National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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RIVM letter report 2021-0161
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Synopsis

Disease burden of food-related pathogens in the Netherlands, 2020

The RIVM analyses how many years are lost on average due to ill health or death (disease burden) as a result of gastrointestinal infections. The 14 pathogens causing these infections are primarily foodborne (60%). People can also come into contact with these pathogens via the environment, for example via surface water, animals, or other people.

The burden of disease from these 14 pathogens was much lower in 2020 than in 2019. This is most probably due to the measures implemented in the Netherlands since March 2020 aimed at stopping the spread of the SARS-CoV-2-virus. Examples of such measures include the closure of restaurants and cafés, a ban on face-to-face meetings, restrictions on international travel, and an increased focus on hygiene, including hand washing. In addition, fewer people might have sought or received medical help for these illnesses, which require a laboratory diagnosis, among other things, to be registered.

An international unit of measure is used to quantify the disease burden, namely Disability Adjusted Life Years (DALYs). The estimated disease burden via food in 2020 was 3,600 DALYs, with a decrease of 22% compared to 2019 (4,600 DALYs). For all the 14 pathogens combined, the total number of DALYs in 2020 was approximately 7,300. That is 34% less than the corresponding figure for 2019, 2018, and 2017 (approximately 11,000 DALYs per year).

The total cost of this disease burden in 2020 was estimated at 282 million euros, which was much less than in 2019 (423 million euros) and 2018 (426 million euros). The estimated cost includes the direct medical costs, for example in hospitals, as well as the costs incurred by the patients and families, such as travelling expenses. It also includes the costs incurred in other sectors, for example as a result of work absenteeism. The costs resulting from contaminated food also decreased significantly: 153 million euros in 2020 compared to 181 million euros in 2019 and 178 million euros in 2018.

The Ministry of Health, Welfare and Sport commissioned this research. The results provide policymakers with insight into the disease burden and the various ways in which people can acquire an infection with food-related pathogens. This research also allows to monitor possible trends in time of the disease burden from foodborne infections, as well as of the associated costs.

Keywords: food-related disease, disease burden, DALY, cost-of-illness, costs

Publiekssamenvatting

Ziektelast van voedseloverdraagbare ziekteverwekkers in Nederland in 2020

Het RIVM brengt in kaart hoeveel jaren mensen een slechte gezondheid hebben of eerder overlijden (ziektelast) door een infectie aan de maag of darm. De 14 verwekkers van deze infecties worden vooral via voedsel overgedragen (60 procent). Mensen kunnen er ook via het milieu, bijvoorbeeld via oppervlaktewater, via dieren of mensen mee in aanraking komen.

De ziektelast door deze 14 ziekteverwekkers was in 2020 veel lager dan in 2019. Dit komt zeer waarschijnlijk door de maatregelen die sinds maart 2020 in Nederland zijn ingevoerd om de verspreiding van het SARS-CoV-2-virus tegen te gaan. Voorbeelden daarvan zijn de sluiting van de horeca, verbod op fysieke bijeenkomsten, beperkingen voor internationale reizen, en meer aandacht voor hygiëne, zoals handen wassen. Het kan ook zijn dat minder mensen medische hulp hebben gezocht of gekregen voor dit soort ziekten. Een laboratoriumtest moet deze ziekten aantonen voordat ze kunnen worden geregistreerd.

Voor de ziektelast wordt een internationale maat gebruikt: DALY's (Disability Adjusted Life Years). In 2020 was de ziektelast via voedsel naar schatting 3.600 DALY's, wat 22 procent lager is dan in 2019 (4.600 DALY's). Voor de 14 ziekteverwekkers is het totaal aantal DALY's in 2020 circa 7.300. Dat is 34 procent lager dan in 2019, 2018 en 2017 (circa 11.000 DALY's per jaar).

De totale kosten van deze ziektelast in 2020 zijn naar schatting 282 miljoen euro en zijn daarmee veel lager dan in 2019 (423 miljoen) en 2018 (426 miljoen). Hierbij wordt gekeken naar de directe medische kosten in onder andere ziekenhuizen, maar ook naar de kosten voor de patiënt en zijn familie, zoals reiskosten. Ook vallen er de kosten van andere sectoren onder, bijvoorbeeld door werkverzuim. De kosten als gevolg van besmet voedsel zijn ook flink gedaald: 153 miljoen euro ten opzichte van 181 miljoen euro in 2019 en van 178 miljoen euro in 2018.

Het ministerie van VWS is de opdrachtgever van dit onderzoek. De resultaten bieden beleidsmakers handvatten om meer zicht te krijgen op de ziektelast en de manieren waarop mensen met de ziekteverwekkers in contact komen. Ook geeft het een beeld hoe de ziektelast van voedselinfecties en kosten zich door de jaren heen ontwikkelen.

Kernwoorden: voedsel-gerelateerde ziekte, ziektelast, DALY, kosten

Contents

Introduction

Foodborne diseases encompass acute and chronic syndromes with varying duration and severity, as well as mortality. Risk-based food safety management (i.e. decisions on control, prevention and surveillance) requires a consistent, quantitative assessment of the relative public health importance of foodborne diseases [1]. As such, we express the public health impact of foodborne pathogens in burden of disease (BoD) and cost-of-illness (CoI). The methodology that is used to estimate the burden of disease (in terms of Disability Adjusted Life Years (DALY)) is described in detail in a peer-reviewed paper [1], and in the disease burden report of food-related pathogens over the year 2015 [2].

Since 2008, the RIVM regularly publishes estimates of the number of incident cases, burden of disease, and costs of food-related infectious disease on its webpages[1], and since 2010 in publicly available reports (e.g. [3, 4]). In the current report, trend information from surveillance, demographic information and consumer price index (a measure for changes in price levels of consumer goods and services) were used to update the information to the year 2020. For 2019 (and onwards), the BoD and CoI for toxin-producing bacteria *Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus* were not estimated due to the absence of national surveillance data for these pathogens. However, these three pathogens were included in the tables and figures regarding the overall estimates (based on data from previous years [4]), to ensure comparability of the total burden and costs with previous years.

Due to the COVID-19 pandemic and the related restrictions to international travel, the number of travel-related cases decreased dramatically in 2020 compared to previous years. For five pathogens (i.e. *Salmonella* spp., *L. monocytogenes, Campylobacter* spp., STEC O157 and hepatitis A), the fraction of the BoD and CoI attributed to travel in 2020 was corrected by a factor equal to the observed decrease in confirmed travel-related cases in their respective surveillance systems. For all other pathogens, the specific fraction attributed to travel for 2020 could not be corrected as this information was not available.

[1] https://www.staatvenz.nl/kerncijfers/voedselinfecties-aantal-verloren-gezonde-levensjaren

1 Methods

1.1 Trend information

Data on the size and age distribution of the Dutch population (Table 1), as well as mortality risks and the number of live births and stillbirths (Table 2) were obtained from Statistics Netherlands[2].

Table 1 Population in the Netherlands by age group, 2016-2020

Age group	2020	2019	2018	2017	2016
0	169,497	168,443	169,566	172,288	170,341
1-4	691,975	697,619	698,533	700,001	706,513
5-11	1,293,205	1,294,145	1,303,023	1,307,281	1,313,978
12-17	1,182,568	1,197,548	1,214,974	1,224,528	1,225,749
18-64	10,677,785	10,610,404	10,555,872	10,517,749	10,477,231
65+	3,392,555	3,314,004	3,239,116	3,159,660	3,085,308
Total	17,407,585	17,282,163	17,181,084	17,081,507	16,979,120

Table 2 Live births by age of mothers in the Netherlands, 2016-2020

Age of mother	2020*	2019	2018	2017	2016
-19	855	915	950	1,023	1,076
20-24	10,173	10,685	11,223	11,722	12,580
25-29	44,260	45,300	45,974	47,197	48,557
30-34	69,927	69,205	68,110	67,575	67,760
35-39	35,944	35,732	34,715	34,905	35,205
40-44	7,544	7,356	7,089	6,941	6,922
45+	489	487	464	473	420
Total	169,191	169,680	168,525	169,836	172,520

* Estimates based on observed trend from 2017-2019

Trend information on the incidence of gastro-enteritis (GE) by pathogen in the general population and consulting the general practitioner was obtained from the following sources:

- Thermophilic *Campylobacter* spp.: RIVM ISIS-AMR laboratory surveillance;
- Non-typhoidal *Salmonella* spp.: RIVM laboratory surveillance;
- Shiga-toxin producing Escherichia coli O157 (STEC O157): mandatory notification and laboratory surveillance;
- Perinatal and acquired listeriosis: mandatory notification and laboratory surveillance;
- Norovirus: estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance;
- Rotavirus: RIVM laboratory surveillance;
- Hepatitis A virus: mandatory notification and laboratory surveillance;
- Hepatitis E virus*:* RIVM laboratory surveillance. Note that this was adapted in 2017 [5] and is therefore different from earlier

[2] Birth; key figures; accessed February 3th 2020

publications [2, 5] where a stable incidence based on Borgen et al. was assumed [6].
- *Cryptosporidium* spp.: RIVM laboratory surveillance data since 2013 until 2018, for 2019 the incidence is estimated based on observed trend from 2016-2018. Although a national surveillance system does not exist anymore, incidence data for *Cryptosporidium* spp. from three peripheral diagnostic laboratories is available and shows a strong decrease in 2020 compared to previous years. We used this rate of decrease to rescale the estimated 2020 incidence.
- *Giardia* spp.: a stable incidence was assumed since 2007 (i.e. the last year of RIVM laboratory surveillance data for *Giardia* spp.). Because the incidence of *Giardia* spp. follows similar trends as the incidence of *Cryptosporidium* spp., we assumed for *Giardia* spp. incidence in 2020 the same decrease rate as the one for *Cryptosporidium* spp.
- No trend information was available for the GE toxin-producing bacteria (*Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus*), and toxoplasmosis. For the latter, trends in reported fatalities are included.

