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REVIEW ARTICLE

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Foodborne Bacteria in Iran: A 23-year Systematic Review of High-risk Foods

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ABSTRACT

Foodborne diseases are a significant global public health concern due to their high prevalence, mortality, and economic losses. The aim of this study was to conduct a systematic review of identified foodborne pathogens and outbreaks in Iran over the past 23 years to provide an overview of the risk assessment and prevention approaches in the country. Using appropriate keywords and searching major databases, such as ScienceDirect, Scopus, PubMed, Google Scholar, and the Iranian Scientific Knowledge Database, we initially identified 4,740 articles. Finally, 328 articles were selected for evaluation. Among these articles, publications on *Salmonella, Staphylococcus aureus*, and *Listeria* were the most numerous. Poultry meat was found to be the main source of major foodborne pathogens in Iran, including *Campylobacter* (46.21%), *Listeria monocytogenes* (38.45), *Salmonella* (24.83%), and *Yersinia enterocolitica* (16.81%). Given the high prevalence of foodborne bacteria in Iranian foods, it is crucial to implement effective control measures to reduce the risk and burden of foodborne diseases. In particular, poultry meat, which poses a high risk for the occurrence of foodborne diseases in Iran, should be subjected to further risk assessment and control measures throughout the food chain.

Keywords

Foodborne bacteria, Salmonella, Staphylococcus aureus, Listeria, food, prevalence

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Abbreviations

EWHO: World Health Organization
CDC: Center for Disease Control and Prevention
RTE: Ready-To-Eat
EFSA: European Food Safety Authority

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Introduction

Foodborne diseases typically result from the consumption of food or water contaminated with pathogens or their toxins [1]. These illnesses often present as acute health problems with diverse symptoms, such as gastrointestinal distress (e.g., diarrhea, vomiting, nausea, and abdominal cramps) or neurological symptoms (e.g., headache, paralysis, and paresthesia) [2, 3]. The bacterial pathogens most commonly associated with foodborne illness worldwide include *Listeria monocytogenes, Escherichia coli* O157:H7, *Staphylococcus aureus, Salmonella enterica, Bacillus cereus, Vibrio spp., Campylobacter jejuni,* and *Clostridium perfringens* [2, 4, 5]. The food products most frequently implicated in outbreaks include poultry, ground meat, seafood, dairy products, as well as fruits and vegetables [6].

The food industry faces significant challenges in ensuring the safety and nutritional quality of food products for consumers due to various sources of contamination, such as animals, soil, water, air, and food handlers during production and storage [7, 8]. However, the implementation of proper cold preservation methods (e.g., refrigeration and freezing) and appropriate thermal processing of foods can effectively prevent foodborne diseases [3].

In the contemporary era, regulatory frameworks and directives pertaining to food safety have been fortified and intensified. Nevertheless, foodborne diseases continue to represent a significant threat to global public health and an economic burden, particularly in developing countries [9]. In its inaugural estimation of the global burden of foodborne diseases in 2015, the WHO attributed 600 million cases of foodborne diseases, 420,000 deaths, and a loss of 33 million years of healthy life worldwide to unsafe food consumption [9].

In 2018, the United States documented 25,606 cases of foodborne infections, resulting in 5,893 hospitalizations and 120 deaths [10]. The burden of foodborne diseases is particularly significant in low- and middle-income countries. Identifying the source of contamination and transmission route is of paramount importance for preventing foodborne illnesses and implementing effective interventions in food safety. However, attributing an infection to specific food and identifying foodborne transmission is challenging and requires source attribution methodologies. Consequently, there is a dearth of studies identifying the sources of foodborne infections, particularly in developing countries [11].

In this study, we aimed to conduct a systematic review of the prevalence of foodborne pathogens in different types of foods in Iran. As a result, we can gain an overview of the role of food in the transmission of infections and emphasize the importance of food safety in controlling foodborne diseases and reducing their health and economic burden on society.

Materials and Methods

Search strategy

A comprehensive and systematic search was conducted in various databases, including ScienceDirect, Scopus, PubMed, Google Scholar, and local Iranian databases, namely the Iranian Scientific Information Database (www.sid.ir). The literature review was limited to studies published during 2000-2023. The keywords used for searching included "prevalence", "detection", and "identification" in conjunction with terms, such as "food", "Iran", "foodborne pathogen", "food infection", "food poisoning", "food illness", "food disease", "foodborne bacteria", "*Campylobacter*", "*Listeria*", "*Salmonella*", "*Helicobacter pylori*", "Vibrio", "*Clostridium botulinum*", "*Clostridium difficile*", "*Clostridium perfringens*", "*Mycobacterium tuberculosis*", "*Coxiella burnetii*", "*Staphylococcus aureus*", "*Shigella*", "*Pseudomonas*", "*Bacillus cereus*", "*Brucella*", and "*Yersinia enterocolitica*".

Eligibility criteria

This systematic review included articles that focused on the prevalence of foodborne pathogens in any type of food in Iran. Duplicate reports and articles without a clear sample size or other essential data were excluded.

Data extraction

Data collection included extracting information, such as the year of publication, types of foods tested for pathogen contamination, sample size, and number of positive samples contaminated with foodborne pathogens.

Results and Discussion

Results and Discussion

Figure 1 illustrates the study selection process presented in the PRISMA diagram. A systematic literature search using Scopus, ScienceDirect, Google Scholar, SID, Magiran, and cross-references yielded an initial total of 4740 articles. After removing duplicates, 1719 articles remained for title/abstract screening. Following this screening, 655 articles were selected for full-text review. Finally, 328 eligible studies were included in the systematic review.

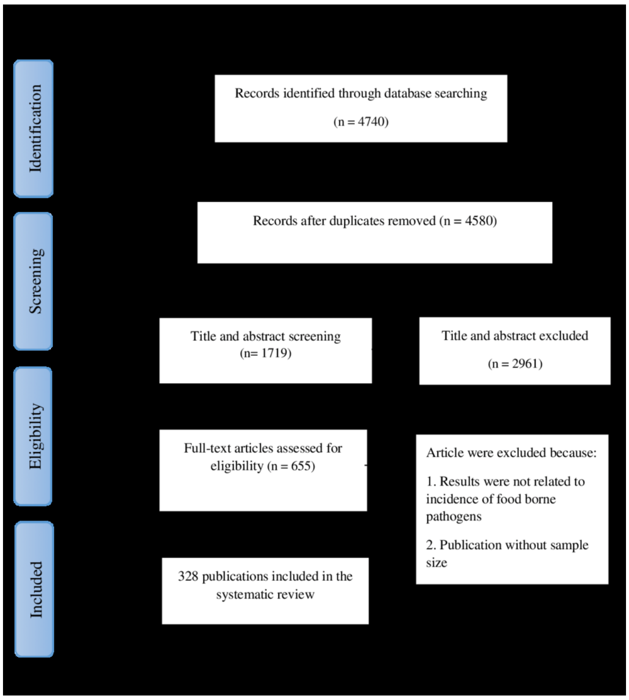

Figure 1.
Flow diagram showing the results of search

1) *Salmonella spp.* prevalence in food

Salmonella (S.) enterica enterica has more than 2300 serotypes, with *S. Enteritidis* and *S. Typhimurium* being the most commonly reported serotypes. Symptoms of salmonellosis include abdominal pain, vomiting, nausea, diarrhea, and fever [12]. Raw meat, particularly poultry, and egg products, are the main sources of foodborne salmonellosis. Other reported foods that transmit *Salmonella* to humans include fish, peanuts, unpasteurized juice, and milk. It is important to cook raw foods thoroughly to a safe minimum internal temperature to prevent foodborne salmonellosis, as *Salmonella* is heat-sensitive. However, processed foods, such as RTE meats and salads can become contaminated through cross-contamination during processing [12]. In Europe in 2020, 0.15% of RTE food samples and 2.4% of non-RTE food samples were positive for *Salmonella* [13].

Table 1 presents the prevalence of *Salmonella* in different foods in Iran based on our review. The highest levels of contamination were found in poultry meat (23.03%), followed by red meat (14.13%), dairy products (11.66%), RTE foods (11.34%), eggs (9.93%), vegetables (7.8%), fish and shrimp (5.93%), raw milk (3%), and water (2.25%) (Figure 2). In a study conducted in China in 2019, out of 1035 different food samples, a total of 147 samples (14.2%) were positive for *Salmonella*. In their study, the highest prevalence of *Salmonella* was found in fresh meat samples (28%), followed by RTE foods (9%), frozen foods (7.1%), and fresh produce (4.5%) [14]. Fresh meat is a common source of *Salmonella* contamination due to the nature of its production and processing [15]. During the slaughter and processing of animals, there is a high risk of cross-contamination with various bacteria, such as *Salmonella* [16]. In addition, fresh meat products consumed raw or undercooked increase the risk of foodborne illness [17]. The handling and storage of fresh meat products can also contribute to *Salmonella* contamination [18]. In contrast, RTE foods and frozen foods undergo processing and packaging that can reduce the risk of *Salmonella* contamination [19]. However, it is still possible for *Salmonella* to be introduced during the processing or packaging of these products [20]. Fresh produce, while less likely to be contaminated with Salmonella compared to fresh meat, can still pose a risk if not properly handled and washed before consumption [18].

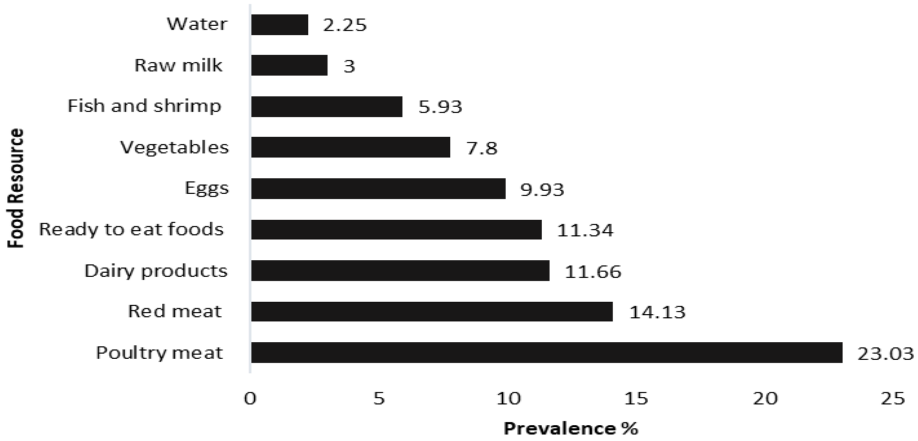

Figure 2.
Prevalence of *Salmonella spp*. in different foods in Iran.

