Preplanned Studies

Diarrheagenic *Escherichia coli* Outbreak Reporting to Foodborne Disease Outbreaks Surveillance System — China, 2011–2022

Tongyu Wang[1]; Yangbo Wu[1]; Weiwei Li[2]; Ping Fu[2]; Hongqiu Li[2]; Ning Li[2]; Yue Dai[3]; Junhua Liang[4]; Xiaochen Ma[1,#]; Yunchang Guo[2,#]

Summary

What is already known about this topic?

Foodborne diarrheagenic *Escherichia coli* (DEC) outbreaks constitute a significant global public health concern, yet comprehensive data on outbreak incidence and epidemiological characteristics in China remain limited.

What is added by this report?

Between 2011 and 2022, there were 413 foodborne DEC outbreaks reported to foodborne disease outbreak surveillance system, resulting in 8,127 illnesses, 2,565 hospitalizations, and one fatality. Enteroaggregative *Escherichia coli* (EAEC) emerged as the predominant causative pathogen (48.82% of outbreaks), with school canteens being the most frequent outbreak setting (21.79%).

What are the implications for public health practice?

This systematic analysis of foodborne DEC outbreak trends and epidemiological characteristics in China over the past decade provides crucial insights for enhancing outbreak investigation capabilities and identifying specific etiologies, food vehicles, and high-risk settings associated with these outbreaks.

Escherichia coli typically exists as a commensal organism in the gastrointestinal tract of humans and animals, remaining harmless under normal conditions (*1*). However, certain pathogenic strains can cause severe clinical manifestations, including acute diarrhea, hemolytic uremic syndrome (HUS), and thrombocytopenic purpura (*2*). Foodborne diarrheagenic *Escherichia coli* (DEC) represents one of the predominant etiological agents of acute diarrhea in low- and middle-income countries (*3*), and has emerged as a significant pathogen in diarrheal cases throughout China (*4*).

DEC outbreaks persist globally, affecting both developed and developing nations, with potential fatal outcomes and substantial public health and economic implications (*5*). Many countries have implemented comprehensive national surveillance systems specifically designed to monitor and track DEC outbreaks, such as the Foodborne Disease Outbreak Surveillance System (FDOSS) in the USA and the Rapid Outbreak Assessment system for multi-country foodborne outbreaks in the European Union (*6*–*7*). This study analyzes DEC outbreaks reported to the FDOSS in China during 2011–2022 to inform evidence-based food safety policies and interventions for the Chinese population.

The FDOSS, established in 2011, serves as a centralized system for managing and mitigating foodborne disease outbreaks. For each outbreak, the system collects comprehensive data including reporting unit, temporal and geographic information, food preparation setting, case counts (illnesses, hospitalizations, and deaths), confirmed etiology, and implicated food vehicles. All outbreak investigation reports undergwent systematic review by dedicated personnel. A foodborne DEC outbreak is defined as two or more cases presenting with similar illness and/or one or more deaths resulting from consumption of a common food source, with laboratory confirmation of *E. coli* as the causative pathogen. Outbreaks involving multiple etiologic agents were excluded from this analysis.

Food source attribution was determined based on epidemiological evidence. Food vehicles were categorized using a two-tiered classification system. The first tier comprises five broad categories (including animal-based foods), while the second tier subdivides foods into 14 mutually exclusive categories. Single-ingredient foods or foods containing ingredients from the same category were classified accordingly. Foods containing ingredients from multiple categories were designated as complex or multiple foods.

Statistical analyses were conducted using R software (version 4.1.2, R Foundation for Statistical Computing, Vienna, Austria). Exact binomial tests were employed to calculate 95% confidence intervals

(*CI*) for outbreak rates, illness rates, and hospitalization rates. Temporal trends were assessed using the Mann-Kendall trend test (M-K test). Population-based rates were computed using demographic data from the National Bureau of Statistics of China (*8*).