Trends in hospitalizations for gastro-enteritis as primary cause (ICD codes 20-93; 558.9) were obtained from the Dutch Hospital Data (DHD) for 2011-2014. Since 2015 the number of hospitalized patients is indirectly estimated from the observed time series of RIVM laboratory surveillance data on rotavirus, norovirus, campylobacteriosis and salmonellosis. Because a substantial part of the estimated hospitalisations are due to other pathogens than those four mentioned before, we corrected the baseline number of hospitalizations (i.e. hospitalizations due to other pathogens). This was done by downscaling the baseline with the average decrease in the number of cases of rotavirus, norovirus, campylobacteriosis and salmonellosis.

Excess mortality risks from campylobacteriosis and salmonellosis were assumed constant across the years. Fatalities due to listeriosis and STEC O157 were obtained from surveillance data based on mandatory notification to RIVM. Age-specific case fatality ratios for norovirus and rotavirus, originally obtained from German surveillance data, and for protozoan pathogens, originally obtained from the international literature, were assumed constant throughout the years (changes in years of life lost therefore reflect changes in incidence on which mortality is based).

1.2 Burden of disease

The method for the burden of disease calculations, in terms of Disability Adjusted Life Years (DALYs), was not changed since 2018 (i.e. reporting over 2017) [3].

1.3 Cost of illness

The method for CoI estimates was not changed since the 2019 report [7]. The cost prices used for the different resources were updated to

2020 euros using consumer price indexes as provided by Statistics Netherlands[3].

1.4 Attribution

The fraction of human cases of enterically transmitted illness by five major pathways (food, environment, direct animal contact, human–human transmission, and travel) and by 11 groups within the food pathway was estimated using structured expert elicitation and is described in detail in Havelaar et al. [8]. For four pathogens (i.e. *Salmonella* spp., *Listeria monocytogenes, Campylobacter* spp. and STEC O157) we did not use the estimates from the aforementioned expert elicitation, but we used the average attributable fractions estimated by a novel Bayesian statistical model that integrates the attribution estimates from the expert elicitation with attribution estimates based on empirical data from microbial subtyping and case-control studies [9]. To allow for comparison with earlier results, we also updated the attribution estimates of previous years for the four aforementioned pathogens by applying the same novel Bayesian statistical model. In addition, due to the COVID-19 pandemic and the related restrictions to international travel, the number of travel-related cases decreased dramatically in 2020 compared to previous years. For 5 pathogens (i.e. *Salmonella* spp., *L. monocytogenes, Campylobacter* spp. STEC O157 and hepatitis A), we corrected the fraction of the BoD and CoI attributed to travel in 2020 by a factor equal to the observed decrease in confirmed travel-related cases in their respective surveillance systems. For *Campylobacter*, we assumed the same factor as *Salmonella* to estimate the (decreased) contribution of travel in 2020. As the attributions sum up to 100%, by reducing the contribution of travel, the other pathways became relatively more important. For all other pathogens, the fraction attributed to travel for 2020 could not be corrected as this information was not available.

[3] Consumer prices; accessed at February 2th, 2021

2 Results

2.1 Trend information

Trend information for the last five years for specific pathogens is presented in Table 3. For trend information since 1999 for the 14 pathogens, see Annex - Table A.1.

A summary of trends (in comparison with 2019) is discussed below:

- The incidence of campylobacteriosis (laboratory confirmed cases) decreased in comparison with 2019, i.e. 23 cases per 100,000 inhabitants in 2020 compared to the 35 cases per 100,000 inhabitants in 2019.
- The incidence of salmonellosis (laboratory confirmed cases) is with 5 cases per 100,000 inhabitants lower than 2017-2019 (range: 8 to 9 per 100,000 inhabitants).
- The incidence of *Cryptosporidium* spp. in 2020 was estimated by rescaling the 2019 incidence by a factor proportional to the decrease in *Cryptosporidium* spp. cases between 2020 and the average of 2016-2019 observed by the three local laboratories. This resulted in an incidence of 2 cases per 100,000 inhabitants, which is much lower than in previous years (8 per 100,000 inhabitants).
- The incidence of gastroenteritis by rotavirus (laboratory confirmed cases) in 2020 (5 per 100,000 inhabitants) was much lower than in 2019 (16 per 100,000 inhabitants).
- The incidence of gastroenteritis by norovirus (laboratory confirmed cases) was with 11 cases per 100,000 inhabitants much lower than in 2019 (25 per 100,000 inhabitants).
- The incidence of acquired listeriosis (laboratory confirmed cases, active surveillance) decreased from 113 cases in 2019 to 94 in 2020. The recorded fatalities slightly increased from 16 cases in 2019 to 18 in 2020. This is the highest recorded number of deceased cases since the start of the surveillance in 2005.
- In 2020 the incidence of perinatal listeriosis (laboratory confirmed cases, active surveillance) was 2 cases and was lower than in 2019 (4 cases). These 2 cases were a twin, therefore in fact there was only 1 mother with listeriosis in 2020. The number of fatalities was 0 and was identical to 2019.
- The incidence of STEC O157 (laboratory confirmed notified cases, surveillance) in 2020 was 36 cases, of which 13 were hospitalized. In 2020, there was just one case more than in 2019 (35 cases, 13 hospitalized). The number of patients with HUS was with 0 cases in 2020 lower than in 2019 (2 cases).
- The incidence of hepatitis A virus (notified cases, surveillance) was 50 reported cases and 12 hospitalized cases in 2020. This is lower than in 2019 (166 reported cases and 135 hospitalized). This is the lowest reported incidence since the start of the surveillance in 2006.
- With 2 cases per 100,000 inhabitants, the incidence of hepatitis E virus (laboratory confirmed cases) was equal to the incidence reported in 2019.
- The number of patients that were admitted to the hospital due to GE was estimated to be 10.838 in 2020 compared with 21.599 in 2019.

Table 3 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 2016-2020.

		Year				
		2016	2017	2018	2019	2020
Campylobacter spp. [a]		*38*	*33*	*35*	*35*	*23*
Salmonella spp. [a]		*11*	*9*	*9*	*9*	*5*
Cryptosporidium spp. [a]		*12*	*8*	*10*	*8*	*2*
Rotavirus [a]		*10*	*16*	*17*	*16*	*5*
Norovirus [a]		*33*[c]	*23*[c]	*27*[c]	*25*[c]	*11*[c]
Acquired listeriosis [b]		89	112	71	113	94
	Fatal	8	10	4	16	18
Perinatal listeriosis [b]		7	3	7	4	2[d]
	Fatal	4	2	2	0	0
STEC O157 [b]		64	58	59	35	36
	Hospitalized	21[f]	23	23[g]	13	13
Hepatitis A virus [b]		81	374[h]	188[i]	166	50
	Hospitalized	22	90[j]	57[k]	135[l]	12[m]
Hepatitis E virus [a]		*3*	*2*	*2*	*2*	*2*

Notes: a) Incidences per 100,000 habitants are presented in italics and the presented numbers are rounded: ≥10 to two significant figures (e.g. 12.5 = 12) and <10 to 1 significant figure (e.g. 0.89=0.9); b) reported cases; c) estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance data and therefore not directly comparable to numbers from before 2012; d) one twins; e) known for 68/76 cases; g) known for 58/59 cases; h) ~ 275 cases are (in)directly linked to an international outbreak in men having sex with men (MSM); i) 65 cases are (in)directly linked to an international outbreak of MSM j) known for 368/374 cases; k) known for 187/188 cases; l) known for 159/166 cases; m) known for 47/50 cases.

2.2 Number of incident cases

Ten of the selected pathogens (i.e. *Campylobacter* spp.; STEC O157; *Salmonella* spp.; all three toxin-producing bacteria; norovirus; rotavirus; *Cryptosporidium* spp.; *Giardia* spp.) cause acute gastroenteritis. The other four pathogens (i.e. *Listeria monocytogenes*; *Toxoplasma gondii*; hepatitis A virus; hepatitis E virus) cause other diseases (e.g. meningitis, sepsis, hepatitis). The estimated number of incident cases of (acute) gastroenteritis by pathogen in 2020 is presented in Table 4. The estimated number of incident cases of diseases by non-gastrointestinal pathogens in 2020 is presented in Table 5. The number of incident cases by the 14 pathogens for the years 2016-2020 is presented in Figure 1 and in Table A.2 in Annex I.

