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ORIGINAL RESEARCH

Epidemiological Characteristics of Foodborne Disease Outbreaks in a Hospital: A 5-Year Retrospective Study

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Introduction: Foodborne disease outbreaks (FBDOs) pose a significant threat to public health globally, leading to substantial morbidity, mortality, and economic losses. However, the underlying causes and impacts of FBDOs often remain underexplored in specific regions, limiting the effectiveness of targeted prevention strategies.

Methods: This study aimed to investigate the epidemiological characteristics, causes, and economic burden of FBDOs in Jinhua city, Zhejiang province, China, between 2018 and 2022. Data were collected from the national surveillance system, encompassing 63 FBDOs with 305 cases. FBD cases were defined as patients with diarrhea, vomiting, or toxic symptoms suspected to be caused by food consumption, with outbreaks referring to incidents where two or more individuals presented similar symptoms after consuming the same food. Descriptive statistics were used to analyze numerical and categorical variables, focusing on outbreak sources, pathogenic factors, and economic consequences.

Results: Data analysis revealed that catering services were the most common source of FBDOs, likely due to the widespread consumption of prepared meals and potential lapses in hygiene. Approximately 50% of the outbreaks were linked to unidentified pathogens. The reported microorganisms, including *Norovirus, Nontyphoidal Salmonella*, and *Vibrio parahaemolyticus*, were among the target pathogens of the national surveillance system and are also recognized as common causes of FBDOs globally. Among the identified causes, *Mushroom toxin* (19.05%) was the leading factor, followed by *Norovirus* (12.70%) and *Nontyphoidal Salmonella* (6.35%). *Norovirus* caused the highest number of cases (52). The total economic burden of FBDOs was estimated at 228,078.74 yuan, with a median cost of 648.29 yuan per case. Two fatalities were attributed to wood ear and nitrite consumption.

Discussion: The findings highlight high-risk foods and vulnerable populations, underscoring the significant public health and economic impacts of FBDOs. To address these challenges, enhanced surveillance systems, the establishment of regional laboratory centers, and the application of new diagnostic technologies are crucial. Collaborative efforts among governments, the food industry, and consumers are essential to strengthening food safety and reducing the burden of foodborne diseases.

Keywords: foodborne disease outbreaks, epidemiology, economic burden, food safety, risk factors, pathogenic factors

Introduction

Foodborne disease (FBD) results from the consumption of food or water contaminated with infectious pathogens or poisonous substances,[1] with clinical symptoms including vomiting, diarrhoea, fever, abdominal pain, and nausea.[2] FBD is predominantly attributed to microbiological infections, toxic animals or plants, and chemical contamination.[3] An FBD outbreak (FBDO) is defined as an incident where two or more persons present with similar symptoms from the same food

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source.[4] Public demands and quality requirements for food grow rapidly with increasing globalization and sustained economic growth. However, population growth and disordered urbanization have posed tremendous challenges to food safety and the food industry. FBD has aroused great concern all over the world and has become an enormous threat to public health. Over the past 60 years, 30% of emerging infectious diseases were associated with pathogens transmitted through food.[5] As estimated by the World Health Organization (WHO) in 2015, 31 foodborne hazards caused 600 million cases of foodborne diseases and 420,000 deaths in 2010, and these FBD cases resulted in a global burden of 33 million healthy life years (DALYs) in 2010.[6] Another study also obtained the same estimate that 1 out of 10 people (estimated 600 million people) get sick and 420,000 deaths occur due to contaminated food every year, resulting in the loss of 33 million DALYs globally.[7] From 2012 to 2015, 3,895,914 cases of FBD occurred in Taiwan, with an annual medical cost of NT$1.3 billion.[8] From 2008 to 2013, 1.28–2.23 million cases of FBD occurred in France, resulting in 16,500 –20,800 hospitalizations and 250 deaths due to 15 major pathogens.[9] As estimated by the United States Centres for Disease Control and Prevention (CDC), 76 million cases of FBD, 325,000 hospitalizations, and 5200 deaths occur annually in the United States.[10] In England and Wales, 2,366,000 cases, 21,138 hospitalizations, and 718 deaths were associated with FBD each year.[11]

The situation may be even worse in developing countries and regions including China and most Southeast Asian and African countries due to the imbalance between economic development and sanitation caused by small-scale family-style economic forms. In China, an estimated 1 in 6.5 people suffer from FBD annually, reflecting the substantial public health burden.[12] In the Western Pacific region, FBD results in 125 million cases and over 50,000 deaths every year.[13] Hospitals, as institutions that provide medical assistance, are usually the first point of contact where FBD cases and outbreaks (FBDOs) are detected. In the hospital setting, FBDOs play a critical role in highlighting potential food safety hazards and identifying vulnerable populations. This particular sentinel hospital in Jinhua city was selected for its regional importance and serves as a referral center for diverse patient populations across both urban and rural areas, making it an ideal setting for studying regional trends in foodborne diseases. Its established surveillance system for foodborne diseases and collaboration with public health authorities made it a suitable choice for the study. They impose a significant burden on healthcare systems, from increased patient admissions to resource allocation for laboratory testing and public health interventions. Moreover, the effects of FBDOs extend beyond the hospital, impacting the population by causing illnesses, productivity losses, and even fatalities. Economically, the consequences include direct medical expenses, reduced workforce productivity, and the financial strain on affected families. In Jinhua city, foodborne diseases represent a pressing public health challenge due to the region's rapid urbanization and reliance on catering services for prepared meals.

