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Original article

First documented outbreak of *Bongkrekic acid* food poisoning in Taiwan, March–April 2024

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ABSTRACT

Background: Between March 19 and March 24, 2024, 33 people became ill after dining at a restaurant in Taipei, Taiwan. Nine were hospitalized, seven of whom were admitted to an intensive care unit (ICU). Six died as a result of the outbreak. The Bongkrekic acid (BA) toxin was identified as the cause of the food poisoning. For the first time in Taiwan, BA food poisoning was documented.
Methods: Using case data and restaurant consumption records, the daily attack rate (AR), case-fatality ratio (CFR) and time to seek healthcare were estimated. The estimated CFR was compared directly against CFRs reported in previous outbreaks.
Results: The AR varied from 43.8 % to 80.4 % during the outbreak (mean: 60.3 %). The mean estimate of the CFR was 20.0 %, with only one patient who was admitted to an intensive care unit surviving (out of seven). The CFR was higher than in past outbreaks in Indonesia (14.0 %) but lower than in China (39.5 %). The time to seek healthcare was shorter for hospitalized cases (mean 3.4 days) than non-hospitalized cases (mean 5.6 days).
Conclusions: The substantial AR and CFR, and poor outcomes for hospitalized cases, indicate that implementing rigorous food safety measures to prevent future outbreaks is crucial. Improved outbreak preparedness, including increasing public awareness and strengthening regulations relating to the production and storage of food products prone to BA contamination, are needed to prevent and mitigate the impacts of future BA poisoning events. This is essential for public health in Taiwan and elsewhere.

Introduction

Taiwan rarely experiences lethal food poisoning events [1]. However, on March 27, 2024, news emerged of 11 people who felt unwell after dining at a restaurant in Taipei. Five of these initial cases were hospitalized, with four admitted to an intensive care unit (ICU), and two died. This incident triggered a full-scale investigation by the Taiwanese government. Initial laboratory tests excluded common foodborne infections such as *E. coli*, ultimately identifying Bongkrekic acid (BA) as the causative agent. This marked the first documented BA food poisoning outbreak in Taiwan, with additional cases and fatalities reported later.

BA poisoning, though rare, is often fatal. It results from consuming food contaminated with *Burkholderia gladioli* pathovar *cocovenenans* (BGC) bacteria [2,3]. Toxins produced by these bacteria, rather than the bacteria themselves, cause excessive morbidity and mortality [4]. There is no reliable cure for BA poisoning and only supportive care is available. The severity and mortality risks are directly related to the amount of the toxin consumed, with as little as 1–1.5 mg sufficient to cause death [5]. Case-fatality ratios (CFRs) as high as 30–100 % have been observed in previous outbreaks [6].

Initial symptoms of BA poisoning include diarrhea, nausea, dizziness and general fatigue, and may later progress to liver and kidney damage, multi-organ failure and hepatic coma, which are life-threatening. Symptoms typically appear 4–6 h after ingestion of contaminated food, with death potentially occurring as soon as

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1–20 h after symptom onset [5]. Precise diagnosis of the cause of death is complicated, as the bacteria that produce BA cannot be observed, and histological changes are not evident via autopsy [7].

BA was first identified as a cause of lethal food poisoning in Indonesia in 1895, linked to tempe bongkrek, a traditional fermented food made of coconut pulp [3,8]. Over nine thousand cases have been reported in Indonesia, with more than one thousand related to consumption of spoiled and fermented coconut products [9]. Production of tempe bongkrek was banned in Indonesia in 1988, with only sporadic outbreaks since then. Similar numbers of cases were reported in mainland China during the 20th century, and at least 10 outbreaks have occurred since 2000 [6]. However, recent outbreaks have involved different foods, such as fermented corn products or mushrooms [10]. Only one substantial outbreak has been detected outside Southeast Asia: in Mozambique in 2015, linked to a contaminated fermented beverage, resulting in 234 cases, including 75 deaths [11]. The 2024 Taiwan BA outbreak demonstrates that unexpected BA poisoning events can occur even in locations where outbreaks have not previously been observed.

Our study aims to provide a quantitative analysis of the BA outbreak in Tawan. We infer epidemiological quantities from data collected during the outbreak, including estimating temporal variations in the attack rate (AR) during the outbreak, the CFR, and epidemiological periods (the time to seek healthcare and the reporting delay). By quantifying the CFR in this outbreak and comparing it to CFRs in previous BA poisoning outbreaks, we contextualize our findings. Our analysis underscores the risk posed by BA and highlights the importance of preparing for future BA outbreaks, even in regions where such outbreaks have not previously occurred.