The estimated total number of cases due to the 14 food-related pathogens strongly decreased from 1,570,000 in 2019 to 963,000 in 2020. This is due to the strong decrease in the incidence of *Campylobacter* spp*., Salmonella* spp., norovirus, rotavirus, hepatitis A and hepatitis E, *Cryptosporidium* spp., *Giardia* spp.. This is most likely due to the COVID-19 pandemic since February 2020 in the Netherlands. A combination of reduced exposure to the pathogens as a result of the lock-down measures (closure of restaurants, ban on gatherings, etc.), increased hygiene, and reduced healthcare-seeking behaviour of people probably played an important role. The estimated incidence of the remaining pathogens did hardly change, mostly because of the following reasons:

a) estimates were based on surveillance data from previous years because no data was available for these pathogens for 2020 (i.e. three toxin producing bacteria)
b) estimates of STEC O157 who were based on laboratory surveillances for 2020 hardly differed from the data of 2019.
c) *Listeria monocytogenes* did not show a strong decrease compared with previous years. This is probably because listeriosis is a serious disease, with symptoms being often severe and requiring medical attention. In addition, listeriosis in the Netherlands is mostly acquired from food consumption at home and, therefore, was seemingly unaffected by the COVID pandemic.

Table 4 Mean estimated number of incident cases and 95% uncertainty interval (between brackets) of gastroenteritis by pathogen in the Netherlands, 2020

Pathogen	Number of incident cases[#]			Fatal cases[#]
	General population (x 1,000)	GP visit (x 1,000)	Hospitalised (x 1,000)	
All causes	4,890 (4060-5820)	224 (1-223)	20 -	NA[#]
Bacteria – infectious				
Campylobacter spp.	47 (5.9-131)	11 (5.5-21)	1 (0.4-2)	36 (24-50)
STEC O157	2.2 (0.2-8.9)	0 (0-0)	0.02 (0.02-0.02)	4 (2-7)
Salmonella spp.	17 (1.5-50)	2 (1.3-4.1)	1 (0.4-2)	23 (20-27)
Bacteria – toxin producing				
Bacillus cereus	53 (18-128)	8 (1.8-21)	0.2 (0.1-0.5)	0 -
Clostridium perfringens	174 (57.8-383)	32 (7.6-84)	0.3 (0.1-0.6)	5 (0-19)
Staphylococcus aureus	289 (125-552)	41 (12-96)	1.5 (0.6-2.8)	7 (0-28)
Viruses				
Norovirus	265 (178-380)	6 (3.5-10)	1.6 (0.8-2.9)	30 (13-57)
Rotavirus	74 (36-132)	4 (2.6-6)	4.8 (3.4-6.5)	12 (4-28)
Protozoa				
Cryptosporidium spp.	19 (6-46)	1 (0.5-2)	0.1 (0-0.3)	1 (0-5)
Giardia spp.	22 (11-43)	2 (1-3)	0.1 (0.01-0.3)	1 (0-2)

#Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 5 Mean estimated number of incident cases and 95% uncertainty interval (between brackets) of non-gastrointestinal pathogen in the Netherlands, 2020

Pathogen	Number of incident cases *mean (95% CI)*		Fatal cases *mean (95% CI)*	
Listeria monocytogenes				
Perinatal	2		0	
Acquired	94		18	
Hepatitis A virus[#]	300	(250-400)	1	(0-1)
Hepatitis E virus[#]	990	(580-1500)	13	(4-24)
Toxoplasma gondii[#]				
Congenital	343	(178-607)	12	(8-19)
Acquired**	431	(199-735)	0	

*No uncertainty because Listeria cases were acquired through surveillance; ** chorioretinitis only. [#]The presented numbers are rounded: ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

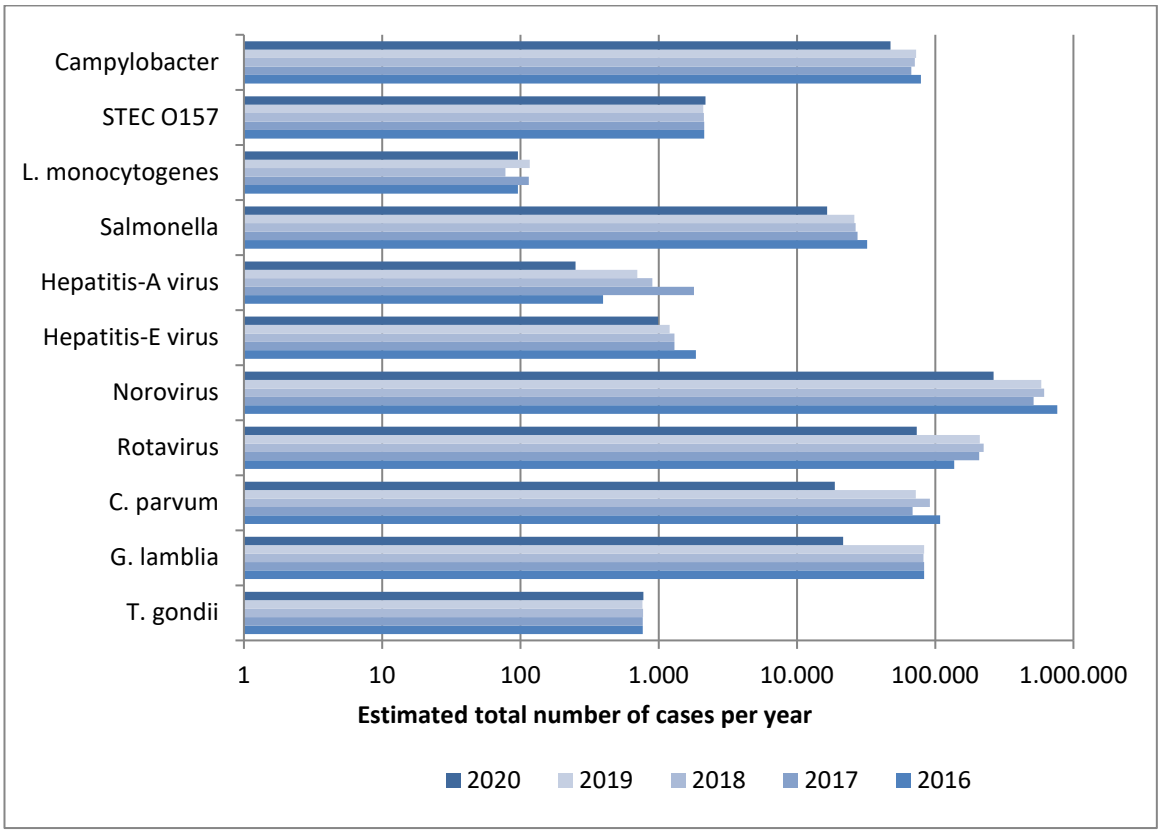

Figure 1 Comparison of mean estimated number of incident cases of food-related pathogens, 2016-2020.

The total number of estimated deaths due to foodborne disease in 2020 was lower than in 2019, 168 deaths compared to 245 deaths in 2019 (see Table A.3 in Annex).

2.3 Disease burden by pathogen

Table 6 presents the estimated burden of disease by pathogen for the total Dutch population in 2020, expressed as DALY per 100,000 inhabitants and DALY per case, both undiscounted and discounted with 1.5% rate.

The total burden of disease of the 14 pathogens in 2020 is estimated at 7,300 DALYs and is much lower than previous years (Table A.4 in Annex). For example, compared with 2019, a decrease in disease burden was found for *Campylobacter* spp. (-1,200 DALYs), *Salmonella* spp. (-300 DALYs), norovirus (-1000 DALYs), rotavirus (-730 DALYs), hepatitis A virus (-62 DALYs) and hepatitis E virus (-70 DALYs), *Cryptosporidium* spp. (-90 DALYs) and *Giardia* spp.(-160 DALYs). The decrease in DALYs largely reflects the decrease in incidence due to the COVID-19 pandemic. The disease outcome with the highest individual burden among all pathogens was perinatal listeriosis (10 DALY per case), followed by congenital toxoplasmosis (5 DALY per case).

In Figure 2, the contributions to total DALYs of the years lived with disability (YLD) associated with acute infections are shown per pathogen, as well as YLD associated with sequelae and years of life lost (YLL) due to premature mortality. YLD associated with acute infections contributed with 12% to the total disease burden; YLD associated with sequelae/residuals contributed 43% and YLL 45% of the total disease burden. The distribution between the different categories varied between pathogens (Figure 2 for details).

