



Epidemiological Evaluation of Water- and Foodborne Outbreaks in the United States and Europe

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ARTICLE INFO	ABSTRACT
<p><i>Article type:</i> Review Article</p>	<p>Introduction: Water- and foodborne illnesses are of major public health concerns. However, the significance of foodborne diseases are generally underestimated. Therefore, in this study we aimed to emphasize on the importance of control of foodborne illnesses through highlighting data about outbreaks, hospitalizations and deaths caused by contaminated food in the developed countries from 2015 to 2020.</p>
<p><i>Article History:</i> Received: 02 Mar 2022 Accepted: 26 Jul 2022 Published: 20 Aug 2022</p>	<p>Method: In this descriptive-analytical study, 105 and 152 cases of water- and foodborne illnesses were reported in the United States (CDC) and Europe (ECDC) in 2015-2020.</p>
<p><i>Keywords:</i> Waterborne diseases Foodborne diseases CDC ECDC Epidemiological assessment</p>	<p>Results: The most reported causative agents were <i>Salmonella</i> spp, <i>Cyclospora</i>, <i>Escherichia coli</i>, <i>Bacillus cereus</i>, <i>Clostridium perfringens</i> spp, and <i>Listeria monocytogenes</i> were in the US and <i>Salmonella</i>, Norovirus, Calicivirus, <i>Campylobacter</i>, <i>B. cereus</i>, and <i>C. perfringens</i> in the EU.</p> <p>Conclusion(s): According to the results, CDC and ECDC analyses could provide insights into the most critical pathogens and food sources help the authorities to control foodborne illnesses.</p>
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Introduction

Many pathogens can infect humans through food consumption (1). According to a CDC report, an outbreak of foodborne illness occurs when two or more people become infected from the same food or drink (2). Foodborne diseases range from mild illnesses to severe problems, which sometimes endanger people's health and lead to their hospitalization and death (3).

Contamination can occur at any stage of the food supply chain (production to distribution) (4). Factors such as cross-contamination, mixing raw and cooked food, undercooking, poor personal hygiene, and favorable conditions for microbial growth may cause food contamination. Foodborne illnesses occur through consuming contaminated food (5). There is also evidence that raw foods may be contaminated by wildlife, soil, air, irrigation water, and fertilizer (6). The fecal-oral route can also transmit pathogenic microorganisms from one person to another (6). The transmission of diseases through contaminated water and food is primarily biological in nature (7-9). More than 250 types of foodborne diseases (FBDs) have been identified worldwide. Bacteria and their toxins, followed by viruses and parasites, are the most common

biological agents (10). Foodborne illnesses are primarily caused by viruses and bacteria (11). The high prevalence of some causes of water- and foodborne diseases such as *Shigella* put them in the group of bioterrorist agents (12). Foodborne diseases can also occur by consuming chemicals such as heavy metals or toxins from plants and animals (3). Food processing environments can also be considered a source of contamination. Therefore, food safety requires inspection of the processing environment, especially when cleaning and disinfection methods fail (13). However, testing the final products is not sufficient to ensure safety, and a negative result does not mean that there are no microbes in the entire product (13). Nowadays, the number of people infected by foodborne pathogens has also been increased due to increasing the number of centers for food preparation and distribution such as restaurants and snack shops and using foods such as fast foods without requiring long cooking and high heat (12).

Additionally, foodborne illnesses are becoming a significant challenge due to emerging microorganisms and toxins and increasing antibiotic resistance and food contamination from new production methods (14).

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Water- and food-borne illnesses are of major causes of death that threaten socioeconomic development worldwide (15). According to World Health Organization (WHO), about 600 million people worldwide become ill each year from contaminated food, of which 420,000 die, and 33 million lose their healthy lives (16). Consequently, a foodborne disease monitoring system is needed to identify, monitor, and warn about FBDs. Such system helps identify the cause and burden of FBDs, and thus, it help reduce FBDs and their harm in the society (15).

Foodborne illness prevalence is monitored by the Centers for Disease Control and Prevention (CDC) in the United States and the European Centers for Disease Control and Prevention (ECDC) in the EU Member States (17).

Each year, the CDC summarizes foodborne diseases in its annual monitoring report and publishes the data through the NORS¹ dashboard. These statistics and epidemiologic data assist policy-making and decision-making.

ECDC is an EU agency, which aims to strengthen the European defense system against infectious diseases. The main tasks cover a broad spectrum of activities, including scientific advice, microbiology, public health training, health communication, international relations, surveillance, epidemic intelligence, response, preparedness, and publishing the scientific journal of Eurosurveillance (18). Water- and

foodborne diseases and common human and animal diseases are among the issues addressed by the ECDC (18,19).

The two monitoring systems provide information such as the patient's location, cause, prevalence, number, severity, as well as the foods associated with reported FBDs and outbreaks (20).

Based on our review, a comparative data collection has been provided by gathering information about the prevalence of water- and foodborne illnesses published by the CDC (in the United States) and ECDC (in Europe). Thus, food safety hazards can be detected faster, warned earlier, and prevented and controlled if we have a clue (21). Providing scientific evidence to authorities may also make it easier for them to develop the most efficient strategies to prevent and control foodborne illnesses.

Materials and Methods

This descriptive-analytical study reviewed reports of foodborne outbreaks in the US and EU during a five-year period from 2015 to 2020, which were available on the CDC and ECDC websites (9,22). Generally, the criteria for diagnosing foodborne diseases were based on epidemiological findings, incubation period, and clinical findings in patients, while laboratory diagnosis relies on determining the cause of outbreaks (23).

Table 1. Reported cases of water- and foodborne outbreaks in the United State of America (CDC)

Year	Type of contaminated food	Contaminating microorganisms	Number of patients	States	Number of hospitalizations	Number of deaths	Recall ²
2015	Raw Sprouted Nut Butter Spreads	<i>Salmonella</i> Paratyphi B variant L(+) tartrate(+)	13	10	0	0	✓
	Rotisserie Chicken Salad	<i>E. coli</i> O157:H7	19	7	5	0	✓
	Mexican Style Restaurant Chain	<i>E. coli</i> O26	55	11	21	0	- ³
			5	3	1	0	-
	Soft Cheeses	<i>Listeria monocytogenes</i>	30	10	28	3	✓
	Cucumbers	<i>Salmonella</i> Poona	907	40	204	6	✓
	Pork	<i>Salmonella</i> I 4,[5],12:i:- and <i>Salmonella</i> Infantis	192	5	30	0	✓
	Unknown	<i>Cyclospora</i>	546	31	21	0	✗
	Raw, Frozen, Stuffed Chicken Entrees	<i>Salmonella</i> Enteritidis	5	1	2	0	✓
	Raw, Frozen, Stuffed Chicken Entrees	<i>Salmonella</i> Enteritidis	15	7	4	0	✓