2) *Staphylococcus aureus* prevalence in food

Although *Staphylococcus* (S.) *aureus* is the primary causative agent of hospital and community-acquired infections, it has also been associated with foodborne diseases. *S. aureus* can cause various gastrointestinal illnesses, which are characterized by nausea, vomiting, abdominal cramps, weakness, and diarrhea [21]. Table

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Table 1.
Summary of the studies reporting the prevalence of *Salmonella spp.* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	Type of *Salmonella spp.*	References	City
1	2023	Eggs	40	4	10	*Salmonella Enteritidis*	[72]	Qazvin
2	2023	poultry meat	440	39	9	*Salmonella enteritidis and Salmonella typhimurium*	[73]	Shahrekord
3	2022	Eggs	500	405	81	*Salmonella spp*	[74]	Lahijan
4	2022	retail raw meat	60	16	26	*Salmonella spp.*	[75]	Urmia
5	2022	poultry products	80	11	13.75	*Salmonella spp.*	[76]	Ardabil
6	2022	Eggs duck	130	21	16.6	*Salmonella spp*	[77]	Qazvin
7	2022	Chicken meat	150	4	2.7	*Salmonella spp.*	[78]	Zahedan
8	2022	cattle raw milk	100	2	2	*Salmonella spp.*	[79]	Mazandaran
9	2022	Red meat	300	35	11	*Salmonella spp*	[80]	Shahrekord
10	2021	Chicken meat	100	6	6	*Salmonella spp.*	[81]	Ardabil
11	2021	poultry and egg	3125	250	8	*Salmonella spp.*	[82]	six provinces of Iran
12	2021	chicken meat, beef	450	40	8	*Salmonella enterica*	[83]	Tehran
13	2019	Olivier salad	26	6	23	*Salmonella spp.*	[84]	Mashhad
14	2019	Raw chicken meat Egg yolk	60 30	29 0	48.3 0	*Salmonella spp.*	[85]	Karaj
15	2019	Eggs (shell & contents)	525	0	0	*Salmonella spp.*	[86]	Isfahan
16	2019	Traditional cheeses	100	0	0	*Salmonella spp.*	[87]	Mohabad
17	2018	Pastry	75	5	6.6	*Salmonella spp.*	[88]	Mashhad
18	2018	Chicken Meat	100	7	7	*Salmonella spp.*	[89]	Mashhad
19	2018	Industrial eggs (shell & contents)	60	0	0	*Salmonella spp.*	[90]	Zanjan
		Local eggs shell	60	0	0			
		Local egg contents	60	2	1.6			

Table 1 cont.

20	2018	Industrial eggs (shell & contents)	34	0	0	*Salmonella spp.*	[91]	Sanandaj
		Local eggs shell	42	6	4.2			
		Local egg contents	42	2	4.7			
		Bulk eggs shell	40	3	7.5			
		Bulk egg contents	40	0	0			
21	2018	Industrial eggs (shell & contents)	60	0	0	*Salmonella spp.*	[92]	Qazvin
22	2018	Shrimp	245	33	13.4	*Salmonella spp.*	[93]	Khuzestan
23	2017	Pizza	90	8	8.8	*S. arizonae*	[94]	Ilam
		Frankfurter	90	22	24.4			
		Sausages	90	19	21.1			
24	2017	Camel meat	150	0	0	*S. Typhimurium*	[95]	Kohgiluyeh & Boyerahmad/ Isfahan
25	2017	Hamburgers	100	2	2	*Salmonella spp.*	[96]	Kashan
26	2016	beaf meat	190	7	3.6	*S. Typhimurium*	[97]	Gilan
		Poultry meat	190	15	7.8	*S. Typhimurium*		
27	2016	Poultry meat	183	52	28.4	*S. Typhimurium*	[98]	Zanjan
28	2016	Industrial Olovier salad	48	0	0	*Salmonella spp.*	[99]	Isfahan
		Traditional Olovier salad	54	11	20.4			
29	2016	Traditional ice cream	90	62	68.8	*Salmonella spp.*	[100]	Zabol
30	2015	Pastry cream	120	0	0	*Salmonella spp.*	[101]	Arak
31	2015	Olivier salad	50	9	18	*S. Ttypimurium*	[102]	Shahrekord
32	2015	Poultry meat	625	35	5.6	*S. Enteritidis*	[103]	Tehran
		Eggs	625	25	4			
33	2015	Eggs	50	5	10	*S. Enteritidis*	[104]	Shiraz
34	2015	Native eggs	64	0	0	*Salmonella spp.*	[105]	Yasuj
35	2015	Traditional & Industrial cheese	200	34	17	*Salmonella spp.*	[106]	Shahrekord
				11	5.5			
36	2015	Eggshells	150	2	1.3	*S. Enteritidis & S. Typimurium*	[107]	Tabriz
		Egg contents	150	0	0			

Table 1 cont.

37	2014	Meat Products (Burgers, Sausages, Kababs, Cutlets	42	0	0	*Salmonella spp*	[108]	Urmia
38	2014	Unpasteurized cream	100	2	2	*S. Paratyphi B*	[109]	Tehran
39	2014	Chicken	190	86	45	*Salmonella spp.*	[110]	Tehran
		Beef meat	189	38	20.2	*Salmonella spp.*		
		Beef meat	189	19	10	*S. thompson*		
		Chicken	190	65	34.2	*S. thompson*		
40	2014	Chicken meat	200	58	29	*Salmonella spp.*	[111]	Alborz
		Liver	120	26	21.6			
		Heart	120	17	14.1			
41	2014	Poultry meat	89	28	31.6	*Salmonella spp.*	[112]	Shahrekord
		Beef meat	98	26	26.1			
42	2013	Olovier salad	50	9	18	*S. Typhimurium*	[112]	Shahrekord
43	2013	Tap water	144	5	3.4	*Salmonella spp*	[113]	Isfahan
		304	304	5	1.1			
44	2013	Poultry slaughtered	250	7	2.8	*S. infantis*	[114]	Brijand
45	2013	Local eggs	210	14	66.6	*Salmonella spp.*	[115]	Kohgiluyeh & Boyerahmad
46	2013	Industrial egg contents	100	0	0	*Salmonella spp.*	[116]	Talesh
		Industrial eggshells	100	19	19			
		Local egg contents	100	0	0			
		Local eggshells	100	4	4			
		Local chicken meat	100	21	21			
		Industrial chicken meat	100	5	5			
		Red meat	150	5	3.3			
47	2013	Industrial Olovieh salad	200	0	0	*Salmonella spp.*	[117]	Yazd
48	2012	Seafood	384	19	5	*Salmonella spp.*	[118]	Bushehr, Hormozgan, Khuzestan
49	2012	Chicken meat	150	14	9.3	*Salmonella spp.*	[119]	Isfahan & Shahrekord
		Turkey meat	105	7	6.7			
		Ostrich meat	45	1	2.2			
50	2012	Beef meat	60	7	11.6	*Salmonella spp.*	[120]	Sanandaj
				4	6.6	*S. Typhimurium*		
51	2012	Packed chicken meat	96	19	19.7	*Salmonella spp.*	[121]	Mazandaran
		Unpacked chicken meat	104	24	23			

Table 1 cont.

52	2012	Salt water fish	70	2	2.9	*Salmonella spp.*	[122]	Ahvaz
		Shrimp	70	3	4.3			
		Shrimp burge	10	1	10			
53	2011	Raw cow's milk	350	14	4	*Salmonella spp.*	[123]	Shahrekord
54	2010	Egg	100	0	0	*Salmonella spp.*	[124]	Shahrekord
55	2010	Chicken meat	190	86	45	*Salmonella spp.*	[125]	Tehran
		Beef meat	189	38	20			
56	2010	Turkey meat	144	14	9.7	*Salmonella spp.*	[126]	Isfahan
		Ostrich meat	65	3	4.6			
		Partridge meat	40	0	0			
57	2009	Eggshells	250	4	1.6	*S. Typhimurium*	[127]	Mashhad
		Egg contents	250	0	0	*Salmonella spp.*		
58	2009	Poultry carcasses	60	5	8.3	*Salmonella spp.*	[128]	Mashhad
			60	1	1.6	*S. Typhimurium*		
59	2009	Egg contents	120	0	0	*Salmonella spp.*	[129]	Zanjan
		Eggshells	120	68	56.6			
		Chicken meat	120	104	86.6			
60	2009	Chicken meat	67	32	47.7	*Salmonella spp.*	[130]	Tehran
		Beef meat	66	19	28.7			
61	2008	Local egg contents	500	1	0.2	*Salmonella spp.*	[131]	Birjand
		Local eggshells	500	2	0.4			
62	2008	Raw poultry	134	24	17.9	*Salmonella spp*	[132]	Isfahan
		Cooked poultry	56	3	5.3			
		Turkey	3	1	33.3			
		Quail	5	2	40			
		Red meat	101	8	7.9			
		Cooked meat	118	2	1.6			
		Vegetables	38	3	7.8			
		Fish	15	0	0			
		Yogurt	32	0	0			
		Olovieh salad	20	0	0			
		Hamburger	5	0	0			
		Mayonnaise souse	8	0	0			
63	2007	Poultry carcasses	132	92	69	*Salmonella spp.*	[133]	Tehran
64	2007	Traditional cheeses	200	0	0	*Salmonella spp.*	[134]	Jahrom
65	2006	Liver	145	12	8.1	*Salmonella spp.*	[135]	Yazd
		Meat (before chiller)	145	28	18.4			
		Meat (after chiller)	145	50	34.4			
66	2006	Local eggs	500	3	0.6	*Salmonella spp.*	[133]	Birjand

Table 2.
Summary of the studies reporting the prevalence of *S. aureus* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	City
1	2023	Poultry meat	94	16	17	Shahrekord
2	2022	Sausages and Bologna	100	31	31	Tehran
3	2022	Raw and ready-to-eat green leafy vegetables	366	134	36.6	Tehran
4	2022	Retail raw meat	60	23	39	Urmia
5	2022	Raw Milk And Traditional Dairy	150	23	15.33	Alborz
6	2022	Ready To Eat Food	320	10	3.12	Tehran
7	2022	Raw Milk	380	42	11.05	Alborz
8	2022	Raw Cow Milk	90	35	38.88	Shahrekord
9	2021	Baghlava	112	3	2.67	Qazvin
10	2021	Raw milk	250	46	18.4	Mashhad
11	2021	Cheese, raw and pasteurized milk	100	10	10	-
12	2019	Meat Products	160	26	16.25	Shahrekord
13	2021	Milk and Cheese	200	23	11	Khuzestan
14	2021	Meat retail	90	31	34.5	Zanjan
15	2021	Ready-to-eat food	415	64	15.42	Tehran
16	2021	Chicken meat	24	6	25	Tehran
17	2019	Zoolbia & Bamieh	75	21	28	Mashhad
18	2019	Fowl meat	240	22	9.6	Tehran
19	2019	Traditional cheese	100	21	21	Maragheh
20	2018	Traditional cheese	100	45	45	Mahabad
21	2017	Raw foods with animal origin	84	20	23.8	Isfahan
		Cooked foods with animal origin	132	12	9	
		Cooked foods without animal origin	269	15	5.7	
22	2017	Season salad	18	0	0	Bandar abbas
		Pasta salad	5	2	40	
		Lettuce	16	0	0	
		Shirazi salad	7	0	0	

Table 2 cont.

23	2017	Pizza	90	11	12.2	Ilam
		Frankfurter	90	25	27.7	
		Sausages	90	22	24.4	
24	2016	Cheese	*120*	*18*	*41.6*	Hamedan
25	2016	Meat	*380*	*78*	*20.5*	Gilan
26	2016	Shrimp	*300*	*84*	*28*	Persian Gulf, Caspian Sea
		Fish	*300*	*122*	*47*	
27	2015	Red meat	*379*	*36*	*9.4*	Hamadan
		Dairy products	*671*	*62*	*7.2*	
28	2015	Raw milk	*320*	*88*	*27.5*	Chaharmahal va Bakhtiyari
		Dairy products	*350*	*87*	*24.8*	
29	2015	Shrimp	*300*	*74*	*24.6*	Persian Gulf, Tehran
30	2015	Raw milk	*1930*	*248*	*12.8*	Mazandaran
		Dairy products	*720*	*80*	*11.1*	
31	2015	Bovine milk	*92*	*44*	*47*	Maku
		Sheep milk	*86*	*32*	*37*	
32	2015	Industrial Olivier salad	*30*	*15*	*50*	Shahrekord
		Traditional Olivier salad	*20*	*8*	*40*	
33	2015	Cheese	*80*	*80*	*100*	Marand
34	2015	Chicken nuggets	*420*	*24*	*5.7*	Isfahan
35	2015	Different food	*606*	*12*	*1.9*	Gilan
36	2014	Cream pastry	*450*	*194*	*43.3*	Gorgan
37	2014	Milk	*100*	*9*	*9*	Tabriz
		Cheese	*100*	*45*	*45*	
38	2014	Traditional ice cream	*30*	*2*	*6.7*	Yasuj
		Olovier salad	*4*	*0*	*0*	
		Cream suit	*30*	*9*	*30*	
39	2014	Raw milk	*300*	*125*	*41.6*	Ahwaz
40	2014	Dairy product	*460*	*127*	27.6	Marand
41	2014	Cheese	*80*	*80*	100	Tehran, Gilan
42	2014	Doogh	*126*	*86*	68	,Mazandaran

Table 2 cont.

