

1 Mini Review

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3 **Etiological Agents Implicated in Foodborne Illness World Wide**

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18 **Running title:** Etiological Agents of Foodborne Illnesses

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## Abstract

This mini review focuses on foodborne illnesses and outbreaks caused by food-producing animals because statistical information of the foodborne illnesses is important in human health and food industry. Contaminated food results in 600 million cases of foodborne diseases and 420,000 deaths worldwide every year. The world population is currently 7.8 billion, and 56 million people die every year; of these, every year, 7.69% of people experience foodborne diseases, and 7.5% of annual deaths (56 million deaths) was died by foodborne illness in the world. A majority of such patients are affected by norovirus and *Campylobacter*. *Listeria monocytogenes* is the most fatal. In the United States, except for those caused by *Campylobacter*, the number of foodborne diseases did not decrease between 1997 and 2017, and cases caused by *Toxoplasma gondii* are still being reported (9 cases in 2017). The percentage of foodborne illnesses caused by food-producing animals was 10.4%–14.1% between 1999 and 2017 in the United States. In Europe, foodborne illnesses affect 23 million people every year and cause approximately 5,000 deaths. Europe has more *Campylobacter*- and *Salmonella*-related cases than in other countries. In Australia, the highest number of cases are due to *Campylobacter*, followed by *Salmonella*. In South Korea, *E. coli* followed by norovirus. *Campylobacter*- and *C. perfringens*-related cases have been reported in Japan as well. This review suggests that *Campylobacter*, *Salmonella*, *L. monocytogenes*, and *E. coli*, which are usually isolated from animal-source food products are associated with a high risk of foodborne illnesses.

**Keywords:** *Campylobacter*; foodborne illness, norovirus, *L. monocytogenes*, *Salmonella*

## 45 **Introduction**

46 Every individual requires nutrients for survival; however, consuming certain types of food  
47 could cause diseases and even death in individuals with symptoms of diarrhea, headache,  
48 vomiting, nausea, abdominal cramps, etc. Recently, foodborne outbreaks have become more  
49 serious owing to globalization and active food trade among countries. One such example is  
50 the 2011 *Escherichia coli* O104:H4 outbreak in Germany, which was spread to other  
51 countries like France, Denmark, Sweden, Switzerland, the Netherlands, the United Kingdom,  
52 Canada, the Czech Republic, Greece, Luxembourg, Norway, Austria, Poland, Spain, and the  
53 United States, causing 2,987 non-hemolytic uremic syndrome (HUS) cases, 855 HUS cases,  
54 and 53 deaths (RKI, 2011). Thus, every country has certain food safety and foodborne disease  
55 control regulations, although the level of control varies according to the economic conditions.  
56 However, despite these regulations, the number of foodborne illnesses is continuously  
57 increasing. Products manufactured from food-producing animals are considered the major  
58 cause of bacterial foodborne illnesses (Heredia and García, 2018); the pathogens involved are  
59 enterohemorrhagic *E. coli*, *Salmonella*, *Listeria monocytogenes*, *Campylobacter*,  
60 *Staphylococcus aureus*, etc. This mini review discusses on foodborne illnesses and outbreaks  
61 in different regions worldwide caused by consumption of products manufactured from food-  
62 producing animals.

## 64 **The World Health Organization**

65 Food unsafe for consumption causes 600 million cases of foodborne diseases and 420,000  
66 deaths every year, and 56 million people die each year (Ritchie and Roser, 2018; WHO,  
67 2015). This data indicates that 7.69% (600 million) individuals of world populations (7.8  
68 billion) suffer from foodborne diseases every year and 7.5% (420,000 death) of all deaths (56

69 million) annually are due to foodborne illnesses. This is almost equivalent to 31.1% of annual  
70 deaths caused by road traffic accidents (1.35 million) worldwide (WHO, 2020).