Methods

Data

The linelist of reported cases and list of orders during the exposure period were compiled from regular reports from the Taipei City Government Department of Health and Taiwan Centers for Diseases Control (CDC) [12,13]. The aggregated data contained information about restaurant attendees who tested positive for BA, and included information describing their age and sex, dining date, meal choice, severity of poisoning (admitted to hospital or clinic, or recuperated at home), final health status (died or recovered), date of attending healthcare services, and date of death (when applicable). The list of orders included the payment time and meal choice for those who dined in the period from March 17–25, 2024.

During the outbreak, suspected cases were identified as those presenting at the emergency department with nausea, vomiting, diarrhea, fatigue, severe oliguria, hematuria, jaundice, unconsciousness, convulsions or shock, and with some link to the restaurant in Taipei that was identified as the likely source of exposure after the initial cases (e.g., either dining at the restaurant itself, or at another restaurant in the same chain) [14–16]. A confirmatory BA toxin test was conducted on blood, urine or bronchial alveolar lavage samples. The analysis was performed using an ultrahigh-performance liquid chromatography system paired with a high-resolution time-of-flight and liquid chromatography-tandem mass spectrometry system [14].

The possible time period in which exposure occurred was found for each case using the list of orders describing the dining date of the case. Exposure was assumed to occur between one hour prior to the earliest payment for that meal type on the dining date and the final payment for that meal type on that day. The reporting dates were identified by comparing sequential updates of the linelist data released by Taiwan CDC. The linelist data were updated once or twice per day (at 10:00 am and/or 5:30 pm) from March 24 to April 8. A case was assumed to be reported in the interval from the previous linelist update to the first linelist in which the case was listed. The reporting delays for the first two cases confirmed on March 24 were left censored (i.e., they could have been reported at any time prior to the release of the first linelist).

To transform the order records to a plausible range describing the total number of diners, information such as the number of main dishes and the number of drinks was extracted from each order. In addition, if an order included the signature dish of the restaurant and another main dish, forming a possible dish set, then this part of the order was assumed to correspond to either one or two diners. We assumed that all diners in one order shared all the food, as is customary in Taiwan. As a result, for each order, plausible ranges in the number of diners and the items consumed were determined.

Epidemiological time intervals

Two intervals – the time from exposure to seeking healthcare and the time from exposure to case reporting – were estimated by fitting generalized gamma distributions (GGDs) [17,18] to the data using data augmentation Markov chain Monte Carlo (MCMC; see Section 2.4). The means and standard deviations (SD) of the fitted distributions were extracted.

In more detail, the linelist data of positive cases, comprising interval-based records (for cases $i = 1,2,3, \ldots, N$), were analyzed. The timing of both exposure, e_i, and the outcome, o_i, were allowed to vary within their plausible time intervals: $E_{L,i} \le e_i \le E_{R,i}$ and $O_{L,i} \le o_i \le O_{R,i}$, respectively. Because exposure always precedes the outcome, an additional constraint was imposed: $e_i < o_i$.

Denoting the probability density function of the GGD by $f(\circ, \theta)$, with θ including the mean, SD and shape parameter, the likelihood (for each case i) used for estimation was of the form:

$$L(\theta) = f(o_i - e_i, \theta)$$

where:

$$e_i \sim \text{Uniform}(\text{lower} = E_{L,i}, \text{upper} = E_{R,i})$$

$$o_i \sim \text{Uniform}(\text{lower} = \max(\{e_i, O_{L,i}\}), \text{upper} = O_{R,i})$$

Additionally, weakly informative priors were imposed on the log-transformed version of the parameters θ: each prior was given by a normal distribution with mean zero and SD two, implying that the 95 % prior interval for each (non-transformed) parameter was 0.02–48.1.

Estimating the AR and CFR

The probability of getting sick after dining at the restaurant on a given day was quantified through estimating the AR. Denoting the number of individuals who were sick after dining on day t by s_t and the number of individuals exposed on day t by n_t, the binomial likelihood was implemented for estimation:

$$s_t \sim \text{Binom}(\text{size} = n_t, \text{prob.} = AR_t)$$

We used a Beta distributed prior for AR_t: $\text{Beta}(\text{shape}_1 = 1, \text{shape}_2 = 1)$, resulting in the posterior Beta distribution:

$$AR_t \sim \text{Beta}(\text{shape}_1 = 1 + s_t, \quad \text{shape}_2 = 1 + n_t - s_t)$$

with mean value $(s_t + 1)/(n_t + 2)$. Since the number of exposed individuals, n_t, was uncertain, we assumed:

$$n_t \sim \text{Uniform}(\text{lower} = n_t^{low}, \text{upper} = n_t^{up})$$

where $[n_t^{low}, n_t^{up}]$ is the range of values obtained from the consumption records (see Section 2.1).