43	2014	Raw milk	*120*	*49*	40.8	Kurdistan	
44	2014	Meat products	*150*	*19*	12.6	Tonekabon	
45	2014	Traditional cheeses	100	16	16		East- Azer-baijan
46	2013	Dairy products	347	20	5.8		Isfahan, Chaharmahal va Bakhtyari, Khuzestan,
47	2013	Industrial Olivier salad	200	40	20	[117]	Yazd
48	2013	Milk	200	22	11	[175]	Fars
49	2012	Traditional white cheese	100	26	26	[176]	Tabriz
		butter	150	24	16		
50	2012	Ground-meat kebab	72	72	100	[177]	Shahrekord
		Bakkhtiyari Kebab	72	72	100		
		Fish	72	72	100		
		Salad	72	72	100		
51	2012	Seafood products	245	22	8.9	[122]	Different mar-kets of Iran
52	2012	Packaged hamburger	256	64	25	[178]	Tehran
53	2012	Raw milk	100	50	50	[176]	Urmia
		Pasteurized milk	100	2	2		
		Ice cream	100	26	26		
54	2012	Raw milk	348	46	13.2	[179]	Shahrekord
55	2010	Fruit juice	360	32	8.8	[180]	Shahrekord
56	2008	Different food	216	30	55.6	[181]	Tehran
57	2006	Fresh fish	67	15	22.3	[182]	Gilan, Caspian Sea

2 presents the findings of studies conducted in Iran regarding the prevalence of this pathogen in different food categories, including seafood (38.51%), meat products (35.47%), dairy products (31.70%), red meat (25.85%), RTE foods (23.59%), raw milk (23.32%), and poultry meat (14.32%) (Figure 3). Seafood and fish are conducive to microbial growth due to their abundant protein and water content. *S. aureus* is not typically found in the natural microflora of fish, therefore, its presence can indicate poor personal hygiene, new contamination, or potential disease in the fish [22]. Improper conditions in the fishery, storage, and non-standard transportation provide conditions for pathogens to grow [23]. Furthermore, the hot climate in Iran can facilitate the growth and proliferation of *S. aureus* bacteria in food products, such as meat and dairy items, particularly if they are not stored and refrigerated correctly [24].

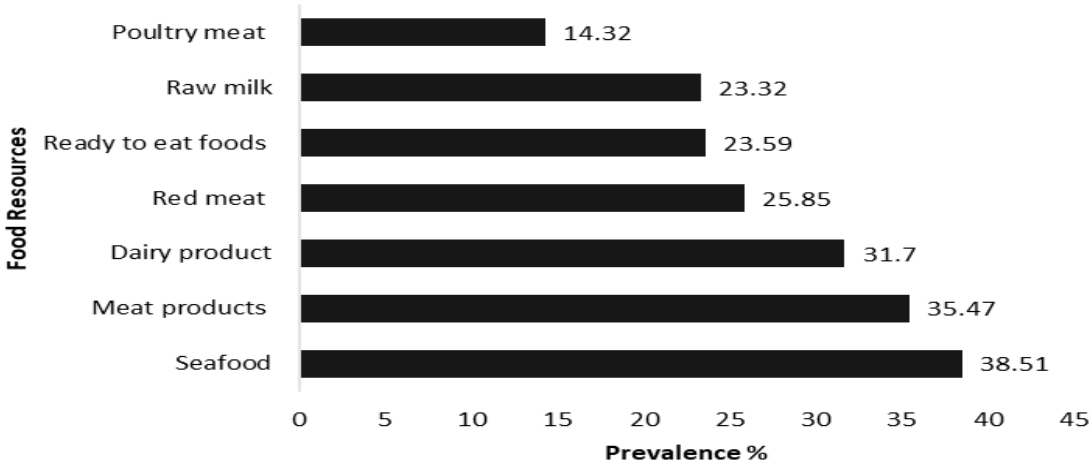

Figure 3.
Prevalence of *S. aureus* in different foods in Iran.

Table 3.
Summary of the studies reporting the prevalence of *Listeria* spp. in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	*Type of Listeria spp.*	References	Area
1	2023	Various Food	900	136	15.1	*L. monocytogenes*	[183]	Mazandaran and Golestan
2	2022	Retail raw meat	60	25	42	*L. monocytogenes*	[75]	Urmia
3	2022	Curd and cheese	150	14	9.33	*L. monocytogenes*	[184]	-
4	2021	Non-Pasteurized Milk	50	30	60	*L. monocytogenes*	[185]	Kerman
5	2021	Traditional cheeses	60	1	1.6	*L. monocytogenes*	[186]	Tehran
6	2021	Raw Milk	100	10	10	*Listeria spp.*	[187]	Tehran
7	2021	Seafood	350	40	11.42	*Listeria spp.*	[188]	Genaveh port
8	2020	Beef and chicken meat	90	45	50	*L. monocytogenes*	[189]	Zanjan
9	2019	Eggs	525	0	0	*Listeria spp.*	[86]	Isfahan
10	2019	Chicken meat retailers	811	257	30.5	*Listeria spp.*	[190]	Mashhad
11	2018	Traditional dairy products	545	64	11.7	*Listeria spp.*	[191]	Yazd
				22	4.3	*L. monocytogenes*		
12	2017	Food (sausage, milk, cheese, chicken and meat)	267	8	2.9	*Listeria spp.*	[192]	Urmia
13	2017	Fresh chicken carcasses	200	80	40	*Listeria spp.*	[193]	Mashhad
14	2016	Dairy products	107	9	8.4	*L. monocytogenes*	[194]	Tehran
		Processed meat	210	11	5.2	*Karaj &*		
15	2016	Seafood	237	7	2.9	*L. monocytogenes*	[195]	Tehran

Table 3 cont.

16	2016	Argyrosomus hololepidotus	240	30	12.5	*Listeria spp.*	[196]	Isfahan& Bandaran-zali
				5	16.6	*Bandaranzali*		
17	2015	Koozeh cheeses	100	3	3	*L. monocytogenes*	*[197]*	Urmia
18	2015	Minced beef	150	4	2.7	*Listeria spp.*	*[198]*	Ahvaz
				1	0.6	*Mazandaran*		
19	2015	Raw fish	488	104	21.3	*Listeria spp.*	*[199]*	Mazandaran
20	2015	Raw milk	60	0	0	*L. monocytogene*	*[200]*	Zanjan
21	2015	Traditional dairy products	292	21	19.7	*Listeria spp.*	*[201]*	Isfahan
22	2015	Raw milk	100	5	5	*L. monocytogene*	[202]	Kerman
23	2014	Ready to eat food (olovier salad, Yogurt stew, macaroni salad and meat salad)	235	20	8.5	*Listeria spp.*	[203]	Shahrekord
24	2014	Meat products	98	12	32.4	*L. monocytogene*	[204]	Qazvin
		Milk products	84	25	29.7	*Fars & Khuzestan*		
25	2014	Bulk milk	260	27	10.4	*Listeria spp.*	[205]	Fars & Khuz-estan
				7	2.7	*Bandar anzali*		
26	2014	Smoked fish	80	7	8.8	*Listeria spp.*	[206]	Isfahan & Bandar anzali
				2	2.5	*L. monocytogene*		
		Salted Fish	40	6	15	*Listeria spp.*		
				1	2.5	*L. monocytogene*		
27	2013	Meat and meat products	60	8	13.3	*Listeria spp.*	[207]	Khoramabad & Tehran
				2	6.6	*L. monocytogene*		
28	2013	Crayfish meat	40	3	7.5	*L. monocytogene*	[208]	Aras
29	2013	Raw cow milk	986	25	2.5	*Listeria spp.*	[209]	Isfahan
				20	2	*L. monocytogene*		
30	2013	Vegetables and ready mayonnaise salads	300	26	8.7	*Listeria spp.*	[210]	Tehran
				21	7	*L. monocytogene*		
31	2013	Raw seafood products	331	16	4.8	*L. monocytogene*	*[211]*	Shahrekord
		RTE seafoods	321	46	14.5	*L. monocytogene*		
32	2013	Raw milk	466	83	18.6	*Listeria spp.*	*[212]*	Tehran
33	2013	Dairy products	185	7	3.8	*Listeria spp.*	*[213]*	Kermanshah
		Meat products	187	51	27.2			
		Ready-to-eat foods	158	8	5.1			
34	2013	Seafood	300	24	8	*Listeria spp.*	*[214]*	Isfahan & Shahrekord
				18	6	*L. monocytogene*		
35	2013	Quail products	150	10	6.6	*Listeria spp.*	*[215]*	Isfahan
				1	0.6	*L. monocytogene*		
36	2013	Lamb	200	5	2.5	*L.ivanovii*	*[216]*	Shahrekord
37	2012	Different types of raw meat	1107	141	12.7	*Listeria spp.*	*[217]*	Shahrekord, Isfahan, Ahvaz ,Shi-raz,Yazd,
				27	2.4			
38	2012	Poultry product	402	134	33.3	*Listeria spp.*	*[218]*	Shahrekord
39	2012	Seafood	264	20	7.6	*Listeria spp.*	[219]	Isfahan & Shahrekord

Table 3 cont.