The research question for this study is grounded in addressing these multifaceted challenges. Specifically, this study aims to quantify the epidemiologic and economic burden of FBDOs in Jinhua, providing evidence to guide public health policies. The years 2018 to 2022 were chosen as the study period to capture recent trends, as these years encompass significant changes in food consumption habits and the implementation of new public health surveillance measures. Additionally, this time frame ensures that the study covers seasonal, annual, and pandemic-related variations in FBDOs, allowing for a comprehensive analysis.

One of the inherent limitations in foodborne disease research is the accuracy of information derived from individual cases. Individual case reports may lack detailed and reliable information due to recall bias or incomplete data collection, leading to potential inaccuracies in identifying causative agents or risk factors. To minimize these biases, our study focuses on analyzing risk factors associated with foodborne disease outbreaks (FBDOs), as outbreaks typically provide a clearer link between exposures and outcomes. This approach allows for more accurate identification of risk factors and enables targeted public health interventions.

Materials and Methods

Case Definition

FBD cases were defined as patients with diarrhoea (stools of abnormal character equal to or greater than three times), vomiting, or toxic symptoms suspected to be caused by food consumption. An outbreak referred to an incident in which two or more persons developed FBD with basically similar clinical manifestations after consumption of the same food at a similar time.

Data Sources

As part of a public health initiative, a specialized database for Foodborne Disease Outbreaks (FBDOs) was established in collaboration with the Jinhua Disease Control and Prevention Center. This database systematically collects and stores data on FBDOs reported in Jinhua city, including demographic details, clinical symptoms, suspected food vehicles, and laboratory test results. The Affiliated Jinhua Hospital of Zhejiang University School of Medicine was chosen as the sentinel hospital due to its comprehensive healthcare coverage, its central role in diagnosing and managing public health issues in the region, and its existing collaboration with the local Disease Control and Prevention Center for epidemiological monitoring. This selection ensures representativeness and reliability in capturing FBD trends within the city. The primary purpose of this database is to serve as a centralized resource for analyzing outbreak patterns, identifying risk factors, and guiding public health policies. This study utilized data from this database to ensure consistent and comprehensive records for analysis.

In addition, data for this study were extracted from the China Food and Drug Administration surveillance system as of March 1, 2023. These data included all reported FBDOs and associated cases occurring between January 1, 2018, and December 31, 2022, as specified in the title. Inclusion criteria required cases to meet the FBD definitions outlined in the study: (1) patients must present with diarrhea, vomiting, or toxic symptoms suspected to be caused by food consumption; (2) cases must be part of an outbreak involving two or more individuals with similar symptoms linked to the same food source; and (3) sufficient case information (eg, demographic details, clinical symptoms, and suspected food vehicle) must be available. Exclusion criteria were: (1) incomplete data, such as missing critical information about food source or clinical symptoms; (2) cases not meeting the FBD definition (eg, sporadic cases without clear evidence of foodborne etiology); and (3) insufficient information to confirm linkage to a specific FBDO.

The dataset included variables such as gender, age, occupation, home address, contact information, diet, duration of disease, clinical symptoms, suspected food vehicle, setting of food preparation or consumption, and the number of cases induced by suspected causative hazards. All identifying information about individual participants was anonymized to protect privacy. The data accessed complied with relevant data protection and privacy regulations.

The statistical methods applied in this study were chosen to align with the characteristics of the dataset and the study objectives. For categorical variables such as gender and occupation, descriptive analyses included frequencies and proportions, while continuous variables such as disease duration and economic burden were analyzed using medians, IQRs, and 95% CIs. These measures allow for a more accurate representation of variability and uncertainty in the findings.

Stool Sample Collection and Testing

Stool samples were collected as part of routine investigations during identified foodborne disease outbreaks (FBDOs) occurring between January 1, 2018, and December 31, 2022. Samples were obtained from patients who presented with diarrhea and other clinical symptoms consistent with FBD and were part of confirmed or suspected outbreaks. The criteria for stool sample collection included the presence of symptoms such as diarrhea and vomiting, as well as a suspected link to a common food source identified during outbreak investigations. Sample collection followed standardized national surveillance guidelines and was performed by trained healthcare professionals at sentinel hospitals.

The stool samples were processed using bacterial culture and molecular biology techniques to detect bacterial and viral pathogens, focusing on common pathogens associated with foodborne diseases. For bacterial culture, stool samples were enriched in buffered peptone water and plated onto selective agar media. The media included Xylose Lysine Deoxycholate (XLD) agar for isolating Salmonella and Shigella species, Thiosulfate-Citrate-Bile-Sucrose (TCBS) agar for Vibrio species, and Sorbitol MacConkey (SMAC) agar for identifying pathogenic Escherichia coli, particularly E. coli O157. Presumptive colonies were confirmed through biochemical tests, such as the triple sugar iron (TSI) test, urea hydrolysis, and oxidase tests. Serological assays with specific antisera were performed for further confirmation.