To account for this uncertainty when estimating AR_t, we allowed n_t to vary within its plausible range as part of the MCMC inference

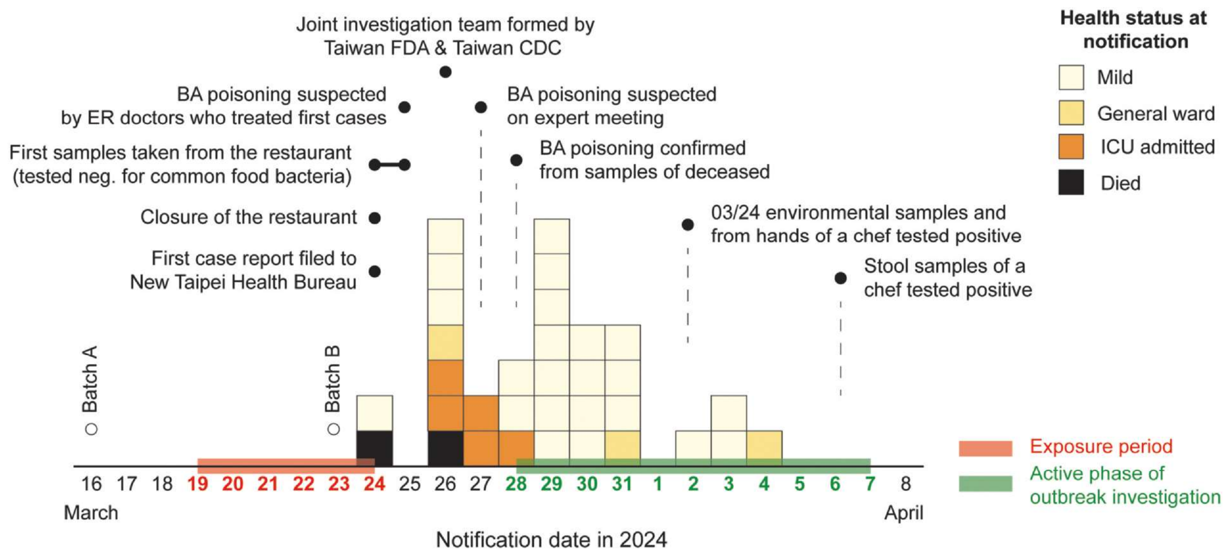

Fig. 1. Timeline of the Bongkrekic acid (BA) poisoning outbreak in Taiwan, March-April 2024. During the exposure period shown in red, all patients consumed dishes with flat rice noodles prepared from two batches of rice flour noodles A and B, indicated using hollow circles. Batch A was a likely source of the outbreak. Milestones of the outbreak response are shown using solid points alongside accompanying text. FDA: Food and Drug Administration; CDC: Centers for Disease Control.

procedure. The average AR was calculated by taking the mean value of AR_t across all days, while the crude AR involved calculating the ratio $\sum_t s_t/\sum_t n_t$.

Similarly, the CFR was estimated assuming: $D \sim$ Binom(N, CFR), where D and N are the total death and case counts, respectively. Similarly, with a Beta$(\text{shape}_1 = 1,\ \text{shape}_2 = 1)$ prior for the CFR, the posterior distribution was given by:

$$CFR \sim \text{Beta}(\text{shape}_1 = D + 1, \quad \text{shape}_2 = 1 + N - D)$$

resulting in a posterior mean of $(D + 1)/(N + 2)$.

Technical details

We undertook our analyses in a Bayesian framework using MCMC, allowing us to explore the space of parameters efficiently rather than performing an exhaustive search across all parameter values. Inference was performed using Stan software, version 2.36.0 (Stan Development Team, https://mc-stan.org). All data, including the anonymized linelist of cases and the computing code used to generate our results, are available at: https://github.com/aakhmetz/FoodPoisoning-in-Taiwan-2024

Results

Outbreak investigation and response

The timeline of the outbreak is shown in Fig. 1. Following hospital admission of the first two cases, one of whom died, BA poisoning was suspected by hospital clinicians [15]. A joint panel consisting of experts from Taiwan's FDA and CDC was formed on March 25. Samples from the first deceased case tested negative for common bacteria (*Salmonella*, *Escherichia coli*, *Vibrio enteritidis*, *Staphylococcus aureus*). However, the BA toxin was detected in their blood samples [14,19]. The BA outbreak was officially confirmed on March 28. The Taiwanese government issued an alert and undertook active case finding through inspection of hospital records from March 25–26 (all individuals with records noting suspected food poisoning were identified and tested). In addition, customers of the restaurant who dined in the period March 19–24 were interviewed. A refund order further helped to increase the case ascertainment rate.