71 Globally, foodborne illnesses caused by bacteria (226,526,634) were more common than  
72 those caused by viruses (138,513,782) and parasites (10,284,561) (Table 1). However,  
73 norovirus caused the highest annual cases (124,803,946) and 34,929 deaths, indicating that it  
74 has a fatality rate of 0.028 (Table 1). Even though norovirus infects people by consumption of  
75 vegetables, fruits, and raw oysters, there were also norovirus outbreaks related to processed  
76 meat (Boxman et al., 2007; Malek et al., 2009). Hence, norovirus should be considered a risk  
77 microorganism in meat products. Hepatitis A virus causes 13,709,836 cases and 27,731  
78 deaths with 0.202 of fatality rate (Table 1). This result suggests that viruses are also high-risk  
79 microorganisms, infecting humans by the consumption of meat products. Among bacteria,  
80 *Campylobacter* caused the highest annual cases (95,613,970), although with a low fatality  
81 rate (0.022), followed by *Salmonella* (78,707,591) (Table 1). In general, fatality rates due to  
82 bacteria were low, except for that due to *L. monocytogenes*. Although the number of *L.*  
83 *monocytogenes*-related cases was lower than that caused by other bacteria, the fatality rate  
84 (22.41%) was much higher than that caused by other bacteria (Table 1). *Campylobacter* and  
85 *L. monocytogenes* are usually found in meat and processed animal source food products (Kim  
86 et al., 2017).

87 Regarding parasite-related foodborne illnesses, *Toxoplasma gondii*-related cases are still  
88 high, much higher than those caused by *Trichinella*. *T. gondii* causes 10,280,089 cases and  
89 684 deaths annually and infects animals (Ferreira et al., 2018); thus, humans can be infected  
90 through the consumption of uncooked meat or raw meat.

91

92 **The United States**

93 In the United States, albeit with a low fatality rate, norovirus causes the highest number of  
94 cases; 4 deaths were observed in 2017 (Table 2). *Salmonella* is the second leading cause,  
95 resulting in 3–8 deaths every year (Table 2). Although *L. monocytogenes* causes fewer cases,  
96 the associated fatality rate is higher (3–35 deaths annually; 9.4%–20.8%) than that due to  
97 other bacteria (Table 2). The number of foodborne illness cases remained unaltered between  
98 1997 and 2017, except for those caused by *Campylobacter* (Table 2). The number of  
99 *Campylobacter*-related foodborne outbreaks, particularly due to poultry products, decreased  
100 from 483 cases in 1998 to 147 cases in 2017 (Table 2). Regarding hepatitis A virus-related  
101 cases, the numbers are low compared to other microorganisms, and the virus generally  
102 causes 1 death annually (Table 2). Regarding the parasite *T. gondii*, there were no cases in  
103 1998, 2002, and 2011, but in 2017, there were 9 cases (Table 2), probably due to the  
104 consumption of not fully cooked meat; this parasite mainly infects via pork consumption and  
105 is rarely found in pigs from developed countries anymore. However, the 2017 outbreak has  
106 indicated that the risk of *T. gondii* infection through pork consumption may exist.

107

### 108 **The European Union (EU)**

109 In Europe, 23 million people are infected with foodborne illnesses and 5,000 people die due  
110 to it every year (WHO, 2015). Norovirus causes the highest number of cases annually  
111 (approximately 15 million), followed by *Campylobacter* (approximately 5 million) (WHO,  
112 2015). Interestingly, in the EU, the number of *Campylobacter*-related foodborne illnesses is  
113 the highest. *Campylobacter* is the most commonly reported gastrointestinal disease-causing  
114 bacterium in the EU, followed by *Salmonella* (Table 3). In 2007, the incidence of  
115 *Campylobacter*-related foodborne illnesses was 45.2 cases per 100,000 people, and broiler  
116 and fresh poultry meat were identified as the largest sources of infections (ECDC, 2020). The

117 total annual cases of the associated illnesses and deaths increased gradually from 2012 to  
118 2016 (Table 3). In the case of the *Salmonella* outbreak, 31.1 cases per 100,000 people were  
119 reported (ECDC, 2020). The temperature was the most influential factor (ECDC, 2020). In  
120 2012, 2014, and 2016, the number of *Salmonella*-related cases was 91,034, 88,715, and  
121 94,530, respectively, with a 0.14–0.25 fatality rate, similar to that of Shiga toxin-producing *E.*  
122 *coli* (Table 3). In the EU, higher fatality rates (15%–17.8%) due to *L. monocytogenes* have  
123 been reported, and the number cases due to Shiga toxin-producing *E. coli* were between  
124 5,671 and 6,378, with 7-12 deaths (Table 3). The most commonly reported Shiga toxin-  
125 producing *E. coli* serogroup in the EU is O157, although its proportion appears to be  
126 decreasing relative to other serogroups (ECDC, 2015). Regarding parasite-related foodborne  
127 illnesses, *Trichinella* caused 2 deaths in 2014 (Table 3)

128

### 129 **South Korea**

130 Unlike that in the countries reviewed above, in Korea, the pathogen causing the highest  
131 number of cases is pathogenic *E. coli* (1,784–2,754 cases from 2010 to 2018) (Table 4). The  
132 second highest number of cases are due to norovirus (Table 4). Besides, the number of *S.*  
133 *aureus*-related cases decreased from 2010 to 2018 (Table 4). Previously, *S. aureus* ranked the  
134 first or the second in Korea; thus, the Ministry of Food and Drug Safety made serious efforts  
135 to control *S. aureus*. This may have gradually decreased the numbers.

