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

Disease burden of food-related pathogens in the Netherlands, 2021

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

Disease burden of food-related pathogens in the Netherlands, 2021

RIVM letter report 2022-0173
E. Benincà et al.

Colophon

E. Benincà (author), RIVM
R. Pijnacker (author), RIVM
I.H.M. Friesema (author), RIVM
M. Kretzschmar (author), RIVM
E. Franz (author), RIVM
L. Mughini Gras (author), RIVM

Contact:
Elisa Benincà
Zoönosen en Omgevingsmicrobiologie\Voedsel
elisa.beninca@rivm.nl

Synopsis

Disease burden of food-related pathogens in the Netherlands, 2021

Each year, RIVM investigates how many people become sick or die from gastrointestinal infections caused by 14 different pathogens. This is termed the 'burden of disease' and it is expressed in Disability Adjusted Life Years (DALYs), an international measure for the number of healthy years of life that are lost to disability or premature mortality.

These 14 gastrointestinal pathogens can infect humans through food (approximately 50% of infections), the environment (through surface water, for example) or direct contact with animals or other people. The relative contributions of the different transmission routes by which humans become infected vary depending on the pathogen in question. The total number of DALYs that these 14 pathogens caused in 2021 (9,100 DALYs) was higher than in 2020 (7,300 DALYs), but lower than in 2019 (11,000 DALYs). The fraction of the disease burden attributed to food in 2021 was estimated at 4,200 DALYs, which was higher than in 2020 (3,600 DALYs), but lower than in 2019 (4,600 DALYs).

The disease burden caused by these 14 pathogens was higher than in 2020, but still lower than in 2019, the year before the COVID-19 pandemic unfolded. This is most likely due to the COVID-19 measures in 2020 and the changes to these measures in 2021. The lower disease burden compared to 2019 may also be due to fewer people seeking or receiving medical help for gastrointestinal infections.

The total cost of this disease burden in 2021 was estimated at 363 million euros, which was much higher than in 2020 (282 million euros), but lower than in 2019 (423 million euros). The estimated costs include the direct medical costs, such as for hospitalisation, as well as the indirect costs incurred by the patients and families, such as travelling expenses. They also include the costs incurred in other sectors, for example as a result of absenteeism. The costs resulting from gastrointestinal infections contracted through food in 2021 (172 million euros) were higher than the 153 million euros in 2020, but lower than the 181 million euros in 2019.

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 become infected through foodborne pathogens. This research also makes it possible to monitor possible trends in time of the disease burden caused by foodborne infections, as well as of the associated costs.

Keywords: food-related disease, disease burden, DALY, costs

Publiekssamenvatting

Ziektelast van voedseloverdraagbare ziekteverwekkers in Nederland in 2021

Het RIVM brengt elk jaar 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 (ongeveer 50 procent). Mensen kunnen er ook via het milieu, zoals via oppervlaktewater, via dieren of andere mensen mee in aanraking komen.

De ziektelast door deze 14 ziekteverwekkers was hoger dan in 2020, maar nog wel lager dan in 2019, het jaar vóórdat de corona-pandemie uitbrak. De coronamaatregelen waren in 2021 anders dan in 2020. Waarschijnlijk zijn mensen hierdoor weer meer via voedsel in contact gekomen met ziekteverwekkers. De lagere ziektelast ten opzichte van 2019 kan ook komen doordat minder mensen medische hulp hebben gezocht of gekregen voor maag-darminfecties. Een laboratoriumtest moet namelijk deze ziekten aantonen voordat ze kunnen worden geregistreerd.

Voor de ziektelast wordt een internationale maat gebruikt: DALY's (Disability Adjusted Life Years). Voor de 14 ziekteverwekkers is het totaal aantal DALY's in 2021 circa 9.100. Dat is hoger dan in 2020 (7.300), maar lager dan in 2019 (ongeveer 11.000). Via voedsel was de ziektelast in 2021 naar schatting 4.200 DALY's, wat hoger was dan in 2020 (3.600), maar lager dan in 2019 (4.600).

