (Owusu-Kwarteng *et al*., 2017; Tatsinkou Fossi *et al*., 2017; Yu *et al*., 2019; Navaneethan & Effarizah, 2021). On the other hand, studies have demonstrated that *B. cereus* is susceptible to antibiotics such as fluoroquinolones, aminoglycosides, imipenem, vancomycin, and chloramphenicol (Farida *et al*., 2018; Mei *et al*., 2021; Rajalingam *et al*., 2022). Understanding the antibiotic resistance profile of *B. cereus* is crucial to guiding appropriate therapeutic approaches and implementing effective control measures to combat this pathogen. Antibiotic overuse and misuse in agriculture can lead to the emergence of multidrug-resistant *B. cereus* via antibiotic-treated animal manure or contaminated irrigation water, and wastewater and sewage treatment plants are reservoirs for antibiotic-resistance genes and multidrug-resistant bacteria (Beattie *et al*., 2020; Chinivasagam *et al*., 2021; Samreen *et al*., 2021). If untreated wastewater is released improperly, resistant *B. cereus* has the potential to contaminate lakes, rivers, and other drinking water supplies and may infect nearby habitats and ecosystems (Hiller *et al*., 2019).

Foodborne infections, particularly those caused by bacteria, fungus, and their accompanying toxins, are a major concern for the food industry today. Several strategies can be used to prevent and control *B. cereus* contamination and rice-associated foodborne illnesses, depending on where the rice is produced and served.

Table 5. Quality assessment of analytical study using Critical Appraisal Tool

	Study design	Assessment of sample and method		Assessment of internal validity				Assessment for control of confounding		Ethics	Assessment for control of analysis		Assessment of applicability		Overall conclusion
	Research question	Study samples of target population	Adequacy of control selection bias	Adequacy of control of misclassification bias	Adequacy of control of information bias	Validity and reliability of data collection instruments	Adequacy of retention and follow-up	Comparability of control group and intervention group	Adequacy of control of major confounders	Adequacy of ethical conduct	Adequacy and interpretation of statistical testing	Power and sample size	Generalizability of results	Feasibility of implementation	
(Agata *et al*., 1995)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Artawinata *et al*., 2023)	Strong	Moderate	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Catania *et al*., 2023)	Strong	Moderate	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Cetin-Karaca & Newman, 2018)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Choma *et al*., 2000)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Moderate	Moderate	Moderate	High
(Fangio *et al*., 2010)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Moderate	Strong	Strong	High
(Fiedler *et al*., 2019)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Gilbert *et al*., 1974)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Harada & Nascimento, 2021)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Ibrahim *et al*., 2022)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Mellegård *et al*., 2011)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Moderate	Strong	High
(Mills *et al*., 2022)	Strong	strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Moderate	Moderate	Moderate	High
(Reddy *et al*., 2021)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Sturmer *et al*., 2022)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Ultee *et al*., 2000)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Guinebretière *et al*., 2013)	Strong	strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Navaneethan & Effarizah, 2021)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Pina-Pérez *et al*., 2009)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Strong	High
(Valdez *et al*., 2022)	Strong	Strong	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Moderate	Strong	Moderate	Strong	Moderate	Moderate	High

Table 6. Summary of included articles

Article titles	Author and year	Study design	Relevancy	Conclusion
A novel dodecadepsipeptide, cereulide, is an emetic toxin of *Bacillus cereus*	(Agata *et al*., 1995)	Analytic research	Food poisoning activity	The article investigated the emetic effect of cereulide in *Suncus murinus* (a new animal model of emesis). The article also demonstrated that cereulide-induced emesis in *Suncus murinus* through oral administration and intraperitoneal injection. The article also explored the impact of cereulide on vacuole formation.
Isolation and characterization of bacteriophages from soil against food spoilage and foodborne pathogenic bacteria	(Artawinata *et al*., 2023)	Analytic research	Food poisoning activity and antimicrobial resistance	The article proved that using bacteriophages could reduce bacterial contamination such as *Bacillus cereus* in food without altering the properties of food. The article suggested that bacteriopaghes would have the potential to be used in the food industry to reduce the risk of foodborne illness.
Evaluation of the biofilm-forming ability and molecular characterization of dairy *Bacillus* spp. isolates	(Catania *et al*., 2023)	Analytic research	Food poisoning activity	The study stated that management of microbial contamination was crucial in dairy products as *B. subtilis* and *B. cereus* were still able to produce biofilm after heat treatments, while *B. subtilis* produced a more robust biofilm than *B. cereus* which could be correlated with the presence of biofilm. They were also affected by cell surface properties. The article also stated that biofilm produced by *Bacillus* spp. in pipelines and tanks during the production of dairy production would be a big threat as they were resistant to normal cleaning agents.
Antimicrobial efficacy of phytochemicals against *Bacillus cereus* in reconstituted infant rice cereal	(Cetin-Karaca & Newman, 2018)	Analytic research	Food poisoning activity and antimicrobial resistance	Trans-cinnamaldehyde is shown to inhibit *B. cereus* spores' growth and serves as a potential natural preservative.
Prevalence, characterization, and growth of *Bacillus cereus* in commercial cooked chilled foods containing vegetables	(Choma *et al*., 2000)	Analytic research	Control measurements	It is observed that *B. cereus* was unable in temperatures below 7 °C, however, *B. cereus* was able to grow at 10°C.
Isolation and identification of *Bacillus* spp. and related genera from different starchy foods	(Fangio *et al*., 2010)	Analytic research	Food poisoning activity	*Bacillus* spp. was indicated in starchy vegetables dude to reside on the vegetables' surface.
Antibiotics resistance and toxin profiles of *Bacillus cereus*-group isolates from fresh vegetables from German retail markets	(Fiedler *et al*., 2019)	Analytic research	Food poisoning activity, control measurements and antimicrobial resistance	It was observed that the *B. cereus* in vegetables in Germany was too low to cause toxin production and foodborne illness. Storage temperature was correlated with a higher risk of contamination. It also strengthens the antibiotic resistance break against *B. cereus*.
The survival and growth of *Bacillus cereus* in boiled and fried rice in relation to outbreaks of food poisoning	(Gilbert *et al*., 1974)	Analytic research	Control measurements	It indicated that the optimal temperature for *B. cereus* in boiled rice to grow was 30°C to 37°C and 15°C to 43°C in storage respectively. It is suggested that boiling smaller quantities of rice and keeping the rice hot cooling the rice quickly and transfer to the refrigerator under two hours after boiling would further prevent the outbreak.
Effect of dry sanitizing methods on *Bacillus cereus* biofilm	(Harada & Nascimento, 2021)	Analytic research	Food poisoning activity and control measures	The study showed the effectiveness of dry sanitizing treatments against *B. cereus*. It indicates that dry sanitizing methods were not as effective as sodium hypochlorite against *B. cereus* biofilms.
Prevalence of *Bacillus cereus* in dairy powders focusing on its toxigenic genes and antimicrobial resistance	(Ibrahim *et al*., 2022)	Analytic research	Food poisoning activity, control measures and antimicrobial resistance	*B. cereus* isolated from dairy powders often harbor toxigenic genes and exhibit multiple antibiotic resistances, which increase food safety risks particularly for infants. Moreover, diary powder should also implement control measures to minimize the risk of *B. cereus* contamination.
Inhibition of *Bacillus cereus* spore outgrowth and multiplication by chitosan.	(Mellegırd *et al*., 2011)	Analytic research	Antimicrobial resistance	The study indicated that chitosan, a polysaccharide with antibacterial properties could inhibit *B. cereus* growth. The chitosan molecular weight and degree of acetylation would affect the effectiveness of inhibiting *B. cereus*.