40	2012	Various seafood products	245	2	0.8	*L. monocytogene*	[122]	Different markets of Iran
41	2011	Eggs	100	0	0	*L. monocytogene*	[124]	Shahrekord
42	2011	Fish	194	24	12.3	*Listeria spp.*	[220]	Urmia
				5	2.5	*L. monocytogene*		
43		Raw cow milk	45	5	1.1	*Listeria spp.*	[221]	Shiraz
				2	4.4	*L. monocytogene*		
		Raw goat milk	32	1	3.1	*Listeria spp.*		
				1	3.1	*L. monocytogene*		
		Traditional cheese	41	10	24.4	*Listeria spp.*		
				4	9.7	*L. monocytogene*		
		Traditional ice-cream	60	8	11.7	*Listeria spp.*		
				2	3.3	*L. monocytogene*		
44		Raw milk	100	4	4	*L. monocytogene*	[222]	
45		Dairy products	360	6	1.6	*L. monocytogene*	[223]	
46		Chilled ready to eat foods	41	3	7.3	*L. monocytogene*	[224]	
		Meat, meat products	332	4	1.2	*L. monocytogene*		
		Milk and dairy products	88	0	0	*L. monocytogene*		
47		Cattle carcasses	203	6	3	*L. monocytogene*	[225]	

3) *Listeria monocytogenes* prevalence in food

Listeria (L.) *monocytogenes* represents a significant public health concern due to its ability to be transmitted from the environment to food, which can lead to foodborne listeriosis in humans [25]. In 2020, the EFSA reported a total of 1876 cases of listeriosis, with 97.1% of these cases necessitating hospitalization [26]. Moreover, the EFSA indicated an increase in the case fatality rate and hospitalization rate associated with *L. monocytogenes* infections in 2020. Among all the reported zoonoses in Europe in 2020, listeriosis had the highest case fatality rate of 13% [26]. Those at the greatest risk of developing listeriosis include pregnant women, the elderly, newborns, and patients with compromised immune systems [27]. Moreover, a multitude of food items were identified as potential sources of listeriosis outbreaks during this period. Specifically, 4.8% of RTE meat products and 0.44% of

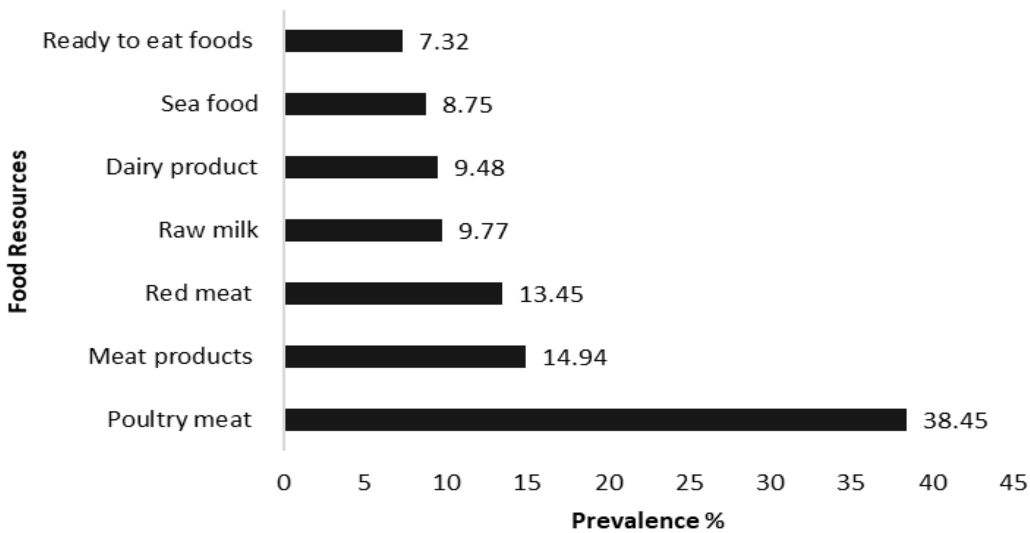

Figure 4.
Prevalence of *Listeria* in different foods in Iran.

Table 4
Summary of the studies reporting the prevalence of C. *burnetii* in Iran..

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	References	Area
1	2022	Unpasteurized Camel Milk	100	6	6	[226]	Mashhad
2	2022	Kope cheese and cattle milk	800	103	12.87	[227]	West Azerbaijan
3	2021	Raw Milk	162	23	14	[228]	Tehran, Hamadan, and Mazandaran
4	2021	Raw milk	100	27	27	[229]	Mazandaran
5	2020	Raw milk	204	21	10.2	[230]	Gilan
6	2020	Sheep and goats milk	420	51	12.1	[231]	West Azerbaijan
7	2019	Milk	126	44	34.9	[232]	Qom
8	2019	Milk	840	14	16.9	[233]	West Azerbaijan
		Cattle milk			14.4		
		Buffalo milk			19.3		
9	2019	Cream & butter	200	6	3	[234]	Shahrekord
		Traditional bovine cream,	69	4	5.7		
		Traditional sheep butter,	20	1	5		
		Traditional bovine butter	39	1	2.5		
10	2018	Raw milk	500	9	1.8	[235]	Khorramabad
		Sheep milk		3			
		Goat milk		6			
11	2018	Bulk milk	100	3	3	[236]	Shiraz
12	2018	Non-pasteurized dairy products	238	20	8.4	[29]	Shiraz
13	2018	Raw milk	100	10	10	[237]	Tehran
		Traditional unpacked cheese	40	3	7.5		
14	2016	Raw sheep milk	72	15	20.8	[238]	Khorramabad
15	2015	Bovine bulk milk	70	12	17.4	[239]	Jahrom
				7	10		
				7	10		
16	2015	Individual raw milk	60	7	11.6	[200]	Zanjan
		Bovine	38	5	8.3		
		Ovine	22	2	3.3		
17	2015	Cow milk	150	18	12	[240]	Tehran
18	2015	Goat milk	31	5	16.1	[241]	Kerman
19	2015	Cow milk	80	20	25	[242]	Ajabshir
20	2014	Cheese	28	2	7.1	[243]	Mashhad
		Yoghurt	26	2	7.6		
		Sheep milk	23	8	34.7		
		Cow milk	60	2	3.3		
21	2014	Bovine bulk tank	100	5	5	[244]	Mashhad
22	2014	milk	51	21	41.1	[245]	Khoramabad.
23	2013	Goat milk	100	14	14	[246]	Qom

Table 4 cont.

24	2013	Bovine bulk milk	100	11	11	[247]	Jahrom
25	2011	Bovine milk	247	8	3.2	[248]	Kerman
		Ovine bulk milk	140	8	5.7		
		Caprine bulk milk					
		Camel bulk milk	110	5	4.5		
26	2010	Bulk milk	296	6	2	[249]	Fars, Ghom, Kerman, Yazd Khuzestan
27	2010	Cow milk	210	13	6.2	[250]	Chaharmahal va Bakhtiari
		Sheep milk	110	0	0		
		Goat milk	56	1	1.8		

milk and milk products were found to be contaminated with *L. monocytogenes* [26]. Table 3 and Figure 4 present the findings of studies conducted in Iran regarding the prevalence of *L. monocytogenes* in various food types. As illustrated in Figure 4, poultry meat exhibited the highest contamination rate of 38.45%, followed by meat products (14.94%), red meat (13.45%), raw milk (9.77%), dairy products (9.48%), seafood (8.75%), and RTE foods (7.32%) (Figure 4). A previous review study conducted in Iran until 2015 yielded comparable results regarding the contamination of food with Listeria. The highest prevalence of *L. monocytogenes* was approximately 9.2%, which was observed in RTE foods [25]. Therefore, RTE foods should be considered a potential hazard to consumers [25]. Similarly, other developing countries have also yielded comparable results. For example, a study conducted in Ethiopia revealed that 28.4% of raw milk and milk products were contaminated with Listeria spp., with 5.6% of these samples testing positive for L. monocytogenes [23].

4) *Coxiella burnetii* prevalence in food

Coxiella burnetii is a zoonotic pathogen that causes Q fever in humans and coxiellosis in livestock. Cattle, goats, and sheep serve as the primary reservoirs for the pathogen, facilitating its transmission to humans [28]. The primary routes of human infection are through the inhalation of contaminated aerosols or the consumption of unpasteurized milk and dairy products [29]. In Europe, 523 cases of Q fever were identified in 2020, resulting in a case fatality rate of 2.1% [30]. Table 4 presents the results of studies conducted in Iran concerning the prevalence of *C. burnetii* in different food items. As illustrated in Figure 5, the foods with the highest contamination rates were raw milk (12.36%) and dairy products (6.40%). *C. burnetii* is a bacterium that causes Q fever, a zoonotic disease that can be transmitted from animals to humans. In numerous rural regions of Iran, milk is still produced and processed using traditional methods that fail to meet the requisite modern hygiene standards [31]. The absence of adequate hygiene protocols in milk

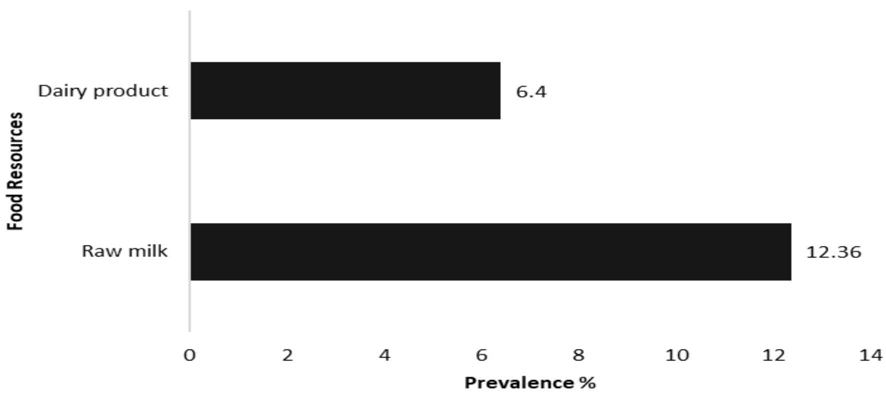

Figure 5.
Prevalence of *C. burnetii* in different foods in Iran.

Table 4

production and processing facilities may result in the contamination of milk with *C. burnetii*. Moreover, the proximity of animals to humans in the rural areas of Iran contributes to the high levels of contamination of raw milk and dairy products with *C. burnetii* [32]. Animals, such as cows and goats, can carry the bacterium and shed it in their milk, which can then be transmitted to humans through consuming contaminated dairy products [33].

A study conducted in Italy in 2017 reported that 15% of milk samples were contaminated with *C. burnetii*, with a higher prevalence of contamination in bovine milk (41%) compared to sheep milk (12%) [34]. In Brazil, in 2020, 9.43% of cheese samples (out of 53 samples) were positive for *C. burnetii* DNA [35]. Another research in the United States reported that 94% of bulk milk samples from dairy herds were contaminated with *C. burnetii* [36]. Our review indicates that the data from Iran align with the reports from other countries. However, it should be noted that the prevalence of *C. burnetii* contamination varies depending on the type of dairy products, including specific variations within milk.

5) *Bacillus cereus* prevalence in food

Bacillus cereus spores are a well-documented contaminant of food that can survive high temperatures during cooking and pasteurization [37]. This bacterium is associated with two distinct types of gastrointestinal diseases: the emetic (vomiting) syndrome and the diarrheal syndrome [38]. In Europe, 835 cases of foodborne illness caused by *B. cereus* were reported in 2020, with a hospitalization rate of 1.2% and a mortality rate of 0.1% [30]. The diarrheal syndrome is typically attributed to the consumption of contaminated foods, including raw and cooked beef, meat products, fish, poultry, soups, sauces, stews, milk, and vegetables. In contrast, the emetic syndrome is associated with the consumption of a toxic dose of the pre-formed emetic (cereulide) toxin produced by *B. cereus* in starchy foods, such as rice, pasta, noodles, potatoes, bread, pastries, and sesame products [39]. Table 5 presents the results of studies conducted in Iran regarding the prevalence of *B. cereus* in different food items. As illustrated in Figure 6, the highest prevalence of *B. cereus* contamination was observed in rice (100%), followed by raw milk (48.8%), poultry meat (42.17%), spices (42%), infant food (32.62%), dried vegetables (31.42%), meat products (11.16%), red meat (9.33%), and dairy products (8.9%) (Figure 6). In Australia, B. cereus contamination was identified in a variety of food samples, including uncooked pizza bases (1.58%), cooked pizzas (4.57%), processed meats (0.28%), cooked meat pies (4.45%), cooked sausage rolls (3.26%), and raw diced chicken (5.45%) out of 1,263 retail food samples [40]. In China, *B. cereus* contamination was observed in 50% of rice and noodle samples, 34% of cooked meat samples, and 22% of cold vegetable dishes [41]. In Poland, the highest prevalence of *B. cereus* contamination was found in herbs and spices, with a rate of 63.3%. Moreover, other food items, including breakfast cereals, pasta, rice, pasteurized milk, infant formulas, as well as fresh and ripening cheeses, were also found to be contaminated with *B. cereus* [37].