De totale kosten van deze ziektelast in 2021 waren naar schatting 363 miljoen euro. Dat was veel hoger dan in 2020 (282 miljoen) maar lager dan in 2019 (423 miljoen). Gekeken wordt naar de directe medische kosten in onder andere ziekenhuizen, maar ook naar de kosten voor de patiënt en zijn familie, zoals reiskosten. Verder vallen er de kosten van andere sectoren onder, bijvoorbeeld door werkverzuim. De kosten als gevolg van besmet voedsel waren met 172 miljoen euro hoger dan in 2020 (153 miljoen euro), maar lager dan de 181 miljoen euro in 2019.

Het ministerie van VWS heeft de opdracht voor dit onderzoek gegeven. 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 ervan zich door de jaren heen ontwikkelen.

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

Contents

Introduction

Foodborne infections 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 another study [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 on disease incidence, demographics, 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 2021. From 2019 onwards, the BoD and CoI for toxin-producing bacteria *Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus* were no longer estimated due to the absence of recent 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 drastically in 2020 and in 2021 compared to the 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 and in 2021 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 and for 2021 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, 2017-2021

Age group	2021	2020	2019	2018	2017
0	168,270	169,497	168,443	169,566	172,288
1-4	689,356	691,975	697,619	698,533	700,001
5-11	1,281,948	1,293,205	1,294,145	1,303,023	1,307,281
12-17	1,171,648	1,182,568	1,197,548	1,214,974	1,224,528
18-64	10,706,658	10,677,785	10,610,404	10,555,872	10,517,749
65+	3,457,535	3,392,555	3,314,004	3,239,116	3,159,660
Total	17,475,415	17,407,585	17,282,163	17,181,084	17,081,507

Table 2 Live births by age of mothers in the Netherlands, 2017-2021

Age of mother	2021*	2020	2019	2018	2017
-19	840	876	915	950	1,023
20-24	9,433	10,015	10,685	11,223	11,722
25-29	42,672	43,666	45,300	45,974	47,197
30-34	71,339	70,258	69,205	68,110	67,575
35-39	36,591	35,868	35,732	34,715	34,905
40-44	7,821	7,571	7,356	7,089	6,941
45+	422	427	487	464	473
Total	169,118	168,681	169,680	168,525	169,836

* Estimates based on observed (2018) and estimated (2019-2020) trend data from 2018-2020

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:
- *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.

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

- *Cryptosporidium* spp.: RIVM laboratory surveillance data since 2013 until 2018, for 2019 the incidence is estimated based on observed trend from 2016-2018. The incidence in 2020 is based on observed (2017-2018) and estimated (2019) trend data from 2017-2019. The incidence in 2021 is based on observed (2018) and estimated (2019-2020) trend data from 2018-2020. Although nationally representative data are not available anymore, the 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 (i.e., COVID-19 rescaling factor for 2020) to rescale the estimated 2020 incidence. As incidence data from the three peripheral diagnostic laboratories was not available for 2021, we looked at the increase in *Salmonella* incidence from 2020 to 2021 and assumed the same increase for the other pathogens (i.e., COVID-19 rescaling factor for 2021).
- *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 and 2021 the same decrease rate as the one for *Cryptosporidium* spp. in 2020 and 2021, respectively.
- 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 [5, 6]. The cost prices used for the different resources were updated to 2021 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. [7]. 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 [8]. 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 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 2021 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 2021. 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 2021 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) is slightly higher in 2021 than in 2020, i.e. 24 cases per 100,000 inhabitants compared to 23 cases per 100,000 inhabitants in 2020.
- The incidence of salmonellosis (laboratory confirmed cases) is with 6 cases per 100,000 inhabitants slightly higher than in 2020 (5 cases per 100,000 inhabitants).
- The estimated incidence of *Cryptosporidium* spp. in 2021 resulted in 4 cases per 100,000 inhabitants, which is slightly higher than in 2020 (2 cases per 100,000 inhabitants).
- The incidence of gastroenteritis by rotavirus (laboratory confirmed cases) in 2021 (13 per 100,000 inhabitants) was much higher than in 2020 (5 per 100,000 inhabitants).
- The incidence of gastroenteritis by norovirus (laboratory confirmed cases) was with 19 cases per 100,000 inhabitants higher than in 2020 (11 per 100,000 inhabitants).
- The incidence of acquired listeriosis (laboratory confirmed cases, active surveillance) decreased from 94 in 2020 to 82 in 2021. The recorded fatalities also decreased from 18 cases in 2020 to 11 cases in 2021.
- In 2021 the incidence of perinatal listeriosis (laboratory confirmed cases, active surveillance) strongly increased from 2 cases in 2020 to 12 cases in 2021. The number of fatalities also increased from 0 cases in 2020 to 4 cases in 2021. The number of cases of perinatal listeriosis is the highest ever recorded since the start of the surveillance in 2005.
- The incidence of STEC O157 (laboratory confirmed notified cases, surveillance) in 2021 was 55 cases, of which 22 were hospitalized, and was much higher than in 2020 (36 cases, 13 hospitalized). The number of patients with HUS was with 4 cases in 2020 higher than in 2020 (0 cases).
- The incidence of hepatitis A virus (notified cases, surveillance) was 78 reported cases and 23 hospitalized cases in 2021. This is higher than in 2020 (50 reported cases and 12 hospitalized).
- With 1 case per 100,000 inhabitants, the incidence of hepatitis E virus (laboratory confirmed cases) was lower to the incidence reported in 2020 (2 cases per 100,000 inhabitants).
- The number of patients that were admitted to the hospital due to GE was estimated to be 15.824 compared with 10.838 in 2020.