Comparative analysis of *Bacillus cereus* group isolates' resistance using disk diffusion and broth microdilution and the correlation between antimicrobial resistance phenotypes and genotypes	(Mills *et al*., 2022)	Analytic research	Antimicrobial resistance	The study showed there was a poor correlation between zones of inhibition obtained with disk diffusion and MICs obtained with broth microdilution. Moreover, there was a high error rate with the disk diffusion test using *Staphylococcus* spp. breakpoints. Breakpoints should be avoided when testing the antimicrobial susceptibility of *B. cereus* isolates. The prevalence of resistance to clinically relevant antibiotics was low.
Evidence for *Bacillus cereus* spores as the target pathogen in thermally processed extended shelf-life refrigerated foods.	(Reddy *et al*., 2021)	Analytic research	Control measurements and antimicrobial resistance	The study showed that untargeted psychrotrophic *B. cereus* isolates were more heat resistant than nonproteolytic *C. botulinum* types B and F strains. It also suggested that if the same resistance trend appeared in the food system, then psychrotrophic *B. cereus* could also be a target pathogen for food. However, there were no regulations for it since it was not a targeted pathogen.
Detection and characterization of *Bacillus cereus* isolated from the dialysis fluid	(Sturmer *et al*., 2022)	Analytic research	Control measures	The article indicated that *B. cereus* has a persistence capacity and produces biofilm, releasing toxins, which would increase the risk of infection and adverse events for patients. The article also suggested that future research should focus on more criteria such as water and dialysis fluid monitoring, analytical methods, and disinfection procedures.
Antimicrobial activity of carvacrol toward *Bacillus cereus* on rice	(Ultee *et al*., 2000)	Analytic research	Antimicrobial resistance	The study showed that carvacrol could inhibit *B. cereus* growth, adding soya sauce and cymene would increase its antimicrobial resistance.
Bacillus cytotoxicus sp. nov. is a novel thermotolerant species of the *Bacillus cereus* group occasionally associated with food poisoning	(Guinebretiϋre *et al*., 2013)	Analytic research	Food poisoning activity	The article stated that taxon (very high genetic proximity of NVH 391-98T) had similarities with their phenotypic features that belonged to *B. cereus* group species. Moreover, taxon should consider novel genomic species.
Prevalence, toxigenic profiles, multidrug resistance, and biofilm formation of *Bacillus cereus* isolated from ready-to eat cooked rice in Penang, Malaysia	(Navaneethan & Effarizah, 2021)	Analytic research	Food poisoning activity and antimicrobial resistance	The article stated that the number of incidents of *B. cereus* in ready-to-eat rice was moderately low. However, there were more than 50% of the sample contained *B. cereus* which could potentially produce toxins. 34 of the *B. cereus* positives were found to have high resistance against beta-lactam classes and folate pathway inhibitors while more than 67% of isolates were susceptible to eight antibiotics. Multidrug resistance and biofilm formation were also found in *B. cereus* isolates.
Synergistic effect of pulsed electric fields and CocoanOX 12% on the inactivation kinetics of *Bacillus cereus* in a mixed beverage of liquid whole egg and skim milk	(Pina-Pırez *et al*., 2009)	Analytic research	Antimicrobial resistance	This study discovered that adding CocoanOX 12% powder to beverages containing pasteurized skim milk and liquid whole milk would reduce counts after PEF treatments. The study found that the highest synergistic effect was observed at the lowest electric field intensity.
Insect chitosan as a natural antimicrobial against vegetative cells of *Bacillus cereus* in a cooked rice matrix	(Valdez *et al*., 2022)	Analytic research	Food poisoning activity and antimicrobial resistance	The study found that insect chitosan could act as an antimicrobial agent against *B. cereus* as it had significant antimicrobial activity against *B. cereus* in rice. It suggested that it could potentially act as a natural preservative and the lower the storage temperature was, the more effective it is.
Bacteriological quality and public health risk of ready-to-eat foods in developing countries: systematic review and meta-analysis	(Mengistu *et al*., 2022)	Systematic review	Food poisoning activity	The study assessed the prevalence of *S. aureus, Enterobacter* species, *Klebsiella, E. coli, Salmonella, B. cereus, Pseudomonas* species, and *Shigella in* ready-to-eat foods and their maximum acceptable limit to cause foodborne diseases in human health.
Bacillus cereus, a volatile human pathogen	(Bottone, 2010)	Narrative review	Food poisoning activity	The article provided an overview of various aspects of *B. cereus* including epidemiology, microbiology, and pathogenesis. Food infection with enteropathogenic *B. cereus* affects human health and the food industry. Moreover, the infection process can be separated into different stages.