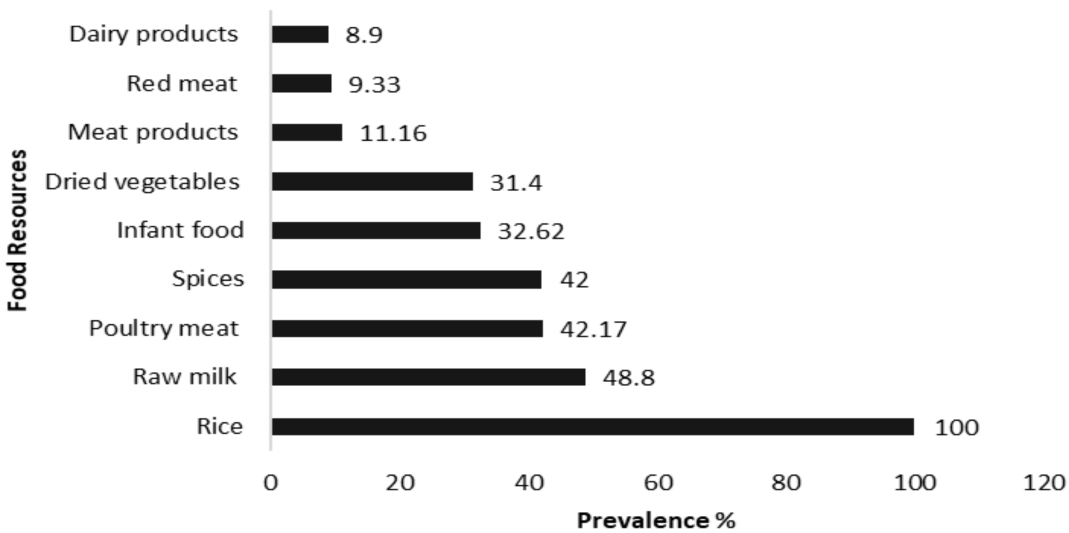

Figure 6.
Prevalence of *B. cereus* in different foods in Iran.

Table 5.
Summary of the studies reporting the prevalence of *B. cereus* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	References	Area
1	2023	Various Spices	200	84	42	[251]	Isfahan
2	2020	Individual meat	200	29	14.5	[252]	Zanjan
		Raw lamb					
		Raw beef	60	7	3.5		
		Cooked beef	60	10	5		
			80	12	6		
3	2020	Traditional dairy products	150	16	10.6	[253]	Tabriz
4	2019	Different rice	10	10	100	[254]	Zanjan
5	2018	Cow's raw milk	120	13	10.8	[255]	Tabriz
6	2018	Dried vegetable	140	44	31.4	[256]	Tehran
7	2018	Cream	62	0	0	[257]	Zanjan
8	2017	Different types of beef burgers	80	18	22.5	[258]	Tehran
9	2017	Milk-based infant food	300	9	3	[259]	
10	2017	Powdered infant formula milk	125	84	67.2	[260]	
11	2017	Cow milk	42	41	97.6	[261]	
12	2016	Cheese	200	10	5	[262]	
13	2016	Beef meat and poultry	380	44	11.8	[97]	
14	2016	Dairy products	230	46		[263]	
15	2015	Poultry meat foods Frozen	104	80	76.5	[264]	Tehran
		Semi cooked	39	9	24.2		
		Refrigerated	46	26	[97]		
16	2014	Rice	408	408	100	[265]	Urmia
17	2013	Infant foods	200	84	42	[266]	Isfahan
18	2012	Kefir type drinks	32	9	28	[267]	
		Pasteurized milk	32	12	Tehran		
19	2007	Infant formula	60	11	18.3	[268]	Tehran

6) *Yersinia enterocolitica* prevalence in food

In Europe, 236 cases of foodborne yersiniosis were reported in 2020, with 4.7% of cases necessitating hospitalization [30]. *Yersinia enterocolitica* contamination has been documented in a variety of foods in Europe, including red meat (beef, pork, and lamb), poultry, seafood, eggs, milk and milk products, bean sprouts, vegetables, tofu, and stewed mushrooms [42]. Table 6 presents the results of studies conducted in Iran regarding the prevalence of *Y. enterocolitica* in different food items. As illustrated in Figure 7, poultry meat exhibited the highest contamination rate of 16.81% in Iran. This was followed by raw milk (11.93%), red meat (11.63%), and dairy products (10%) (Figure 7). In Europe, 5.2% of RTE meat was found to be positive for *Yersinia* in 2020, which is a relatively high and concerning rate [30]. A study conducted in Argentina in 2019 reported chicken (12.4%) and bovine-originated foods (10.2%) as the most contaminated foods with *Y. enterocolitica* [43], which aligns with the findings in Iran. However, the latter study reported a lower prevalence of contamination in dairy products (0.7%) compared to the findings in Iran [43]. The elevated contamination rates of *Y. enterocolitica* in poultry meat observed in Iran and Argentina can be attributed to several factors, including the hygiene practices employed during the processing, transportation, and

Table 6.
Summary of the studies reporting the prevalence of *Y. enterocolitica* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	References	Area
1	2022	Raw Milk	360	3	0.83	[269]	Tehran
2	2021	red meat	200	26	13	[270]	Shiraz
3	2021	Bovine Raw Milk	100	33	33	[271]	Mashhad
4	2021	Traditional Cheeses	200	38	19	[272]	Khorasan Razavi and Golestan
5	2020	Raw milk	360	3	0.8	(Soltan Dallal, 2020)	Tehran
6	2019	Cheeses	200	38	19	[273]	Khorasan Razavi and Golestan
		Raw milk	100	33	33		
7	2018	Chicken meat	100	25	25	[274]	Mashhad
8	2018	Raw milk (sheep & goats)	100	9	9	[275]	Shahrekod
9	2018	Turkey meat	300	55	18.3	[276]	Shahrekord
10	2015	Meat	450	56	12.4	[277]	Tehran
		Chicken meat	226	35	15.4		
		Beef meat	224	21	9.3		
11	2015	Raw milk	446	19	4.3	[278]	Varamin
12	2014	Dairy products	552	28	5	[279]	Isfahan
13	2014	Raw chicken meat	300	65	21.6	[280]	Shahrekod
14	2014	Unpasteurized cream	100	3	3	[281]	Tehran
15	2013	Chicken meat	720	132	18.3	[282]	Shahrekod
16	2012	Bulk raw milk	354	8	2.6	[283]	Eastern Azerbaijan
		Cheeses	200	8	4		
17	2012	Chicken meat	200	18	9	[121]	Mazandaran
18	2012	Broiler meat	120	19	15.8	[284]	Tabriz
19	2011	Beef and chicken meat	379	48	12.6	[285]	Tehran

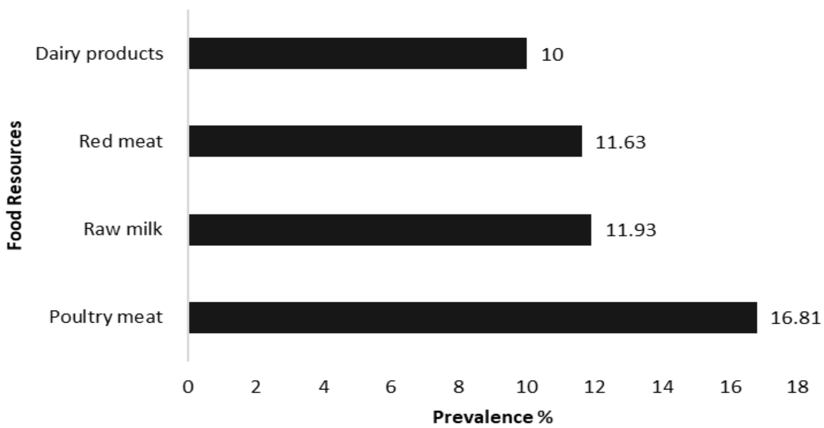

Figure 7.
Prevalence of *Y. enterocolitica* in different foods in Iran.

storage of these products [44]. Poultry meat has been identified as a significant source of *Y. enterocolitica* contamination due to the presence of the bacterium in the intestinal tracts of birds [45]. Inappropriate handling and processing of poultry can result in the cross-contamination of the meat with *Y. enterocolitica*. In addition, raw milk, red meat, and dairy products can serve as reservoirs for *Y. enterocolitica* if not properly pasteurized or handled [46].

7) *Campylobacter* prevalence in food

Campylobacter spp. has been identified as the leading cause of foodborne gastroenteritis in Europe since 2005 [30]. In addition to acute gastroenteritis, *Campylobacter* infections can also result in chronic manifestations in humans [47]. Among the various species within the genus Campylobacter, *C. jejuni* and *C. coli* are the most commonly reported causes of Campylobacteriosis in humans [48]. Table 7 presents the results of studies conducted in Iran regarding the prevalence of *Campylobacter* in different food items. As illustrated in Figure 8, the most prevalent occurrence of *Campylobacter* contamination in Iran was observed in poultry meat (46.21%), followed by red meat (40%) and eggs (28.06%). The contamination of dairy products and raw milk was observed in 2.36% and 2.5% of samples, respectively (Figure 8). A study conducted in

Table 7.
Summary of the studies reporting the prevalence of *Campylobacter* spp. in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	*Campylobacter spp.*	References	Area
1	2023	chicken meat	100	81	81	*Campylobacter spp.*	[286]	Hamedan
2	2023	chicken meat	255	64	25.09	*Campylobacter spp*	[287]	Shahrekord
3	2023	Mushrooms	740	74	10	*Campylobacter spp*	[288]	-
4	2022	poultry meat	380	24	6.25	*Campylobacter spp*	[289]	Shahrekord
5	2022	poultry meat	100	35	35	*Campylobacter spp*	[290]	Tehran
6	2022	raw meat	200	27	13.5	*Campylobacter jejuni*	[291]	-
7	2022	cattle raw milk	100	7	7	*Campylobacter jejuni*	[292]	Mazandaran
8	2021	Poultry Carcasses	370	203	54.8	*Campylobacter spp*	[293]	south of Iran
9	2021	Camels meat	40	5	12.5	*Campylobacter spp.*	[294]	Chaharmahal and Bakhtiari
10	2019	poultry meat	328	217	66.7	*Campylobacter spp.*	[295]	Jahrom
11	2019	Industrial chicken meat		1	0.6	*Campylobacter spp.*	[295]	Ahvaz
				0	0			
		Traditional chicken meat		8	16	*C. jejuni*		
				3	37.5	*Campylobacter spp*		
		Fresh packed chicken meat		0	0	*C. jejuni* *Campylobacter spp*		
		Beef meat		7	14	*Campylobacter spp.*		
				7	100			
		Mutton meat		12	24	*C. jejuni*		
				12	100			
		Water buffalo meat	50	4	8	*Campylobacter spp.*		
				4	100	*C. jejuni*		
12	2019	Packed chicken meat		26	28.9	*Campylobacter spp.*	[296]	Shiraz

Table 7 cont.