1. National Outbreak Reporting System

2. If you have recalled products, don't eat them. Throw them away.

3. There was no report

Year	Type of contaminated food	Contaminating microorganisms	Number of patients	States	Number of hospitalizations	Number of deaths	Recall ²	
2016	Frozen Raw Tuna	<i>Salmonella</i> Paratyphi B variant L(+) tartrate(+) and <i>Salmonella</i> Weltevreden	65	11	11	0	✓	
	Ice Cream	<i>Listeria monocytogenes</i>	10	4	10	3	✓	
	Shell Eggs	<i>Salmonella</i> Oranienburg	8	3	2	0	✓	
	Unknown	<i>Cyclospora</i>	384	-	-	-	-	
	Beef Products	<i>E. coli</i> O157:H7	11	5	7	0	✓	
	Frozen Strawberries	Hepatitis A	143	9	56	0	✓	
	Frozen Scallops	Hepatitis A	-	-	-	-	✓	
	Alfalfa Sprouts	<i>Salmonella</i> Reading and <i>Salmonella</i> Abony	36	9	7	0	✓	
	Flour	<i>E. coli</i> O121 and O26	63	24	17	0	✓	
	Frozen Vegetables	<i>Listeria monocytogenes</i>	9	4	9	3	✓	
	Raw Milk	<i>Listeria monocytogenes</i>	2	2	2	1	✗	
	Pistachios	<i>Salmonella</i> Montevideo and <i>Salmonella</i> Senftenberg	11	9	2	0	✓	
	Alfalfa Sprouts	<i>E. coli</i> O157	11	2	2	0	✓	
	Alfalfa Sprouts	<i>Salmonella</i> Muenchen and <i>Salmonella</i> Kentucky	26	12	8	0	✗	
	Organic Shake & Meal Products	<i>Salmonella</i> Virchow	33	23	6	0	✓	
	Packaged Salads	<i>Listeria monocytogenes</i>	19	9	19	1	✓	
	2017	Leafy Greens	<i>E. coli</i> O157:H7	25	15	9	1	✗
		Unknown	<i>Cyclospora</i>	1065	-	-	-	-
Maradol Papayas		<i>Salmonella</i> Urbana	7	3	4	0	✗	
Maradol Papayas		<i>Salmonella</i> Newport and <i>Salmonella</i> Infantis	4	4	2	0	✗	
Maradol Papayas		<i>Salmonella</i> Anatum	20	3	5	1	✓	
Maradol Papayas		<i>Salmonella</i> Infections	220	23	68	1	✓	
Vulto Creamery Soft Raw Milk Cheese		<i>Listeria monocytogenes</i>	8	4	8	2	✓	
I.M. Healthy SoyNut Butter		<i>E. coli</i> O157:H7	32	12	12	0	✓	
2018	Tahini Produced by Achdut Ltd.	<i>Salmonella</i> Concord	8	4	0	0	✓	
	-	<i>Salmonella</i> Agbeni	7	5	0	0	✓	
	Pork Products	<i>Listeria monocytogenes</i>	4	4	4	0	✓	
	Romaine Lettuce	<i>E. coli</i> O157:H7	62	16	25	0	✓	
	Raw Chicken Products	<i>Salmonella</i> Infantis	129	32	25	1	-	
	Ground Beef	<i>Salmonella</i> Newport	403	30	117	0	✓	
	Deli Ham	<i>Listeria monocytogenes</i>	4	2	4	1	✓	
	Ground Beef	<i>E. coli</i> O26	18	4	6	1	✓	
	Gravel Ridge Farms Shell Eggs	<i>Salmonella</i> Enteritidis	44	11	12	0	✓	
	Chicken	<i>Salmonella</i> I 4,[5],12:i:-	25	6	11	1	-	
	Raw Turkey Products	<i>Salmonella</i> Reading	358	42	133	1	✓	
	Hy-vee Spring Pasta Salad	<i>Salmonella</i> Sandiego	101	10	25	0	✓	

Year	Type of contaminated food	Contaminating microorganisms	Number of patients	States	Number of hospitalizations	Number of deaths	Recall ²
	Fresh Express Salad Mix Sold at McDonald's Restaurants	<i>Cyclospora</i>	511	16	24	0	✗
	Del Monte Fresh Produce Vegetable Trays	<i>Cyclospora</i>	250	4	8	0	✓
	Imported Fresh Crab Meat	<i>Vibrio parahaemolyticus</i>	26	8	9	0	✗
	Kellogg's Honey Smacks Cereal	<i>Salmonella</i> Mbandaka	135	36	34	0	✓
	Pre-Cut Melon	<i>Salmonella</i> Adelaide	77	9	36	0	✓
	Shell Eggs	<i>Salmonella</i> Braenderup	45	10	11	0	✓
	Romaine Lettuce	<i>E. coli</i> O157:H7	210	36	96	5	✗
	Dried Coconut	<i>Salmonella</i> Typhimurium	14	8	3	0	✓
	Chicken Salad	<i>Salmonella</i> Typhimurium	265	8	94	1	✓
	Kratom	<i>Salmonella</i> I 4,[5],12:b:-	199	41	50	0	✓
	Raw Sprouts	<i>Salmonella</i> Montevideo	10	3	0	0	✗
	Frozen Shredded Coconut	<i>Salmonella</i> I 4,[5],12:b:- and <i>Salmonella</i> Newport	27	9	6	0	✓
	Hard-boiled Eggs	<i>Listeria monocytogenes</i>	8	5	5	1	✓
	Cut Fruit	<i>Salmonella</i> Javiana	165	14	73	0	✓
	Fresh Express Sunflower Crisp Chopped Salad Kits	<i>E. coli</i> O157:H7	10	5	4	0	✗
	Romaine Lettuce	<i>E. coli</i> O157:H7	167	27	85	0	✓
	Ground Beef	<i>Salmonella</i> Dublin	13	8	9	1	✓
	-	<i>Listeria monocytogenes</i>	24	13	22	2	-
	Fresh Basil from Siga Logistics de RL de CV of Morelos, Mexico	<i>Cyclospora</i>	241	11	6	0	✓
2019	Northfork Bison	<i>E. coli</i> O103 and O121	33	8	18	0	✓
	Papayas	<i>Salmonella</i> Uganda	81	9	27	0	✓
	Flour	<i>E. coli</i> O26	21	9	3	0	✗
	Karawan Brand Tahini	<i>Salmonella</i> Concord	6	3	1	0	✓
	Raw Oysters	Multiple Pathogens	16	5	2	0	✓
	Deli-Sliced Meats and Cheeses	<i>Listeria monocytogenes</i>	10	5	10	1	-
	Frozen Raw Tuna	<i>Salmonella</i> Newport	15	8	2	0	✓
	Pre-Cut Melon	<i>Salmonella</i> Carrau	137	10	38	0	✓
	Ground Beef	<i>E. coli</i> O103	209	10	29	0	✓
	Butterball Brand Ground Turkey	<i>Salmonella</i> Schwarzengrund	7	3	1	0	✓
	Unknown Source 3	<i>E. coli</i> O157:H7	18	9	6	0	✓
	Leafy Greens	<i>E. coli</i> O157:H7	40	19	20	0	✗
	Unknown Source 1	<i>E. coli</i> O157:H7	32	12	15	1	-
2020	Deli Meats	<i>Listeria monocytogenes</i>	12	4	12	1	-
	Wood Ear Mushrooms	<i>Salmonella</i> Stanley	55	12	6	0	✓
	Peaches	<i>Salmonella</i> Enteritidis	101	17	28	0	✓
	Onions	<i>Salmonella</i> Newport	1127	48	167	0	✓
	Bagged Salad Mix	<i>Cyclospora</i>	701	14	38	0	✓