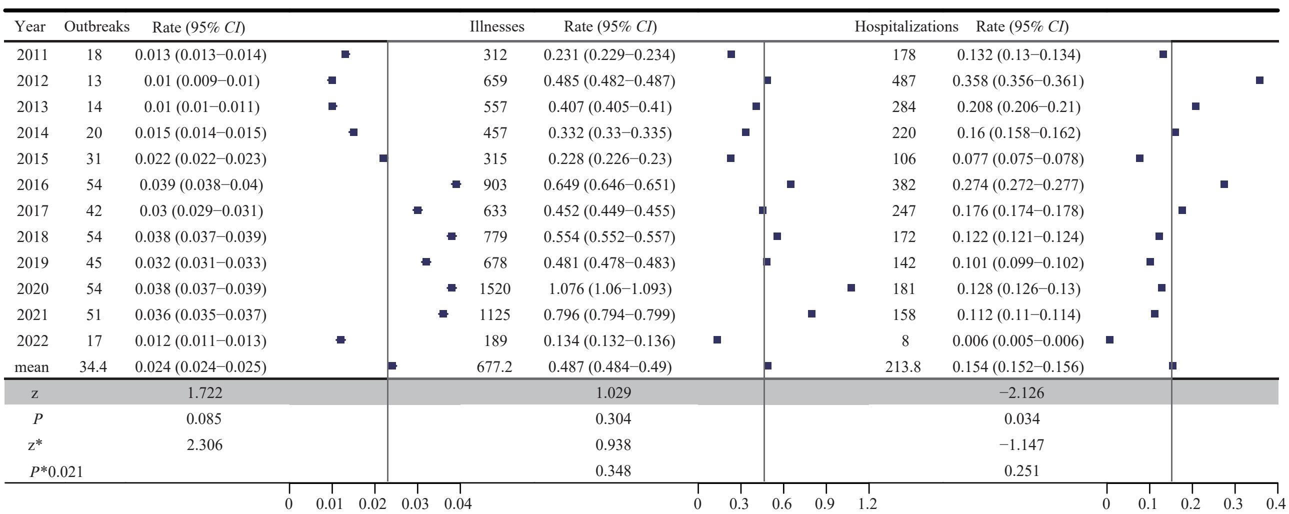
Given the seasonal nature of foodborne DEC infections, we employed a Seasonal Autoregressive Integrated Moving Average (SARIMA) model to generate short-term forecasts (2020–2022) based on historical time series data. The SARIMA model, widely applied across various fields, has demonstrated utility in time series analysis and prediction. For example, it was successfully used to model USA oil consumption patterns during the COVID-19 pandemic, enabling assessment of pandemic-related impacts on consumption from January 2020 to March 2021 (*9*).

During 2011–2022, 413 foodborne DEC outbreaks were documented in China, resulting in 8,127 illnesses, 2,565 hospitalizations, and one death (Figure 1). The annual averages (rates) were 34.4 outbreaks [0.024 (95% *CI*: 0.024, 0.025) per 100,000], 677.2 illnesses [0.487 (95% *CI*: 0.484, 0.490) per 100,000], and 213.8 hospitalizations [0.154 (95% *CI*: 0.152, 0.156) per 100,000]. The annual rate of reported foodborne DEC outbreaks showed a significant increasing trend from 2011 to 2019 (0.013–0.032 per 100,000) (*P* for trend =0.021), followed by a declining trend from 2020 to 2022 (0.038 to 0.012 per 100,000, *P* for trend =0.085).

School canteens were the predominant outbreak setting, accounting for 21.79% of all outbreaks and the highest proportions of outbreak-related illnesses (3,206, 39.45%) and hospitalizations (1,002, 39.06%). In contrast, fast food establishments were associated with the lowest numbers of illnesses (27, 0.33%) and hospitalizations (10, 0.39%). The single reported death occurred in a workplace cafeteria. Food vehicles were identified in 76.76% (317) of outbreaks, with 187 (58.99%) attributed to a single food category, resulting in 6,000 illnesses and 2,220 hospitalizations. Animal-based foods were the most frequently implicated single commodity (113 outbreaks, 27.36%). The sole outbreak-associated death was linked to multiple foods (fried lesser croaker, quail eggs, lamb liver) served in a workplace cafeteria (Table 1).