To evaluate the reliability of diagnostic results, 95% CIs were calculated for the proportions of confirmed cases attributed to each pathogen. This provides an additional measure of uncertainty in laboratory findings and enhances the robustness of pathogen identification.

For molecular assays, techniques including real-time PCR (qPCR) and reverse transcription PCR (RT-PCR) were employed to identify bacterial and viral pathogens. All laboratory tests were conducted in accordance with national standards (GB47894-2010, GB47895-2003, GB47897-2008, and GB47896-2003) and the testing procedures outlined in the Manual of 2014 National Foodborne Disease Monitoring Work. These analyses were performed in collaboration with an accredited public health laboratory under the guidance of national foodborne disease surveillance programs.

Economic Burden Estimation

The economic burden was estimated by adding up transportation costs, income loss, and medical costs. The distance travelled by car from home to the hospital was obtained from AMAP. The gas price was estimated from the average price of No. 95 gas at the beginning and end of the year published by the Zhejiang Provincial Development and Reform Commission. The income loss of patients was estimated by multiplying the number of outpatient or inpatient days by (per capita disposable income for the residents of the whole city in the current year/365). The income loss of minor patients referred to the income loss of their guardians.

Medical costs were estimated as out-of-pocket expenses incurred by patients during their hospital visits. These costs included pharmaceutical expenses (eg, medication costs), physician consultation fees, diagnostic and laboratory testing charges, and hospital bed charges for inpatients. Data on medical costs were extracted from hospital billing records, which provided a detailed breakdown of these expenses. To ensure consistency, the average pricing data for similar treatments and procedures were used when specific cost details were unavailable in the records.

Given the skewed distribution of cost-related data, the median and interquartile range (IQR) were used as measures of central tendency and variability, respectively, instead of the mean. Additionally, 95% confidence intervals (CIs) for median values were calculated using bootstrapping methods to provide robust uncertainty estimates. This approach ensures that the reported economic burden reflects both the central tendency and the variability inherent in the data.

Data Analysis

EXCEL 2010 and SPSS 12.0 were used for the collation of data and the descriptive analyses of numerical variables and frequency and proportion of variables. To ensure the robustness of the statistical analyses and account for uncertainty in the data, measures such as 95% confidence intervals (CIs) were calculated alongside point estimates (eg, median values) for key outcomes, including economic burden, outbreak duration, and patient demographics.

For group comparisons, Chi-square tests were employed to analyze categorical variables, while Mann–Whitney *U*-tests were used for continuous variables with non-normal distributions. These statistical methods were chosen to align with the study's objectives of assessing epidemiological trends and the economic burden of foodborne disease outbreaks. Statistical significance was defined as $p < 0.05$.

Results

Basic Information Distribution

There were 63 FBDOs and 305 cases from 2018 to 2022. Two cases died due to accidental ingestion of wood ear and nitrite, respectively. Outbreak-associated FBD occurred more frequently in males (55.08%, 95% CI: 50.22%–59.93%) than in females (44.92%, 95% CI: 40.07%–49.78%), with a gender ratio of 1.23:1. In addition, the percentage of individuals aged 5~ and 10~ years, students (56.72%, 95% CI: 51.65%–61.79%), and farmers (12.46%, 95% CI: 8.88%–16.04%) was higher among all cases (Table 1). Among the 305 cases, 257 (84.26%) were outpatients, while 48 (15.74%) were inpatients. For inpatients, the median length of stay was 3 days (IQR: 2–5 days), with a maximum stay of 12 days. This information is critical for estimating inpatient-related medical costs.

Time Distribution

FBDOs occurred maximally in 2020 (17 outbreaks, 26.99%, 95% CI: 18.88%–35.10%) and minimally in 2022 (3 outbreaks, 4.76%, 95% CI: 0.65%–8.87%). The number of FBD cases was the highest in 2018 (81 cases, 26.56%, 95% CI: 21.64%–31.48%) and the lowest in 2022 (8 cases, 2.62%, 95% CI: 0.85%–4.39%) (Table 1). Mushroom and bacterial

Table 1 Basic Information Distribution of FBDOs and FBD Cases

Classification	Number	Percentage (%)	Classification	Number of FBDOs (cases)	Percentage (%)
Gender			Year		
Male	169	55.08	2017	8 (35)	12.70 (11.48)
Female	138	44.92	2018	13 (81)	20.63 (26.56)
Age group(yr.)			2019	11 (75)	17.46 (24.59)
0~	9	2.95	2020	17 (63)	26.99 (20.66)
5~	66	21.64	2021	11 (43)	17.46 (14.10)
10~	43	14.1	2022	3 (8)	4.76 (2.62)
15~	70	22.95	Season		
20~	27	8.85	Spring	16	25.4
30~	28	9.18	Summer	18	28.57
40~	24	7.87	Autumn	23	36.51
50~	23	7.54	Winter	6	9.52
60~	11	3.61			
70~	4	1.31			
Occupation					
Students	173	56.72			
Farmers	38	12.46			
Commercial service	30	9.84			
Workers	27	8.85			
Preschoolers	17	5.57			
Office staff	10	3.28			
Unemployed	10	3.28			
Total	305	100	Total	63 (305)	100

food poisoning mainly occurred during warm weather, while *Norovirus* infections primarily occurred during cold weather, such as autumn and winter. There was no significant seasonal difference in food poisoning due to *Vibrio cholerae, Bongkrek acid*, and nitrite due to insufficient numbers (Figure 1).