13	2016	Red meat	90	21	23	*Campylobacter spp.*	[297]	Zanjan
				13	61.9			
		Chicken-meat	120	33	27.5	*C. jejuni*		
				22	66.6	*Campylobacter spp.*		
		Eggshells	120	38	31.6	*C. jejuni*		
				20	52.6	*Campylobacter spp.*		
14	2015	Chicken wing	96	37	38.5	*Campylobacter spp.*	[298]	Urmia
15	2015	Meat	360	227	63.1	*Campylobacter spp.*	[299]	Mashhad
				200	88.1	*C. jejuni*		
16	2015	Raw ovine milk	38	0	0	*C. jejuni*	[300]	Zanjan
		Raw bovine milk	22	0	0	*C. jejuni*		
17	2014	Chicken	250	110	44	*Campylobacter spp.*	[300]	Tehran
				87	79			
18	2013	Pasteurized milk	30	0	0	*Campylobacter spp.*	[301]	Isfahan & Chaharmahal va Bakhtyari
		Camel milk	37	0	0			
		Commercial dairy	290	0	0			
		Raw cow milk	80	5	6.2	*Campylobacter spp.*		
		Raw sheep milk	60	1	1.6	*Campylobacter spp.*		
		Raw goat milk	60	2	3.3	*Campylobacter spp.*		
		Traditional cheese	60	3	5	*Campylobacter spp.*		
		Traditional ice-cream	35	1	2.8	*Campylobacter spp.*		
		Traditional butter	25	1	4	*Campylobacter spp.*		
19	2012	Packed chicken meat	96	22	22.9	*Campylobacter spp.*	[121]	Mazandaran
		Unpacked chicken meat	104	31	28.8	*Campylobacter spp.*		
20	2011	Eggs	100	0	0	*C. jejuni*	[124]	Shahrekord
21	2011	Raw bovine milk	120	3	2.5	*Campylobacter spp.*	[302]	Isfahan
22	2011	Chicken	200	94	47	*Campylobacter spp.*	[303]	Shahrekord
				91	96.8	*C. jejuni*		
		Turkey	49	49	49	*Campylobacter spp.*		
				41	83.7	*C. jejuni*		
		Quail	33	37	43	*Campylobacter spp.*		
				33	89.2	*C. jejuni*		
		Partridge	6	6	35.3	*Campylobacter spp.*		
				6	100	*C. jejuni*		
		Ostrich	21	1	4.8	*Campylobacter spp.*		
				1	100	*C. jejuni*		
23	2010	Chicken meat	60	37	61.7	*Campylobacter spp.*	[304]	Ahvaz
				35	94.6	*C. jejuni*		
		Turkey meat	50	18	83.3	*Campylobacter spp.*		
				15	36	*C. jejuni*		
		Sheep meat	50	3	6	*Campylobacter spp.*		
				1	33.3	*C. jejuni*		
		Goat meat	45	17	4.4	*Campylobacter spp.*		
				17	100	*C. jejuni*		

Table 7 cont.

24	2010	Raw camel meat	107	1	0.9	*Campylobacter spp.*	[305]	Isfahan & Yazd
				0	0	*C. jejuni*		
		Beef meat	190	5	2.4	*Campylobacter spp.*		
				3	60	*C. jejuni*		
		Lamb meat	225	27	12	*Campylobacter spp.*		
				23	92	*C. jejuni*		
		Goat meat	180	17	9.4	*Campylobacter spp.*		
				16	94.1	*C. jejuni*		
25	2008	Raw chicken meat	280	157	56.1	*Campylobacter spp.*	[306]	Isfahan
				140	89.2	*C. jejuni*		
		Quail meat	248	68	27.4	*Campylobacter spp.*		
				53	77.9	*C. jejuni*		
		Turkey meat	212	145	68.4	*Campylobacter spp.*		
				92	63.4	*C. jejuni*		
		Ostrich meat	60	7	11.7	*Campylobacter spp.*		
				3	42.9	*C. jejuni*		

the United States in 2020 reported that while various broiler products carry the risk of *Campylobacter spp.* contamination, the highest prevalence of contamination was observed in chicken carcasses [49]. Similarly, in the European Union, *C. jejuni* has been identified as the most prevalent species (51%) in broiler meat, followed by *C. coli* (35.5%) [47]. Consequently, poultry meat represents the greatest risk of *Campylobacter* transmission to humans worldwide. The consistent reporting of the highest prevalence of *Campylobacter* contamination in poultry meat in multiple studies, including those conducted in Iran, the United States, and the European Union, underscores the importance of addressing this issue [47, 49]. This finding highlights the necessity of implementing rigorous food safety measures and regulations in the poultry industry to prevent the transmission of *Campylobacter* to consumers.

8) *Helicobacter pylori* prevalence in food

Helicobacter pylori is associated with several digestive diseases, including peptic ulcer, mucosa-associated lymphoid tissue lymphoma, gastritis, and an increased risk of gastric cancer [50]. It is estimated that approximately 50% of the global population is infected with *H. pylori* [51]. The prevalence of *H. pylori*

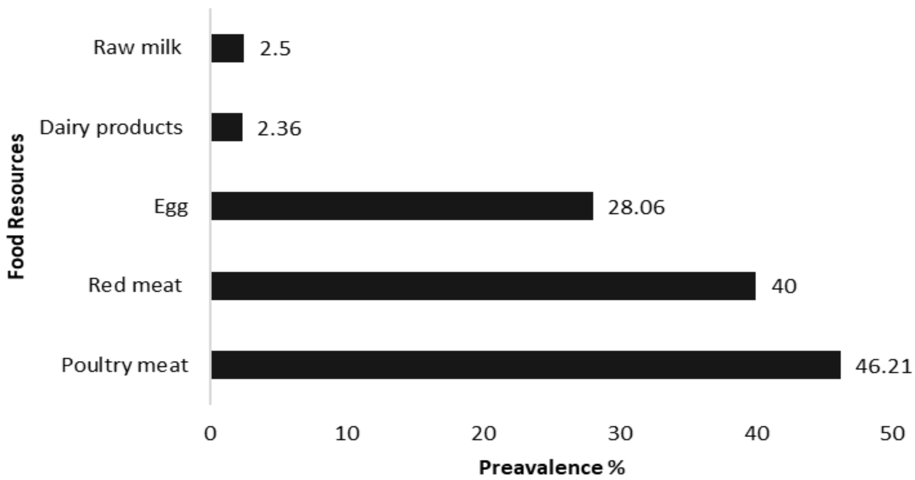

Figure 8.
Prevalence of *Campylobacter* in different foods in Iran.

infection is observed to be higher in developing countries, with rates ranging from 70% to 90%, compared to developed countries, where rates are reported to be 25%-50%. Iran is considered a high-risk region for *H. pylori* infection due to the high prevalence (60%-90%) among its population [52]. *H. pylori* can be found in a variety of animal-derived foods, vegetables, and water sources, which contribute to its transmission [50]. Table 8 presents the findings of studies conducted in Iran regarding the prevalence of *H. pylori*

Table 8.
Summary of the studies reporting the prevalence of *H. pylori* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	References	Area
1	2023	Raw Poultry Meat	320	20	6.25	[307]	Shahrekord
2	2020	Red meat	*600*	*52*	8.6	[308]	Tehran
3	2018	Traditional dairy products	800	31	3.8	[309]	Isfahan
4	2017	Red meat	220	11	5	[310]	Isfahan
5	2017	Meat	150	11	7.3	[311]	Alborz
		Milk	150	24	16		
		Vegetable	40	5	12.5		
6	2016	Cream-candy	50	9	18	[312]	Isfahan
		Traditional bread	50	3	6		
		Sausage	50	0	0		
		Salami	50	0	0		
		Hamburger	50	1	2		
		Soup	50	11	22		
		Restaurant salad	50	15	30		
		Falafel	50	3	6		
		Olivier salad	50	18	36		
		Chicken nugget	50	0	0		
		Fruit salad	50	14	28		
7	2016	Milk	420	92	21.9	[313]	Shahrekord
		Meat	400	105	26.2		
8	2016	Meat products	150	11	7.3	[314]	Isfahan
9	2016	Drinking water (total)	120	5	4.2	[315]	Isfahan
			110	2	1.8		Shiraz
			100	3	3		Yazd Shahrekord
10	2016	Ready to eat fish	70	2	2.8	[316]	Shiraz
		Ham	60	9	15		
		Chicken sandwich	60	5	8.3		
		Vegetable sandwich	40	2			
		Meat sandwich	40	18	5		
		Minced meat	50	10	45		
		Minced meat	50	16	20		
					32		
11	2015	Raw milk	210	28	13.3	[317]	Tehran
12	2015	Bovine milk	120	20	16.6	[318]	
		Traditional cheese	80	10	[318]		
		Traditional cream	40	3	7.5		
		Total	240	33	[319]		

Table 8 cont.

13	2014	Vegetable and salad	460	44	9.5	[319]	Shahrekord
14	2014	Vegetable and salad	430	59	13.7	[320]	Isfahan
15	2013	Water	200	14	7.2	[51]	Isfahan
16	2012	Milk	447	56	12.5	[321]	Isfahan, Fars, Chaharmahal & Bakhtiari, Khuzestan

in various food items. As illustrated in Figure 9, the highest prevalence of *H. pylori* in food samples in Iran was observed in RTE foods (25.5%) and vegetables (22.14%), followed by raw milk (16.06%), red meat (15.82%), dairy products (7.93%), meat products (6.26%), and water (3.8%) (Figure 9). In other countries, studies have also identified the presence of *H. pylori* in a variety of food sources. In Japan, the ureA gene of *H. pylori* was found in 72.2% of raw milk samples and 55% of pasteurized milk samples [53]. In Italy, the glmM gene of *H. pylori* was identified in 34.7% of raw milk samples [54]. In the United States, *H. pylori* was detected in 44% of RTE raw tuna meat and 36% of raw chickens using a multiplex PCR assay [55]. These findings underscore the potential presence of *H. pylori* in various food sources and the significance of food as a potential route of transmission.

9) *Clostridium* prevalence in food

Clostridium botulinum

Clostridium botulinum is a gram-positive, anaerobic bacterium that is capable of producing spores. It is known to cause botulism, a severe illness characterized by the production of a potent neurotoxin. Table 9 presents the findings of research conducted in Iran on the prevalence of *C. botulinum* in various food items. As illustrated in Figure 10, the most prevalent contamination of *C. botulinum* in Iran was observed in seafood (12.56%), followed by red meat (12.23%), dairy products (9.02%), and honey (2%) (Figure 10). Honey is recognized as a reservoir for *C. botulinum* spores, particularly types B and A, and has been implicated in cases of neonatal botulism [30]. Studies conducted in various countries, including Turkey, Brazil, Denmark, Sweden, and Norway, have demonstrated the presence of *C. botulinum* spores in honey samples, with prevalence rates ranging from 2% to 26% [30]. In Iran, the prevalence of *C. botulinum* contamination in honey samples was reported to be 2% (Figure 10), indicating a relatively lower level of contamination compared to some other regions.

While *C. botulinum* spores may be present in certain foods, the risk of botulism is contingent upon the conditions that facilitate the germination of spores and toxin production, such as inadequate food processing, storage, or handling. Proper food safety practices, including adequate cooking, storage at appropriate temperatures, and hygienic handling, can help prevent the growth and toxin production of *C. botulinum* in food.

Clostridium perfringens

C. perfringens is a significant contributor to foodborne gastrointestinal illnesses in both humans and animals. The spores of *C. perfringens* exhibit remarkable resilience to external influences. In Europe in 2020, there

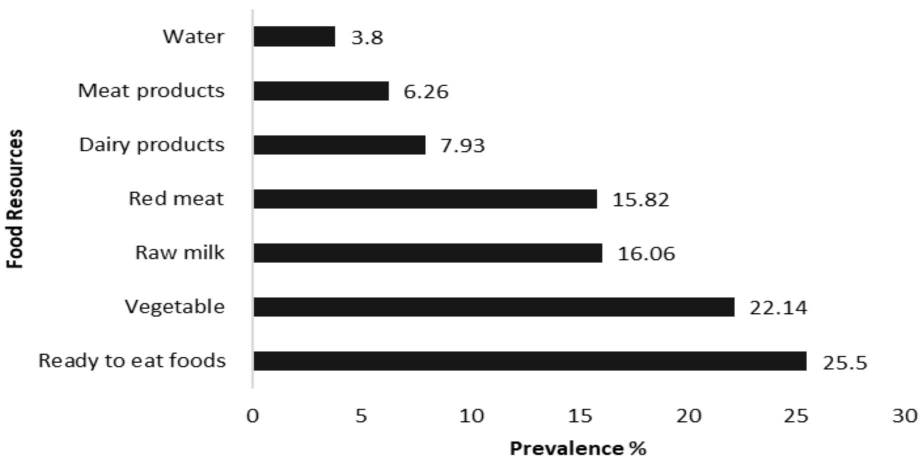

Figure 9.
Prevalence of *H. pylori* in different foods in Iran.