The food poisoning toxins of *Bacillus cereus*	(Dietrich *et al*., 2021)	Narrative review	Food poisoning activity	This study covered knowledge of the distribution and genetic organization of the toxin genes, as well as mechanisms of enterotoxin gene regulation and toxin secretion mainly Hbl and Nhe, cereulide and CytK.
The *Bacillus cereus* food infection as multifactorial process	(Jessberger *et al*., 2020)	Narrative review	Food poisoning activity and control measures	This study emphasizes the importance of risk assessment in shutting down or continuing to release the product once contamination happens. Moreover, it covered various factors causing manifestation of the disease.
Bacillus cereus food intoxication and toxicoinfection	(Jovanovic *et al*., 2021)	Narrative review	Food poisoning activity	The study provided information about types of *B. cereus*, characteristics, and emetic *B. cereus* presented on food products and toxicoinfection (the second form) presented in human GI.
Risk of *Bacillus cereus* in relation to rice and derivatives	(Rodrigo *et al*., 2021)	Narrative review	Food poisoning activity and control measures	Carbohydrate-rich foods were the most important food source for *B. cereus.* Mild heat application in rice cooking, regular pasteurization and refrigerated processed food will not stop all *B. cereus* spores. Only sterilization would inactivate *B. cereus* spores, however, sterilization would not be used in the production process in restaurants. It also suggested rapid cooling and storage in the refrigerator after as it will avoid vegetative cell growth. High water-content food should be stor at 4-8°C.
Physiological and mathematical aspects in setting criteria for decontamination of foods by physical means.	(Smelt *et al*., 2002)	Narrative review	Control measures	This study discusses the physiology of denaturation by heat, high pressure, and pulse electric field. Moreover, it discussed about choice of test strain, the effect of culture conditions during processing and recovery.
Regulation of toxin production by *Bacillus cereus* and its food safety implications	(Ceuppens *et al*., 2011)	Narrative review	Food poisoning activity	*B. cereus* is a significant food-borne pathogen that can cause both emetic and diarrheal syndromes. The toxin production by *B. cereus* would be affected by various environmental factors and strain-dependent variability.
Bacillus cereus invasive infections in preterm neonates: an up-to-date review of the literature.	(Lotte *et al*., 2022)	Narrative review	Food poisoning activity and control measures	The study suggested that *B. cereus* invasive infections in preterm neonates were a major concern in public health. It also emphasizes the importance of implementing infection control measurements to prevent *B. cereus*.
From soil to gut: *Bacillus cereus* and its food poisoning toxins.	(Stenfors Arnesen *et al*., 2008)	Narrative review	Food poisoning activity	The article introduced the emetic illness associated with *B. cereus* that is caused by cereulide, a small ring-formed dodecadepsipeptide. Moreover, the article suggested three pore-forming cytotoxins: Hbl, Nhe and cytotoxin K associated with diarrheal syndrome of *B. cereus*.

Rice relies heavily on temperature during cooking, storage, and reheating to avoid *B. cereus* contamination. Rice should be cooked at 105°C to kill *B. cereus* spores (Rodrigo *et al*., 2021). Rice-based meals should be frozen or refrigerated at temperatures below 4 °C to treat *B. cereus* (Choma *et al*., 2000; Valero *et al*., 2000). Home, fast-food restaurants, local diners, and buffets or catering businesses that serve fresh hot rice should follow stringent food handling practices, such as storing raw and cooked rice separately to avoid cross-contamination (Hasnan & Mohd Ramli, 2020; Owusu *et al*., 2023). Another form of rice such as ready-to-eat rice refers to pre-packaged cooked rice that is typically consumed without further cooking. Manufacturers play an important role in protecting public health because ready-to-eat rice is distributed globally and serves the majority of customers (Milstien & Kaddar, 2010). Due to the hydrophobic properties of *B. cereus*, cleaning the machinery or equipment where rice circulates in the industry is the first barrier to preventing cell attachment on surfaces such as polymers, glass, and stainless steel (Catania *et al*., 2023). Foods may become contaminated when they are passed through pipes, surfaces, or belts of machinery or equipment during processing due to *B. cereus* spores' capacity to form biofilms and their adhesive characteristics. Other than the chilling method, sodium hypochlorite (NaClO) and hydrogen peroxide (H_2O_2) are recommended to sensitize the surface of machinery or equipment for 20 to 30 minutes at 30°C to 40°C for spore elimination or significant bacterial cell reduction (DeQueiroz & Day, 2008; Friedline *et al*., 2015).

The use of natural antibacterial agents for moderate food preservation, such as plant extracts, herbs, and spices, helps to prevent microbial infestation and toxin production in food products during postharvest storage. Carvacrol has been identified as a bactericidal agent and *B. cereus* growth inhibitor. It can be found in the essential oils of oregano and thyme (Azimzadeh *et al*., 2023). *B. cereus* growth was suppressed at concentrations of 0.15 mg/g carvacrol or higher, with inhibition varying with inoculum size (Ultee *et al*., 2000). Carvacrol weakens the membrane integrity of *B. cereus* vegetative cells by allowing protons and potassium ions to pass through, causing the membrane potential to dissipate and the internal pH to fall. Consequently, ATP synthesis is slowed, resulting in cell death (El-Saber Batiha *et al*., 2021). Chitosan, another naturally occurring, non-toxic biopolymer, is produced by deacetylating chitin, which is a fundamental component of insect and crustacean exoskeletons (Rinaudo, 2006; Mellegırd *et al*., 2011). Chitosan is a legal food component in Europe, Japan, Korea, and the United States, where it has been used as a natural antioxidant and food preservative to preserve food from rotting (Abd El-Hack *et al*., 2020). Chitosan causes cell membrane rupture by interacting with the negatively charged surface of *B. cereus* (Fernandes *et al*., 2009; Qi et al., 2023). Thus, using insect chitosan as an antibacterial against *B. cereus* in ready-to-eat meals containing precooked rice and its derivatives may be helpful (Valdez *et al*., 2022). Additionally, trans-cinnamaldehyde (TC) can be utilized to limit the growth of *B. cereus* (Cetin-Karaca & Newman, 2018). TC is a phytochemical derived from cinnamon that the FDA (21 CFR 182.60) has approved for use in food, and it is generally recognized as safe (GRAS) antimicrobial (FDA, 2015).