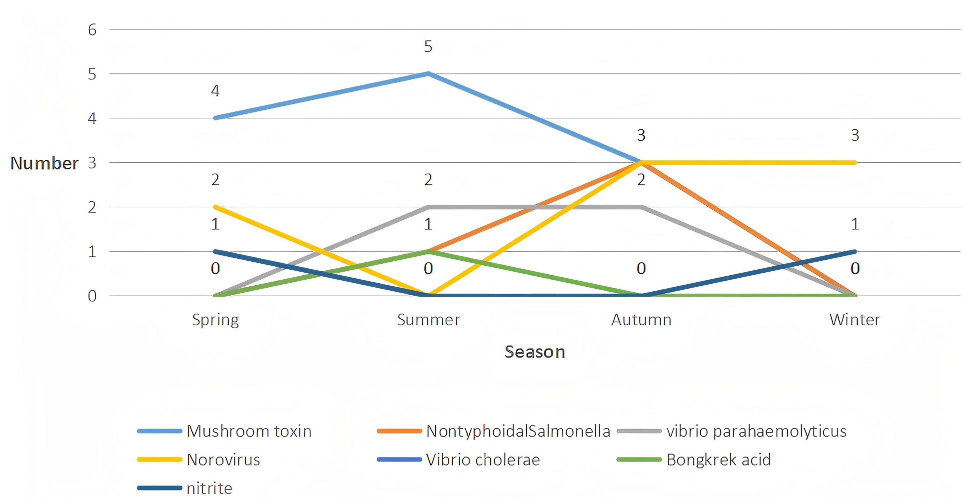

Figure 1 Seasonal distribution of FBDOs with identified risk factors.

Main Clinical Symptoms

The major symptoms of patients were diarrhoea (69.51%, 95% CI: 64.50%–74.51%), vomiting (49.51%, 95% CI: 44.35%–54.68%), abdominal pain (31.48%, 95% CI: 26.69%–36.26%), nausea (30.16%, 95% CI: 25.40%–34.92%), and fever (20.33%, 95% CI: 16.08%–24.58%). The clinical symptoms of cases are detailed in Table 2.

Food Preparation or Consumption Setting and Suspected Food Vehicles

Catering services were associated with the highest number of outbreaks and cases, accounting for 38 outbreaks (60.31%, 95% CI: 48.65%–71.96%) and 172 cases (56.39%, 95% CI: 50.89%–61.89%). Bulk food resulted in 4 outbreaks (6.35%, 95% CI: 0.34%–12.37%) and 64 cases (20.98%, 95% CI: 16.39%–25.58%), followed by homemade food (20 outbreaks, 31.75%, 95% CI: 20.69%–42.80%) and fixed packaged food (1 outbreak, 1.59%, 95% CI: 0.00%–4.68%) (Table 3). We explored the relationships between food preparation settings and the severity of cases (outpatient vs inpatient encounters) using descriptive statistics. A higher frequency of inpatient admissions was observed among cases linked to homemade food preparation,

Table 2 Clinical Symptoms of Foodborne Disease Cases

Main Clinical Symptoms	Number of Cases	Rate (%)
Diarrhoea	212	69.51
Vomiting	151	49.51
Abdominal pain	96	31.48
Nausea	92	30.16
Fever	62	20.33
Hypourocrinia	14	4.59
Thirst	13	4.26
Weakness	10	3.28
Dehydration	7	2.3

Table 3 Number and Proportion of Food Preparation or Consumption and Vehicle

	FBDOs [n (%)]	FBD cases [n (%)]
Setting of food preparation or consumption		
Catering services (Including canteen)	38 (60.31)	172 (56.39)
Bulk food	4 (6.35)	64 (20.98)
Homemade	20 (31.75)	56 (18.36)
Fixed package	1 (1.59)	13 (4.26)
Suspected food vehicle		
Meat products	13 (20.64)	80 (26.23)
Multiple foods	15 (23.81)	78 (25.57)
Fungi	14 (22.23)	68 (22.30)
Packed drinking water	2 (3.17)	16 (5.25)
Aquatic products	4 (6.35)	11 (3.93)
Beans products	3 (4.76)	12 (3.61)
Blended foods	3 (4.76)	11 (3.61)
Fruits	3 (4.76)	10 (3.28)
Cereal foods	2 (3.17)	7 (2.30)
Vegetables	1 (1.59)	6 (1.97)
Drinks	1 (1.59)	2 (1.31)
Condiments	2 (3.17)	4 (0.66)
Total	63 (100)	305 (100)

suggesting that cases associated with homemade food were more likely to require hospitalization, potentially due to improper food handling at home. No significant associations were found between catering services and inpatient encounters.