Year	Type of contaminated food	Contaminating microorganisms	Number of patients	States	Number of hospitalizations	Number of deaths	Recall ²
	Enoki Mushrooms	<i>Listeria monocytogenes</i>	36	17	31	4	✓
	Clover Sprouts	<i>E. coli</i> O103	51	10	3	0	✓

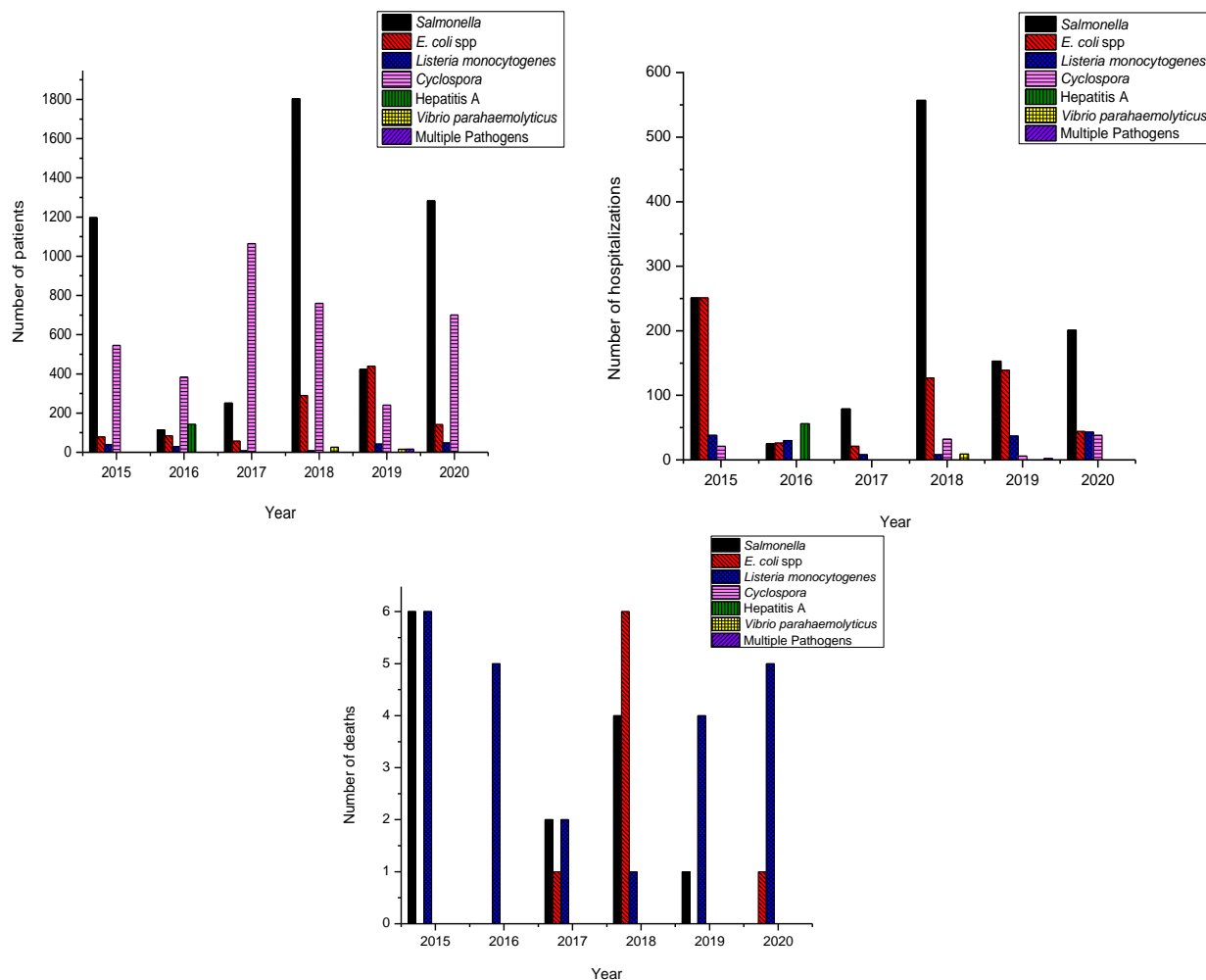


Figure 1. Reported cases of water- and foodborne outbreaks in the United State of America (CDC)

Results

CDC reported a total of many water- and foodborne pathogens were transmitted from water and food during 2015-2020. According to these reports, the lowest bacterial foodborne cases occurred in 2017 (8 cases), and the highest prevalence was in 2018 (24 cases). A total of 11 foodborne and waterborne illnesses occurred in the US in 2015, with cucumbers being the most common source and Salmonella Poona as the most common responsible pathogen. In 2016, a total of 14 water- and foodborne occurred and frozen strawberries were the most common

source of FBDs, while cyclospora and hepatitis A were the most common causative pathogens. There were 8 cases of water- and food-borne illness in 2017. Maradol papayas were the most common source of FBDs, and Cyclospora and Salmonella Thompson were the most common causative pathogens. A total of 24 water- and foodborne illnesses were reported in 2018. Salad Mix Sold at McDonald's Restaurants and ground beef were the most common source of FBDs. In this regard, the most common causative pathogens were Cyclospora and Salmonella Newport. There were 17 water- and food-borne

outbreaks in 2019. Eating fresh basil from Siga Logistics de RL de CV from Morelos, Mexico, and ground beef were the most common source of FBDs. In addition, Cyclospora and *E. coli* O103 were the most common causative pathogens. There were a total of 10 water- and foodborne illnesses in 2020. Onions and bagged Salad Mix were the most common source of FBDs, and *Salmonella* Newport and Cyclospora were the most common causative pathogens. Table 1 presents the reported cases of water- and foodborne outbreaks in the United States (CDC). Table 1. Reported cases of water- and foodborne outbreaks in the United State of America (CDC) Figure 1. Reported cases of water- and foodborne outbreaks in the United State of America (CDC) According to ECDC, several pathogens were transmitted from water and food during 2015-2020 in Europe. The highest number of FBDs (35 cases) were reported in 2018 and the lowest number (17 cases) in 2016. There were 18 waterborne and foodborne illnesses reported in 2015 in Europe. Vegetables, fruits, cereals, sprouts, herbs, spices, and products thereof, Fish, shellfish, mollusks, crustaceans, eggs, and egg-based products, as well as meat and meat-based products were the most common source of FBDs, and *Salmonella* was the most common causative pathogen. There were 17 incidences of water- and food-borne diseases in 2016 that occurred. Vegetables, fruits,

cereals, sprouts, herbs, spices and products, mixed food, Buffet meals, eggs, and egg-based products were the most common source of FBDs in these reports, and *Salmonella* was the most common causative pathogen. There were 21 cases of water- and foodborne diseases in 2017. Water, eggs, and egg-based products were the most common source of FBDs, and *Salmonella* was the most common causative pathogen. There were 35 water- and foodborne diseases reported in 2018. Water, eggs, and egg-based products were the most common source of FBDs in these outbreaks, and *Salmonella* was the most common causative pathogen. A total of 32 water- and foodborne diseases were reported in 2019. Water, eggs, and egg-based products were the most common source of FBDs, and *Salmonella* and Norovirus were the most common causative pathogens. The number of water-borne and foodborne diseases in 2020 reached 29. Fish and fishery products, water and other beverages, eggs, egg-based products, meat and meat-based products, were the most common source of FBDs, and *Salmonella* was the most common causative pathogen. Table 2 represents the reported cases of water- and foodborne outbreaks in Europe (ECDC). Table 2. Reported cases of water- and foodborne outbreaks in Europe (ECDC) Figure 2. Reported cases of water- and foodborne outbreaks in Europe (ECDC).