CONCLUSION

This review extensively examined foodborne illness, antibiotic resistance patterns, and strategies for managing *B. cereus* contamination in rice. Rice contamination by *B. cereus* can be greatly reduced by employing stringent cultivation procedures, such as using proper irrigation techniques, keeping the growing area clean, and avoiding the use of contaminated water or animal waste. Proper temperature storage and handling techniques for rice are critical to eliminating any potential contamination of *B. cereus* cells or spores. Improving wastewater treatment techniques can play a major role in preventing foodborne pathogens from transferring antibiotic resistance higher up the food chain. Wastewater treatment plants can reduce the number of antibiotics present in wastewater by installing cutting-edge treatment technologies that efficiently remove antibiotics from wastewater. Implementing antibiotic-restriction regulations in agriculture, particularly rice production, can help to lessen the selective pressure that favors the development of antimicrobial resistance in foodborne pathogens across the food chain. This could include advocating for alternative disease management strategies such as crop rotation, the use of biological control agents, and better irrigation practices.

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Declaration of interest
None.

REFERENCES

Abd El-Hack, M.E., El-Saadony, M.T., Shafi, M.E., Zabermawi, N.M., Arif, M., Batiha, G.E., Khafaga, A.F., Abd El-Hakim, Y.M. & Al-Sagheer, A.A. (2020). Antimicrobial and antioxidant properties of chitosan and its derivatives and their applications: A review. *International Journal of Biological Macromolecules* **164**: 2726-2744. https://doi.org/10.1016/j.ijbiomac.2020.08.153

Agata, N., Mori, M., Ohta, M., Suwan, S., Ohtani, I. & Isobe, M. (1994). A novel dodecadepsipeptide, cereulide, isolated from *Bacillus cereus* causes vacuole formation in HEp-2 cells. *FEMS Microbiol Lett* **121**: 31-34. https://doi.org/10.1111/j.1574-6968.1994.tb07071.x

Agata, N., Ohta, M., Mori, M. & Isobe, M. (1995). A novel dodecadepsipeptide, cereulide, is an emetic toxin of *Bacillus cereus*. *FEMS Microbiol Letter* **129**: 17-20. https://doi.org/10.1016/0378-1097(95)00119-p

Albaridi, N. (2022). Risk of *Bacillus cereus* contamination in cooked rice. *Food Science and Technology* **42**. https://doi.org/10.1590/fst.108221

Artawinata, P.C., Lorraine, S. & Waturangi, D.E. (2023). Isolation and characterization of bacteriophages from soil against food spoilage and foodborne pathogenic bacteria. *Scientific Reports* **13**: 9282. https://doi.org/10.1038/s41598-023-36591-6

Ash, C., Farrow, J.A.E., Dorsch, M., Stackebrandt, E. & Collins, M.D. (1991). Comparative analysis of *Bacillus anthracis, Bacillus cereus*, and related species on the basis of reverse transcriptase sequencing of 16S rRNA. *International Journal of Systematic and Evolutionary Microbiology* **41**: 343-346. https://doi.org/https://doi.org/10.1099/00207713-41-3-343

Azimzadeh, Z., Hassani, A., Mandoulakani, B.A., Sepehr, E. & Morshedloo, M.R. (2023). Intraspecific divergence in essential oil content, composition and genes expression patterns of monoterpene synthesis in *Origanum vulgare subsp. vulgare* and *subsp. gracile* under salinity stress. *BMC Plant Biology* **23**: 380. https://doi.org/10.1186/s12870-023-04387-5

Baethge, C., Goldbeck-Wood, S. & Mertens, S. (2019). SANRA – a scale for the quality assessment of narrative review articles. *Research Integrity and Peer Review* **4**: 5. https://doi.org/10.1186/s41073-019-0064-8

Bauer, T., Sipos, W., Stark, T.D., Käser, T., Knecht, C., Brunthaler, R., Saalm ller, A., Hofmann, T. & Ehling-Schulz, M. (2018). First insights into within host translocation of the *Bacillus cereus* toxin cereulide using a porcine model. *Frontiers in Microbiology* **9**: 2652. https://doi.org/10.3389/fmicb.2018.02652

Beattie, R.E., Skwor, T. & Hristova, K. R. (2020). Survivor microbial populations in post-chlorinated wastewater are strongly associated with untreated hospital sewage and include ceftazidime and meropenem resistant populations. *Science of The Total Environment* **740**: 140186. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.140186

Bottone, E.J. (2010). *Bacillus cereus*, a volatile human pathogen. *Clinical Microbiology Reviews* **23**: 382-398. https://doi.org/10.1128/cmr.00073-09

Callegan, M.C., Novosad, B.D., Ramirez, R., Ghelardi, E. & Senesi, S. (2006). Role of swarming migration in the pathogenesis of *Bacillus* endophthalmitis. *Investigative Ophthalmology & Visual Science* **47**: 4461-4467. https://doi.org/10.1167/iovs.06-0301

Catania, A.M., Di Ciccio, P., Ferrocino, I., Civera, T., Cannizzo, F.T. & Dalmasso, A. (2023). Evaluation of the biofilm-forming ability and molecular characterization of dairy *Bacillus* spp. isolates. *Frontiers in Cellular and Infection Microbiology* **13**: 1229460. https://doi.org/10.3389/fcimb.2023.1229460

Cetin-Karaca, H. & Newman, M.C. (2018). Antimicrobial efficacy of phytochemicals against *Bacillus cereus* in reconstituted infant rice cereal. *Food Microbiology* **69**: 189-195. https://doi.org/10.1016/j.fm.2017.08.011