136 Regarding *L. monocytogenes*, which is a serious problem in other countries, in Korea, no  
137 foodborne outbreak had been reported until 2018 (Table 4). However, recalls of processed  
138 meat products due to *L. monocytogenes* contamination are continuously occurring. Thus, the  
139 risk of *L. monocytogenes*-related foodborne illness may increase, which may result in  
140 foodborne outbreaks of *L. monocytogenes*.

141

## 142 **Australia**

143 In Australia, *Campylobacter* caused the highest number of cases, with the number ranging  
144 from 15,640 to 15,973 from 2004 to 2012 (Table 5). This was followed by *Salmonella*. The  
145 number of *L. monocytogenes*-related cases increased from 66 to 93 from 2004 to 2012 (Table  
146 5). The trend in terms of etiological agents in Australia is very similar to that observed in the  
147 EU and the United States. In Korea (Table 4) and Japan (Table 6), *Campylobacter* was not an  
148 agent, causing the highest number of cases. This is the different one between Korea and  
149 Japan, and Australia, the EU, and the United States.

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## 151 **Japan**

152 In general, the number of cases, especially those caused by pathogenic *E. coli*, *Salmonella*,  
153 and *S. aureus*, decreased between 2000 and 2018 (Table 6). This might be due to the ban on  
154 raw beef liver served at a restaurant in 2012. In Japan, norovirus causes the highest number of  
155 cases, and the number of cases caused by *Campylobacter* is also high, ranging from 551 to  
156 2,643 between 2000 and 2018 (Table 6). Unlike that in other countries, in Japan, *Clostridium*  
157 *perfringens* causes a relatively high number of cases, higher than that caused by  
158 *Campylobacter* in 2018, among others.

159

## 160 **Conclusion**

161 In summary, norovirus causes the highest number of foodborne illness cases worldwide,  
162 followed by *Campylobacter*, *Salmonella*, *L. monocytogenes*. The trend observed was mostly  
163 similar for the EU, the United States, and Australia. However, in Korea, pathogenic *E. coli*  
164 caused the highest number of cases, and *L. monocytogenes* was not reported to be as fatal. In

165 Japan, the number of *Campylobacter*-, norovirus-, and *C. perfringens*-related cases was high.  
166 These data suggest that apart from norovirus, *Campylobacter*, *Salmonella*, pathogenic *E. coli*,  
167 and *L. monocytogenes*, which are generally isolated from food-producing animals, are  
168 associated with foodborne illnesses and outbreaks in the world.

#### 169 **Conflict of Interest**

170 The authors declare no potential conflict of interest.

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#### 172 **AUTHOR CONTRIBUTIONS**

173 Conceptualization, data curation and writing - original draft: Lee H.

174 Conceptualization, writing - review & editing: Yoon Y.

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242 28, 2020.

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245 **Tables**

246 **Table 1.** Median global number of major foodborne illnesses and deaths in 2010 (WHO,  
 247 2015)

Hazard		Foodborne illnesses	Foodborne deaths	Fatality rates (%)
Bacteria	<i>Campylobacter</i>	95,613,970	21,374	0.022
	Shiga toxin-producing <i>E. coli</i>	1,176,854	128	0.011
	Non-typhoidal <i>Salmonella</i>	78,707,591	59,153	0.075
	<i>Shigella</i>	51,014,050	15,156	0.030
	<i>L. monocytogenes</i>	14,169	3,175	22.41
	Subtotal	226,526,634	98,986	0.044
Viruses	<i>Norovirus</i>	124,803,946	34,929	0.028
	Hepatitis A virus	13,709,836	27,731	0.202
	Subtotal	138,513,782	62,660	0.045
Parasites	<i>Toxoplasma gondii</i>	10,280,089	684	0.007
	<i>Trichinella</i>	4,472	4	0.090
	Subtotal	10,284,561	688	0.007