Pathogenic Factors of FBDOs and the Number of Cases for Each Identified Factor

Nearly half of the outbreaks were caused by unidentified pathogenic factors (31 outbreaks, 49.21%, 95% CI: 37.48%–60.94%). Among the identified factors, *Mushroom toxin* (12 outbreaks, 19.05%, 95% CI: 9.22%–28.88%) was the primary factor for FBDOs, followed by *Norovirus* (8 outbreaks, 12.70%, 95% CI: 4.48%–20.92%), *Nontyphoidal Salmonella* (4 outbreaks, 6.35%, 95% CI: 0.34%–12.37%), *Vibrio parahaemolyticus* (4 outbreaks, 6.35%, 95% CI: 0.34%–12.37%), nitrite (2 outbreaks, 3.17%, 95% CI: 0.00%–7.50%), *Vibrio cholerae* (1 outbreak, 1.59%, 95% CI: 0.00%–4.68%), and *Bongkrek acid* (1 outbreak, 1.59%, 95% CI: 0.00%–4.68%) (Figure 2). Hypothesis testing (Chi-square test) was performed to evaluate the relationship between specific pathogens and the severity of cases (inpatient vs outpatient). *Norovirus*-related cases showed a significantly higher proportion of inpatient encounters compared to cases caused by *Mushroom toxin* ($p = 0.02$), likely due to the severity of dehydration and gastrointestinal symptoms associated with *Norovirus* infections.

Microbiological findings from stool samples identified four bacterial pathogens and one virus. The bacterial pathogens included *Nontyphoidal Salmonella* (18 cases), *Vibrio parahaemolyticus* (12 cases), *Vibrio cholerae* (1 case), and Shigella (no cases identified in this study), while *Norovirus* accounted for 52 cases (Table 4). These pathogens were confirmed using bacterial culture and molecular biology techniques, in compliance with national standards. Among the bacterial pathogens, *Nontyphoidal Salmonella* and *Vibrio parahaemolyticus* were the most frequently identified, consistent with their global association with foodborne outbreaks. *Norovirus* was the leading cause of viral infections and contributed to a significant number of outbreaks during cold seasons, particularly in autumn and winter.

Suspected Food Vehicle of the Identified Factors

Suspected food vehicles of 32 outbreaks related to the identified factors are displayed in Table 4. *Mushroom toxin* poisoning was entirely attributed to the consumption of wild mushrooms. *Norovirus* poisoning was associated with multiple foods, meat products, fungi, and Beans products. *Nontyphoidal Salmonella* poisoning was related to many foods and meat products. *Vibrio*

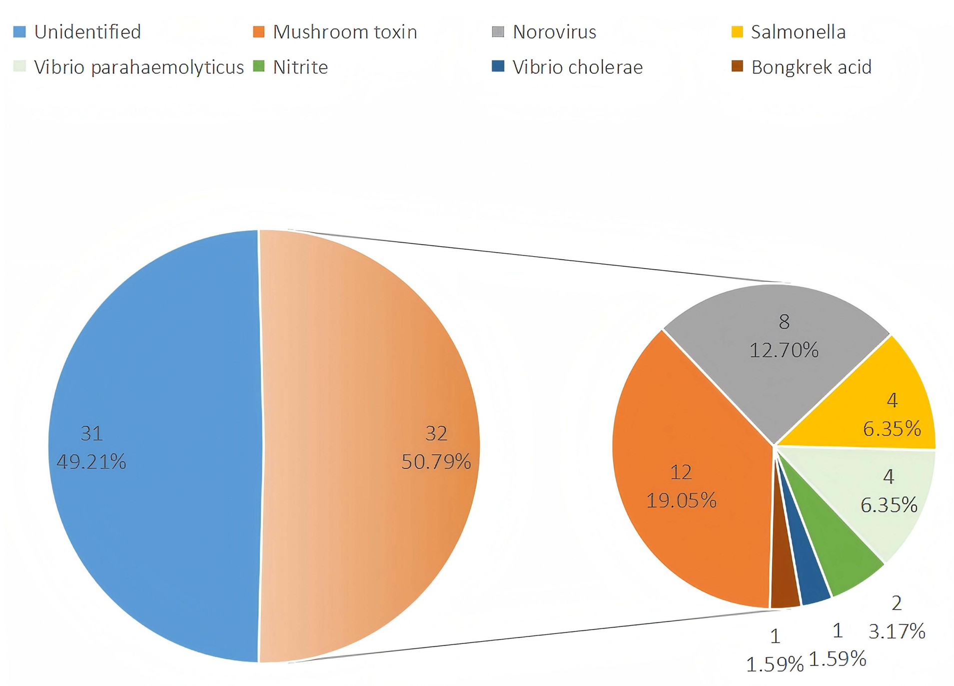

Figure 2 Pathogenic factors of FBDOs.