Outbreak analysis

Over the course of the outbreak, there were 33 cases (Table 1; Fig. 2). All positive cases dined at the restaurant between March 19 and March 24 and consumed meals containing flat rice noodles. No individuals who dined on March 20 became sick. The ages of positive cases ranged from 10 to 66 years with a mean of 40.9 years, and 60.6 % of cases were female. Most cases experienced symptoms including nausea, abdominal pain, vomiting, and dizziness, while hospitalized cases were nearly twice as likely to experience co-occurrence of the symptoms (Fig. 3**A**).

In addition, four suspected cases experienced symptoms of food poisoning but subsequently tested negative for BA. The first two dined at a different branch of the restaurant. Another dined on March 18 (prior to the exposure period), ate fried wheat noodles, and was hospitalized. The other suspected but negative case dined during the exposure period on March 22, ordered a signature dish with rice noodles, but reported symptoms one month after the outbreak including persistent abdominal pain and general fatigue.

Out of the 33 confirmed cases, nine were hospitalized, seven of whom required admission to ICU. Hospitalized cases tended to seek healthcare earlier than non-hospitalized cases. The mean time from dining to seeking healthcare was 3.4 days (95 % CrI: 2.0–6.0 days) for hospitalized cases and 5.6 days (95 % CrI: 3.9–8.2 days) for non-hospitalized cases. However, the estimated time interval from dining to case reporting was similar for hospitalized and non-hospitalized cases, with an overall mean of 6.5 days (95 % CrI: 5.3–8.2 days) (Fig. 3BC).

Six of the cases who were admitted to ICU died. Two died in the first two weeks of the outbreak, two and eight days after dining at the restaurant, respectively, while the other four died more than one month after their admission to ICU. While the cause of death for the first deceased case was acute renal failure, all others died of multi-organ failure. The CFR (accounting for the prior) was estimated to be 20.0 % (95 % CrI: 8.6 %-34.3 %).

In total, 71 consumption records were attributed to the exposure period, 55 (77 %) of which included a dish with flat rice noodles. Following our analysis of the order list, we estimated that 87–107 people dined at the restaurant between March 19 and 24, and 57–71 of those ordered dishes with rice noodles (Table 1). The crude AR was 46.5 %-57.8 % when data from March 20 were included in the

Table 1
Descriptive statistics of the Bongkrekic acid (BA) outbreak in Taiwan, March-April 2024. The demographic characteristics of cases and severity of their illness are listed alongside the number of orders per day at the restaurant during the exposure period (March 19–24, 2024). In addition, estimated numbers of customers each day based on the consumption records are shown (final column). Numbers shown in parentheses denote the percentage of individuals within a given subgroup, while the numbers in square brackets reflect the possible range in estimated counts.

	Cases (*n* = 33)	Orders (*n* = 71)	People at risk (*n* = [87–107])
Age	40.9 [10–66]		
Sex			
Female	20 (60.6)		
Male	13 (39.4)		
Initial admission			
Hospital	22 (66.7)		
Clinic	7 (21.2)		
Recuperating at home	4 (12.1)		
Symptoms			
Diarrhea	24 (72.7)		
Stomach pain	17 (51.5)		
Vomiting	17 (51.5)		
Fever	17 (51.5)		
Nausea	16 (48.5)		
Fatigue	5 (15.2)		
Dizziness	3 (9.1)		
Jaundice	1 (3.0)		
Clinical outcome at two-week mark (as of April 7, 2024)			
Dead	2 (6.1)		
Admitted to ICU	4 (12.1)		
Admitted to general ward	3 (9.1)		
Recuperating at home	24 (72.7)		
Meal*			
Rice noodles	33 (100.0)	55 (77.4)	[57–71]
Fried noodles	0 (0.0)	23 (32.4)	[18–20]
Fried rice	0 (0.0)	12 (16.9)	[11–15]
Fried set	0 (0.0)	1 (1.4)	1
Dining date			
2024–03–19	5 (15.2)	9 (12.7)	[9–11]
2024–03–20	0 (0.0)	10 (14.1)	[11–13]
2024–03–21	6 (18.2)	12 (16.9)	[13–15]
2024–03–22	8 (24.2)	18 (25.4)	[20–23]
2024–03–23	6 (18.2)	12 (16.9)	[20–27]
2024–03–24	8 (24.2)	10 (14.1)	[14–18]

* Meals were reported in this table based on the assessed risk of BA contamination (e.g., if an order included both fried noodles and rice noodles, it was listed under rice noodles).

analysis, and 51.6 %-66.0 % when data from March 20 were excluded. When the AR was assumed to vary by day (with March 20 excluded), it took its highest value (80.3 %) on March 19 and its lowest value (43.8 %) on March 23 (95 % credible interval (CrI): 20.4 %-99.2 %). The average AR was estimated to be 60.3 % (95 % CrI: 48.0 %-71.3 %).