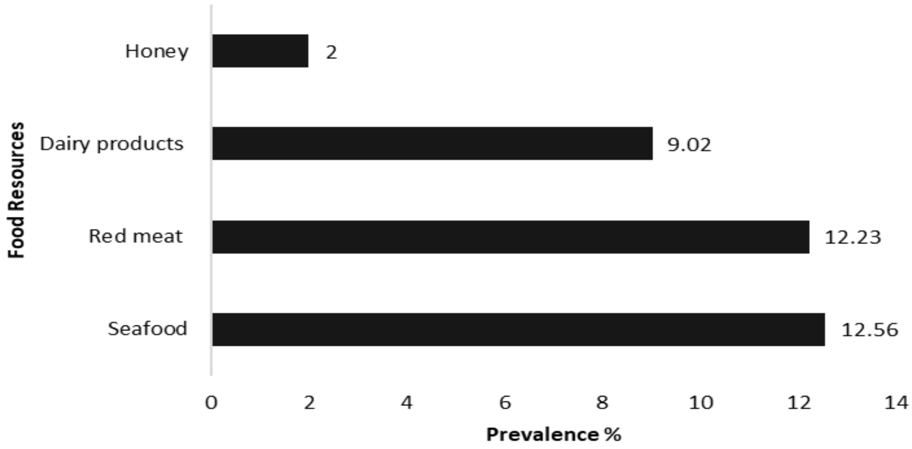

Figure 10.
Prevalence of *Clostridium* in different foods in Iran.

were 682 reported cases of food poisoning caused by *C. perfringens* toxins, with a hospitalization rate of 1.5%. Conversely, there were fewer cases (n = 34) of food poisoning due to *C. botulinum* toxins, yet the hospitalization rate for botulism cases was 100%. It is noteworthy that no fatalities were reported in these cases. Early diagnosis, hospitalization, and treatment are essential for reducing the severity of botulism [30]. Table 9 presents the findings of studies conducted in Iran regarding the prevalence of *C. perfringens* in various food items. *C. perfringens* type A is the most prevalent cause of food poisoning associated with this bacterium. The available data indicate that *C. perfringens* was most commonly isolated from red meat in Iran. It is of paramount importance to ensure that meat is cooked and handled properly to minimize the risk of contamination with *C. perfringens* and subsequent foodborne illnesses. In Europe in 2019, two outbreaks were associated with pig meat and products, one caused by toxins produced by *C. perfringens* and the other by *C. botulinum*. Conversely, vegetables, juices, and other related products were linked to a greater number of outbreaks, with two outbreaks reported for each category during the same period [30]. Nevertheless, only one study has been conducted in Iran regarding the presence of *C. perfringens* in vege-

Table 9.
Summary of the studies reporting the prevalence of *Clostridium spp*. in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	Clostridium spp.	References	Area
1	2023	Meat native birds	300	35	11.6	*C. perfringens*	[322]	Shahrekord
2	2023	Meat Nuggets	600	7	1.17	*C. perfringens*	[323]	Isfahan
3	2023	Ground Beef	133	24	18.04	*C. perfringens*	[324]	Qazvin
			94	3	3.22			
4	2022	Raw Meat	240	7	2.91	*C. perfringens*	[325]	Mazandaran
5	2022	Raw Beef Meats	133	18	13.53	*C. perfringens*	[326]	Qazvin
6	2022	raw and ready-to-eat green leafy vegetables	366	66	18	*C. perfringens*	[139]	Tehran
7	2022	Olivier Salad	26	0	0	*C. perfringens*	[327]	Mashhad
8	2021	Cattle and sheep carcasses	200	61	30.5	*C. perfringens*	[328]	Shiraz

Table 9 cont.

9	2021	Broiler chickens	122	95	77.8	*C. perfringens*	[329]	Kerman
10	2019	Broiler chickens	400	169	42.2	*C. perfringens*	[330]	Chaharmahal & Bakhtiari
11	2019	Honey	130	0	0	*C. perfringens*	[331]	
12	2017	Traditional curds	50	12	25	*C. perfringens*	[332]	Shahrekord
		Commercial curds	50	5	10			
		Beef meat	20	1	6			
		Lamb meat	23	3	13			
13	2015	Broiler meat	200	31	15.5	*C. perfringens*	[333]	Mashhad
14	2015	Minced meat	200	25	12.5	*C. perfringens*	[334]	Mashhad
15	2013	Honey	100	2	2	*C. perfringens*	[335]	Shiraz
16	2013	Fish	80	4	5	*C. perfringens*	[336]	Shiraz
		Honey	50	2	4			
		Kashk	80	2	2.5			
		Dough	80	1	1.2			
17	2013	Dairy products	57	12	21	*C. perfringens*	[337]	Gilan, Tehran, Golestan, Hamedan
		Fish	68	18	26.4			
		Meat	14	1	7.1			
18	2010	Cheese	57	2	3.5	*C. perfringens*	[338]	Gilan
		Kashk	11	0	0			
		Salted fish	63	4	6.3			

tables and juices, and other related products. Further research and surveillance are necessary to gain a more comprehensive understanding of the prevalence and sources of *C. perfringens* in various food items in Iran.

10) *Brucella* prevalence in food

Brucella spp. are the causative agents of brucellosis [56], an infectious disease of humans that presents with chronic and recurring febrile symptoms that can be life-threatening [57]. The primary etiological agent of the disease is *B. melitensis*, although other species, including *B. abortus, B. canis,* and *B. suis*, can also result in human brucellosis [58]. The infection can be transmitted to humans from various animals, including buffalo, cattle, yak, elk, camel, domestic pig, and rodents [58]. Globally, approximately 500,000 cases of human brucellosis are reported annually, with animals and animal-derived foods serving as the primary sources of infection [57]. A global systematic review conducted in 2020 revealed that the Southeast Asia region exhibited the highest prevalence of *Brucella spp.* at 25.55% [57]. The consumption of unpasteurized dairy products plays a significant role in the transmission of *Brucella spp*. to humans [57]. Table 10 presents the results of studies conducted in Iran on the prevalence of *Brucella spp*. in food. As illustrated in Figure 11, the primary sources of reported contamination with *Brucella spp.* are dairy products (34.28%) and raw milk (16.64%). Dairy products, particularly unpasteurized or inadequately pasteurized ones, can serve as reservoirs for *Brucella* contamination [57]. This can occur due to infected dairy animals shedding the bacteria in their milk. Raw milk, in particular, has been identified as a common source of *Brucella* infection in various parts of the world, including Iran. Improper handling and processing of raw milk can contribute to the transmission of *Brucella spp.* to humans [59].

In Iran, where dairy products hold cultural and dietary significance, ensuring the safety of these products from *Brucella* contamination is crucial for public health [60]. Implementing stringent control measures in dairy production, processing, and distribution can help mitigate the risk of *Brucella* transmission through dairy products and raw milk [57, 59, 60].

11) *Vibrio* prevalence in food

Vibrio spp. are halophilic marine bacteria. Some species, including *V. cholerae, V. parahaemolyticus,* and *V. vulnificus*, have the potential to cause gastroenteritis or septicemia in humans. The primary mode of transmission for this foodborne illness is the ingestion of raw, undercooked, or mishandled seafood contaminated by bacteria [61]. Table 11 presents the re-

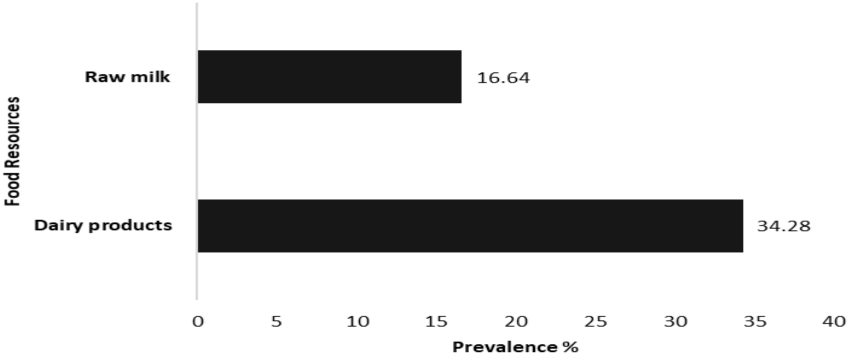

Figure 11.
Prevalence of *Brucella* in different foods in Iran.

Table 10.
Summary of the studies reporting the prevalence of *Brucella spp.* in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	*Brucella spp.*	References	Area
1	2022	Unpasteurized Milk and Dairy	291	12	4.1	*Brucella spp.*	[339]	Hamadan
2	2021	Bovine Milk	240	16	6.66	*Brucella spp.*	[340]	Kurdistan
3	2020	Dairy products	227	9	4	*Brucella spp.*	[341]	Hamadan
		Non boiling milk	43	1	2.3			
		Fresh cheese Cream	21	2	[341]			
4	2019	Raw camel milk	96	3	3	*Brucella spp.*	[342]	Isfahan, Semnan
			51	2	[342]			
			45	1				
5	2018	Dairy Products	208	60	28.8	*Brucella spp.*	[58]	Tehran
		Goat raw milk	33	15	45.5			
		Non-pasteurized cheese	23	9	39.1			
		Sheep raw milk	33	9	27.3			
		Cow raw milk	57	15	26.3			
		Pasteurized cheese	28	7	25			
		Pasteurized milk	34	5	14.7			
6	2017	Dairy Products	14	11	78.6	*Brucella spp.*	[343]	Tehran
				8	72.7	*B. melitensis*		
				3	27.3	*B. abortus*		
7	2017	Sheep raw milk Goat raw milk	530	41	8.1	*Brucella spp.*	[344]	Kerman
8	2017	Raw milk	700	9	1.28	*Brucella spp.*	[345]	Kerman
		Sheep's raw milk	300	3	1			
		Goats raw milk	400	6	1.5			
9		Unpasteurized milk	132	4	3	*Brucella spp.*	[346]	Isfahan
		Dairy products	65	1	1.5			
10	2016	Cow's raw milk	48	4	8.3	*Brucella spp.*	[347]	Kerman

Table 10 cont.