Table 4 Number of Cases for Each Identified Factor

Identified Factor	Number of Cases
Norovirus	52
Mushroom toxin	32
Nontyphoidal Salmonella	18
Vibrio parahaemolyticus	12
Nitrite	4
Bongkrek acid	2
Vibrio cholerae	1
Total	**121**

Table 5 Suspected Food Vehicles of the Identified Factors

Identified Factor	Suspected Food Vehicle	Number [percentage (%)]
Mushroom toxin	Fungi (wild mushroom)	12 (100%)
Norovirus	Multiple foods	4 (50.00%)
	Meat products	2 (25.00%)
	Fungi	1 (12.50%)
	Beans products	1 (12.50%)
Nontyphoidal Salmonella	Multiple foods	2 (50.00%)
	Meat products	2 (50.00%)
Vibrio parahaemolyticus	Multiple foods	2 (50.00%)
	Meat products	1 (25.00%)
	Aquatic products	1 (25.00%)
Nitrite	Condiments	2 (100%)
Vibrio cholerae	Cereal foods	1 (100%)
Bongkrek acid	Fungi (wood ear)	1 (100%)
Total		**32**

parahaemolyticus poisoning was related to numerous foods, meat products, and aquatic products. Nitrite poisoning was associated with misuse of condiments, and *Bongkrek acid* poisoning was related to wood ear (Table 5).

Economical Burden of FBDOs

The total economic burden was estimated at 228,078.74 yuan (95% CI: 215,674.32–240,483.16 yuan) (US dollar 33,885.64) for the 305 cases from 2018 to 2022, with an average economic burden of 648.29 yuan (95% CI: 598.64–698.12 yuan) (US dollar 95.29). The average transportation costs, income loss, and medical costs were 38.46 yuan (6.00%, 95% CI: 4.50%–7.50%), 132.05 yuan (22.00%, 95% CI: 18.00%–26.00%), and 440.00 yuan (72.00%, 95% CI: 68.00%–76.00%) respectively (Figure 3). We further stratified the economic burden based on outpatient and inpatient encounters. The median cost for inpatients was 1567.89 yuan (IQR: 1265.34–1898.45), which was significantly higher than that for outpatients (median: 385.24 yuan, IQR: 320.15–462.08, $p < 0.01$). This difference is largely attributed to prolonged hospital stays and additional diagnostic testing required for inpatients.

Discussion

In our previous study, we focused on the epidemiological characteristics of sporadic FBD cases.[14] In this study, we extended the analysis to FBDOs, which offer more insights into public health risks by identifying common risk factors and contamination sources. FBDOs in educational institutions such as schools or kindergartens reflect specific risks to students' health. In our study, students accounted for 56.72% of cases, highlighting the need for targeted interventions in these settings. Individual FBD cases are often affected by recall bias, complicating the identification of reliable risk

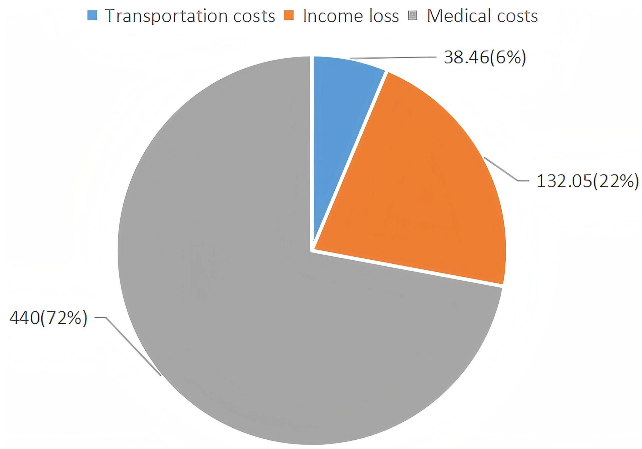

Figure 3 Economical burden of FBDOs.

factors. By focusing on FBDOs, our study reduces bias and enhances result reliability. To support this work, we established a database for FBDOs to systematically collect data and provide information to the CDC and regulatory agencies for public health action.

To enhance the surveillance and analysis of FBDOs in Jinhua, we established a specialized database. This database systematically collects data on FBDOs, including demographics, clinical symptoms, suspected food vehicles, and laboratory results. The primary purpose is to analyze outbreak patterns, identify risk factors, and guide public health policies. Building upon our earlier findings on individual FBD cases, this study utilizes the newly established database to provide a more comprehensive analysis of FBDOs.

The incidence of FBD is closely linked to climatic factors such as temperature, rainfall, and humidity, which favor the growth of foodborne pathogens.[15,16] Different pathogens exhibit distinct seasonal patterns, with bacterial infections such as *Nontyphoidal Salmonella* and *Vibrio parahaemolyticus* more frequent in warmer months, while viral infections such as *Norovirus* peak in cooler months.[17,18] Consistent with findings from other regions of China and internationally, our study showed that *Norovirus* peaked in autumn and winter, while *Vibrio parahaemolyticus* and *Nontyphoidal Salmonella* were predominant in summer.

Estimating the overall burden of FBD is challenging due to the diverse contamination sources, including bacteria, viruses, parasites, and chemicals.[19] Some suspected FBD cases or outbreaks are not foodborne, complicating the identification of vehicles and increasing the likelihood of misclassification. For instance, the WHO estimated that 46–74% of human cases of Nontyphoidal Salmonellosis were foodborne, while only 14% of *Norovirus* outbreaks were linked to contaminated food.[20,21] FBD cases may be excluded due to insufficient food history surveys during diagnosis. Additionally, person-to-person transmission and occupational exposure, such as during slaughtering, contribute to the spread of pathogens. In our study, unidentified pathogens were responsible for nearly 50% of FBDOs, highlighting diagnostic challenges. Advanced methods, such as whole genome sequencing, are essential to improve outbreak investigations and reduce misclassification.