Discussion

In this study, we presented an epidemiological analysis indicating that the 2024 outbreak of BA poisoning at a restaurant in central Taipei, Taiwan, had an estimated overall AR of 60.3 % and CFR of 20.0 %. This CFR value lies between previous estimates for outbreaks in Indonesia and mainland China. We undertook a supplementary analysis (Supplementary Materials A) in which we obtained pooled estimates of CFRs from previous outbreaks in Indonesia (14.0 %) and mainland China (39.5 %). Although cases were hospitalized and treated in the Taiwan outbreak, only one of the seven ICU-admitted cases survived. The poor outcomes for ICU-admitted cases in this outbreak indicate that prevention of future outbreaks through rigorous food safety measures and public awareness is crucial.

Previous literature suggests that the differences in CFRs between outbreaks could be due to varying doses of BA consumed. We caution against direct quantitative comparison of BA concentration measurements between outbreaks due to different sampling methods being used, but report examples of previous measurements here. Li *et al.* reported a CFR of 29 % with BA concentrations detected between 0.002–0.3 mg/kg [9]. In contrast, Yuan *et al.* reported a 100 % fatality rate in an outbreak with high measured BA concentrations of 330 mg/kg in food samples and 3 mcg/mL in biological samples [20]. In the 2024 outbreak in Taiwan, one of the first reported cases had BA concentration measurements of 487.9 ng/mL in blood and 4.97 ng/mL in urine on day three after hospitalization [15]. Other patients were found to have lower BA concentrations in blood samples (*personal communication*). There was a relatively long interval between exposure and seeking healthcare observed in the 2024 Taiwan outbreak when compared to historical data from mainland China. We note that the dependence of patient outcomes on the time to seek healthcare is a complex one. While seeking healthcare quickly allows treatment to be administered earlier, a short period from exposure to seeking healthcare can be indicative of a larger dose, which is more likely to lead to a negative outcome. Higher doses are often linked to shorter incubation periods (and therefore shorter periods from exposure to seeking healthcare); this has been observed for other toxins such as the *Botulinum* toxin [21].

Zhang *et al.* [6] reviewed fatality rates across 19 documented outbreaks in mainland China from 2010 to 2020 and found the lowest CFR in outbreaks involving mushroom dishes or wet rice noodles, and the highest when homemade fermented corn flour products were involved. We performed a supplementary analysis (Supplementary Materials B) in which we re-analyzed those data, finding that geographical location was a significant factor, likely reflecting environmental conditions and food preparation customs affecting the consumed BA dosage.

Similarities could be also found between current and historical outbreaks. In a family outbreak reported by Li *et al.* [9], contaminated wet rice noodles showed no color changes or taste abnormalities, similarly to reports from the Taiwan outbreak. In another family outbreak reported by Yuan *et al.* [20], homemade fermented corn noodles were refrigerated for over a year. Both outbreaks highlighted that improper food storage and environmental conditions likely contributed to BA poisoning.

BGC bacteria are not easily grown in laboratory settings and require highly specific conditions [3,5]. Basic measures to prevent bacterial proliferation include lowering the pH during fermentation below 5.5 or maintaining temperatures away from 30°C (86 °F). Public health officials speculated that manufactured flat rice noodles, linked to cases in the Taiwan BA outbreak, could have been the cause of the outbreak, and that the outbreak may have been exacerbated by using soybean oil or other soy-based sauces. Experimental contamination of rice noodles coated with various concentrations of soybean oil with BGC bacteria has demonstrated bacterial growth when the oil was added, resulting in higher BA concentrations [4].

During an initial outbreak investigation in March-April 2024, extensive food and environmental sampling was undertaken by the Taiwan FDA, including samples at the restaurant, the homes of restaurant employees, other restaurants within the same chain, and a manufacturing site that produced and supplied flat rice noodles. Only two knives, one chopping board, and a sample taken from the hands of a restaurant chef were found to contain traces of the BA toxin, but all other samples tested negative. Following the initial positive result, blood, urine and stool samples from the chef were analyzed, with the stool samples testing positive. Despite this, the chef did not experience symptoms of BA poisoning, which is unusual as asymptomatic BA poisoning has not previously been reported.