Table 2. Reported cases of water- and foodborne outbreaks in Europe (ECDC)

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
2015	Eggs, and egg products	<i>Salmonella</i>	953	6616	1719	3
	Meat, and meat products					
	Milk, cheeses, and dairy	<i>Campylobacter</i>	387	1440	129	1
	Milk, cheeses, and dairy					
	Mixed food, and Buffet meals	Shiga toxin-producing <i>E. coli</i> (STEC)	69	674	62	0
	Other foods					
	Mixed food, and Buffet meals	<i>Listeria</i>	14	230	25	4
	Meat, and meat products	<i>Yersinia</i>	13	54	9	0
	-	<i>Vibrio</i>	4	29	0	0
	-	<i>Brucella</i>	1	2	1	0
	Eggs, and egg products	Other bacterial agents ⁴	29	337	23	0
	Meat, and meat products					
Meat, and meat products	<i>C. botulinum</i>	24	60	43	0	
Other foods						
Milk, cheeses, and dairy	Other bacterial toxins ⁵	825	8787	454	3	
Mixed food, and Buffet meals						

4 . 'Other bacterial agents' include *Francisella*, *Shigella*, pathogenic *E. coli* other than Shiga toxin-producing *E. coli*, and other unspecified bacteria.

5 . 'Other bacterial toxins' include toxins produced by *Bacillus*, *Clostridium* other than *Clostridium botulinum*, *staphylococcal* toxins, and other unspecified bacterial toxins.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Other foods					
	Vegetables, fruits, cereals, sprouts, herbs and spices, and products thereof	Calicivirus including norovirus (Norwalk-like virus)	289	13536	352	1
	Other foods	Hepatitis A	13	78	49	1
	Milk, cheeses, and dairy	Other viruses/unspecified ⁶	99	1140	130	3
	-	<i>Cryptosporidium</i>	9	120	3	0
	Meat, and meat products	<i>Trichinella</i>	15	119	34	0
	-	Other parasites/unspecified ⁷	28	63	7	0
	Fish, shellfish, mollusks, crustaceans, and products thereof	Other causative agents ⁸	127	648	64	0
	Vegetables, fruits, cereals, sprouts, herbs and spices, and products thereof	Unknown	1463	11941	788	1
	Fish, shellfish, mollusks, and crustaceans and products thereof					
	Milk, and milk products	<i>Campylobacter</i>	461	4606	140	0
	Meat, and meat products	<i>Listeria</i>	5	25	14	2
	Eggs, and egg products	<i>Salmonella</i>	1067	9061	1766	10
	Other foods					
	Milk, and milk products					
	Vegetables, fruits, cereals, sprouts, herbs and spices, and products thereof	Shiga toxin-producing <i>E. coli</i> (STEC)	42	735	125	3
	-	<i>Vibrio</i>	8	76	50	0
	Vegetables, fruits, cereals, sprouts, herbs, spices, and products thereof	<i>Yersinia</i>	8	41	3	0
	Eggs, and egg products	Other bacterial agents ⁹	30	279	51	1
	Other foods					
	Meat, and meat products	<i>C. botulinum</i>	18	49	39	0
	Meat, and meat products	Other bacterial toxins ¹⁰	830	8918	362	1
2016	Mixed, food and Buffet meals					
	Mixed food, and Buffet meals	Calicivirus including norovirus (Norwalk-like virus)	379	11993	404	1
	Other foods					
	Meat, and meat products	Hepatitis A	16	155	63	0
	Other foods					
	Milk, and milk products	Other viruses/unspecified ¹¹	75	937	97	0
	Meat, and meat products					
	Vegetables, fruits, cereals, sprouts, herbs, spices, and products thereof	<i>Cryptosporidium</i>	6	62	0	0
	Meat, and meat products					
	Other foods	<i>Trichinella</i>	5	14	9	0
	-	Other parasites/unspecified	7	17	0	0
	Fish, and Fisheries	Other causative agents	106	489	74	0
	Vegetables, fruits, cereals, sprouts, herbs and spices, and products thereof	Unknown	1723	12493	672	2

6. 'Other viruses' include adenovirus, flavivirus, rotavirus, and other unspecified viruses.

7. Other parasites include *Giardia* and other unspecified parasites.

8. 'Other causative' agents include chemical agents, histamine, marine biotoxins, mushroom toxins, and scrombotoxin.

9. Other bacterial agents include *Shigella* and other unspecified bacteria

10. Bacterial toxins include toxins produced by *Bacillus*, *Clostridium* other than *Clostridium botulinum*, *Staphylococcus*, and other unspecified bacterial toxins.

11. Other viruses include flavivirus and other unspecified viruses. Other causative agents include ciguatoxin and other unspecified toxins.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Mixed food, and Buffet meals					
	-	<i>Brucella</i>	1	2	1	0
	Milk, and milk products ¹²	<i>Campylobacter</i>	395	1445	207	1
	Meat, and meat products ¹³					
	Food of non-animal origin ¹⁴	<i>Listeria</i>	10	39	22	2
	Milk, and milk products					
	Eggs, and egg products	<i>Salmonella</i>	1241	9600	2227	11
	Bakery products					
	Milk, and milk products	Shiga toxin-producing <i>E. coli</i> (STEC)	48	260	65	2
	-	<i>Vibrio</i>	3	59	7	0
	Food of non-animal origin	Other bacterial agents/Unspecified ¹⁵	46	816	67	0
	Mixed food					
	Meat, and meat products	<i>C. botulinum</i>	9	26	26	2
	Other foods ¹⁶					
	Buffet meals	Other bacterial toxins ¹⁷	809	8442	577	5
	Mixed food					
	Water	Norovirus, and other caliciviruses	211	6550	153	2
	Buffet meals					
	Food of non-animal origin	Hepatitis A	90	591	452	2
	Milk, and milk products	Other viruses/unspecified ¹⁸	97	1379	107	0
	Food of non-animal origin					
	-	<i>Cryptosporidium</i>	5	15	0	0
	Meat, and meat products	<i>Trichinella</i>	11	199	125	0
	-	Other parasites/unspecified	13	28	1	0
	Fish, and Fisheries ¹⁹	Histamine	117	572	51	0
	Fish, and Fisheries	Marine biotoxins ²⁰	54	170	14	0
	Other foods	Mushroom toxins	7	22	16	0
	-	Other/Unspecified	3	6	0	0
	Water					
	Other foods	Unknown	1882	12794	423	6
	-	Unspecified	27	385	20	0
	Food of non-animal origin ²¹	<i>Aeromonas</i>	1	7	2	0
	Milk, and milk products ²²					
	Milk, and milk products	<i>Campylobacter</i>	524	2335	135	0
	Meat, and meat products ²³					
	Food of non-animal origin	<i>Enterococcus</i>	1	4	4	0
	Milk, and milk products					

12 . Milk and milk products include 'Cheese', 'Dairy products (other than cheeses)' and 'Milk'.