Table 6 Mean total DALY per year, DALY per 100,000 inhabitants and DALY per case of illness in the Netherlands, 2020[#]

Pathogen	DALY/year		DALY per 100,000/year		DALY per case	
Discount rate	0%	1.5%	0%	1.5%	0%	1.5%
Bacteria – infectious						
Campylobacter spp.	2,100	1,900	12	11	0.05	0.04
STEC O157	150	120	0.9	0.7	0.07	0.05
Salmonella spp.	800	700	4.4	3.8	0.05	0.04
L. monocytogenes (perinatal)	20	10	0.1	0.1	10	6
L. monocytogenes (acquired)	159	151	0.9	0.9	2	2
L. monocytogenes (total)	180	160	1	0.9	2	2
Bacteria – toxin producing						
Bacillus cereus	33	33	0.2	0.2	0.001	0.001
Clostridium perfringens	200	190	1	1	0.001	0.001
Staphylococcus aureus	220	210	1	1	0.001	0.001
Viruses						
Norovirus	800	800	5	4	0.003	0.003
Rotavirus	400	350	2	2	0.005	0.005
Hepatitis A virus	30	20	0.2	0.1	0.11	0.09
Hepatitis E virus	390	310	2	2	0.4	0.3
Protozoa						
Cryptosporidium spp.	30	30	0.2	0.2	0.002	0.002
Giardia spp.	60	60	0	0	0.003	0.003
Toxoplasma gondii (congenital)	1,600	970	9	6	5	3
Toxoplasma gondii (acquired)	290	1,100	2	6	0.7	3
Toxoplasma gondii (total)	1,900	1,100	11	6	2	1
TOTAL	**7,300**	**5,900**	**41**	**35**		

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure(e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

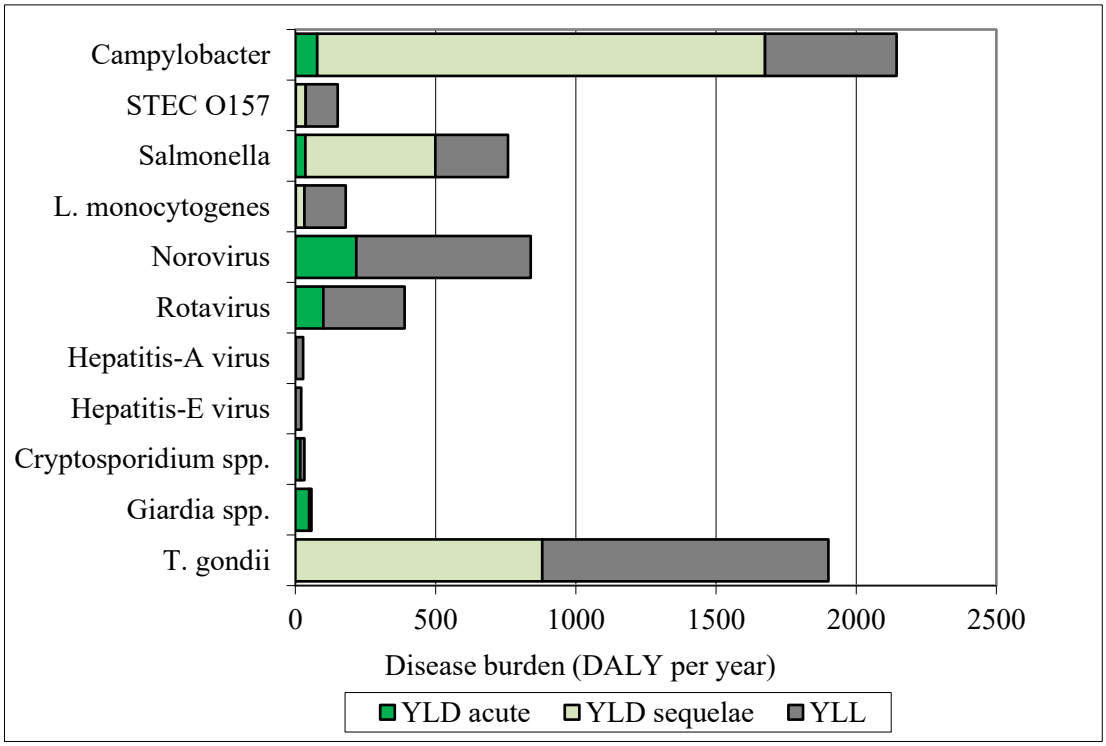

Figure 2 Mean DALY per year of food-related pathogens in 2020, split up into YLD associated with acute infections; YLD associated with sequelae and YLL.

The mean disease burden by the 14 pathogens for the years 2015-2020 is presented in Figure 3 and in Table A.4 in Annex.

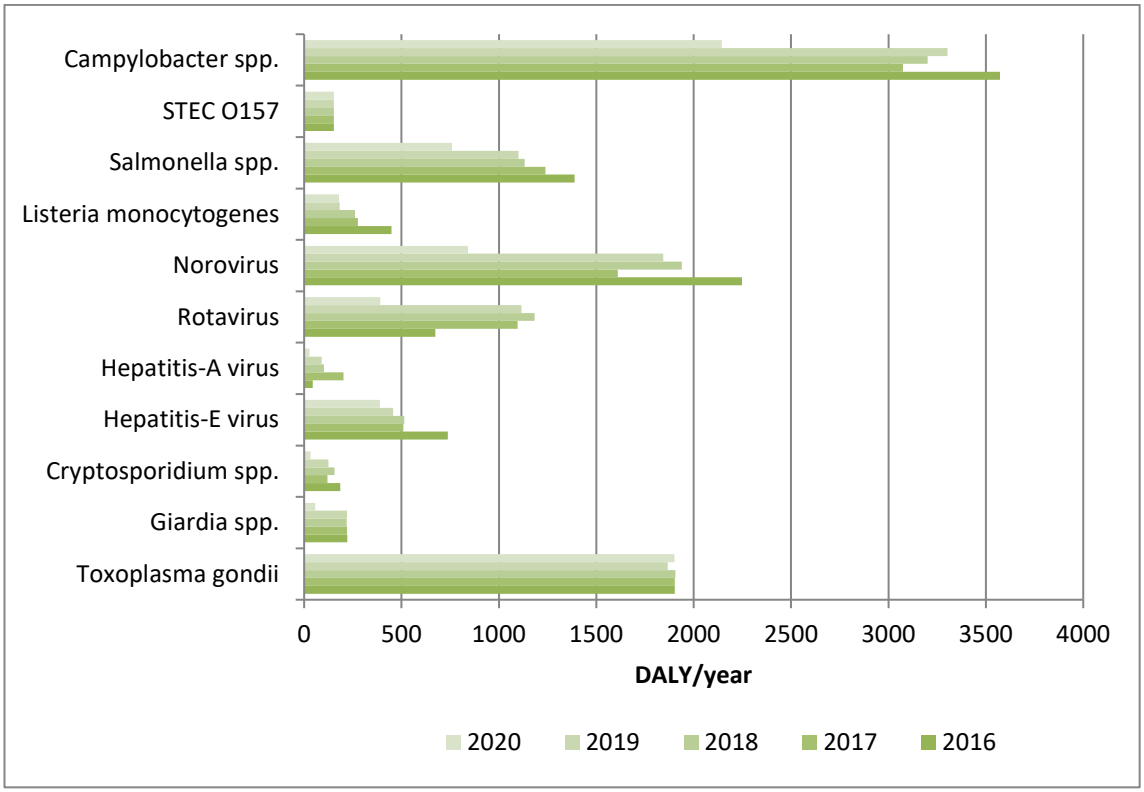

Figure 3 Comparison of disease burden (undiscounted DALYs) of food-related pathogens in 2016-2020

2.4 Cost-of-illness by pathogen

The total CoI in 2020 (282 M€; discounted at 4%) was much lower than in 2019 (423 M€) and in previous years (Table 7, Figures 4-5, and Annex Table A.5). The four pathogens causing the largest CoI were *Staphylococcus aureus* toxin (64 M€), norovirus (52 M€) and *Campylobacter* (42 M€). The lowest contribution to the CoI was by hepatitis A virus (0.4 M€). The largest changes in CoI compared to 2019 were for norovirus (-54 M€), rotavirus (-33 M€) and *Campylobacter* (-20 M€). The average cost per case was largest for perinatal *Listeria monocytogenes* infections (€292,000/case). The lower values of CoI of some pathogens in 2020, compared to previous years, are due to the COVID-19 pandemic.

Table 7 Estimated mean total costs of illness (COI), mean COI per 100,000 inhabitants and mean COI per case of illness in the Netherlands, 2020

Pathogen	COI/year (M€)*		COI per 100,000 (k€)*		COI per case (€)*	
Discount rate	0%	4%	0%	4%	0%	4%
Bacteria – infectious						
Campylobacter spp.	45	42	257	239	940	880
STEC O157	11	6	66	33	5,200	2,600
Salmonella spp.	14	14	83	78	860	820
L. monocytogenes (perinatal)	2	0.6	10	3	859,000	292,000
L. monocytogenes (acquired)	3	3	17	16	31,000	29,000
L. monocytogenes (total)	5	3	27	19	48,000	35,000
Bacteria – toxin producing						
Bacillus cereus	12	12	68	68	220	220
Clostridium perfringens	30	30	174	174	170	170
Staphylococcus aureus	64	64	365	365	220	220
Viruses						
Norovirus	52	52	296	296	190	190
Rotavirus	31	31	177	177	150	420
Hepatitis A virus	0	0.4	2	2	1,700	1,700
Hepatitis E virus	5	5	27	27	4,800	4,800
Protozoa						
Cryptosporidium spp.	5	5	28	28	260	260
Giardia spp.	4	4	25	25	200	200
Toxoplasma gondii (congenital)	46	15	264	84	771,000	43,000
Toxoplasma gondii (acquired)	1	1	7	7	16,600	2,900
Toxoplasma gondii (total)	47	16	272	91	61,000	21,000
TOTAL	**325**	**282**	**1870**	**1620**		

Used abbreviations: million € (M€); 1000 € (k€). * Total COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). COI per 100,000 and COI per case are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000 or 123 k€); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300 or 1.3 k€). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

In Figure 4, the mean CoI per year was split up in healthcare costs, patient/family costs and costs in other sectors. Healthcare costs accounted for 26% of the total costs for the 14 pathogens, patient/family costs for 2% and costs in other sectors accounted for 72%. The distribution between the different cost categories varied between pathogens.