Using the SARIMA model, we analyzed and predicted DEC outbreak patterns in China. The model forecasted 51, 57, and 57 outbreaks for 2020–2022, while actual reported numbers were 54, 51, and 17, respectively. Similarly, predicted illness counts for 2021 (1,137) and 2022 (1,389) exceeded actual reported cases (1,125 and 189). Hospitalization predictions (252,240,240) also surpassed actual numbers (181,158,8) during 2020–2022 (Supplementary Table S1, available at https://weekly.chinacdc.cn/).

Geographic distribution analysis revealed substantial regional variation in outbreak occurrence. Yunnan province reported the highest number of outbreaks (*n*=42), while Beijing, Xinjiang Autonomous Region, and Hebei province each reported the lowest (*n*=2) during the 12-year period. Provincial outbreak rates



Year	Outbreaks	Rate (95% *CI*)	Illnesses	Rate (95% *CI*)	Hospitalizations	Rate (95% *CI*)
2011	18	0.013 (0.013−0.014)	312	0.231 (0.229−0.234)	178	0.132 (0.13−0.134)
2012	13	0.01 (0.009−0.01)	659	0.485 (0.482−0.487)	487	0.358 (0.356−0.361)
2013	14	0.01 (0.01−0.011)	557	0.407 (0.405−0.41)	284	0.208 (0.206−0.21)
2014	20	0.015 (0.014−0.015)	457	0.332 (0.33−0.335)	220	0.16 (0.158−0.162)
2015	31	0.022 (0.022−0.023)	315	0.228 (0.226−0.23)	106	0.077 (0.075−0.078)
2016	54	0.039 (0.038−0.04)	903	0.649 (0.646−0.651)	382	0.274 (0.272−0.277)
2017	42	0.03 (0.029−0.031)	633	0.452 (0.449−0.455)	247	0.176 (0.174−0.178)
2018	54	0.038 (0.037−0.039)	779	0.554 (0.552−0.557)	172	0.122 (0.121−0.124)
2019	45	0.032 (0.031−0.033)	678	0.481 (0.478−0.483)	142	0.101 (0.099−0.102)
2020	54	0.038 (0.037−0.039)	1520	1.076 (1.06−1.093)	181	0.128 (0.126−0.13)
2021	51	0.036 (0.035−0.037)	1125	0.796 (0.794−0.799)	158	0.112 (0.11−0.114)
2022	17	0.012 (0.011−0.013)	189	0.134 (0.132−0.136)	8	0.006 (0.005−0.006)
mean	34.4	0.024 (0.024−0.025)	677.2	0.487 (0.484−0.49)	213.8	0.154 (0.152−0.156)
z		1.722		1.029		−2.126
P		0.085		0.304		0.034
z*		2.306		0.938		−1.147
*P**0.021				0.348		0.251

FIGURE 1. Annual incidence and rate of foodborne DEC outbreaks in China, 2011–2022.
Note: Z and *P* values indicate trend analysis results for the entire period 2011–2022; Z* and *P** values indicate trend analysis results for the pre-pandemic period 2011–2019.
Abbreviation: DEC=diarrheagenic *Escherichia coli*; *CI*=confidence interval.

TABLE 1. Number and percentage of foodborne diarrheagenic *Escherichia coli* outbreaks, illnesses, and hospitalizations by setting and food vehicle in China, 2011–2022.

