



REVIEW

Etiological Agents Implicated in Foodborne Illness World Wide

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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 Korea, *Escherichia coli* followed by norovirus. *Campylobacter*- and *Clostridium 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, *Listeria monocytogenes*, *Salmonella*

Introduction

Every individual requires nutrients for survival; however, consuming certain types of food could cause diseases and even death in individuals with symptoms of diarrhea, headache, vomiting, nausea, abdominal cramps, etc. Recently, foodborne outbreaks have become more serious owing to globalization and active food trade among countries. One such example is the 2011 *Escherichia coli* O104:H4 outbreak in Germany, which was spread to other countries like France, Denmark, Sweden,

Switzerland, the Netherlands, the United Kingdom, Canada, the Czech Republic, Greece, Luxembourg, Norway, Austria, Poland, Spain, and the United States, causing 2,987 non-hemolytic uremic syndrome (HUS) cases, 855 HUS cases, and 53 deaths (RKI, 2011). Thus, every country has certain food safety and foodborne disease control regulations, although the level of control varies according to the economic conditions.

However, despite these regulations, the number of foodborne illnesses is continuously increasing. Products manufactured from food-producing animals are considered the major cause of bacterial foodborne illnesses (Heredia and García, 2018); the pathogens involved are enterohemorrhagic *E. coli*, *Salmonella*, *Listeria monocytogenes*, *Campylobacter*, *Staphylococcus aureus*, etc. This mini review discusses on foodborne illnesses and outbreaks in different regions worldwide caused by consumption of products manufactured from food-producing animals.

The World Health Organization

Food unsafe for consumption causes 600 million cases of foodborne diseases and 420,000 deaths every year, and 56 million people die each year (Ritchie and Roser, 2018; WHO, 2015). This data indicates that 7.69% (600 million) individuals of world populations (7.8 billion) suffer from foodborne diseases every year and 7.5% (420,000 death) of all deaths (56 million) annually are due to foodborne illnesses. This is almost equivalent to 31.1% of annual deaths caused by road traffic accidents (1.35 million) worldwide (WHO, 2020).

Globally, foodborne illnesses caused by bacteria (226,526,634) were more common than those caused by viruses (138,513,782) and parasites (10,284,561) (WHO, 2015). However, norovirus caused the highest annual cases (124,803,946) and 34,929 deaths, indicating that it has a fatality rate of 0.028 (WHO, 2015). Even though norovirus infects people by consumption of vegetables, fruits, and raw oysters, there were also norovirus outbreaks related to processed meat (Boxman et al., 2007; Malek et al., 2009). Hence, norovirus should be considered a risk microorganism in meat products. Hepatitis A virus causes 13,709,836 cases and 27,731 deaths with 0.202 of fatality rate (WHO, 2015). This result suggests that viruses are also high-risk microorganisms, infecting humans by the consumption of meat products. Among bacteria, *Campylobacter* caused the highest annual cases (95,613,970), although with a low fatality rate (0.022), followed by *Salmonella* (78,707,591) (WHO, 2015). In general, fatality rates due to bacteria were low, except for that due to *L. monocytogenes*. Although the number of *L. monocytogenes*-related cases was lower than that caused by other bacteria, the fatality rate (22.41%) was much higher than that caused by other bacteria (WHO, 2015). *Campylobacter* and *L. monocytogenes* are usually found in meat and processed animal source food products (Kim et al., 2017).

Regarding parasite-related foodborne illnesses, *Toxoplasma gondii*-related cases are still high, much higher than those caused by *Trichinella*. *T. gondii* causes 10,280,089 cases and 684 deaths annually and infects animals (WHO, 2015); thus, humans can be infected through the consumption of uncooked meat or raw meat.

The United States

In the United States, albeit with a low fatality rate, norovirus causes the highest number of cases; 4 deaths were observed in 2017 (Table 1). *Salmonella* is the second leading cause, resulting in 3–8 deaths every year (Table 1). Although *L. monocytogenes* causes fewer cases, the associated fatality rate is higher (3–35 deaths annually; 9.4%–20.8%) than that due to other bacteria (Table 1). The number of foodborne illness cases remained unaltered between 1997 and 2017, except for those caused by *Campylobacter* (Table 1). The number of *Campylobacter*-related foodborne outbreaks, particularly due to poultry

Table 1. Number of reported foodborne illnesses and deaths in the United States

Hazards	1998		2002		2011		2017		
	Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths	Foodborne illnesses	Foodborne deaths	
Bacteria	<i>Bacillus cereus</i>	213	0	42	0	100	0	341	0
	<i>Campylobacter</i>	483	0	350	0	291	0	147	0
	<i>Clostridium botulinum</i>	8	0	14	0	11	0	17	2
	<i>Clostridium perfringens</i>	1,328	0	2,207	0	667	0	843	0
	Pathogenic <i>Escherichia coli</i>	1,613	0	486	2	411	2	562	1
	<i>Listeria 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>Staphylococcus aureus</i>	615	0	495	0	113	0	128	0
	<i>Yersinia enterocolitica</i>	9	0	13	0	16	1	0	0
Parasites	<i>Trichinella</i>	0	0	5	0	2	0	5	0
	<i>Toxoplasma 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

Adopted from CDC (2014, 2019) with public domain; Lynch et al. (2006) with public domain.
NA, not applicable.

products, decreased from 483 cases in 1998 to 147 cases in 2017 (Table 1). Regarding hepatitis A virus-related cases, the numbers are low compared to other microorganisms, and the virus generally causes 1 death annually (Table 1). Regarding the parasite *T. gondii*, there were no cases in 1998, 2002, and 2011, but in 2017, there were 9 cases (Table 1), probably due to the consumption of not fully cooked meat; this parasite mainly infects via pork consumption and is rarely found in pigs from developed countries. However, the 2017 outbreak has indicated that the risk of *T. gondii* infection through pork consumption may exist.