Ceuppens, S., Rajkovic, A., Heyndrickx, M., Tsilia, V., Van De Wiele, T., Boon, N. & Uyttendaele, M. (2011). Regulation of toxin production by *Bacillus cereus* and its food safety implications. *Critical Reviews in Microbiology* **37**: 188-213. https://doi.org/10.3109/1040841x.2011.558832

Chemat, F., Rombaut, N., Meullemiestre, A., Turk, M., Perino, S., Fabiano-Tixier, A.-S. & Abert-Vian, M. (2017). Review of green food processing techniques. preservation, transformation, and extraction. *Innovative Food Science & Emerging Technologies* **41**: 357-377. https://doi.org/https://doi.org/10.1016/j.ifset.2017.04.016

Chinivasagam, H.N., Pepper, P.M. & Blackall, P.J. (2021). Impact of antibiotics on fluorescent *Pseudomonas* group and *Bacillus cereus* group isolated from soils exposed to effluent or waste from conventional and organic pig farming. *Journal of Applied Microbiology* **130**: 1130-1141. https://doi.org/10.1111/jam.14819

Choma, C., Guinebretiٻre, M.H., Carlin, F., Schmitt, P., Velge, P., Granum, P.E. & Nguyen The, C. (2000). Prevalence, characterization and growth of *Bacillus cereus* in commercial cooked chilled foods containing vegetables. *Journal of Applied Microbiology* **88**: 617-625. https://doi.org/10.1046/j.1365-2672.2000.00998.x

Darwish, W.S., El-Ghareeb, W.R., Alsayeqh, A.F. & Morshdy, A.E.M.A. (2022). Chapter 4 - Foodborne intoxications and toxicoinfections in the Middle East. In: Food Safety in The Middle East, Savvaidis, I.N. & Osaili, T.M. (editors). Academic Press, pp. 109-141. https://doi.org/10.1016/B978-0-12-822417-5.00001-5

Dattani, S., Spooner, F., Ritchie, H. & Roser, M. (2023). Causes of death. Our World in Data. https://ourworldindata.org/causes-of-death. Accessed 15 January 2024.

DeQueiroz, G.A. & Day, D.F. (2008). Disinfection of *Bacillus subtilis* spore-contaminated surface materials with a sodium hypochlorite and a hydrogen peroxide-based sanitizer. *Letters in Applied Microbiology* **46**: 176-180. https://doi.org/10.1111/j.1472-765X.2007.02283.x

Dietrich, R., Jessberger, N., Ehling-Schulz, M., Märtlbauer, E. & Granum, P.E. (2021). The food poisoning toxins of *Bacillus cereus*. *Toxins* **13**: 98. https://doi.org/10.3390/toxins13020098

Ehling-Schulz, M., Fricker, M. & Scherer, S. (2004). *Bacillus cereus*, the causative agent of an emetic type of foodborne illness. *Molecular Nutrition & Food Research* **48**: 479-487. https://doi.org/https://doi.org/10.1002/mnfr.200400055

El-Saber Batiha, G., Hussein, D.E., Algammal, A.M., George, T.T., Jeandet, P., Al-Snafi, A.E., Tiwari, A., Pagnossa, J.P., Lima, C.M., Thorat, N.D. *et al*. (2021). Application of natural antimicrobials in food preservation: Recent views. *Food Control* **126**: 108066. https://doi.org/10.1016/j.foodcont.2021.108066

Fangio, M.F., Roura, S.I. & Fritz, R. (2010). Isolation and identification of *Bacillus* spp. and related genera from different starchy foods. *Journal of Food Science* **75**: M218-221. https://doi.org/10.1111/j.1750-3841.2010.01566.x

Farida, I., Yahaya, O. & Zakari, L. (2018). Isolation, characterisation, antibiotic susceptibility and molecular profile of enterotoxigenic *Bacillus cereus* from fried soya bean cake (Awara). *American Journal of BioScience* **6**: 45-51. https://doi.org/10.11648/j.ajbio.20180604.11

FDA. (2015). Food and drugs. U.S. Food & Drug Administration. Title 21. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm. Accessed 27 February 2024.

Fernandes, J.C., Eaton, P., Gomes, A.M., Pintado, M.E. & Xavier Malcata, F. (2009). Study of the antibacterial effects of chitosans on *Bacillus cereus* (and its spores) by atomic force microscopy imaging and nanoindentation. *Ultramicroscopy* **109**: 854-860. https://doi.org/10.1016/j.ultramic.2009.03.015

Fiedler, G., Schneider, C., Igbinosa, E.O., Kabisch, J., Brinks, E., Becker, B., Stoll, D.A., Cho, G.-S., Huch, M. & Franz, C.M.A.P. (2019). Antibiotics resistance and toxin profiles of *Bacillus cereus*-group isolates from fresh vegetables from German retail markets. *BMC Microbiology* **19**: 250. https://doi.org/10.1186/s12866-019-1632-2

Friedline, A., Zachariah, M., Middaugh, A., Heiser, M., Khanna, N., Vaishampayan, P. & Rice, C. V. (2015). Sterilization of hydrogen peroxide resistant bacterial spores with stabilized chlorine dioxide. *AMB Express* **5**: 24. https://doi.org/10.1186/s13568-015-0109-4

Gilbert, R.J., Stringer, M.F. & Peace, T.C. (1974). The survival and growth of *Bacillus cereus* in boiled and fried rice in relation to outbreaks of food poisoning. *Journal of Hygiene* **73**: 433-444. https://doi.org/10.1017/s0022172400042790

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 foodborne outbreaks in France, 2007 to 2014: epidemiology and genetic characterisation. *Eurosurveillance* **21**: 30413. https://doi.org/10.2807/1560-7917.ES.2016.21.48.30413

Granum, P.E. & Lund, T. (1997). *Bacillus cereus* and its food poisoning toxins. *FEMS Microbiology Letters* **157**: 223-228. https://doi.org/10.1111/j.1574-6968.1997.tb12776.x