248 This table is modified from a study conducted by the WHO (2015).

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258 **Table 2.** Number of reported foodborne illnesses and deaths in the United States (CDC, 2014, 2019; Lynch et al. 2006)

Hazards		1998		2002		2011		2017	
		Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths
Bacteria	<i>B. cereus</i>	213	0	42	0	100	0	341	0
	<i>Campylobacter</i>	483	0	350	0	291	0	147	0
	<i>C. botulinum</i>	8	0	14	0	11	0	17	2
	<i>C. perfringens</i>	1,328	0	2,207	0	667	0	843	0
	Pathogenic <i>E. coli</i>	1,613	0	486	2	411	2	562	1
	<i>L. monocytogenes</i>	105	21	54	8	168	35	32	3
	Non-typhoidal <i>Salmonella</i>	2,731	6	4,636	3	3,047	5	3,061	8
	<i>Shigella</i>	1,266	0	318	0	40	0	54	0
	<i>S. aureus</i>	615	0	495	0	113	0	128	0
	<i>Y. enterocolitica</i>	9	0	13	0	16	1	0	0
Parasites	<i>Trichinella</i>	0	0	5	0	2	0	5	0
	<i>T. gondii</i>	NA	NA	NA	NA	NA	NA	9	0
Virus	Hepatitis A	293	1	50	1	7	0	35	1
	Norovirus	2,563	0	6,559	0	5,135	0	6,340	4

259 NA: not applicable

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262 **Table 3.** Number of foodborne illnesses in the European Union (EFSA-ECDC 2014, 2015, 2017)

Hazards	Years									
	2012			2014			2016			
	Foodborne illnesses	Foodborne deaths	Fatality rates	Foodborne illnesses	Foodborne deaths	Fatality rates	Foodborne illnesses	Foodborne deaths	Fatality rates	
Bacteria	<i>Campylobacter</i>	214,268	31	0.03	236,851	25	0.01	246,307	62	0.03
	Non-typhoidal <i>Salmonella</i>	91,034	61	0.14	88,715	65	0.15	94,530	128	0.25
	<i>L. monocytogenes</i>	1,642	198	17.8	2,161	210	15	2,536	247	16.2
	Shiga toxin-producing <i>E. coli</i>	5,671	12	0.36	5,955	7	0.20	6,378	10	0.27
	<i>Y. enterocolitica</i>	NA	NA	NA	6,625	5	0.13	6,861	5	0.11
Parasite	<i>Trichinella</i>	301	0	0	319	2	0.84	101	0	0

263 NA: not applicable

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267 **Table 4.** Number of foodborne illnesses in Korea (MFDS, 2020)

Hazards	Years					
	2010	2012	2014	2016	2018	
Bacteria	Pathogenic <i>E. coli</i>	1,926	1,844	1,784	2,754	2,715
	Non-typhoidal <i>Salmonella</i>	677	147	1,416	354	3,516
	<i>Campylobacter</i>	380	639	490	831	453
	<i>S. aureus</i>	372	35	195	4	52
	<i>C. perfringens</i>	171	297	1689	449	679
Virus	<i>Norovirus</i>	1,994	1,665	739	1,187	1,319

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Hazards		Years		
		2004	2009	2012
<b>Bacteria</b>	<i>Campylobacter</i> spp.	15,640	15,973	15,668
	<i>L. monocytogenes</i>	66	88	93
	Shiga toxin-producing <i>E. coli</i>	46	130	112
	Non-typhoidal <i>Salmonella</i>	7,842	9,533	11,249
	<i>Shigella</i>	520	622	546
	<i>Yersinia enterocolitica</i>	108	NA	NA
Virus	Hepatitis A	NA	563	166

269 **Table 5.** Median number of foodborne illnesses in Australia (OzFoodNet, 2005, 2009, 2018)

270 NA: not applicable

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275 **Table 6.** Number of foodborne illnesses in Japan (PSOSJ, 2020)

Hazards	Years					
	2000	2005	2010	2015	2018	
	Pathogenic <i>E. coli</i>	3,164	1,839	1,406	518	860
	Non-typhoidal <i>Salmonella</i>	6,940	3,700	2,476	1,918	640
Bacteria	<i>Campylobacter</i>	1,784	3,439	2,092	2,089	1,995
	<i>S. aureus</i>	14,722	1,948	836	619	405
	<i>C. perfringens</i>	1,852	2,643	1,151	551	2,319
	Virus	<i>Norovirus</i>	NA	8,727	13,904	14,876

276 NA: not applicable

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