The European Union (EU)

In Europe, 23 million people are infected with foodborne illnesses and 5,000 people die due to it every year (WHO, 2015). Norovirus causes the highest number of cases annually (approximately 15 million), followed by *Campylobacter* (approximately 5 million) (WHO, 2015). Interestingly, in the European Union (EU), the number of *Campylobacter*-related foodborne illnesses is the highest. *Campylobacter* is the most commonly reported gastrointestinal disease-causing bacterium in the EU, followed by *Salmonella* (Table 2). In 2007, the incidence of *Campylobacter*-related foodborne illnesses was 45.2 cases per 100,000 people, and broiler and fresh poultry meat were identified as the largest sources of infections (ECDC, 2020). The total annual cases of the associated illnesses and deaths increased gradually from 2012 to 2016 (Table 2). In the case of the

Table 2. Number of foodborne illnesses in the European Union

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>Listeria monocytogenes</i>	1,642	198	17.8	2,161	210	15	2,536	247	16.2
	Shiga toxin-producing <i>Escherichia coli</i>	5,671	12	0.36	5,955	7	0.20	6,378	10	0.27
	<i>Yersinia 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

Adopted from EFSA-ECDC (2014, 2015, 2017) with CC-BY-ND.

NA, not applicable.

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

Korea

Unlike that in the countries reviewed above, in Korea, the pathogen causing the highest number of cases is pathogenic *E. coli* (1,784–2,754 cases from 2010 to 2018) (Table 3). The second highest number of cases are due to norovirus (Table 3). Besides, the number of *S. aureus*-related cases decreased from 2010 to 2018 (Table 3). Previously, *S. aureus* ranked the first or the second in Korea; thus, the Ministry of Food and Drug Safety made serious efforts to control *S. aureus*. This may have gradually decreased the numbers.

Regarding *L. monocytogenes*, which is a serious problem in other countries, in Korea, no foodborne outbreak had been reported until 2018 (Table 3). However, recalls of processed meat products due to *L. monocytogenes* contamination are continuously occurring. Thus, the risk of *L. monocytogenes*-related foodborne illness may increase, which may result in foodborne outbreaks of *L. monocytogenes*.

Australia

In Australia, *Campylobacter* caused the highest number of cases, with the number ranging from 15,640 to 15,973 from 2004 to 2012 (OzFoodNet 2005, 2010, 2018). This was followed by *Salmonella*. The number of *L. monocytogenes*-related

Table 3. Number of foodborne illnesses in Korea

Hazards		Years				
		2010	2012	2014	2016	2018
Bacteria	Pathogenic <i>Escherichia 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>Staphylococcus aureus</i>	372	35	195	4	52
	<i>Clostridium perfringens</i>	171	297	1,689	449	679
Virus	Norovirus	1,994	1,665	739	1,187	1,319

Adopted from MFDS (2020) with public domain.

cases increased from 66 to 93 from 2004 to 2012 (OzFoodNet 2005, 2010, 2018). The trend in terms of etiological agents in Australia is very similar to that observed in the EU and the United States. In Korea and Japan, *Campylobacter* was not an agent, causing the highest number of cases. This is the different one among Korea and Japan, Australia, the EU, and the United States.

Japan

In general, the number of cases, especially those caused by pathogenic *E. coli*, *Salmonella*, and *S. aureus*, decreased between 2000 and 2018 (PSOSJ, 2020). This might be due to the ban on raw beef liver served at a restaurant in 2012. In Japan, norovirus causes the highest number of cases, and the number of cases caused by *Campylobacter* is also high, ranging from 551 to 2,643 between 2000 and 2018 (PSOSJ, 2020). Unlike that in other countries, in Japan, *Clostridium perfringens* causes a relatively high number of cases, higher than that caused by *Campylobacter* in 2018, among others.

Conclusion

In summary, norovirus causes the highest number of foodborne illness cases worldwide, followed by *Campylobacter*, *Salmonella*, and *L. monocytogenes*. The trend observed was mostly similar to the EU, the United States, and Australia. However, in Korea, pathogenic *E. coli* caused the highest number of cases, and *L. monocytogenes* was not reported to be as fatal. In Japan, the number of *Campylobacter*-, norovirus-, and *C. perfringens*-related cases was high. These data suggest that apart from norovirus, *Campylobacter*, *Salmonella*, pathogenic *E. coli*, and *L. monocytogenes*, which are generally isolated from food-producing animals, are associated with foodborne illnesses and outbreaks in the world.

Conflict of Interest

The authors declare no potential conflict of interest.

Author Contributions

Conceptualization: Lee H, Yoon Y. Data curation: Lee H. Writing - original draft: Lee H. Writing - review & editing: Lee H, Yoon Y.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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