Griffiths, M.W. & Schraft, H. (2017). Chapter 20 - *Bacillus cereus* food poisoning. In: Foodborne Diseases. Dodd, C.E.R., Aldsworth, T., Stein, R.A., Cliver, D.O. & Riemann, H.P. (editors) 3rd edition. Academic Press, pp. 395-405. https://doi.org/https://doi.org/10.1016/B978-0-12-385007-2.00020-6

Guinebretière, M.H., Auger, S., Galleron, N., Contzen, M., De Sarrau, B., De Buyser, M.L., Lamberet, G., Fagerlund, A., Granum, P.E., Lereclus, D. *et al*. (2013). *Bacillus cytotoxicus* sp. nov. is a novel thermotolerant species of the *Bacillus cereus* group occasionally associated with food poisoning. *International Journal of Systematic and Evolutionary Microbiology* **63**: 31-40. https://doi.org/10.1099/ijs.0.030627-0

Hall, B.G. & Barlow, M. (2004). Evolution of the serine *β-lactamases*: past, present and future. *Drug Resistance Updates* **7**: 111-123. https://doi.org/10.1016/j.drup.2004.02.003

Harada, A.M.M. & Nascimento, M.S. (2021). Effect of dry sanitizing methods on *Bacillus cereus* biofilm. *Brazilian Journal of Microbiology* **52**: 919-926. https://doi.org/10.1007/s42770-021-00451-0

Hasnan, N.Z.N. & Mohd Ramli, S.H. (2020). Modernizing the preparation of the Malaysian mixed rice dish (MRD) with cook-chill central kitchen and implementation of HACCP. *International Journal of Gastronomy and Food Science* **19**: 100193. https://doi.org/10.1016/j.ijgfs.2019.100193

Hill, H.A.O., Sammes, P.G., Waley, S.G., Baddiley, J. & Abraham, E.P. (1980). Active sites of *β-lactamases* from *Bacillus cereus*. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences* **289**: 333-344. https://doi.org/10.1098/rstb.1980.0050

Hiller, C.X., H bner, U., Fajnorova, S., Schwartz, T. & Drewes, J.E. (2019). Antibiotic microbial resistance (AMR) removal efficiencies by conventional and advanced wastewater treatment processes: A review. *Science of the Total Environment* **685**: 596-608. https://doi.org/10.1016/j.scitotenv.2019.05.315

Ibrahim, A.S., Hafiz, N.M. & Saad, M.F. (2022). Prevalence of *Bacillus cereus* in dairy powders focusing on its toxigenic genes and antimicrobial resistance. *Archives of Microbiology* **204**: 339. https://doi.org/10.1007/s00203-022-02945-3

Jessberger, N., Dietrich, R., Granum, P.E. & Märtlbauer, E. (2020). The *Bacillus cereus* food infection as multifactorial process. *Toxins* **12**: 701.

Jovanovic, J., Ornelis, V.F.M., Madder, A. & Rajkovic, A. (2021). *Bacillus cereus* food intoxication and toxicoinfection. *Comprehensive Reviews in Food Science and Food Safety* **20**: 3719-3761. https://doi.org/10.1111/1541-4337.12785

Kotiranta, A., Lounatmaa, K. & Haapasalo, M. (2000). Epidemiology and pathogenesis of *Bacillus cereus* infections. *Microbes and Infection* **2**: 189-198. https://doi.org/10.1016/S1286-4579(00)00269-0

Larsson, D.G.J. & Flach, C.-F. (2022). Antibiotic resistance in the environment. *Nature Reviews Microbiology* **20**: 257-269. https://doi.org/10.1038/s41579-021-00649-x

Lee, H. & Yoon, Y. (2021). Etiological agents implicated in foodborne illness worldwide. *Food Science of Animal Resources* **41**: 1-7. https://doi.org/10.5851/kosfa.2020.e75

Leong, S.S., Korel, F. & King, J.H. (2023). *Bacillus cereus*: A review of "fried rice syndrome" causative agents. *Microbial Pathogenesis* **185**: 106418. https://doi.org/10.1016/j.micpath.2023.106418

Li, T., Zou, Q., Chen, C., Li, Q., Luo, S., Li, Z., Yang, C., Yang, D., Huang, Z., Zhang, H. *et al*. (2023). A foodborne outbreak linked to *Bacillus cereus* at two middle schools in a rural area of Chongqing, China, 2021. *PLoS One* **18**: e0293114. https://doi.org/10.1371/journal.pone.0293114

Lotte, R., Chevalier, A., Boyer, L. & Ruimy, R. (2022). *Bacillus cereus* invasive infections in preterm neonates: an Up-to-date review of the literature. *Clinical Microbiology Reviews* **35**: e0008821. https://doi.org/10.1128/cmr.00088-21

Luna, V.A., King, D.S., Gulledge, J., Cannons, A.C., Amuso, P.T. & Cattani, J. (2007). Susceptibility of *Bacillus anthracis, Bacillus cereus, Bacillus mycoides, Bacillus pseudomycoides* and *Bacillus thuringiensis* to 24 antimicrobials using Sensititre® automated microbroth dilution and Etest® agar gradient diffusion methods. *Journal of Antimicrobial Chemotherapy* **60**: 555-567. https://doi.org/10.1093/jac/dkm213

Mei, F., Lin, J., Liu, M., Yang, Y., Lin, X. & Duan, F. (2021). Posttraumatic *Bacillus cereus* endophthalmitis: Clinical characteristics and antibiotic susceptibilities. *Journal of Ophthalmology* **2021**: 6634179. https://doi.org/10.1155/2021/6634179

Mellegırd, H., From, C., Christensen, B.E. & Granum, P.E. (2011). Inhibition of *Bacillus cereus* spore outgrowth and multiplication by chitosan. *International Journal of Food Microbiology* **149**: 218-225. https://doi.org/10.1016/j.ijfoodmicro.2011.06.013

Memish, Z.A., Zumla, A., Alhakeem, R.F., Assiri, A., Turkestani, A., Al Harby, K.D., Alyemni, M., Dhafar, K., Gautret, P., Barbeschi, M. *et al.* (2014). Hajj: infectious disease surveillance and control. *The Lancet* **383**: 2073-2082. https://doi.org/10.1016/S0140-6736(14)60381-0