In our study, males were more vulnerable to FBD than females, likely due to their higher consumption of "high-risk" foods and greater exposure to risk factors through dining out, as also reported in other studies.[11,22] People aged < 15 and > 60 years accounted for 43.61% of all cases, likely due to their lower immunity, as also noted in Zhang et al's study.[1] This difference in risk could also be related to dietary habits and food choices, as males may have different eating behaviors and preferences, such as consuming more street food or processed foods, which could increase their exposure to foodborne pathogens. Students and farmers accounted for over 69% of cases, which may be influenced by various factors such as socioeconomic status, food availability, and lifestyle. Although it is common to associate low-cost food with increased FBD risk, other factors, such as food handling and storage practices, also play significant roles in contamination.[23] In China, most FBDOs occur in restaurants, schools, or canteens, while other studies suggest that the home is a common site, often linked to food purchased from catering facilities.[1,2,11,24] The rapid growth of online food delivery platforms has increased the popularity of takeaway food, particularly among young people. Cases associated with takeaway food may be dispersed across locations, making them harder to trace and often misclassified as sporadic cases.[25–27] The potential of takeaway food to trigger large-scale FBDOs highlights the need for stricter regulation and monitoring.

Mushroom toxin, the leading cause of FBDOs in our study (19.05% of outbreaks), underscores the risks of wild mushroom consumption in Zhejiang province, where residents may lack awareness of toxic species. Public health campaigns to raise awareness and promote the avoidance of toxic wild mushrooms are essential for preventing such outbreaks.

Food can be contaminated at any stage "from farm to fork", including storage, transportation, and cooking.[28] Food handlers are the primary sources of FBDOs,[21] especially foodborne *Norovirus* outbreaks.[29] Asymptomatic infected food handlers, also called "Typhoid Mary", are significant sources of such outbreaks, as they transmit pathogens imperceptibly.[21,30] High-risk foods, such as raw and ready-to-eat foods, are particularly vulnerable to contamination during processing. Hand hygiene, including regular health checkups, hand washing, and using gloves and masks, is essential for preventing FBDOs. Guidelines recommend that infected food handlers avoid work for 48 hours after symptoms resolve.[31]

In this study, specific etiologic agents and food vehicles were undetermined in nearly 50% of FBDOs, reflecting the challenges in identifying sources of outbreaks. The diversity of food types, preparation methods, and cooking techniques in China further complicates the identification of causative agents or contaminated foods. This inability to pinpoint specific foods hinders efforts to restrict the circulation of suspected foods and identify potential cases.[22,32]

Under-reporting is a global issue, with actual cases of FBDs and FBDOs far exceeding reported numbers. For instance, Mead et al estimated that only 0.008% of all FBD cases in the United States were identified in an outbreak,[10] while 95% of cases in developing countries, including China, go unreported.[11] In our study, limited surveillance and diagnostic capacity, especially for asymptomatic or mild cases, exacerbates this challenge. Consequently, the economic burden reported in this hospital is likely a substantial underestimate. Given China's large population, the actual economic cost imposes a significant burden on society and individuals. To quantify the degree of this underestimation, we suggest that future studies should use more comprehensive data sources, including national-level surveys and household expenditure data, to improve the accuracy of economic burden estimates. A more robust method, such as incorporating indirect costs (eg, lost productivity and informal care costs), would likely yield a more accurate picture of the total economic burden. This highlights the urgent need to improve reporting systems and strengthen laboratory diagnostics to better estimate the true burden of FBDOs.

To improve the accuracy of cost estimations in the future, it is essential for policymakers to invest in strengthening public health infrastructure and surveillance systems. Improved data collection on both direct and indirect costs, along with better integration of surveillance systems, would allow for more accurate cost assessments. Furthermore, enhancing food safety regulations, improving foodborne disease reporting, and promoting public awareness could contribute to better cost estimations and ultimately reduce the economic burden of FBDOs in China.

As a result of the COVID-19 epidemic and government containment measures, the number of FBDOs declined sharply in 2022 compared with previous years. FBD imposes a significant disease burden on both individuals and society. The reduction in FBDOs highlights the potential benefits of enhanced hygiene practices and stricter food handling regulations during the pandemic, offering valuable lessons for long-term food safety improvements.

With China's economic growth, concerns have shifted from food supply to food safety, requiring greater investment in public health infrastructure and surveillance systems.[33,34] Globally, systems like the Foodborne Diseases Active Surveillance Network (FoodNet) in the United States have been established to monitor FBDOs.[35–37] In China, a food safety risk monitoring platform was established in 2009, followed by a laboratory-based FBD surveillance system launched in 2011.[17,23] Despite these developments, challenges remain in coverage, timeliness, and integration, especially in resource-limited regions. Expanding regional laboratory centers and fostering collaboration between public health agencies and hospitals could significantly enhance the effectiveness of FBD surveillance.