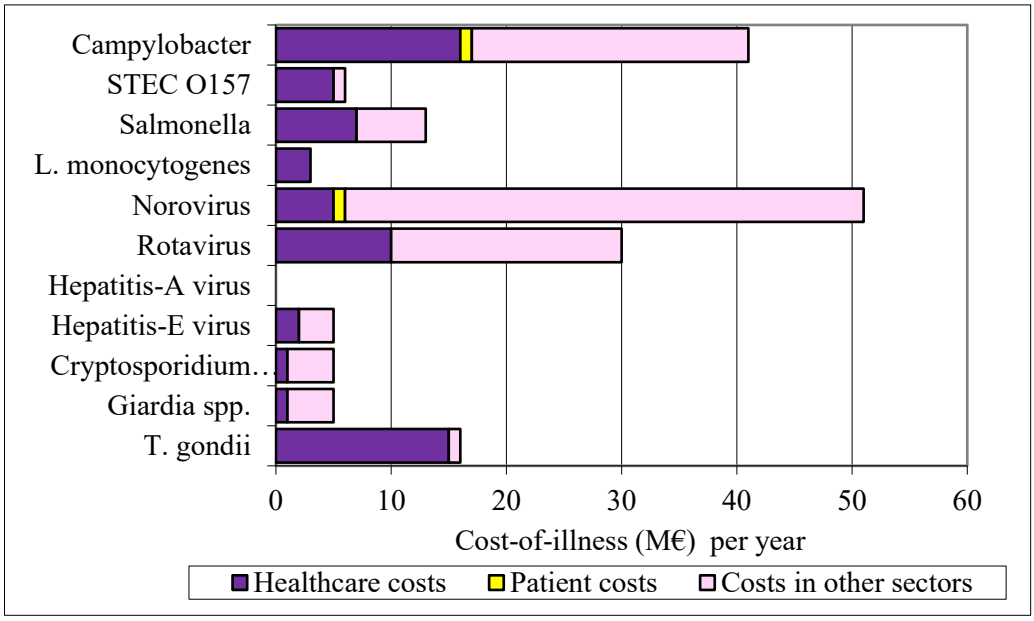

Figure 4 Mean cost-of-illness (discounted) per year of food-related pathogens in 2020, split up into healthcare costs, patient costs and costs in other sectors.

The mean CoI estimates per pathogen for the years 2016-2020 is presented in Figure 5 and in Table A.5 in Annex.

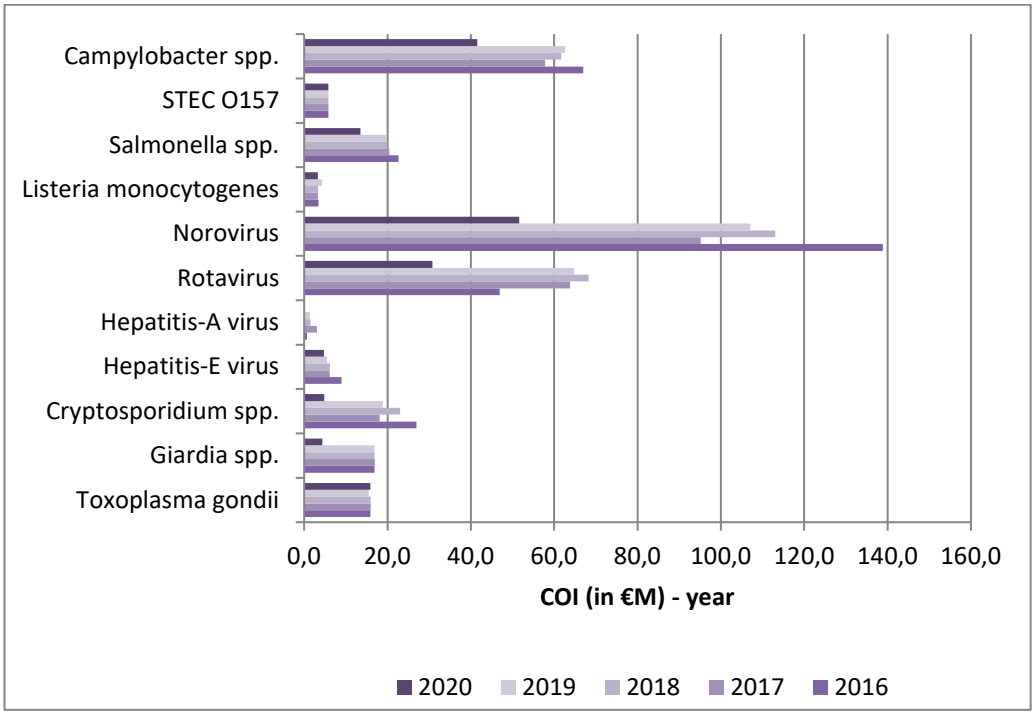

*Figure 5 Comparison of cost-of-illness (M€, discounted at 4% and expressed in 2020 euros) of food-related pathogens in 2016-2020**

2.5 Attribution

The attribution results for the DALYs and CoI in 2020 are presented in Table 8 for the main pathways and in Table 9 for the different food groups. More details can be found in the Tables A.6–A.13 of the Annex.

Foodborne disease burden accounted for 49% of the total burden (i.e. 3,600 DALYs of the total burden of 7,300 DALYs per year), and 54% of the total CoI (i.e. 153 M€ of the 282 M€). About 61% of the foodborne burden was associated with meat (i.e. poultry, pork, beef & lamb). These foods caused 47% of all food-related fatal cases, indicating that the pathogens associated with these foods are considered to cause more severe infections than pathogens associated with other foods. The attributions are estimated using the proportions from the expert elicitation of Havelaar et al. [8]. For four pathogens (i.e. *Salmonella* spp., *Listeria monocytogenes, Campylobacter* spp. and STEC O157), however, we did not use the estimates from the aforementioned expert elicitation, but we used the average attributable fractions estimated by a novel Bayesian statistical model that integrates the attribution estimates from the expert elicitation with attribution estimates based on empirical data from microbial subtyping and case-control studies [9]. In addition, due to the COVID-19 pandemic and the related restrictions to international travel, the number of travel-related cases decreased dramatically in 2020 compared to previous years. For five pathogens (i.e. *Salmonella* spp., *L. monocytogenes, Campylobacter* spp., STEC O157 and hepatitis A), we corrected the fraction of the BoD and CoI attributed to travel in 2020 by a factor equal to the observed decrease in confirmed travel-related cases in their respective surveillance systems. For *Campylobacter*, we assumed the same factor as *Salmonella* to estimate the (decreased) contribution of travel in 2020. As the attributions sum up to 100%, by reducing the contribution of travel, the other pathways became relatively more important. For all other pathogens, the fraction attributed to travel for 2020 could not be corrected as this information was not available.

The attribution results for incidence, number of fatal cases, DALYs and CoI estimates of foodborne diseases for the years 2016-2020 are presented in Tables 10-13. The foodborne disease burden strongly decreased by 1,000 DALYs from 4,600 DALYs in 2019 to 3,600 DALYs in 2020. The CoI also strongly decreased by 21 M€ from 181 M€ in 2019 to 153 M€ in 2020. The strong decrease in the DALYs and CoI from 2019 to 2020 is due to the COVID-19 pandemic.

Table 8 Attribution of the mean estimated number of incident cases, fatalities, disease burden and cost-of-illness of foodborne disease[a] to the major transmission pathways in the Netherlands, 2020

Main pathway	Food	Environment	Human	Animal	Travel	Total
Number of incident cases (per year)[b]	553,000	86,000	222,000	40,000	61,000	963,000
Number of fatal cases (per year)[b]	76	26	34	14	14	163
Disease burden (DALY, undiscounted)[b]	3,600	1,500	1,100	600	500	7,300
Disease burden (DALY, discounted (1.5%))[b]	2,900	1,100	1,000	520	400	5,900
Cost of illness (M€, undiscounted)[c]	177	48	60	19	21	325
Cost of illness (M€, discounted (4%))[c]	153	35	59	17	19	282

a) Due to the 14 pathogens included in this study
b) Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).
c) Costs are expressed in million € (M€).