Mengistu, D.A., Belami, D.D., Tefera, A.A. & Alemeshet Asefa, Y. (2022). Bacteriological quality and public health risk of ready-to-eat foods in developing countries: Systematic review and meta analysis. *Microbiology Insights* **15**: 11786361221113916. https://doi.org/10.1177/11786361221113916

Mills, E., Sullivan, E. & Kovac, J. (2022). Comparative analysis of *Bacillus cereus* group isolates' resistance using disk diffusion and broth microdilution and the correlation between antimicrobial resistance phenotypes and genotypes. *Applied and Environmental Microbiology* **88**: e0230221. https://doi.org/10.1128/aem.02302-21

Milstien, J.B. & Kaddar, M. (2010). The role of emerging manufacturers in access to innovative vaccines of public health importance. *Vaccine* **28**: 2115-2121. https://doi.org/10.1016/j.vaccine.2009.12.036

Ming, L.I.U., Mengsi, C.A.O., Xuefei, P., Lin, W.E.I., Xinguang, G.U.O., Chunlei, L.I., Jin, X.U., Jianzhong, Z. & Fengqin, L.I. (2021). Food safety risk assessment and risk rating study for foodborne disease at major events. *Chinese Journal of Food Hygiene* **33**: 657-665.

Moravek, M., Dietrich, R., Buerk, C., Broussolle, V., Guinebretiыre, M.-H., Granum, P.E., Nguyen-the, C. & Mдrtlbauer, E. (2006). Determination of the toxic potential of *Bacillus cereus* isolates by quantitative enterotoxin analyses. *FEMS Microbiology Letters* **257**: 293-298. https://doi.org/10.1111/j.1574-6968.2006.00185.x

Murray, C.J.L., Ikuta, K.S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., Han, C., Bisignano, C., Rao, P., Wool, E. *et al*. (2022). Global burden of bacterial antimicrobial resistance in 2019: A systematic analysis. *The Lancet* **399**: 629-655. https://doi.org/10.1016/S0140-6736(21)02724-0

Muthayya, S., Sugimoto, J.D., Montgomery, S. & Maberly, G.F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences* **1324**: 7-14. https://doi.org/10.1111/nyas.12540

Navaneethan, Y. & Effarizah, M.E. (2021). Prevalence, toxigenic profiles, multidrug resistance, and biofilm formation of *Bacillus cereus* isolated from ready-to eat cooked rice in Penang, Malaysia. *Food Control* **121**: 107553. https://doi.org/10.1016/j.foodcont.2020.107553

Nicholson, W.L., Munakata, N., Horneck, G., Melosh, H.J. & Setlow, P. (2000). Resistance of *Bacillus* endospores to extreme terrestrial and extraterrestrial environments. *Microbiology and Molecular Biology Reviews* **64**: 548-572. https://doi.org/10.1128/mmbr.64.3.548-572.2000

O'Neill, J. (2014). Antimicrobial resistance: Tackling a crisis for the health and wealth of nations. World Health Organization. https://www.who.int/news/item/29-04-2019-new-report-calls-for-urgent-action-to-avert-antimicrobial-resistance-crisis. Accessed 15 January 2024.

Owusu-Kwarteng, J., Wuni, A., Akabanda, F., Tano-Debrah, K. & Jespersen, L. (2017). Prevalence, virulence factor genes and antibiotic resistance of *Bacillus cereus sensu lato* isolated from dairy farms and traditional dairy products. *BMC Microbiology* **17**: 65. https://doi.org/10.1186/s12866-017-0975-9

Owusu, E.A., Luthra, K., Bruce, R. & Atungulu, G. (2023). Cooked rice safety: A review of status and potential of radiative pasteurization. *Journal of Food Safety* **43**: e13090. https://doi.org/10.1111/jfs.13090

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E. *et al*. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **372**: n71. https://doi.org/10.1136/bmj.n71

Pereira, A.P.M. & Sant'Ana, A.S. (2018). Diversity and fate of spore forming bacteria in cocoa powder, milk powder, starch and sugar during processing: A review. *Trends in Food Science & Technology* **76**: 101-118. https://doi.org/10.1016/j.tifs.2018.04.005

Pina-Pпrez, M.C., Silva-Angulo, A.B., Rodrigo, D. & Martнnez-Lуpez, A. (2009). Synergistic effect of pulsed electric fields and CocoanOX 12% on the inactivation kinetics of *Bacillus cereus* in a mixed beverage of liquid whole egg and skim milk. *International Journal of Food Microbiology* **130**: 196-204. https://doi.org/10.1016/j.ijfoodmicro.2009.01.021

Pizarro, A.B., Carvajal, S. & Buitrago-Lуpez, A. (2020). Assessing the methodological quality of systematic reviews using the AMSTAR tool. *Colombian Journal of Anesthesiology* **49**: e913. https://doi.org/10.5554/22562087.e913

Public Health Agency of Canada. (2014). Infection prevention and control guidelines: Critical appraisal tool kit.

Qi, Y., Chen, Q., Cai, X., Liu, L., Jiang, Y., Zhu, X., Huang, Z., Wu, K., Luo, H. & Ouyang, Q. (2023). Self-assembled amphiphilic chitosan nanomicelles: Synthesis, characterization and antibacterial activity. *Biomolecules* **13**: 1595.