After we performed our analysis, a final investigation was undertaken by the Taipei District Prosecutors' Office, concluding in January 2025. They found no traces of BGC bacteria or BA toxin in

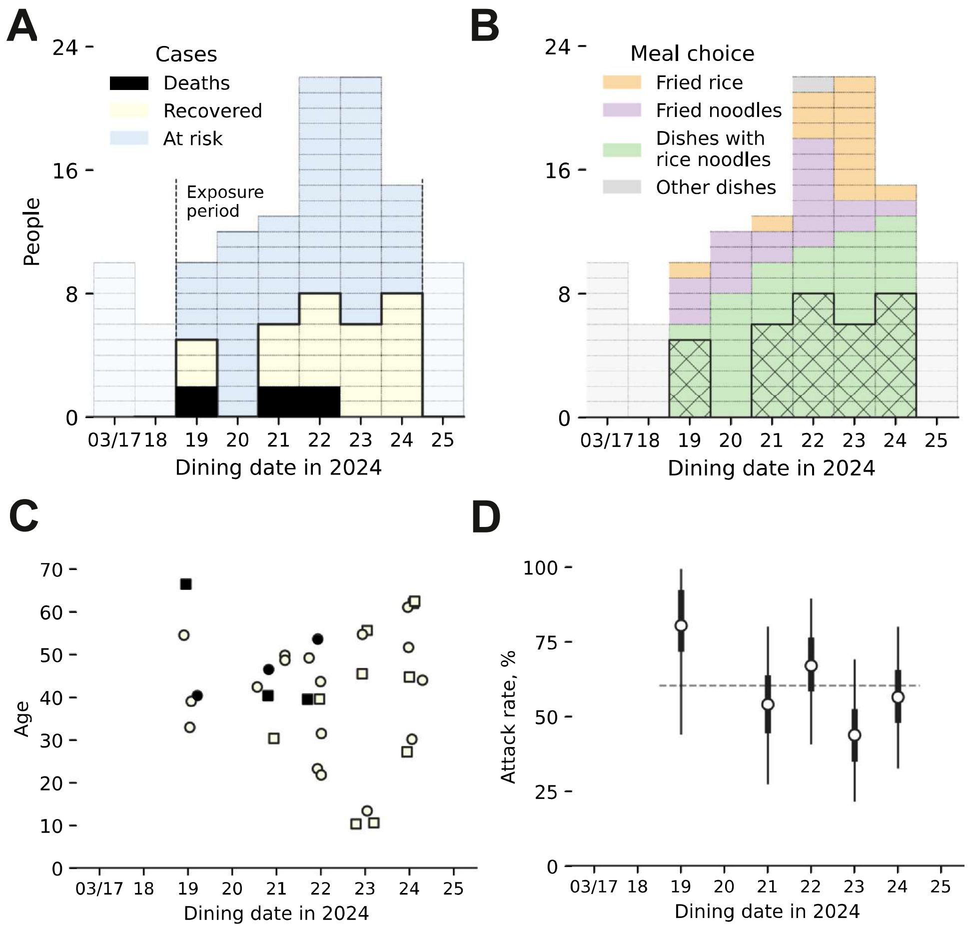

Fig. 2. Epidemiological analysis. (A) Daily numbers of cases and at-risk individuals during the exposure period (March 19–24, 2024). (B) Variation in dish preference among customers at the restaurant, with cases marked (hashed). (C) Variation in age and sex among cases, with females indicated using circles and males using squares. (D) Estimated attack rate (AR) per day. The circles indicate posterior means, while the thin whiskers reflect the 95 % credible intervals. Thicker lines indicate the posterior interquartile range. The horizontal dashed line shows the average AR over all five days (March 20 was excluded from the analysis, as described in the text).

upstream and downstream supply chains of the restaurant. However, they determined that a batch of rice noodles was left unrefrigerated for more than 63 h before serving, and that the air conditioning system was turned off during that time. Coupled with a humid environment, this created environmental conditions that were suitable for proliferation of BGC bacteria. They also concluded that the batch of rice noodles was not used on March 20, on which no diners became sick [22]. We note that, while improper food storage and handling provided conditions in which the outbreak could occur, the precise mode by which the bacteria were introduced to the restaurant cannot be established definitively. However, the final investigation concluded that the probability that the outbreak resulted from intentional poisoning is extremely low.

In our analyses, we used a Bayesian modelling framework in which uncertainty is accounted for rigorously. For example, when we estimated the CFR, we not only obtained a mean estimate of 20.0 % but also a 95 % CrI of 8.7 %-34.7 %. Of course, we could have estimated the CFR more straightforwardly by simply dividing the number of deaths in the outbreak by the total number of reported cases (generating an estimated CFR of 18.2 %). However, this would have neglected uncertainty due to the limited number of observed cases, and a CrI would not have been obtained.