13 . Meat and meat products include 'Bovine meat', 'Pigmeat', 'Poultry meat', 'Sheep meat', 'Other or mixed red meat and their products, 'Meat and Meat products unspecified'.

14 . Food of non-animal origin includes 'Confections, 'Fruits (and juices)', 'Herbs and spices, and 'Vegetables (and juices)'

15 . Other bacterial agents include enteroaggregative *E. coli* (EAEC), enteroinvasive *E. coli* (EIEC), *Shigella flexneri*, *Yersinia enterocolitica*.

16 . Other foods include 'Canned food products', 'Cereal products and legumes', 'Other foods (Unspecified)'

17 . Bacterial toxins other than *Clostridium botulinum* include toxins produced by *Bacillus*, *Clostridium* other than *Clostridium botulinum* and *Staphylococcus*, and other unspecified bacterial toxins.

18 . Other viruses include adenovirus, flavivirus (TBE virus), rotavirus, and other unspecified viruses.

19 . Fish and fishery products include: 'Fish', 'Crustaceans, shellfish, mollusks, and their products.

20 . Marine biotoxins include ciguatoxin and other unspecified toxins.

21 . Food of non-animal origin includes fruits (and juices), herbs and spices, sweets and chocolate, and vegetables (and juices). Milk and milk

22 . Milk and milk products include cheese, dairy products (other than cheeses), and milk.

23 . Meat and meat products include bovine meat, pig meat, poultry meat, sheep meat, other or mixed red meat and products thereof, meat and meat products, unspecified.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Food of non-animal origin Milk, and milk products	<i>E. coli</i> other than STEC	9	240	11	0
	Food of non-animal origin Milk, and milk products	<i>Leptospira</i>	1	8	6	0
	Buffet meals Food of non-animal origin Other foods ²⁴	<i>Listeria</i>	14	158	98	21
	Eggs, and egg products Bakery products	<i>Salmonella</i>	1581	11581	2298	8
	Milk, and milk products	Shiga toxin-producing <i>E. coli</i>	48	381	36	0
	Food of non-animal origin Milk, and milk products	<i>Shigella</i>	33	472	63	0
	Food of non-animal origin Milk, and milk products	<i>Vibrio parahaemolyticus</i>	10	31	0	0
	Food of non-animal origin Milk, and milk products	<i>Yersinia enterocolitica</i>	12	58	7	0
	Food of non-animal origin Milk, and milk products	Other unspecified bacteria ²⁵	3	29	4	0
	Mixed food, other foods, and unknown	<i>B. cereus</i>	98	1539	111	1
	Mixed food, other foods, and unknown	<i>C. botulinum</i>	15	48	35	2
	Mixed food, other foods, and unknown	<i>C. perfringens</i>	71	1783	18	2
	Mixed food, other foods, and unknown	<i>S. aureus</i>	114	1124	167	0
	Other foods Mixed food	Bacterial toxins, unspecified ²⁶	652	5232	203	1
	Food of non-animal origin Milk, and milk products	Adenovirus	1	2	0	0
	Food of non-animal origin Milk, and milk products	Flavivirus including tick-borne encephalitis virus	10	34	29	0
	Food of non-animal origin Water	Hepatitis A	56	380	281	0
	Food of non-animal origin Milk, and milk products	Hepatitis E	3	6	1	0
	Fish and Fisheries ²⁷ Buffet meals, and Water	Norovirus, and other caliciviruses	389	8507	219	2
	Food of non-animal origin Milk, and milk products	Rotavirus	20	249	70	0
	Food of non-animal origin	Other viruses, unspecified ²⁸	50	748	6	0
	Food of non-animal origin	<i>Anisakis</i>	3	20	1	0
	Water	<i>Cryptosporidium</i>	9	43	1	0

24 . Other foods include canned food products, cereal products, legumes, drinks, including bottled water, and other foods, unspecified.

25 . Other bacterial agents include *Aeromonas hydrophila*, *Escherichia coli*, enteroinvasive *Escherichia coli* (EIEC), enterotoxigenic *Escherichia coli* (ETEC), *Enterococcus*, *Leptospira* spp., *Shigella* spp., *Shigella flexneri*, *Shigella sonnei*, *Yersinia enterocolitica*, and other unspecified bacteria.

26 . Bacterial toxins other than *Clostridium botulinum* include toxins produced by *Bacillus*, *Clostridium* other than *Clostridium botulinum*, *Staphylococcus*, and other unspecified bacterial toxins.

27 . Fish and fishery products include crustaceans, shellfish, mollusks, and products thereof, fish and fish products.

28 . Other viruses include adenovirus, flavivirus, hepatitis E, rotavirus, and other unspecified viruses.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Food of non-animal origin	<i>Giardia</i>	18	45	2	0
	Meat, and meat products ²⁹	<i>Trichinella</i>	10	114	76	0
	Food of non-animal origin	<i>Taenia saginata</i>	1	2	0	0
	Fish, and Fisheries	Histamine/Scombrototoxin	80	488	115	0
	Fish, and Fisheries	Marine biotoxins	53	266	6	0
	Food of non-animal origin	Mushroom toxins/Mycotoxins	13	71	26	3
	Other foods					
	Milk, and milk products	Other causative agent/Unspecified ³⁰	21	296	32	0
	Food of non-animal origin					
	Unknown	Unknown/Unspecified	1223	12071	527	0
	Water					
	-	<i>Arcobacter</i>	1	40	0	0
	Milk, and milk products	<i>Brucella</i>	1	2	1	0
	Meat, and meat products ³¹	<i>Campylobacter</i>	319	1254	125	0
	Food of non-animal origin ³²	<i>E. coli</i> other than STEC	10	277	9	0
	Buffet meals					
	Meat, and meat products	<i>Listeria monocytogenes</i>	21	349	236	31
	Eggs, and egg products	<i>Salmonella</i>	926	9169	1915	7
	Bakery products					
	Food of non-animal origin	<i>Shigella</i>	22	106	19	0
	Buffet meals					
	Water ³³	STEC	42	273	50	1
	Milk, and milk products ³⁴					
	Food of non-animal origin	<i>Vibrio</i>	4	15	6	0
	Buffet meals					
2019	-	<i>Yersinia</i>	15	149	14	0
	Food of non-animal origin	Other bacteria, unspecified ³⁵	3	33	0	0
	Buffet meals					
	Mixed food					
	Other foods ³⁶	<i>B. cereus</i>	155	1636	44	7
	Unknown					
	Food of non-animal origin	<i>C. botulinum</i>	7	17	15	1
	Other foods					
	Buffet meals	<i>C. perfringens</i>	75	2426	27	3
	Meat, and meat products					
	Milk, and milk products	<i>S. aureus</i>	74	1400	141	0
	Buffet meals					
	Unknown	Bacterial toxins, unspecified	686	5076	134	3
	Mixed food					
	-	Adenovirus	1	8	0	0
	Milk, and milk products	Flavivirus including Tick-Borne Encephalitis virus	3	15	12	0

29 . Meat and meat products include bovine meat, pig meat, poultry meat, sheep meat, other or mixed red meat and products thereof, meat and meat products, unspecified.