Table 3 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 2017-2021.

| | | **Year** | | | | |
		2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.[a] *(x 100,000 inhabitants)*		*33*	*35*	*35*	*23*	*24*
Salmonella spp.[a] *(x 100,000 inhabitants)*		*9*	*9*	*9*	*5*	*6*
Cryptosporidium spp.[a] *(x 100,000 inhabitants)*		*8*	*10*	*8*	*2*	*4*
Rotavirus[a] *(x 100,000 inhabitants)*		*16*	*17*	*16*	*5*	*13*
Norovirus[a] *(x 100,000 inhabitants)*		*23[c]*	*27[c]*	*25[c]*	*11[c]*	*19[c]*
Acquired listeriosis[b] *(Total reported cases)*		112	71	113	94	82
	Fatal	10	4	16	18	11
Perinatal Listeriosis[b] *(Total reported cases)*		3	7	4	2[d]	12
	Fatal	2	2	0	0	4
STEC O157[b] *(Total reported cases)*		58	59	35	36	55
	Hospitalized	23	23[e]	13	13	22
Hepatitis A virus[b] *(Total reported cases)*		374[f]	188[g]	166	50	78
	Hospitalized	90[h]	57[i]	135[j]	12[k]	23[l]
Hepatitis E virus[a] *(x 100,000 inhabitants)*		*2*	*2*	*2*	*2*	*1*

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 58/59 cases; f) ~ 275 cases are (in)directly linked to an international outbreak in men having sex with men (MSM); g) 65 cases are (in)directly linked to an international outbreak of MSM h) known for 368/374 cases; i) known for 187/188 cases; j) known for 159/166 cases; k) known for 47/50 cases; l) known for 76/78 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 mainly acute gastroenteritis. The other four pathogens (i.e. *Listeria monocytogenes*; *Toxoplasma gondii*; hepatitis A virus; hepatitis E virus) cause also other diseases (e.g. meningitis, sepsis, hepatitis). The estimated number of incident cases of (acute) gastroenteritis by pathogen in 2021 is presented in Table 4. The estimated number of incident cases of diseases by non-gastrointestinal pathogens in 2021 is presented in Table 5. The number of incident cases by the 14 pathogens for the years 2017-2021 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 increased from 963,000 in 2020 to 1,287,000 in 2021, but remained lower than in 2019. This is most likely due to the COVID-19 pandemic, which was spreading 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. However, not all of these measures and not with same intensity as in 2020 were implemented in 2021. This might explain why the total number of cases in 2021 is higher than in 2020, but lower than in pre-pandemic 2019.