As with any quantitative analysis, our study has limitations. A key limitation is the resolution of the data that we analyzed. In particular, ideally a case-control analysis would have been undertaken, in which the characteristics of cases and unaffected diners were compared. However, only group order records were available, rather than detailed data describing the food consumed by each diner, and the results of any interviews undertaken with unaffected diners were not publicly available. For that reason, we assumed that all diners associated with each order consumed all dishes in the order, noting that this assumption is plausible due to the custom of sharing food in Taiwan, and we analyzed epidemiological quantities that could be inferred from the available data. Another potential limitation associated with the data that we analyzed is that the restaurant consumption records, compiled from official sources, could be incomplete. However, restaurants in Taiwan are required to report purchases to ensure that appropriate taxes are paid, and this is incentivized by the national receipt lottery (which encourages customers to demand receipts). As such, we expect that few consumption records were missing. Additionally, as with most outbreak investigations, the case data may be subject to ascertainment bias, as cases with mild symptoms (or who remain asymptomatic) may have gone undetected. Underreporting of mild cases could lead to overestimation of the CFR.

Since we only used publicly available data, it is possible that other data may already exist from which further details of this outbreak can be obtained, including measurements of BA concentrations in samples taken from cases during the outbreak and additional clinical details of hospitalized cases. If such datasets exist, then it may be possible to obtain additional information about the Taiwan outbreak" this would be an important target for future research.