30 . Other causative agents include atropine, lectin, monosodium glutamate, and chemical agents unspecified.

31 . Meat and meat products include bovine meat and products thereof, broiler meat (*Gallus*) and products thereof, other or mixed red meat and products thereof, other, mixed or unspecified poultry meat and products thereof, pig meat and products thereof, sheep meat and products thereof, turkey meat and products thereof.

32 . Foods of non-animal origin include 'Cereal products including rice and seeds/pulses (nuts, almonds)', 'Fruit, berries and juices and other products thereof', 'Fruit - the whole', 'Herbs and spices', 'Nuts and nut products', 'Vegetables', 'Vegetables - pre-cut', 'Vegetables and juices and other products thereof'.

33 . 'Water' includes Tap water, including well water.

34 . 'Milk and milk products' include cheese, dairy products (other than cheeses), and milk.

35 . 'Other bacteria' includes enteropathogenic *Escherichia coli* (EPEC), enterotoxigenic *Escherichia coli* (ETEC), *Escherichia coli*, unspecified, *Shigella*, *Vibrio parahaemolyticus*, *Yersinia*, and other unspecified bacteria.

36 . 'Other foods' include canned food products and other foods, unspecified.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Food of non-animal origin	Hepatitis A, and other Hepatitis viruses unspecified	22	135	99	0
	Bakery products	Hepatitis E	3	6	1	0
	-	Norovirus	457	11125	279	0
	Water	Rotavirus	8	85	51	0
	Buffet meals	Sapovirus	1	89	0	0
	-	Other viruses, unspecified ³⁷	59	764	14	0
	Milk, and milk products	<i>Cryptosporidium</i>	11	468	4	0
	Food of non-animal origin	<i>Giardia</i>	14	233	2	0
	Water	<i>Trichinella</i>	5	44	12	0
	-	Other parasites, unspecified	1	2	0	0
	Meat, and meat products	Histamine / Scombrototoxin	96	428	52	0
	-	Marine biotoxins	48	214	14	0
	Fish, and fishery products ³⁸	Mushroom toxins	5	43	11	1
	Fish, and fishery products	Other causative agent/Unspecified ³⁹	6	88	3	0
	Other foods	<i>Brucella</i>	1	2	2	0
	-	<i>Campylobacter</i>	317	1319	112	0
	Milk, and milk products ⁴⁰	<i>E. coli</i> other than STEC	2	12	10	0
	Water (and other beverages)	<i>Listeria monocytogenes</i>	16	120	83	17
	Meat, and meat products ⁴¹	<i>Salmonella</i>	694	3686	812	7
	Fish, and fishery products ⁴²	<i>Shigella</i>	5	58	14	0
	Milk, and milk products	Shigatoxin-producing <i>E. coli</i> (STEC)	34	208	30	1
	Eggs, and egg products ⁴³	<i>Vibrio parahaemolyticus</i>	4	56	0	0
	Meat, and meat products	<i>Yersinia</i>	16	236	11	0
	Meat, and meat products	Bacteria, unspecified	3	58	5	0
	Water (and other beverages) ⁴⁴					
	Milk, and milk products					
	Meat, and meat products					
	Composite foods, multi-ingredients, and other foods ⁴⁵					
	-					

37 . 'Other viruses' includes flavivirus and other unspecified viruses.

38 . 'Fish and fishery products' include 'crustaceans, shellfish, mollusks, and products thereof, as well as 'fish and fish products.

39 . 'Other causative agents include atropine, mushroom toxins/mycotoxins, and unspecified toxins.

40 . Milk and milk products include 'Cheese', 'Cheeses made from cows' milk', 'Dairy products (other than cheeses)', 'Milk, cows' - pasteurized milk', 'Milk, cows' - raw milk', 'Milk, goats' - raw milk', 'Milk, sheep's - raw milk.

41 . Meat and meat products include 'Bovine meat and products thereof', 'Broiler meat (Gallus) and products thereof', 'Meat and meat products', 'Meat from bovine animals - meat products', 'Meat from bovine animals - meat products - ready-to-eat', 'Meat from a pig - fresh', 'Meat from a pig - meat products - fresh raw sausages', 'Meat from poultry, unspecified - meat products - non-ready-to-eat', 'Meat from wild boar - meat products - fresh raw sausages', 'Meat, mixed meat - meat products - ready-to-eat', 'Other or mixed red meat and products thereof', 'Other, mixed or unspecified poultry meat and products thereof', 'Pig meat and products thereof.

42 . Fish and fishery products include 'Crustaceans, shellfish, mollusks, and products thereof', 'Fish - smoked', 'Fish - smoked - hot-smoked', 'Fish and fish products', 'Live bivalve mollusks - oysters'.

43 . Eggs and egg products include 'Eggs', 'Eggs - raw material (liquid egg) for egg products', 'Eggs - table eggs - the mixed whole', 'Eggs and egg products.

44 . Water (and other beverages) includes 'Tap water, including well water', 'Water'.

45 . Composite foods, multi-ingredients foods, and other foods include 'Bakery products', 'Bakery products - cakes', 'Bakery products - cakes -containing raw cream', 'Bakery products - desserts - containing raw eggs', 'Bakery products - pastry - yeast leavened pastry', 'Buffet meals', 'Canned food products', 'Mixed food', 'Other foods', 'Other processed food products and prepared dishes', 'Other processed food products and prepared dishes-meat based dishes', 'Other processed food products and prepared dishes - pasta', 'Other processed food products and prepared dishes - pasta based dishes', 'Other processed food products and prepared dishes -sushi', 'Soups', 'Sweets and chocolate'.

Year	Type of contaminated food	Contaminating microorganisms	Total outbreaks	Human cases	Hospitalized	Deaths
	Foods of non-animal origin ⁴⁶					
	Composite foods, multi-ingredients, and other foods	<i>B. cereus</i> toxins	71	835	10	1
	Foods of non-animal origin					
	Composite foods, multi-ingredients, and other foods	<i>C. botulinum</i> toxins	9	34	34	0
	Composite foods, multi-ingredients, and other foods	<i>C. perfringens</i> toxins	32	682	10	2
	Foods of non-animal origin					
	Milk, and milk products	<i>S. aureus</i> toxins	43	402	32	0
	Meat, and meat products					
	Meat, and meat products					
	Composite foods, multi-ingredients, and other foods	Bacterial toxins, unspecified	372	2564	96	3
	Raw sheep's milk and/or raw goat's milk	Flavivirus (including Tick-borne Encephalitis virus)	5	12	12	0
	Foods of non-animal origin	Hepatitis A	7	206	105	0
	-	Hepatitis E	3	6	2	0
	Fish, and fishery products					
	Composite foods, multi-ingredients, and other foods	Norovirus, and other Calicivirus ⁴⁷	130	2633	90	1
	Milk, and milk products	Other viruses, unspecified	10	151	2	0
	-	<i>Anisakis</i>	2	6	0	0
	Foods of non-animal origin	<i>Cryptosporidium</i>	3	34	1	0
	-	<i>Enterocytozoon bienersi</i>	1	77	0	0
	-	<i>Giardia</i>	2	4	0	0
	Meat, and meat products	<i>Trichinella</i>	6	119	13	0
	Fish, and fishery products	Histamine, and Scombrotoxin	43	183	17	1
	Fish, and fishery products	Marine biotoxins ⁴⁸	23	120	6	0
	Foods of non-animal origin	Other causative agents	3	55	0	0
	Fish, and fishery products					
	Water (and other beverages)	Unknown / Unspecified	1229	6139	166	0