11	2016	Milk	225	20	8.9	*Brucella spp.*	[348]	Shahrekord & Isfahan
		Sheep milk	125	12	9.6			
		Goat milk	100	18	18			
12	2016	Raw goat milk	470	51	10.8	*Brucella spp.*	[344]	Southeast region of Iran
		Raw sheep milk	330	18	5.4			
13	2015	Raw milk	60	32	53.3	*Brucella spp.*	[200]	Zanjan
14	2014	Raw cow milk	57	19	33	*Brucella spp.*	[349]	Tehran
		Pasteurized cow milk	34	10	29			
		Pasteurized cheese	28	8	28			
		Traditional cheese	23	14	60			
		Raw goat milk	33	21	63			
		Raw sheep milk	33	19	57			
15	2013	Cattle milk	1117	18	1.6	*Brucella spp.*	[350]	Urmia
		Sheep milk	598	99	16.5			

sults of studies conducted in Iran on the prevalence of Vibrio spp. in different types of food. *Vibrio spp*. were predominantly detected in seafood, including lobster, fish products, crayfish, fish, and shrimp, as well as drinking water. As illustrated in Figure 12, the prevalence of Vibrio spp. was highest in seafood, with fish exhibiting the greatest incidence (49.33%), followed by lobster (21.53%), crayfish (8.63%), shrimp (8.12%), fish products (7.8%), and drinking water (1.3%) (Figure 12). The findings from Iran are in alignment with those from other countries. For instance, a comprehensive systematic review conducted in 2016 revealed that V. parahaemolyticus contamination was observed in 63.4% of oysters, 52.9% of clams, 51% of fish, and 48.3% of shrimps [62]. A similar study in China in 2020 reported that 15.34% of shrimp samples, 14.17% of fish samples, and 3.67% of RTE food were contaminated with *V. parahaemolyticus* [63]. However, there are no reports available from Iran regarding the prevalence of *V. parahaemolyticus* in RTE foods.

12) *Shigella* prevalence in food

The *Shigella* genus encompasses four known species: *S. dysenteriae, S. boydii, S. flexneri,* and *S. sonnei,* which have also been classified as subgroups A to D, respectively [64]. While *S. flexneri* has traditionally been reported as the main cause of shigellosis in developing countries, recent studies have shown that *S. sonnei* has become the predominant species of Shigella in Iran [64]. According to the WHO, *Shigella*

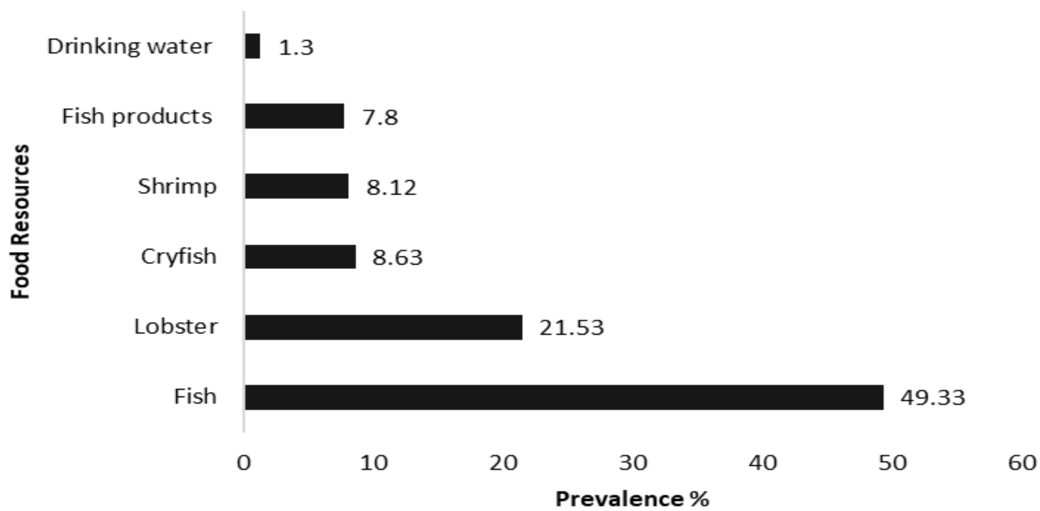

Figure 12.
Prevalence of *Vibrio* in different foods in Iran.

Table 11.
Summary of the studies reporting the prevalence of *Vibrio spp*. in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	Type of *Vibrio spp.*	References	Area
1	2021	Fish	64	61	95	*Vibrio species*	[351]	Isfahan
2	2020	Frozen fish	*200*	*0*	*0*	*V. parahaemolyticus*	[352]	Mazandaran
3		Shrimp	70	12	17.1	*V. parahaemolyticus*	[353]	Zanjan
4	2018	Cold Smoked Salted Fishes	200	46	23	*Vibrio spp.*	[354]	Mazandaran
5	2016	Fish	58	18	31	*V. parahaemolyticus*	[355]	Persian Gulf
		Shrimps	55	7	12.7			
6	2015	Fresh shrimps	30	2	6.6	*V. parahaemolyticus*	[356]	Genaveh seaport
		Salted shrimps	30	2	6.6			
7	2014	Shrimps	36	7	19.4	*Vibrio spp.*	[357]	South coast of Iran
8	2014	Fish	100	22	22	*V. parahaemolyticus*	[358]	Bushehr, Persian Gulf
		Lobster	60	13	21.6			
		Crab caught	40	7	17.5			
9	2014	Crayfish	97	11	11.3	*V. vulnificus*	[357]	Aras
				7	7.2	*V. harveyi*		
				2	2	*V. alginolyticus*		
				1	1	*V. mimicus*		
10	2013	Tap-water	144	3	2	*V. cholerae*	[360]	Isfahan
		Bottled mineral water	304	3	0.6			
11	2012	Fresh shrimp	70	5	7.1	*V. parahaemolyticus*	[122]	
		Salted fishes	70	2	2.9			
		Fish nugget	10	0	0			
		Shrimp burger	10	0	0			
12	2012	Lobsters	100	40	40	*Vibrio spp.*	[361]	Persian Gulf
			100	3	3	*V. parahaemolyticus*		
		Crab	32	4	12.5	*Vibrio spp.*		
			32	1	3.1	*V. parahaemolyticus*		
13	2010	Fresh shrimp	300	29	9.6	*V. parahaemolyticus*	[361]	Bohsher. Hormozgan,Khoozcstan
14	2004	Fresh shrimp	770	16	2.1	*Vibrio spp.*	[361]	Bohsher. Hormozgan, Khoozestan

spp. cause approximately 165 million cases of *bacillary* dysentery and 1 million deaths worldwide each year [64]. In general, *Shigella spp*. are among the most prevalent causes of acute diarrhea in Iran, with a particularly high incidence among children and young adults. A diverse array of foods, encompassing meat, dairy products, and vegetables, have been identified as potential sources of shigellosis outbreaks worldwide [64]. Table 12 presents the results of studies conducted in Iran on the prevalence of *Shigella spp.* in different types of food. As illustrated in Figure 13, contamination with *Shigella spp*. is most commonly reported in RTE foods (1.72%) and vegetables (1.05%), followed by red meat (0.4%). In contrast to the data from Iran, a high prevalence of *Shigella spp*. contamination has been reported in vegetables (25.25%) in India [65], and in beef, chicken, and dairy products in Egypt [66]. According to our review, poultry meat should be considered a high-risk food with the potential to spread foodborne zoonoses in Iran. In general, poultry meat is more susceptible to contamination during processing and handling due to its higher water con-

Table 12.
Summary of the studies reporting the prevalence of *Shigella spp*. in Iran.

	Year	Sample type	Sample size	Positive samples (N)	Prevalence (%)	Type of *Shigella spp.*	References	Area
1	2022	raw milk, ground meat, and raw vegetable	580	13	2.24	*Shigella sonnei*	[364]	Tehran and Qazvin
2	2021	Vegetable salad, ground meat, and raw cow's milk	*405*	*18*	*4.44*	*Shigella spp.*	[365]	Qazvin
3	2021	meat, vegetable salad and raw milk	165	8	4.84	*Shigella spp.*	[366]	Qazvin
4	2019	Ready to eat food	250	2	0.8	*S. sonnei*	[64]	Isfahan, Fars, Hormozgan, Kohkiloyeh va Boyer Ahmad
				0	0	*S. flexneri*		
				0	0	*S. dysenteriae*		
				0	0	*S. boydii*		
		Fresh meat	150	1	0.7	*S. sonnei*		
				2	1.3	*S. flexneri*		
				0	0	*S. dysenteriae*		
				0	0	*S. boydii*		
		Frozen meat	150	0	0	*Shigella spp.*		
		Cow milk	100	0	0	*Shigella spp.*		
		Domestic cheese	100	0	0	*Shigella spp.*		
		Vegetables	650	8	1.2	*S. sonnei*		
				6	0.9	*S. flexneri*		
				0	0	*S. dysenteriae*		
				0	0	*S. boydii*		
		1400		19	1.4	*Shigella spp.*		
5	2018	Ready-to-Eat Salad	90	7	7.8	*Shigella spp.*	[367]	Tehran
6	2018	Food (vegetables, chicken, minced meat, fish)	100	6	6	*Shigella spp.*	[368]	Shiraz
7	2014	Camel milk	18	0	0	*Shigella spp.*	[369]	Golestan

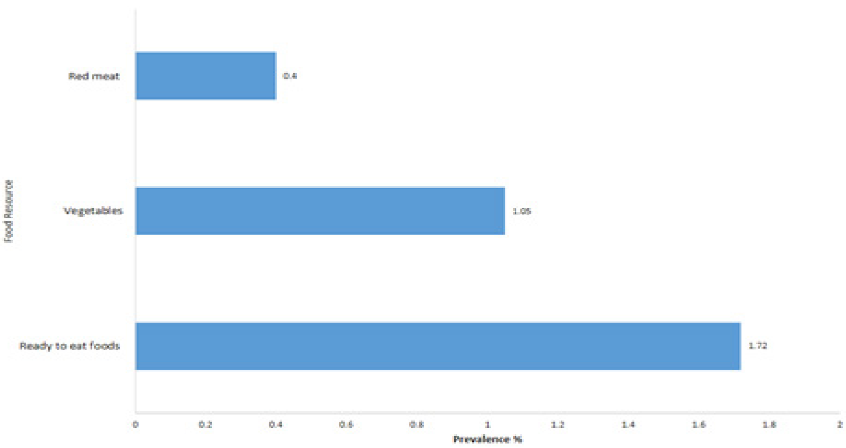

Figure 13.
Prevalence of Shigella in different foods in Iran.

tent and pH levels, which provide an optimal environment for the proliferation of bacteria [67]. Moreover, poultry meat is frequently sold and consumed in its raw state, thereby increasing the probability of contamination if the requisite hygiene standards are not observed during slaughter, processing, and storage. In contrast, red meat and seafood have lower contamination rates compared to poultry meat, likely due to differences in processing and handling practices [68]. These findings underscore the necessity of developing strategies to reduce the contamination levels of poultry meat to effectively control and prevent foodborne illnesses in Iran.

The risk of food contamination, particularly in meat products, is significant. However, to effectively underscore the importance of foodborne diseases, it is imperative to document the consequences of infection with these pathogens and generalize this information to the population in Iran. Currently, foodborne diseases in Iran are not generally reported, leading to a likely gross underestimation of their burden. This underestimation is attributable to the fact that many foodborne illnesses do not exhibit sufficient severity, duration, or specific diagnostic criteria for accurate identification and intervention. Similar circumstances exist in developed countries, such as the United States. For instance, the CDC estimates that foodborne pathogens cause approximately 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths annually in the US [70].

Therefore, it is crucial to emphasize the necessity of establishing robust monitoring systems in Iran. Such a surveillance network would require the collaboration of multidisciplinary teams comprising medical doctors, veterinarians, microbiologists, public health specialists, and other relevant experts, in alignment with the One Health concept. By adopting a methodology similar to that employed by the CDC's Foodborne Diseases Active Surveillance Network (FoodNet), which monitors the incidence of nine foodborne pathogens in ten US cities, representing approximately 15% of the American population [71], Iran can enhance the awareness of foodborne disease events and trends. These practices enable the implementation of effective intervention and prevention strategies.

Authors' Contributions

MH suggested the topic and supervised the conduction of the systematic review. SA wrote the first draft of the manuscript. FA and SA performed the literature review. GS was the major contributor in writing the manuscript. AA gave advice for conducting and writing the manuscript. All authors read and approved the final manuscript.

Competing Interests

The authors declare that there is no conflict of interest.

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