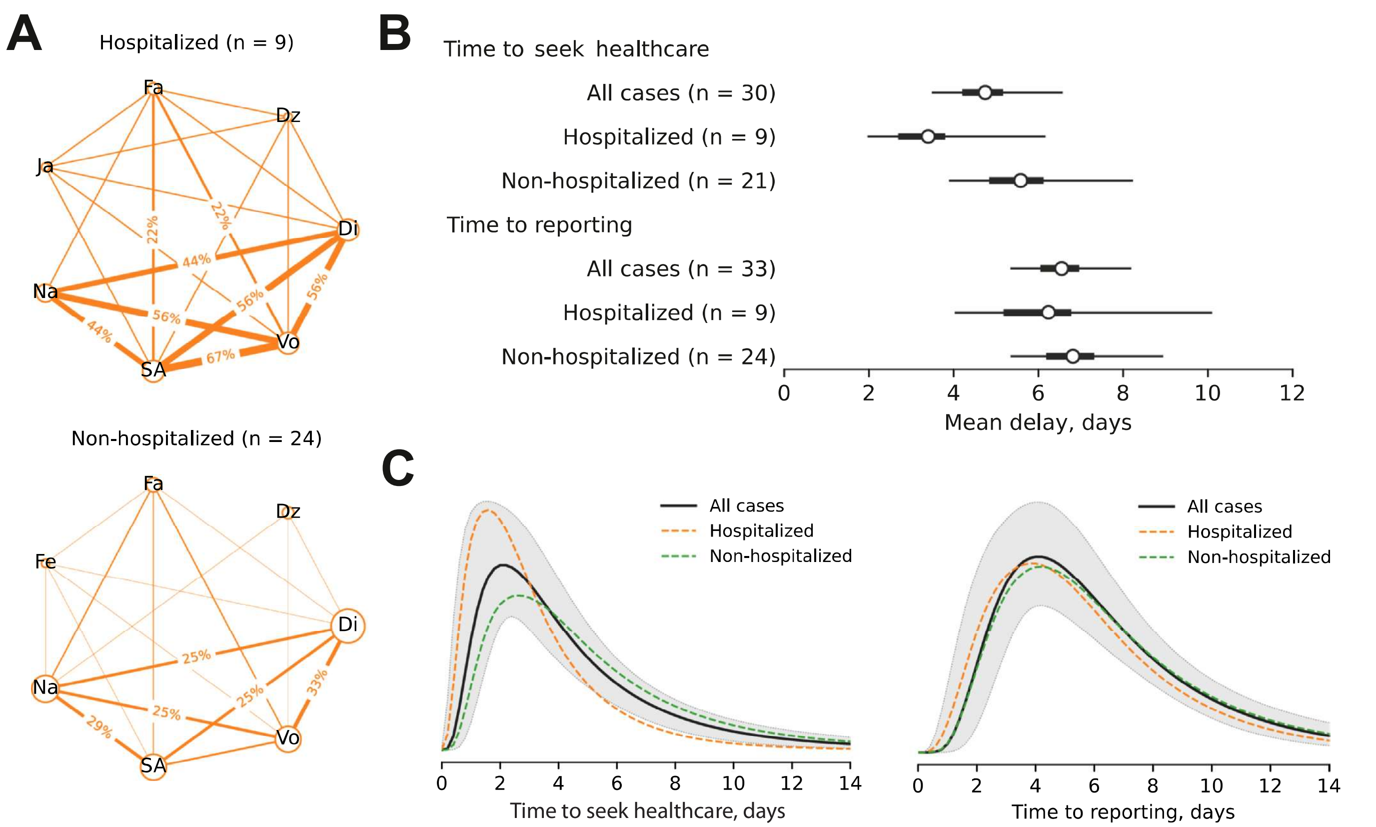

Fig. 3. Time periods from exposure to reporting and from exposure to hospitalization. (A) Co-occurrence of specific symptoms among hospitalized and non-hospitalized individuals. The percentages shown on the lines reflect the percentage of cases with both of those symptoms; only values > 20 % are shown. The following abbreviations were used: "Di" = diarrhea including watery or bloody stool, "Vo" = vomiting, "SA" = stomachache including abdominal pain, "Na" = nausea, "Ja" = jaundice, "Fe" = fever, "Fa" = general fatigue, "Dz" = dizziness. (B) The estimated time to seek healthcare and time to reporting, both relative to the time of consumption of the contaminated meal. In panel B, circles indicate the posterior means, thinner lines reflect 95 % credible intervals and thicker lines reflect the posterior interquartile ranges. (C) The posterior distributions, with the solid lines showing the median posteriors and shaded areas showing the 95 % credible intervals.

Conclusions

The 2024 BA poisoning outbreak in the cosmopolitan area of Taiwan demonstrates the potential for BA outbreaks to have substantial negative consequences for public health. While this outbreak arose in an urban center and was identified quickly, future outbreaks may not be detected as promptly, particularly if they arise in rural locations. Public health authorities must ensure that outbreaks are detected swiftly, and patients can access healthcare resources, wherever and whenever outbreaks occur. Additionally, the identification of an asymptomatic positive case of a restaurant chef indicates that some cases (and potentially outbreaks) may remain undetected, further besetting the possibility of a rapid outbreak response.

In the outbreak analyzed here, some suspected cases who were identified had dined at other restaurants within the same chain. While those individuals did not test positive for BA, the possibility that outbreaks may occur across entire restaurant chains, rather than being confined to individual source locations, should be considered.

Our estimates of the AR and CFR highlight the potential for severe outcomes of foodborne pathogen outbreaks. Outbreak preparedness and prevention are essential, facilitated by screening commercially available food products and conducting rigorous inspections of food service premises [23]. Enhancing public awareness of foodborne pathogens could increase the speed at which outbreaks are reported, leading to a faster outbreak response, and could encourage the public to take measures to prevent outbreaks (e.g., safer food preservation practices). Following this outbreak, the Taiwanese authorities advised local governments to develop guidelines regarding when patients with non-specific symptoms should be tested for BA poisoning and encouraged additional screening of food for BGC bacteria. Similar actions could also be implemented proactively in other countries. A lethal case of BA poisoning was recently reported for the first time in the United States [24], associated with ingestion of a corn-fermented product imported from Nigeria. This case underscores the importance of maintaining awareness of potential BA food poisoning, even in locations where outbreaks have not previously been reported.

Finally, we note the potential future benefits of a range of technologies when preparing for or responding to future outbreaks. For example, social media could be used to raise public awareness about the risks of BA outbreaks [25]. Artificial intelligence could aid responses to future food poisoning events, as has also been proposed in the context of infectious diseases [26,27]. Preparedness for and rapid responses to outbreaks due to foodborne toxins going forward is crucial for public health.

List of Abbreviations

AR	attack rate
BA	Bongkrekic acid
BGC	*Burkholderia gladioli* pathovar *cocovenenans*
CDC	Centers for Diseases Control
CFR	case-fatality ratio
FDA	Food and Drug Administration
GGD	generalized gamma distribution
ICU	intensive kare unit
MCMC	Markov chain Monte Carlo
SD	standard deviation

Authors' contributions

Conceived and designed the project: ARA. Collected and processed data: ARA. Conducted statistical analysis: ARA, BP. Discussed and interpreted results: ARA, RNT. Wrote first draft of the manuscript: ARA. Revised and approved the manuscript: ARA, RNT, BP, CSW.

Statement of Ethics

A Statement of Ethics is not applicable because this study is based exclusively on publicly available data.

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Data Availability

All data, including an anonymised linelist of cases, and computing code used to generate results, are available at: https://github. com/aakhmetz/FoodPoisoning-in-Taiwan-2024.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI and AI-assisted technologies in the writing process

Generative AI and AI-assisted technologies have not been used by the authors for this work.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jiph.2025.103056.

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