Table 9 Attribution of the mean incidence, fatalities, disease burden and cost-of-illness of foodborne disease[a] to food group in the Netherlands, 2020

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans& animals	Total
Number of incident cases (per year) [b]	107,000	40,000	48,000	17,000	49,000	38,000	25,000	12,000	35,000	116,000	66,000	553,000
Number of fatal cases (per year) [b]	11	10	15	3	8	5	8	2	2	4	8	76
Disease burden (DALY, undiscounted) [b]	680	750	770	110	210	210	210	57	80	170	330	3,600
Disease burden (DALY, discounted (1.5%)) [b]	530	480	670	100	180	180	170	50	73	150	280	2,900
Cost of illness (M€, undiscounted)[c]	33	24	22	5	14	11	9	3	8	27	18	177
Cost of illness (M€, discounted (4%)) [c]	28	15	20	5	13	10	8	3	8	26	17	153

a) Due to the 14 pathogens included in this study
b) Presented numbers are rounded: ≥100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).
c) Costs are expressed in million € (M€).

Table 10 Attribution of mean incidence to food in the Netherlands for 2016-2020, total and by pathogen

Pathogen	**Incidence/year**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	44,000	38,000	40,000	41,000	28,000
STEC O157	790	790	780	770	850
Salmonella spp.	15,000	13,000	12,000	12,000	8,700
Listeria monocytogenes	76	91	61	92	77
B. cereus toxin	47,000	47,000	47,000	48,000	48,000
C. perfringens toxin	154,000	155,000	155,000	157,000	157,000
S. aureus toxin	250,000	251,000	251,000	252,000	252,000
Norovirus	128,000	86,000	103,000	98,000	44,000
Rotavirus	18,000	27,000	29,000	27,000	10,000
Hepatitis A virus	45	55	69	75	62
Hepatitis E virus	260	180	180	160	140
Cryptosporidium spp.	13,000	8,200	10,900	8,600	2,200
Giardia spp.	11,000	11,000	11,000	11,000	2,800
Toxoplasma gondii	430	430	430	430	430
Total	**681,000**	**636,000**	**660,000**	**655,000**	**553,000**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure(e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 11 Attribution of mean number of fatal cases to food in the Netherlands for 2016-2020, total and by pathogen

Pathogen	**Number of fatal cases/year**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	32	28	26	30	21
STEC O157	1	1	1	1	2
Salmonella spp.	15	16	12	11	12
Listeria monocytogenes	9	9	5	13	15
B. cereus toxin	0.0	0.0	0.0	0.0	0
C. perfringens toxin	4	4	4	4	4
S. aureus toxin	6	6	6	6	6
Norovirus	14	9	11	11	5
Rotavirus	3	5	5	5	2
Hepatitis A virus	0.1	0.2	0.2	0.3	0.2
Hepatitis E virus	3	2	2	2	2
Cryptosporidium spp.	1	1	1	1	0
Giardia spp.	0.3	0.3	0.3	0.3	0.1
Toxoplasma gondii	7	7	7	7	7
Total	**96**	**88**	**81**	**90**	**76**

Table 12 Attribution of mean disease burden (DALY per year, undiscounted) to food in the Netherlands for 2016-2020, total and by pathogen

Pathogen	**DALY (undiscounted)/year**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	2,000	1,700	1,800	1,800	1,300
STEC O157	56	56	56	56	59
Salmonella spp.	640	570	520	510	400
Listeria monocytogenes	350	220	210	140	140
B. cereus toxin	28	29	29	29	29
C. perfringens toxin	180	180	180	180	180
S. aureus toxin	190	190	190	190	190
Norovirus	380	270	320	310	140
Rotavirus	90	140	150	150	50
Hepatitis A virus	5	6	8	8	6
Hepatitis E virus	102	70	71	63	54
Cryptosporidium spp.	22	14	19	15	4
Giardia spp.	29	29	28	29	7
Toxoplasma gondii	1,100	1,100	1,100	1,000	1,100
Total	**5,100**	**4,600**	**4,600**	**4,600**	**3,600**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 13 Attribution of mean COI (M€/year discounted at 4%) to food in the Netherlands for 2016-2020, total and by pathogen

Pathogen	**COI per year (4%)/year (Million €)**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	35	31	33	35	25
STEC O157	2	2	2	2	2
Salmonella spp.	10	9	9	9	7
Listeria monocytogenes	3	3	3	3	3
B. cereus toxin	10	10	10	10	11
C. perfringens toxin	26	26	27	27	27
S. aureus toxin	52	52	53	55	55
Norovirus	22	15	18	18	9
Rotavirus	6	8	9	8	4
Hepatitis A virus	0.1	0.1	0.1	0.1	0.1
Hepatitis E virus	1.2	0.8	0.8	0.8	0.7
Cryptosporidium spp.	3	2	3	2	1
Giardia spp.	2	2	2	2	1
Toxoplasma gondii	8	9	9	9	9
Total	**178**	**169**	**178**	**181**	**153**

Total COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

3 Discussion

This report provides an integrated public health perspective on the burden of 14 food-related pathogens in the Netherlands. The ranking of foodborne pathogens when using burden of disease metrics is very different compared to the ranking based on incidence only. We observed a strong decrease in the number of incident cases of most of the 14 enteric food-related pathogens, especially for *Campylobacter* spp., *Salmonella* spp., norovirus, rotavirus, hepatitis A, and hepatitis E. As mentioned before, this is most likely due to the COVID-19 pandemic. A combination of reduced exposure to the pathogens as a result of the lock-down measures (closure of restaurants and entertainment venues, ban on gatherings, etc.), restrictions to international travel, increased hygiene, and reduced healthcare-seeking behaviour of patients, probably played an important role.

Because of the COVID-19 pandemic, the overall BoD of the 14 food-related pathogens in 2020 (7,300 DALYs) was much lower than in 2019 (-34%) and in previous years in general. The burden attributable specifically to foodborne transmission also decreased compared to 2019 (from 4,600 to 3,600 DALYs; -22%), albeit proportionally less than the overall BoD. Also the overall CoI and the foodborne-related CoI strongly decreased in 2020 as compared to 2019. However, the contribution of the foodborne pathway accounted for 54% of the burden and was higher than in 2019 (about 43%). This is also an effect of the COVID-19 pandemic, as during the pandemic, international travel decreased considerably, thereby increasing the relative importance of the other pathways.

For four pathogens, we used the average attributable fractions estimated by a novel Bayesian statistical model that integrates the attribution estimates from the expert elicitation with attribution estimates based on empirical data from microbial subtyping and case-control studies. To allow for comparison with the results from previous years, we also updated the previous attribution estimates of the four pathogens by applying the novel model. In this way, we could corroborate that the changes observed in the 2020 attribution estimates for the BoD and CoI are due to the COVID-19 pandemic and not to the attribution method.

Some pathogens, such as the three toxin-producing bacteria, show a stable incidence. This is not because they are not affected by underreporting as some of the other pathogens, but because a stable incidence has been assumed due to lack of up-to-date surveillance data. This means that the related DALYs and COI do not reflect the actual trends in incidence. For *Cryptosporidium* and *Giardia*, no up-to-date incidence data at the national level were available for 2020. However, data on *Cryptosporidium* incidence in 2020 as compared to 2019 were obtained from a few peripheral diagnostic laboratories, allowing us to adjust the decreased incidence accordingly, as observed for other pathogens as well (e.g. *Salmonella*, *Campylobacter*, norovirus, etc.). For

Giardia, the incidence was adjusted with the same decrease as observed for *Cryptosporidium*.

In addition, for *T. gondii* there is no trend information in the incidence (only on live births and stillbirths). We aim to update the incidence estimates of *T. gondii* in the coming year since new serological results will soon become available. Besides the assumed stable incidence of *T. gondii*, there are more assumptions made for this disease. Firstly, it is uncertain how many congenitally infected children actually experience or develop long-term complication due to this parasite. The actual percentage of infected children that later in life experience problems, and the severity of these complications are uncertain. Secondly, the number of acquired infections with *Toxoplasma* is uncertain. The (sero-)incidence is based on seroprevalence in the population and this may overestimate the actual occurrence of symptoms due to acquired infections. Updating the incidence of symptoms due to congenitally or acquired infections of *Toxoplasma* requires a new study or (active) surveillance with (long) follow-up time.

Based on our surveillance data, we estimated the number of gastroenteritis incident cases in the general population and visiting the GP using multiplication factors mostly from studies (i.e. SENSOR study) conducted in the late 1990s. We also aim to update the disease models for some pathogens using novel insights from the literature, e.g. the addition of long-term complications of *Cryptosporidium* spp. and *Giardia* spp. infections, and extrahepatic symptoms of hepatitis E, among others.