Settings	Outbreaks, *n* (%)	Illnesses, *n* (%)	Hospitalizations, *n* (%)
Canteens			
School canteens	90 (21.79)	3,206 (39.45)	1,002 (39.06)
Workplace cafeteria	43 (10.41)	737 (9.07)	87 (3.39)
Catering services			
Restaurant	89 (21.55)	1,609 (19.80)	593 (23.12)
Street stall	19 (4.60)	127 (1.56)	28 (1.09)
Takeaway	6 (1.45)	91 (1.12)	4 (0.16)
Fast food service	5 (1.21)	27 (0.33)	10 (0.39)
Homes			
Household	63 (15.25)	297 (3.65)	152 (5.93)
Rural banquet	34 (8.23)	745 (9.17)	483 (18.83)
Markets			
Food supermarket	6 (1.45)	80 (0.98)	63 (2.46)
Other locations	8 (1.94)	66 (0.81)	7 (0.27)
Unknown locations	50 (12.11)	1,142 (14.05)	136 (5.30)
Food vehicles			
Animal-based food			
Meat	91 (22.03)	1,735 (21.35)	609 (23.74)
Aquatic animals	15 (3.63)	124 (1.53)	53 (2.07)
Egg	6 (1.45)	91 (1.12)	2 (0.08)
Dairy	1 (0.24)	23 (0.28)	23 (0.90)
Plant-based food			
Vegetable	22 (5.33)	296 (3.64)	133 (5.19)
Grains	21 (5.08)	248 (3.05)	56 (2.18)
Bean	8 (1.94)	112 (1.38)	63 (2.46)
Fruit	4 (0.97)	13 (0.16)	0 (0)
Pastry	3 (0.73)	68 (0.84)	59 (2.30)
Multiple/complex food			
Multiple food	46 (11.14)	873 (10.74)	59 (2.30)
Complex food	84 (20.34)	1,869 (23.00)	964 (37.58)
Drinks			
Drinking water	13 (3.15)	431 (5.30)	199 (7.76)
Beverages	3 (0.73)	117 (1.44)	0 (0)
Unknown food	96 (23.24)	2,127 (26.17)	345 (13.45)
Total	413 (100)	8,127 (100)	2,565 (100)

ranged from 0.027 per 1,000,000 population in Hebei to 0.899 per 1,000,000 in Yunnan. Illness rates showed similar variation, from 9 cases (0.372 per 1,000,000) in Xinjiang to 1,202 cases (25.74 per 1,000,000) in Yunnan (Figure 2). The single reported death occurred in Inner Mongolia Autonomous Region, with no cross-provincial outbreaks documented.

Laboratory confirmation of DEC pathotypes was available for 254 outbreaks (60.50%), accounting for 5,070 illnesses (62.38%) and 1,077 hospitalizations (41.99%). Enteroaggregative *E. coli* (EAEC) emerged as the predominant etiologic agent, responsible for 124 outbreaks (48.82%), 2,124 illnesses (41.87%), and 235

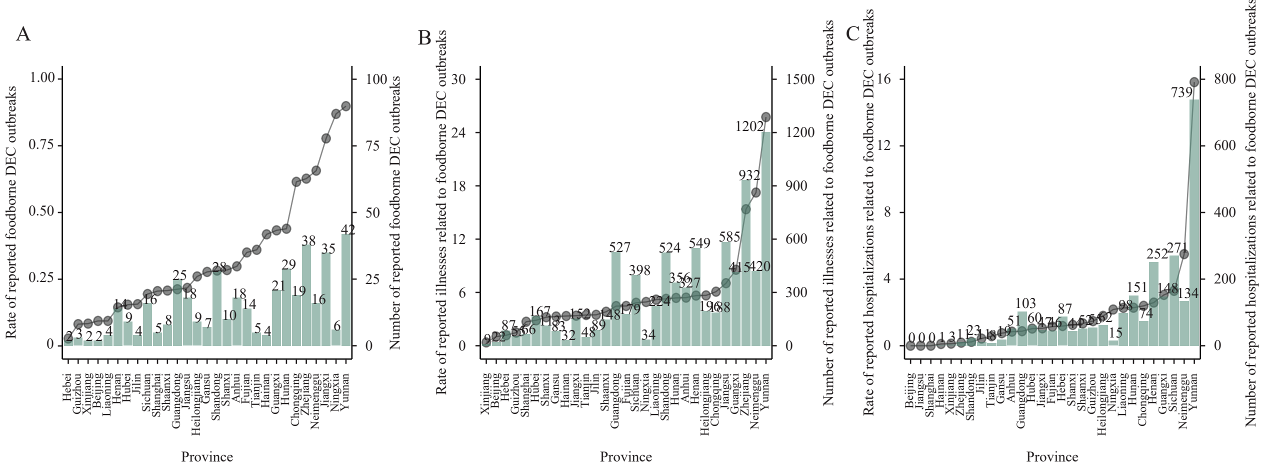


FIGURE 2. Geographic distribution of foodborne DEC outbreaks, illnesses, and hospitalizations by PLAD in China, 2011–2022.
Abbreviation: DEC=diarrheagenic *Escherichia coli*; PLAD=provincial-level administrative division.