Approximately 90% of FBD cases are caused by seven pathogens, including Salmonella, *Norovirus*, and Campylobacter, which alone account for over 70% of cases.[9,17] In this hospital, only five pathogens (four bacteria and one virus) were monitored, reflecting the limited laboratory capacity for FBD surveillance at single hospitals and cities. Advances in microbial genome methods, such as Whole Genome Sequencing (WGS), have enhanced pathogen detection and outbreak investigation.[20] Establishing regional laboratory centers is a cost-effective way to increase laboratory capacity, enabling more FBD cases to be diagnosed and reported to public health agencies. Such advancements could also uncover previously undetected outbreaks and pathogens, providing a clearer understanding of FBD epidemiology in China.

In our study, *Mushroom toxin* was the principal factor for FBDOs among all identified factors. Wild poisonous mushrooms are the leading cause of FBDO-associated deaths in China, particularly in the warm and humid southwest region.[38] Poisonous mushroom species are difficult to differentiate due to regional variations in appearance, increasing the risk of ingestion.[39] The poor awareness of poisonous mushrooms, particularly in rural areas, highlights the need for targeted health education to discourage their consumption and sale. The "Toxic Biological Sample Bank" project in Yunnan province facilitates mushroom taxonomy and clinical diagnosis, offering a model for expansion to regions like Zhejiang.[40]

Unfortunately, there were two deaths in our study, attributed to the accidental consumption of wood ear (*Bongkrek acid*) and nitrite, respectively. *Bongkrek acid*, a deadly toxin produced by Pseudomonas cocovenenans, can cause severe symptoms such as abdominal pain, vomiting, organ failure, and even death.[41] It is typically generated by inappropriate long-term storage of starch-based foods like wood ear, tremella, and cornmeal in warm seasons. Nitrite, commonly used as a permitted additive in meat processing, can be fatal when ingested excessively. Its resemblance to salt often leads to accidental ingestion and fatalities. Foods like wood ear and tremella should be stored properly and consumed promptly, while nitrite must be stored securely and its use strictly regulated to prevent accidental ingestion.

Ensuring food safety requires a systematic and collaborative approach involving governments, the food industry, and consumers. The risk of contamination exists throughout the food supply chain, including improper storage, cooking, and cross-contamination.[1] Governments should strengthen policies, regulations, and supervision to create a favourable environment for food safety, while the food industry must adhere to strict standards and provide health education to employees to maintain professional skills. Consumers should prioritize safe food choices and maintain good dietary habits to minimize risks.

This study highlights key findings on the epidemiology and economic burden of FBDOs in Jinhua city. The findings emphasize the need for strengthened surveillance and public health interventions to reduce the burden of foodborne diseases.

To address the limitations highlighted in this study, future efforts should focus on improving the granularity and integration of data collection methods to capture a more comprehensive picture of foodborne disease (FBD) epidemiology. Furthermore, this study highlights several areas for future research and development in the field of FBD prevention and control. There is a critical need to enhance the coverage and integration of surveillance systems, particularly in resource-limited regions, to ensure timely and comprehensive monitoring of FBD outbreaks. Innovative diagnostic techniques, such as whole genome sequencing, should be further explored and applied to improve pathogen identification and outbreak investigation. Future studies should also aim to better understand the economic burden of FBD in different demographic and regional settings, providing evidence for cost-effective interventions. Lastly, public health campaigns tailored to local cultural and dietary habits should be developed and evaluated to raise awareness about food safety practices. These efforts will contribute to a deeper understanding of FBD epidemiology and more effective strategies to mitigate its impact on public health.

Limitation of Study

This study has several limitations. First, the data were collected from a single hospital, which may limit the generalizability of the findings to other regions. Second, certain self-reported variables, such as dietary habits, may introduce recall bias. Third, the study period was relatively short, which may not fully capture long-term trends in foodborne diseases. Finally, while laboratory-confirmed cases were analyzed, the lack of molecular typing may have limited the ability to identify specific outbreaks or trace their sources. Despite these limitations, the findings provide valuable insights into the regional trends of foodborne diseases and can serve as a foundation for future research.

Conclusions

This study provides a detailed analysis of the epidemiological characteristics of FBDOs within the specific context of a hospital-based setting. Unlike general studies that often discuss FBDOs in broader or regional terms, our research focuses on understanding the patterns of disease transmission and the contributing factors specific to this hospital. The findings highlight the critical role of infection control measures and emphasize the need for improved surveillance systems within healthcare institutions to better manage and mitigate foodborne outbreaks. Moreover, the study contributes to a deeper understanding of how hospital-related factors, such as food handling practices and patient demographics, influence the spread of foodborne diseases. These insights provide valuable implications for developing targeted strategies to prevent and control FBDOs in hospital environments.

Abbreviations

FBD, Foodborne disease; FBDOs, FBD outbreaks; WHO, World Health Organization.

Data Sharing Statement

All data generated or analysed during this study are included in this published article.

Ethics Statement and Informed Consent

The study was conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Affiliated Jinhua Hospital, Zhejiang University School of Medicine (2022-ethical review-105), and a waiver of informed consent was granted by the IRB.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors have declared that no competing interests exist in this work.

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