4 References

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5 Annex: Detailed results

Table A.1 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 1999-2020

Year	Ca[a]	Sa[a]	Cryp[a]	RV[a]	NV[a]	aLm[b]	aLm fatal[b]	pLm[b]	pLm fatal[b]	O157[b]	O157 hosp[b]	HAV[b]	HAV hosp[b]	HEV[a]
1999	39	21		19	14					32				
2000	42	20		16	13					43				
2001	44	20		18	11					41				
2002	41	15		17	12					49				
2003	33	21		18	13					57				
2004	40	16		15	13					37				
2005	44	13		21	16	85	15	6		53				
2006	40	16		26	17	59	17	5	1	40		258	39	
2007	41	12		20	15	60	12	6	1	83		168	27	
2008	39	16		27	18	51	6	1	1	45		183	35	
2009	44	12		31	18	76	4	3	1	57	21	176	29	
2010	50	14		35	23	73	13	4	1	51	21	262	52	0.8
2011	51	12		24	21	79	4	9	1	65	18[d]	125	25	0.9
2012	49	21		20	26[c]	71	8	6	0	85	31[e]	121	28	1
2013	48	9	6	23	26[c]	76	7	3	0	90	36[f]	109	30	0.9
2014	48	9	6	9	25[c]	92	9	4	2	79	31[g]	105	23	2
2015	43	9	10	20	27[c]	69	15	3	1	76	27[h]	80	23	3
2016	38	11	12	10	33[c]	89	8	7	4	64	21[i]	81	22	3
2017	33	9	8	16	23[c]	112	10	3	2	58	23	374[k]	90[m]	2
2018	35	9	10	17	27[c]	71	4	7	2	59	23[j]	188[l]	57[n]	2
2019	35	9	8	16	25[c]	113	16	4	0	35	13	166	135[o]	2
2020	**23**	**5**	**2**	**5**	**11[c]**	**94**	**18**	**2**	**0**	**36**	**13**	**50**	**12[p]**	**2**

Used abbreviations: Ca: *Campylobacter* spp. ; Sa: *Salmonella* spp.; Cryp: *Cryptosporidium* spp.; RV: rotavirus; NV: norovirus; aLm: acquired listeriosis; pLm: perinatal listeriosis: O157: STEC o157; HAV: hepatitis A virus; hosp: hospitalized; HEV: hepatitis E virus.

Notes: a).per 100,000 inhabitants whereby presented numbers are rounded: ≥10 to two significant numbers (e.g. 12.5 = 12) and <10 to 1 significant number (e.g. 0.89=0.9); b) reported cases; c) estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance data and therefore not directly comparable to numbers from before 2012; d) known for 57/65 cases; e) known for 77/85 cases; f) known for 84/90 cases; g) known for 71/79 cases; h) known for 68/76 cases; i) known for 60/64 cases; j) known for 58 out of 59 cases; k) ~ 275 cases are (in)directly linked to an international outbreak in men-having sex with men (MSM); l) 65 cases are (in)directly linked to an international outbreak of MSM m) known for 368/374 cases; n) known for 187/188 cases; o) known for 159/166 cases; p) known for 47/50 cases

Table A.2 Mean number of incident cases by pathogen in the Netherlands, 2016-2020

Pathogen	**Estimated mean number of incident cases/year**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	79,000	67,000	71,000	73,000	47,000
STEC O157	2,100	2,100	2,100	2,100	2,200
Salmonella spp.	32,000	27,000	27,000	26,000	17,000
Listeria monocytogenes	96	115	78	120	96
B. cereus toxin	52,000	53,000	53,000	53,000	53,000
C. perfringens toxin	171,000	171,000	171,000	173,000	174,000
S. aureus toxin	287,000	287,000	288,000	289,000	289,000
Norovirus	765,000	515,000	615,000	585,000	265,000
Rotavirus	138,000	209,000	224,000	211,000	74,000
Hepatitis A virus	400	1,800	900	700	200
Hepatitis E virus	1,900	1,300	1,300	1,200	1,000
Cryptosporidium spp.	109,000	69,000	91,000	72,000	19,000
Giardia spp.	83,000	83,000	82,000	83,000	22,000
Toxoplasma gondii	770	770	770	760	770
Total	**1,720,000**	**1,490,000**	**1,630,000**	**1,570,000**	**963,000**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figures (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.3 Mean number of fatal cases by pathogen in the Netherlands, 2016-2020

Pathogen	**Estimated mean number of fatal cases/year**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	57	49	47	53	36
STEC O157	4	4	4	4	4
Salmonella spp.	32	34	25	24	23
Listeria monocytogenes	12	12	6	16	19
B. cereus toxin	0	0	0	0	0
C. perfringens toxin	5	5	5	5	5
S. aureus toxin	7	7	7	7	7
Norovirus	82	56	69	66	30
Rotavirus	23	35	38	36	12
Hepatitis A virus	1	6	3	3	1
Hepatitis E virus	21	15	15	13	13
Cryptosporidium spp.	7	4	6	4	1
Giardia spp.	2	2	2	2	1
Toxoplasma gondii	12	12	12	12	12
Total	**270**	**240**	**238**	**245**	**163**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure(e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.4 Mean estimated disease burden (undiscounted DALY/year) in the Netherlands for the years 2016- 2020, total and by pathogen

Pathogen	**2016**	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	3,600	3,100	3,200	3,300	2,100
STEC O157	150	150	150	150	150
Salmonella spp.	1,400	1,200	1,100	1,100	800
Listeria monocytogenes	450	280	260	180	180
B. cereus toxin	32	32	32	33	33
C. perfringens toxin	200	200	200	200	200
S. aureus toxin	220	220	220	220	220
Norovirus	2,200	1,600	1,900	1,800	800
Rotavirus	670	1,100	1,200	1,100	390
Hepatitis A virus	44	200	100	90	28
Hepatitis E virus	740	510	510	460	390
Cryptosporidium spp.	190	120	160	120	30
Giardia spp.	220	220	220	220	60
Toxoplasma gondii	1,900	1,900	1,900	1,900	1,900
Total	**12,000**	**11,000**	**11,000**	**11,000**	**7,300**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figures(e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.5 Mean discounted COI (4%) in million euros in the Netherlands for 2016-2020, total and by pathogen

Pathogen	**COI per year (4%)/year (Million €, expressed in 2020 euros)**				
	2016	**2017**	**2018**	**2019**	**2020**
Campylobacter spp.	65	56	60	62	42
STEC O157	6	6	6	6	6
Salmonella spp.	22	20	19	19	14
Listeria monocytogenes	3	3	3	4	3
B. cereus toxin	11	11	11	12	12
C. perfringens toxin	29	29	29	30	30
S. aureus toxin	61	61	61	63	64
Norovirus	134	92	109	106	52
Rotavirus	45	62	66	64	31
Hepatitis A virus	0.6	3	1	1	0.4
Hepatitis E virus	9	6	6	5	5
Cryptosporidium spp.	26	17	22	19	5
Giardia spp.	16	16	16	17	4
Toxoplasma gondii	15	15	15	15	16
Total	**443**	**397**	**426**	**423**	**282**

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure(e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.6 Attribution of mean estimated number of incident cases by pathogen to main pathways in the Netherlands, 2020

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	28,000	8,000	3,000	7,000	1,400	47,000
STEC O157	850	380	260	450	240	2,200
Salmonella spp.	9,000	1,800	2,800	2,300	1,000	17,000
Listeria monocytogenes	77	7	6	6	0	100
B. cereus toxin	48,000	590	640	590	3,900	53,000
C. perfringens toxin	157,000	3,800	3,600	3,600	5,600	174,000
S. aureus toxin	252,000	10,000	9,000	6,300	11,000	289,000
Norovirus	44,000	38,000	147,000	13,000	23,000	265,000
Rotavirus	10,000	13,000	43,000	2,200	7,000	74,000
Hepatitis A virus	62	62	100	0	40	200
Hepatitis E virus	140	250	75	110	420	1,000
Cryptosporidium spp.	2,200	5,000	5,000	2,500	4,000	19,000
Giardia spp.	3,000	5,000	7,000	2,300	4,000	22,000
Toxoplasma gondii	430	280	7	19	36	770
Total	**553,000**	**86,000**	**222,000**	**40,000**	**61,000**	**963,000**

Presented numbers are rounded: ≥ 100,000 to three significant figures(e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.7 Attribution of mean estimated number of fatal cases to main pathways in the Netherlands, 2020

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	21	6	2	5	1	36
STEC O157	2	0.7	0.5	0.8	0.4	4
Salmonella spp.	12	3	4	3	1	23
Listeria monocytogenes	15	1.3	1.2	1.2	0	19
B. cereus toxin	0	0	0	0	0	0
C. perfringens toxin	4	0.1	0.1	0.1	0.1	5
S. aureus toxin	6	0.3	0.2	0.2	0.3	7
Norovirus	5	4	17	2	3	30
Rotavirus	2	2	7	0	1	12
Hepatitis A virus	0.2	0.2	0	0	0.1	1
Hepatitis E virus	2	3	1	1	6	10
Cryptosporidium spp.	0.1	0	0	0.2	0.2	1
Giardia spp.	0.1	0.1	0.2	0.1	0.1	1
Toxoplasma gondii	7	4	0.1	0.3	0.6	12
Total	**76**	**26**	**34**	**14**	**14**	**163**

Presented numbers are rounded: ≥10 to two significant figures(e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.8 Attribution of mean disease burden (DALY per year, undiscounted) to main pathways in the Netherlands, 2020