hospitalizations (21.82%). Enteroinvasive *E. coli* (EIEC) was the least common pathotype, associated with 21 outbreaks (8.27%), 217 illnesses (4.28%), and 150 hospitalizations (19.39%) (Supplementary Table S2, available at https://weekly.chinacdc.cn/).

DISCUSSION

This comprehensive analysis characterizes the epidemiological patterns of foodborne DEC outbreaks across China from 2011 to 2022. The observed number of DEC outbreaks during this period showed a sixfold increase compared to 2003–2008 (*10*). This substantial rise can be attributed to enhanced surveillance measures implemented under the Food Safety Law of 2011, including the deployment of an advanced web-based reporting system, improved reporting compliance, and sophisticated trace-back technologies (*11*).

The COVID-19 pandemic has profoundly impacted public health and socioeconomic systems globally over the past three years. In China, the implementation of comprehensive non-pharmacological interventions (NPIs) - including social distancing measures, mandatory face mask usage, stay-at-home orders, closure of public spaces (restaurants and educational institutions), and travel restrictions - has affected the transmission dynamics of various infectious diseases. These interventions have demonstrated measurable effects on gastrointestinal infections, including DEC, with our findings showing a consistent reduction in reported foodborne DEC outbreaks that aligns with previous research (*12*).

Our analysis revealed significant provincial variations in foodborne DEC outbreak rates. These disparities likely reflect differences in lifestyle behaviors, including regional food consumption patterns (such as the consumption of raw meat in southwest China), dining habits, and hygiene awareness (*10*). For instance, the practice of consuming raw meat in Yunnan Province has been previously associated with increased risk of foodborne DEC illness (*13*). However, these regional differences should be interpreted cautiously, as they may partially reflect variations in FDOSS management capabilities and laboratory capacity across PLADs rather than true epidemiological differences.

Among outbreaks with determined etiology, EAEC emerged as the predominant pathotype, consistent with its status as the most frequently isolated pathogen in acute diarrhea cases in China (*4*). EAEC has been implicated in significant outbreaks worldwide (*2*). Our findings indicate that EPEC and ETEC contributed to a smaller proportion of foodborne DEC outbreaks compared to EAEC, which aligns with PCR detection rates observed among outpatients with acute diarrhea in China (*4*).

School canteens represented the most frequent outbreak setting, primarily due to inadequate cooking procedures or cross-contamination during food preparation. Given children's heightened susceptibility to DEC infections, there is an urgent need to enhance oversight of school food service operations and implement comprehensive professional training programs for food service workers.

Several limitations warrant consideration when interpreting FDOSS data. The reported outbreaks likely represent only a fraction of actual occurrences due to constraints in outbreak investigation capacity. Furthermore, the dynamic nature of our web-based system means that data may vary at different time points, potentially leading to discrepancies with earlier or subsequent studies. Additionally, the absence of comprehensive surveillance for all DEC strains historically limits our ability to present a complete epidemiological picture. These limitations highlight areas for future research focus. Nevertheless, prompt investigation and reporting of foodborne DEC outbreaks remain crucial for developing effective prevention strategies.

Conflicts of interest: No conflicts of interest.

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[#] Corresponding authors: Yunchang Guo, gych@cfsa.net.cn; Xiaochen Ma, maxch@bjcdc.org.

[1] Institute for Nutrition and Food Hygiene, Beijing Center for Disease Prevention and Control, Beijing, China; [2] Division of Foodborne Disease Surveillance, China National Center for Food Safety Risk Assessment, Beijing, China; [3] Jiangsu Provincial Center for Disease Prevention and Control, Nanjing City, Jiangsu Province, China; [4] Guangdong Provincial Center for Disease Prevention and Control, Guangzhou City, Guangdong Province, China.