Table 4 Mean estimated number of incident cases and 95% uncertainty interval (between brackets) of gastroenteritis by pathogen in the Netherlands, 2021

Pathogen	Number of incident cases#			Fatal cases#
	General population (x 1,000)	GP visit (x 1,000)	Hospitalised (x 1,000)	
All causes	4,900	220	21	NA#
	(4,100-5,800)	(70-530)	-	
Bacteria – infectious				
Campylobacter spp.	51	12	1	37
	(7-140)	(6-23)	(0.4-2)	(24-52)
STEC O157	2	0	0.02	4
	(0.2-9)	(0-0)	(0.02-0.02)	(2-7)
Salmonella spp.	20	3	1	28
	(2-59)	(2-5)	(0.4-2)	(25-32)
Bacteria – toxin producing				
Bacillus cereus	54	8	0.2	0
	(18-140)	(2-22)	(0.07-0.5)	(0-0)
Clostridium perfringens	170	32	0.3	5
	(58-380)	(8-82)	(0.1-0.6)	(0.1-19)
Staphylococcus aureus	290	41	1	7
	(120-560)	(11-96)	(0.6-3)	(0.2-28)
Viruses				
Norovirus	450	10	2	52
	(300-660)	(6-17)	(0.9-3)	(22-100)
Rotavirus	170	10	5	31
	(83-310)	(6-15)	(4-7)	(9-69)
Protozoa				
Cryptosporidium spp.	32	2	0.2	2
	(10-82)	(0.9-3)	(0.1-0.5)	(0.03-9)
Giardia spp.	38	3	0.2	1
	(19-75)	(2-6)	(0.02-0.6)	(0.02-4)

#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, 2021

Pathogen	Number of incident cases mean (95% CI)		Fatal cases mean (95% CI)	
Listeria monocytogenes				
Perinatal	12		4	
Acquired	82		11	
Hepatitis A virus#	380	(250-620)	1	(0.7-2)
Hepatitis E virus#	790	(470-1,200)	9	(3-19)
Toxoplasma gondii#				
Congenital	340	(180-600)	12	(8-19)
*Acquired**	430	(200-730)	0	

*No uncertainty because Listeria cases were acquired through surveillance. The reported number of cases of listeriosis includes only cases with systemic symptoms. Mild cases of listeriosis are not monitored and the number is thus unknown. ; ** 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).
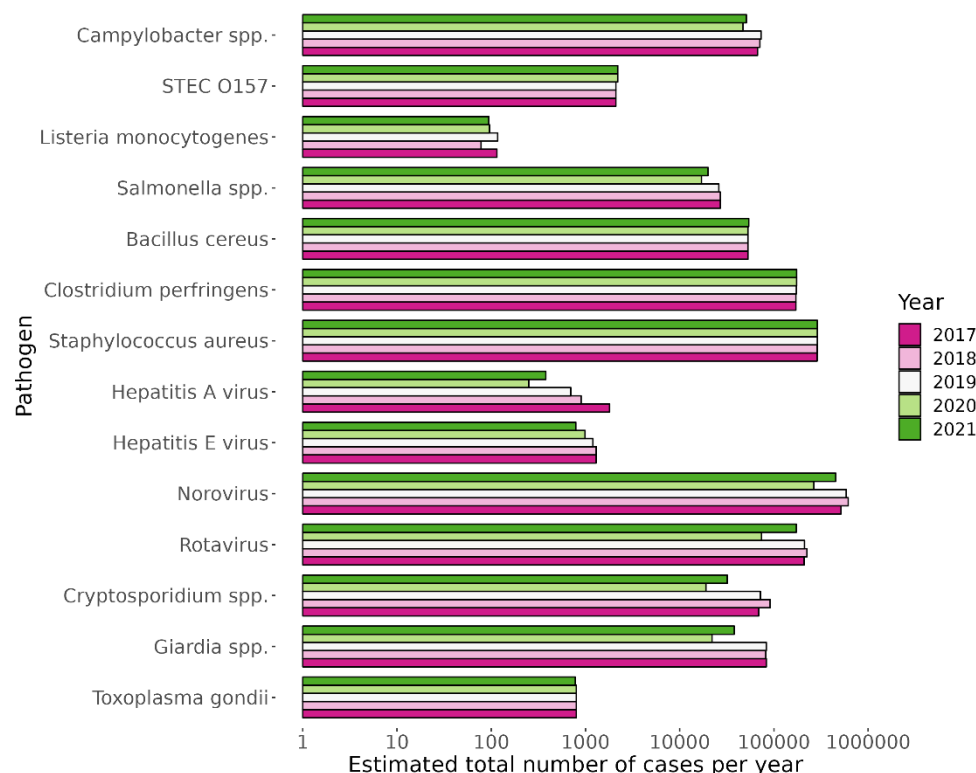
Figure 1 Comparison of mean estimated number of incident cases of food-related pathogens, 2017-2021