Discussions

Factors such as the globalization of food supply, large-scale production, widespread distribution of food, emergence of new pathogens, eating out, and increasing proportion of consumers facilitate the risk of foodborne disease outbreaks, which are difficult to control (24, 25). A small percentage of foodborne diseases are reported, which may be due to the scattered pattern of foodborne diseases (26). In addition, more attention from authorities is paid to this issue due to the widespread interstate, restaurant-related outbreaks, or those that can cause serious illness, hospitalization, or even death (26). As a

result, these systems represent only a small portion of the foodborne disease burden (26). This study does not include all outbreaks, but only those that are confirmed by surveillance systems (26). CDC reports that foodborne disease outbreaks (FBDOs) are increasing annually, which does not correspond to the actual increase in FBDOs and illustrates the positive effect of government oversight (26). Food contamination due to poor hygiene should be more considered in developing countries at every production stage, from farm to table (25). The cases reported in both databases include bacterial, parasitic and viral pathogens as well as

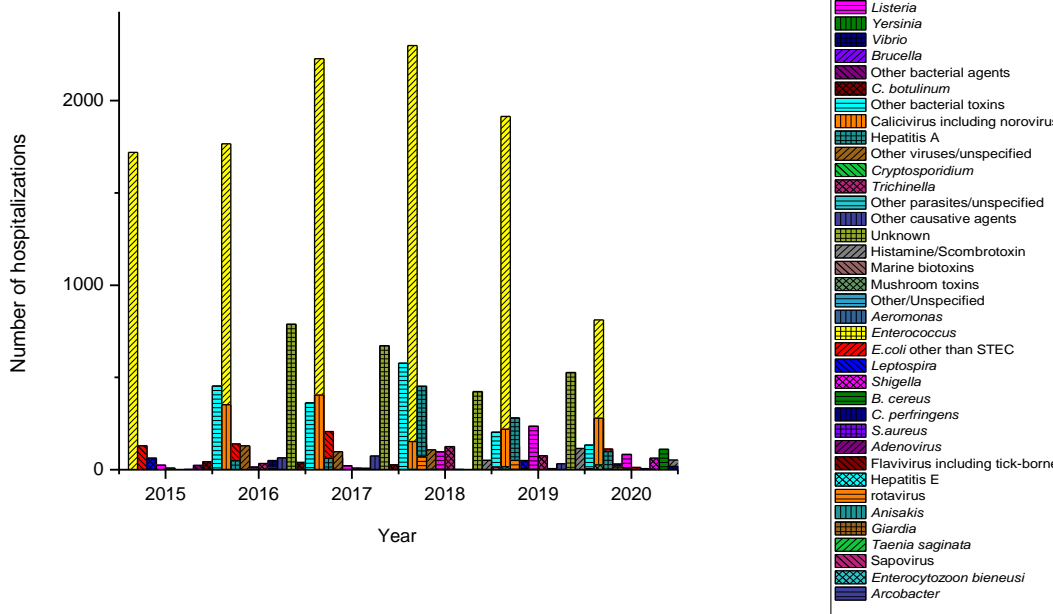
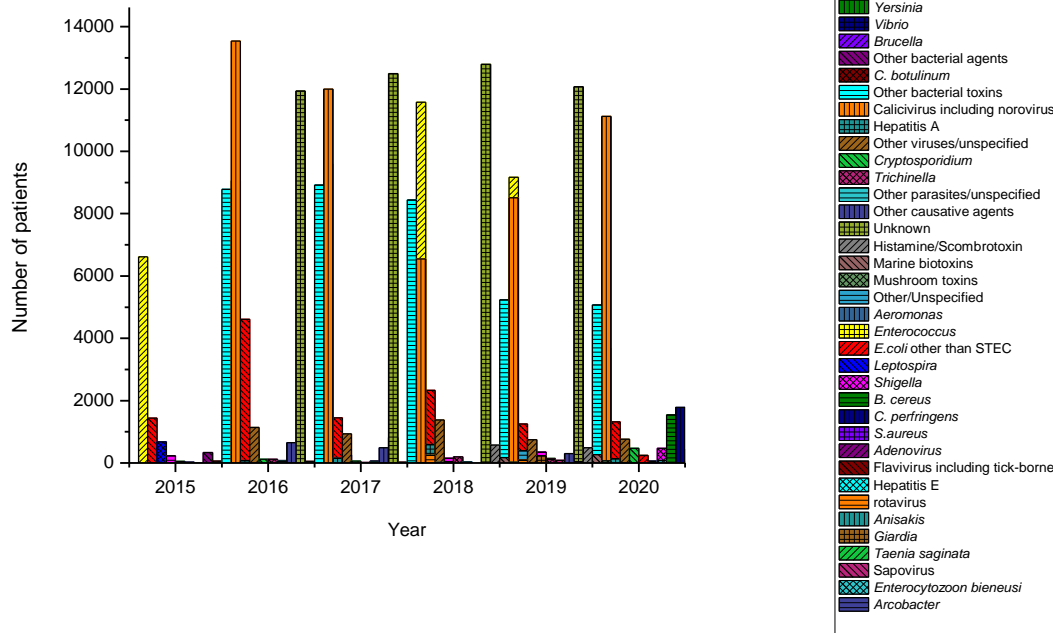
46 . Foods of non-animal origin include 'Cereal products including rice and seeds/pulses (nuts, almonds)', 'Fruit, berries and juices and other products thereof', 'Fruit - a whole', 'Herbs and spices', 'Nuts and nut products', 'Vegetables', 'Vegetables - pre-cut', 'Vegetables and juices and other products thereof'.

47 . 'Norovirus and other caliciviruses include norovirus (Norwalk-like virus), sapovirus (Sapporo-like virus), and calicivirus unspecified.

48 . Marine biotoxins include ciguatoxin and other unspecified marine toxins.

chemicals and toxins (27). Based on this study, bacterial pathogens cause most outbreaks and infections among the mentioned outbreaks. According to the results of this study, 50 food-

and water-borne pathogens led to morbidity and mortality in consumers in the US. The most important of which were *Salmonella* spp, *Cyclospora*, *E. coli* spp, *Listeria monocytogenes*.