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SUPPLEMENTAL MATERIALS

The analysis utilized monthly data on foodborne DEC outbreaks, illnesses, and hospitalizations from 2011 to 2019 extracted from the Foodborne Disease Outbreaks Surveillance System. Given the seasonal patterns of foodborne DEC infections, we employed a Seasonal Autoregressive Integrated Moving Average (SARIMA) model to forecast outbreak metrics in China for 2020-2022.

The ARIMA (p,d,q) model incorporates three key components: the autoregressive term p, which captures relationships between current and historical values; the difference term d; and the moving average term q, which addresses random fluctuations. The SARIMA model extends the standard ARIMA framework by combining non-seasonal ARIMA (p,d,q) with seasonal ARIMA (P,D,Q)s components. This integrated model is formally expressed as SARIMA (p,d,q)(P,D,Q)s, where P and Q represent seasonal autoregressive and moving average orders, D denotes the seasonal difference number, and s indicates the seasonal period.

Modeling Process

We employed the Augmented Dickey-Fuller (ADF) test to assess time series stationarity and determine the model order d. Initial analysis revealed non-stationary data with pronounced seasonal trends.

Model parameters p and q were determined by analyzing the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots.

The Box.test function was utilized to conduct residual white noise testing. The model demonstrated statistical validity ($P>0.05$), confirming its appropriateness for analyzing temporal patterns in foodborne DEC outbreaks, illnesses, and hospitalizations.

The validated model was then applied to generate predictions for foodborne DEC metrics from 2020 through 2022.

Seasonal Distribution

Foodborne DEC outbreaks showed significant seasonal trends, with peak incidence during summer and autumn months. The majority of outbreaks (74.50%) occurred between May and September. July recorded the highest number of outbreaks (*n*=63, 18.05%), while September showed peak numbers for both illnesses (*n*=1,444, 20.46%) and hospitalizations (*n*=748, 29.09%). Conversely, December demonstrated minimal outbreak activity with the lowest number of outbreaks (*n*=4, 1.15%) and illnesses (*n*=44, 0.62%).

SUPPLEMENTARY TABLE S1. Prediction results of foodborne DEC outbreaks, illnesses and hospitalizations by SARIMA, China, 2011–2022.

ARIMA(p,d,q)(P,D,Q)$_{12}$	Model used years	ADF test	Box. test	Predicted year	Predicted type	Predicted number	Actual number	Number (predicted)-Number (actual)
ARIMA(1,0,0)(0,1,1)$_{12}$	2011–2019	0.01	0.50	2020	Outbreaks	51	54	−3
ARIMA(0,0,1)(0,1,1)$_{12}$	2011–2020	0.01	0.87	2021	Outbreaks	57	51	6
ARIMA(1,0,0)(0,1,1)$_{12}$	2011–2021	0.01	0.56	2022	Outbreaks	57	17	40
ARIMA(0,0,0)(1,0,1)$_{12}$	2011–2019	0.01	0.69	2020	Illnesses	635	1,520	−885
ARIMA(0,1,1)(2,0,0)$_{12}$	2011–2020	0.01	0.36	2021	Illnesses	1,137	1,125	12
ARIMA(2,1,1)(2,0,0)$_{12}$	2011–2021	0.01	0.83	2022	Illnesses	1,389	189	1,200
ARIMA(0,0,0)	2011–2019	0.01	0.93	2020	Hospitalizations	252	181	71
ARIMA(0,0,0)	2011–2020	0.01	0.87	2021	Hospitalizations	240	158	82
ARIMA(0,0,0)	2011–2021	0.01	0.85	2022	Hospitalizations	240	8	232