Rahnama, H., Azari, R., Yousefi, M.H., Berizi, E., Mazloomi, S.M., Hosseinzadeh, S., Derakhshan, Z., Ferrante, M. & Conti, G.O. (2023). A systematic review and meta-analysis of the prevalence of *Bacillus cereus* in foods. *Food Control* **143**: 109250. https://doi.org/10.1016/j.foodcont.2022.109250

Rajalingam, N., Jung, J., Seo, S.-M., Jin, H.-S., Kim, B.-E., Jeong, M.-I., Kim, D., Ryu, J.-G., Ryu, K.-Y. & Oh, K.K. (2022). Prevalence, distribution, enterotoxin profiles, antimicrobial resistance, and genetic diversity of *Bacillus cereus* group isolates from lettuce farms in Korea. *Frontiers in Microbiology* **13**: 906040. https://doi.org/10.3389/fmicb.2022.906040

Reddy, N.R., Morrissey, T.R., Aguilar, V.L., Schill, K.M. & Skinner, G.E. (2021). Evidence for *Bacillus cereus* spores as the target pathogen in thermally processed extended shelf life refrigerated foods. *Journal of Food Protection* **84**: 442-448. https://doi.org/10.4315/jfp-20-267

Rinaudo, M. (2006). Chitin and chitosan: Properties and applications. *Progress in Polymer Science* **31**: 603-632. https://doi.org/10.1016/j.progpolymsci.2006.06.001

Rodrigo, D., Rosell, C.M. & Martinez, A. (2021). Risk of *Bacillus cereus* in relation to rice and derivatives. *Foods* **10**: 302. https://doi.org/10.3390/foods10020302

Rouzeau-Szynalski, K., Stollewerk, K., Messelhäusser, U. & Ehling-Schulz, M. (2020). Why be serious about emetic *Bacillus cereus*: Cereulide production and industrial challenges. *Food Microbiology* **85**: 103279. https://doi.org/10.1016/j.fm.2019.103279

Rusnan, A.N., Radu, S., Nordin, N. & Abdul Mutalib, N.A. (2020). Pathogenic *Bacillus cereus*, an overlooked food contaminants in Southeast Asia. *Pertanika Journal of Tropical Agricultural Science* **43**: 1-17.

Samapundo, S., Heyndrickx, M., Xhaferi, R. & Devlieghere, F. (2011). Incidence, diversity and toxin gene characteristics of *Bacillus cereus* group strains isolated from food products marketed in Belgium. *International Journal of Food Microbiology* **150**: 34-41. https://doi.org/10.1016/j.ijfoodmicro.2011.07.013

Samreen, Ahmad, I., Malak, H.A. & Abulreesh, H.H. (2021). Environmental antimicrobial resistance and its drivers: A potential threat to public health. *Journal of Global Antimicrobial Resistance* **27**: 101-111. https://doi.org/10.1016/j.jgar.2021.08.001

Smelt, J.P., Hellemons, J.C., Wouters, P.C. & van Gerwen, S.J. (2002). Physiological and mathematical aspects in setting criteria for decontamination of foods by physical means. *International Journal of Food Microbiology* **78**: 57-77. https://doi.org/10.1016/s0168-1605(02)00242-8

Smith, D.P., Berrang, M.E., Feldner, P.W., Phillips, R.W. & Meinersmann, R.J. (2004). Detection of *Bacillus cereus* on selected retail chicken products. *Journal of Food Protection* **67**: 1770-1773. https://doi.org/10.4315/0362-028X-67.8.1770

Stenfors Arnesen, L.P., Fagerlund, A. & Granum, P.E. (2008). From soil to gut: *Bacillus cereus* and its food poisoning toxins. *FEMS Microbiology Reviews* **32**: 579-606. https://doi.org/10.1111/j.1574-6976.2008.00112.x

Sturmer, F.C.R., Moreira, P.R., Cargnelutti, J.F., Lopes, L.Q.S., Lorenzett, E., Burgo, T.A.L. & Santos, R.C.V. (2022). Detection and characterization of *Bacillus cereus* isolated from the dialysis fluid. *Revista do Instituto de Mediciana Tropical de Sao Paulo* **64**: e67. https://doi.org/10.1590/s1678-9946202264067

Tatsinkou Fossi, B., Tatah Kihla Akoachere, J.-F., Nchanji, G.T. & Wanji, S. (2017). Occurrence, heat and antibiotic resistance profile of *Bacillus cereus* isolated from raw cow and processed milk in Mezam Division, Cameroon. *International Journal of Dairy Technology* **70**: 43-51. https://doi.org/10.1111/1471-0307.12315

Thirkell, C.E., Sloan-Gardner, T.S., Kacmarek, M.C. & Polkinghorne, B. (2019). An outbreak of *Bacillus cereus* toxin-mediated emetic and diarrhoeal syndromes at a restaurant in Canberra, Australia 2018. *Communicable Diseases Intelligence* **2019**: 43. https://doi.org/10.33321/cdi.2019.43.40

Tooke, C. L., Hinchliffe, P., Bragginton, E. C., Colenso, C. K., Hirvonen, V. H. A., Takebayashi, Y., & Spencer, J. (2019). ג*-Lactamases* and ג*-Lactamase* inhibitors in the 21st century. *Journal of Molecular Biology* **431**: 3472-3500. https://doi.org/10.1016/j.jmb.2019.04.002

Ultee, A., Slump, R.A., Steging, G. & Smid, E.J. (2000). Antimicrobial activity of carvacrol toward *Bacillus cereus* on rice. *Journal of Food Protection* **63**: 620-624. https://doi.org/10.4315/0362-028X-63.5.620

Valdez, M.I., Garcia, J., Ubeda-Manzanaro, M., Martinez, A. & Rodrigo, D. (2022). Insect chitosan as a natural antimicrobial against vegetative cells of *Bacillus cereus* in a cooked rice matrix. *Food Microbiology* **107**: 104077. https://doi.org/10.1016/j.fm.2022.104077

Valero, M., Leontidis, S., Fernבndez, P.S., Martלnez, A. & Salmerףn, M.C. (2000). Growth of *Bacillus cereus* in natural and acidified carrot substrates over the temperature range 5–30°C. *Food Microbiology* **17**: 605-612. https://doi.org/10.1006/fmic.2000.0352

WHO (World Health Organization). (2015). *WHO estimates of the global burden of foodborne diseases*. World Health Organization. Retrieved 29 November from https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases. Accessed 29 November 2023.

Yu, P., Yu, S., Wang, J., Guo, H., Zhang, Y., Liao, X., Zhang, J., Wu, S., Gu, Q., Xue, L. *et al*. (2019). *Bacillus cereus* isolated from vegetables in China: Incidence, genetic diversity, virulence genes, and antimicrobial resistance. *Frontiers in Microbiology* **10**. https://doi.org/10.3389/fmicb.2019.00948