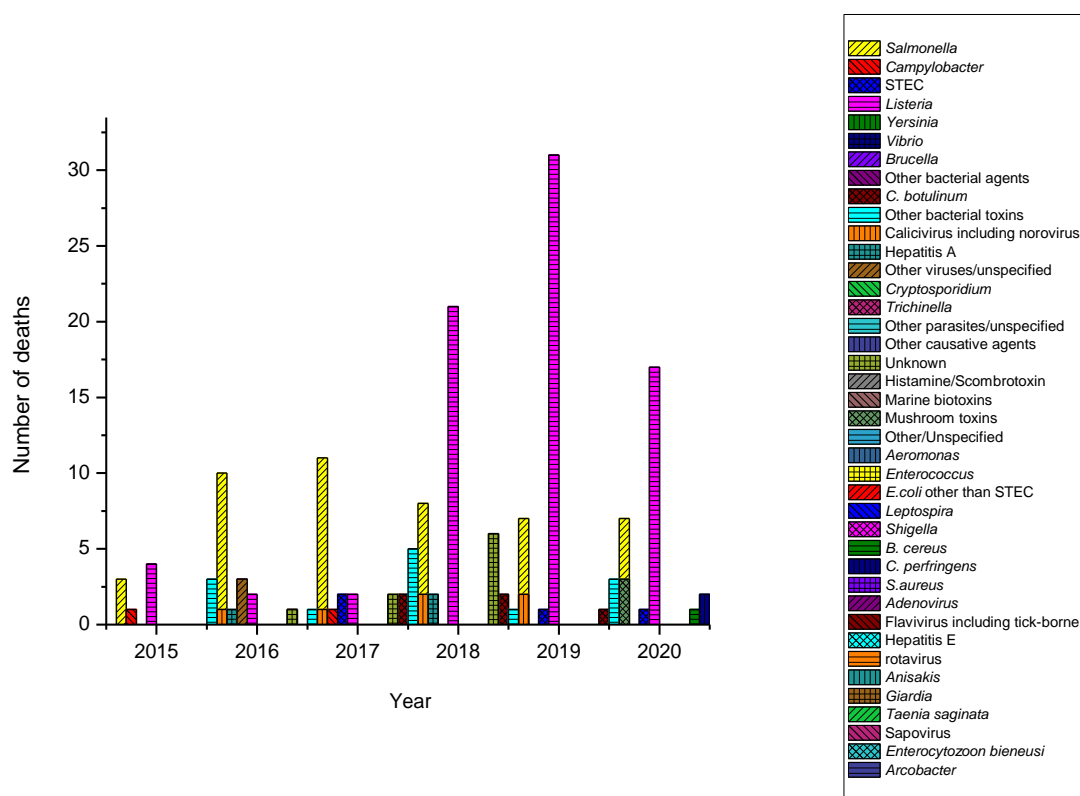


Figure 2. Reported cases of water- and foodborne outbreaks in Europe (ECDC)

In Europe, 36 food- and water-borne pathogens were reported by ECDC, and according to our review the most important of which were Salmonella, Norovirus, and other Calicivirus, Campylobacter, *B. cereus*, *C. perfringens*. Based on both monitoring systems, *Salmonella* resulted in the highest incidence of FBDOs and hospitalization of people and *Listeria monocytogenes* caused the highest mortality rate in the US and EU. As a part of the gut microbiota of animals, *Salmonella* spp. is one of the most common bacteria that contaminates food and causes hospitalization. Intestinal infections are commonly caused by *Salmonella*. Food poisoning caused by *Salmonella*, especially in children, is one of the public health problems nowadays (28). This microorganism has been growing rapidly due to the progress of the food industry, food preparation, and international transport and imports and exports (28). The use of raw and half-cooked foods such as chicken meat, eggs, and their products, milk and dairy products, meat and meat-based products and flour, as well as eating in restaurants, causes this disease (28). *Listeria* is another concerning foodborne pathogen causing deaths even in developed

countries. There is a concern about the ability of *L. monocytogenes* to remain viable and grow at freezer temperatures equal and lower than 4°C. *L. monocytogenes* can also form biofilm on various surfaces, making it more resistant to environmental stress and leading to problems in disinfection and surface hygiene (29). The primary way of *L. monocytogenes* infection is through consuming contaminated food (29). Listeriosis can be asymptomatic or cause febrile gastroenteritis in healthy individuals. However, invasive infection cases can lead to septicemia, meningoenzephalitis, and fetal loss (29). Although listeriosis has a low prevalence, it has the highest hospitalization rate (94%) among the main pathogens of food poisoning (29).

In the US, contaminated fruits were the primary cause of foodborne illnesses from 2015 to 2020, followed by ground beef as the second case. In Europe, the highest incidence of FBDOs was associated with eggs and egg-based products. Raw products have an increasing role in outbreaks. Crops such as fruits are the most common foods associated with raw produce outbreaks. The consumption of some fruits has increased, and improved transportation methods

for raw products may not accompany the increase in consumption. In addition, FDA recommendations are not always followed during the washing process. Consequently, improper food storage practices during washing and preparation can contribute to outbreaks associated with raw fruits. Fruits may be contaminated at many stages of production, from farm to table through contact with surfaces contaminated with feces of wild or domestic animals, soil, contaminated irrigation water or rainwater spray, equipment used during washing, chemicals, cooling, sorting, storing or packaging, and workers hands. In addition, using inappropriate time and temperature during storage may lead to the growth of bacteria from opening produce, such as cutting, slicing, shredding, or peeling. The lack of any further steps before consumption (e.g., cooking) and mentioned points emphasize the importance of promoting improved production and processing practices to reduce the contamination of raw products (30).

Contaminated food products of animal origin, especially eggs and egg-based products, are often implicated in outbreaks of human salmonellosis worldwide (31). Only 10^2 colony-forming units (CFU) of pathogenic *Salmonella* strains (*Salmonella Typhimurium* and *Enteritidis*) are required to cause disease in susceptible humans. Some *salmonella* species form a biofilm on the eggshell and spread the contamination. There is also evidence that *Salmonella* can survive on eggshells and grow in harsh conditions (31).

Undercooked or raw bovine products pose a risk for foodborne pathogens. Food items such as meat are considered to be among the most vulnerable perishable foods because of providing a favorable environment for microbe growth (32). Ground beef is a widely consumed food item in the United States, and diseases and outbreaks are commonly associated with the consumption of ground beef, especially undercooked ground beef (32). The small pieces of minced meat can act as a reservoir for bacteria, since it has a higher surface area and is cut into small pieces (32).

Viruses are also involved in FBDOs, and Chatziprodromidou (33) reported that norovirus and hepatitis A are viral pathogens commonly associated with fresh produce consumption. Fresh produce outbreaks are also often associated with *Cyclospora* and *Cryptosporidium* parasites (25, 34). From 2015 to 2020, in the US,

contaminated fruits were the major cause of FBDOs and the second main source of foodborne infections was ground Beef. While in Europe, the highest incidence of FBDOs was attributed to eggs and egg products. Stricter hygiene measures are needed to reduce the cases of FBDOs with these interpretations.

Food safety risks can be controlled by the use of good agricultural practices, the HACCP program, good manufacturing practices, employee training to prevent food contamination, proper cleaning and disinfection of food contact surfaces, preventing cross-contamination, and maintaining good personal hygiene (25). Additionally, more attention should be paid to preventing foodborne diseases in homes (27).

Conclusion

According to the results, detecting foodborne outbreaks, determining the source of infection, and monitoring the food chain's hygiene are crucial to prevent and control FBDOs. Therefore, establishing a comprehensive and specific system, such as the CDC and ECDC, for monitoring and assessing food safety is essential to improve public health, particularly in developing countries. Monitoring and prevention can effectively reduce the prevalence of FBDOs in countries since most of them are considered controllable infections.

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Conflicts of Interest

The authors declared no conflict of interest.

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