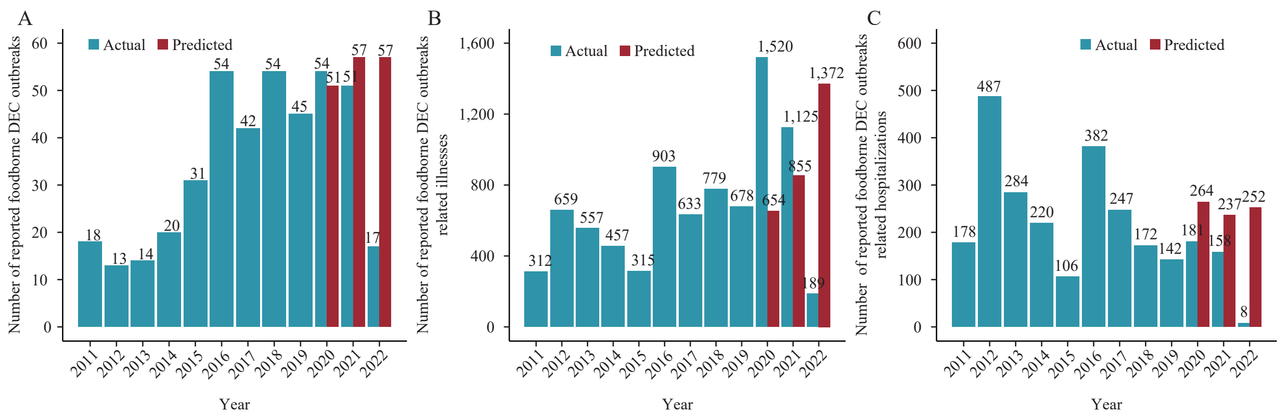
Abbreviation: ARIMA=autoregressive integrated moving average; DEC=diarrheagenic *Escherichia coli*; SARIMA=seasonal autoregressive integrated moving average.

SUPPLEMENTARY TABLE S2. Numbers and percentages of five pathotypes of reported foodborne DEC outbreaks, illnesses, and hospitalizations, China, 2010–2022.

DEC pathotypes	Outbreaks, *n* (%)	Illnesses, *n* (%)	Hospitalizations, *n* (%)
EAEC	124 (48.82)	2,123 (41.87)	235 (21.82)
EPEC	49 (19.29)	1,180 (23.27)	324 (30.08)
ETEC	35 (13.78)	831 (16.39)	197 (18.29)
EHEC	25 (9.84)	719 (14.18)	171 (15.88)
EIEC	21 (8.27)	217 (4.28)	150 (13.93)

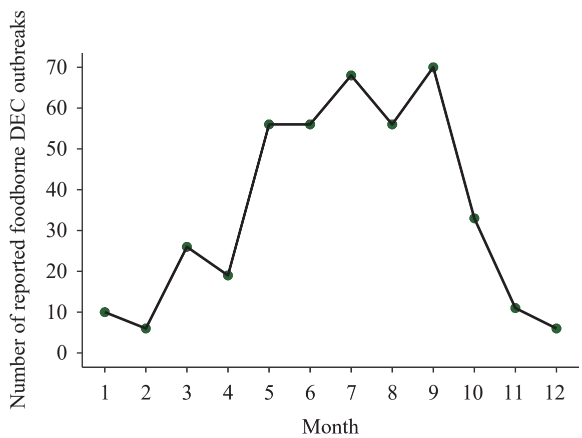
Note: The total number of pathotype-specific cases (EAEC, EPEC, ETEC, EIEC, and EHEC) did not equal the total DEC-positive cases due to 163 unpathotyped outbreaks.

Abbreviation: *E. coli*=*Escherichia coli*; DEC=diarrheagenic *E. coli*; EAEC=Enteroaggregative *E. coli*; EHEC=Enterohaemorrhagic *E. coli*; EIEC=Enteroinvasive *E. coli*; EPEC=Enteropathogenic *E. coli*; ETEC=Enterotoxigenic *E. coli*.



SUPPLEMENTARY FIGURE S1. Number of actual reported and predicted foodborne DEC (A) outbreaks, (B) illnesses and (C) hospitalizations by year in China, 2011–2022.

Abbreviation: DEC=diarrheagenic *Escherichia coli*.



SUPPLEMENTARY FIGURE S2. Seasonal distribution of reported foodborne DEC outbreaks in China, 2011–2022.