Main pathway	**Food**	**Environment**	**Human**	**Animal**	**Travel**	**Total**
Campylobacter spp.	1,300	380	140	300	60	2,100
STEC O157	59	26	18	32	17	150
Salmonella spp.	400	80	130	100	50	800
Listeria monocytogenes	140	13	11	11	0	180
B. cereus toxin	29	0	0	0	2	33
C. perfringens toxin	180	4	4	4	6	200
S. aureus toxin	190	8	7	5	8	220
Norovirus	140	120	470	42	70	800
Rotavirus	50	70	230	12	35	400
Hepatitis A virus	6	6	10	0	4	30
Hepatitis E virus	54	100	30	42	170	390
Cryptosporidium spp.	4	9	9	4	6	30
Giardia spp.	7	14	20	6	10	60
Toxoplasma gondii	1,100	690	17	48	87	1,900
Total	**3,600**	**1,500**	**1,100**	**600**	**500**	**7,300**

Presented numbers are rounded: ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure(e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.9 Attribution of mean cost-of-illness (M€ per year, discounted at 4%) to main pathways in the Netherlands, 2020

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	25	7	3	6	1	42
STEC O157	2	1	0.7	1	0.6	6
Salmonella spp.	7	2	2	2	1	14
Listeria monocytogenes	3	0.2	0.2	0.2	0.0	3
B. cereus toxin	11	0.1	0.1	0.1	0.9	12
C. perfringens toxin	27	0.7	0.6	0.6	1.0	30
S. aureus toxin	55	2	2	1	2	64
Norovirus	9	7	29	3	5	52
Rotavirus	4	5	18	1	3	31
Hepatitis A virus	0.1	0.1	0	0.0	0.1	0.4
Hepatitis E virus	0.7	1	0.4	0.5	2	5
Cryptosporidium spp.	1	1	1	1	1	5
Giardia spp.	1	1	2	1	1	4
Toxoplasma gondii	9	6	0.1	0.4	0.7	16
Total	**153**	**35**	**59**	**17**	**19**	**282**

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.10 Attribution of mean incidence by pathogen to food groups in the Netherlands, 2020

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Campylobacter spp.	5,500	900	14,000	650	1,200	1,900	900	510	510	510	1,900	28,000
STEC O157	550	78	20	15	30	20	30	22	19	22	40	850
Salmonella spp.	600	1,900	1,100	1,300	600	350	510	270	350	500	1,060	8,700
Listeria monocytogenes	5	4	9	2	22	5	22	2	2	2	2	77
B. cereus toxin	3,400	1,700	760	1,700	2,800	950	950	810	8,100	25,000	1,100	48,000
C. perfringens toxin	75,000	13,000	11,000	4,400	6,400	10,000	11,000	3,900	4,100	12,000	5,700	157,000
S. aureus toxin	19,000	20,000	20,000	8,300	37,000	15,000	5,000	4,500	19,000	74,000	30,000	252,000
Norovirus	1,400	1,400	1,300	800	900	7,000	3,200	1,400	2,300	2,200	22,000	44,000
Rotavirus	0	270	0	0	160	1,900	2,300	400	700	400	3,400	10,000
Hepatitis A virus	0	0	0	0	0	8	8	2	2	2	39	62
Hepatitis E virus	0	10	0	0	0	0	1	0	0	0	1	10
Cryptosporidium spp.	600	100	60	60	210	500	500	70	0	70	140	2,200
Giardia spp.	600	130	90	0	220	400	900	90	0	90	300	2,800
Toxoplasma gondii	99	220	21	0	20	16	25	0	0	10	25	430
Total	**107,000**	**40,000**	**48,000**	**17,000**	**49,000**	**38,000**	**25,000**	**12,000**	**35,000**	**116,000**	**66,000**	**553,000**

Presented numbers are rounded: ≥ 100,000 to three significant figures (e.g. 123,256 = 123,000); between <100,000 and ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.11 Attribution of mean number of fatal cases by pathogen to food groups in the Netherlands, 2020

Food groups	Beef& lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans& animals	Total
Campylobacter spp.	4	1	10	0.5	1	1	1	0.4	0.4	0.4	1	21
STEC O157	1	0.1	0	0	0.1	0.0	0.1	0	0	0	0.1	2
Salmonella spp.	1	3	2	2	1	0.5	1	0.4	0.5	1	1	12
Listeria monocytogenes	1	0.9	1.7	0.4	4	1	4.4	0.3	0.5	0.5	0.4	15
B. cereus toxin	0	0	0	0	0	0	0	0	0	0	0	0
C. perfringens toxin	2	0.3	0.3	0.1	0.2	0.3	0.3	0.1	0.1	0.3	0.1	4
S. aureus toxin	0.5	0.5	0.5	0.2	0.9	0.4	0.1	0.1	0.5	2	0.7	6
Norovirus	0.2	0.2	0.1	0.1	0.1	1	0.4	0.2	0.3	0.3	3	5
Rotavirus	0	0	0	0	0	0.3	0	0.1	0.1	0.1	1	2
Hepatitis A virus	0	0	0	0	0	0	0	0	0	0	0.1	0.2
Hepatitis E virus	0	1	0	0	0	0	0	0	0	0	0	2
Cryptosporidium spp.	0	0	0	0	0	0	0	0	0	0	0	0
Giardia spp.	0	0	0	0	0	0	0	0	0	0	0	0.1
Toxoplasma gondii	2	3	0.3	0.0	0.3	0.2	0.4	0	0	0.2	0.4	7
Total	**11**	**10**	**15**	**3**	**8**	**5**	**8**	**2**	**2**	**4**	**8**	**76**

Presented numbers are rounded: ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.12 Attribution of mean disease burden (DALY per year, undiscounted) by pathogen to food groups in the Netherlands, 2020

Food groups	**Beef & Lamb**	**Pork**	**Poultry**	**Eggs**	**Dairy**	**Fish& shellfish**	**Produce**	**Beverages**	**Grains**	**Other foods**	**Humans & animals**	**Total**
Campylobacter spp.	247	39	620	29	52	87	39	23	23	23	87	1,300
STEC O157	39	5	1	1	2	1	2	2	1	2	3	59
Salmonella spp.	29	86	50	60	27	16	23	12	16	23	49	400
Listeria monocytogenes	9	8	16	4	41	9	41	3	5	5	4	140
B. cereus toxin	2	1	0.5	1	2	0.6	0.6	0.5	5	16	0.7	29
C. perfringens toxin	86	15	13	5	7	12	12	4	5	14	6	180
S. aureus toxin	14	15	15	6	28	11	4	3	14	56	23	190
Norovirus	4	4	4	3	3	22	10	4	7	7	70	140
Rotavirus	0	1	0	0	1	10	12	2	4	2	18	50
Hepatitis A virus	0	0	0	0	0	0.7	0.7	0.2	0.2	0.2	4	6
Hepatitis E virus	0	40	0	0	0	3	4	2	0	0	6	54
Cryptosporidium spp.	1	0.2	0.1	0.1	0	1	1	0.1	0	0.1	0	4
Giardia spp.	1	0	0.2	0	1	1	2	0.2	0	0.2	1	7
Toxoplasma gondii	240	530	51	0	49	39	62	0	0	24	60	1,100
Total	**680**	**750**	**770**	**110**	**210**	**210**	**210**	**57**	**80**	**170**	**330**	**3,600**

Presented numbers are rounded: ≥10 to two significant figures(e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.13 Attribution of mean cost-of-illness (M€ per year, discounted at 4%) by pathogen to food groups in the Netherlands, 2020[a]

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Campylobacter spp.	5	1	12	0.6	1	2	1	0.4	0.4	0.4	2	25
STEC O157	1	0.2	0.05	0.04	0.1	0.05	0.1	0.06	0.05	0.06	0.1	2
Salmonella spp.	1	2	1	1	0.5	0.3	0.4	0.2	0.3	0.4	0.9	7
Listeria monocytogenes	0.2	0.1	0.3	0.07	0.8	0.2	0.8	0.06	0.1	0.1	0.1	3
B. cereus toxin	0.8	0.4	0.2	0.4	0.6	0.2	0.2	0.2	2	6	0.3	11
C. perfringens toxin	13	2	2	0.8	1	2	2	0.7	0.7	2	1	27
S. aureus toxin	4	5	4	2	8	3	1	1.0	4	17	7	56
Norovirus	0.3	0.3	0.2	0.2	0.2	1	1	0.3	0.4	0.4	4	9
Rotavirus	0	0.1	0	0	0	1	1	0.2	0.3	0.2	1	4
Hepatitis A virus	0	0	0	0	0	0.01	0.01	0.004	0.004	0.003	0.07	0
Hepatitis E virus	0	0.5	0	0	0	0.03	0.05	0.02	0	0	0.07	1
Cryptosporidium spp.	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0	0.0	0.04	1
Giardia spp.	0.1	0.0	0.0	0	0.0	0.1	0.2	0.0	0	0.0	0.1	1
Toxoplasma gondii	2	5	0.4	0.0	0.4	0.3	0.5	0	0	0.2	0.5	9
Total	**28**	**15**	**20**	**5**	**13**	**10**	**8**	**3**	**8**	**26**	**17**	**153**

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

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