The total number of estimated deaths due to foodborne disease in 2021 was higher than in 2020, 200 deaths in 2021 compared to 168 deaths in 2020 (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 2021, 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 2021 is estimated at 9,100 DALYs and is higher than in 2020 but still lower than in the years preceding the pandemic (Table A.4 in Annex). For example, compared with 2020, an increase in disease burden was found for *Campylobacter* spp. (+200 DALYs), *Salmonella* spp. (+100 DALYs), norovirus (+600 DALYs), rotavirus (+530 DALYs), hepatitis A virus (+14 DALYs) *Cryptosporidium* spp. (+26 DALYs) and *Giardia* spp.(+40 DALYs). Hepatitis E showed a slight decrease from 360 DALYS in 2020 to 310 DALYS in 2021(-50 DALYs). The DALYs estimated for *Listeria monocytogenes* are remarkably high and are much higher than in previous years. This is due to the high number of cases and the high number of fatalities of perinatal listeriosis.

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 36% and YLL 52% of the total disease burden. The distribution between the different categories varied between pathogens (see 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, 2021

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.	2,300	2,000	13	12	0.05	0.04
STEC O157	150	120	0.9	0.7	0.07	0.05
Salmonella spp.	900	790	5	5	0.05	0.04
L. monocytogenes (perinatal)	420	240	2	1	35	20
L. monocytogenes (acquired)	94	90	0.5	0.5	1	1
L. monocytogenes (total)	510	330	3	2	5	3
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	1,400	1,300	8	7	0.003	0.003
Rotavirus	920	820	5	5	0.005	0.005
Hepatitis A virus	42	34	0.2	0.2	0.1	0.09
Hepatitis E virus	310	250	2	1	0.4	0.3
Protozoa						
Cryptosporidium spp.	56	54	0.3	0.3	0.002	0.002
Giardia spp.	100	99	0.6	0.6	0.003	0.003
Toxoplasma gondii (congenital)	1,600	920	9	5	5	3
Toxoplasma gondii (acquired)	290	210	2	1	0.7	0.5
Toxoplasma gondii (total)	1,900	1,100	11	6	2	1

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).
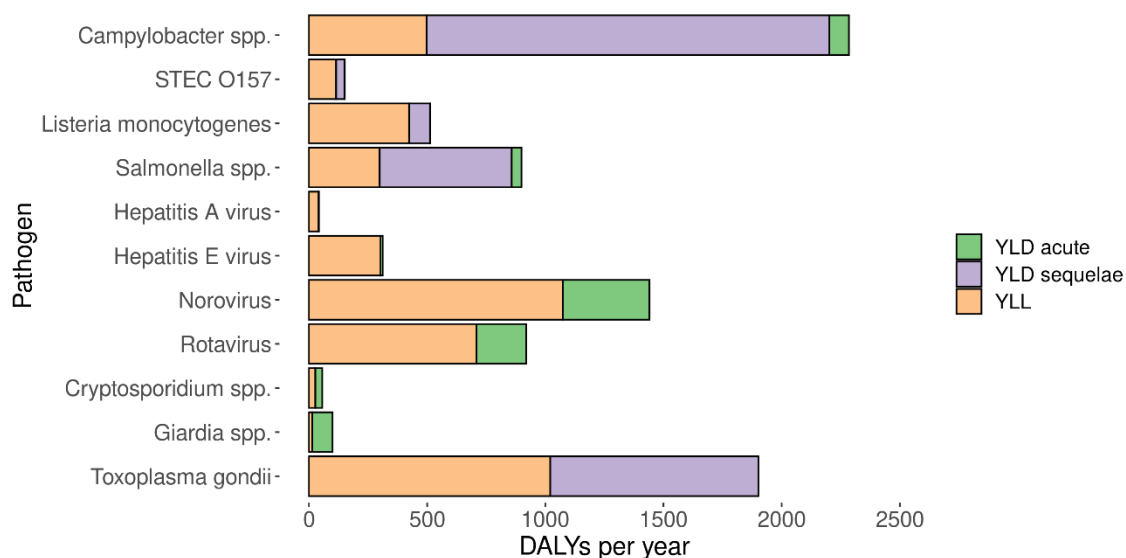
Figure 2 Mean DALY per year of food-related pathogens in 2021, split up into YLD associated with acute infections; YLD associated with sequelae and YLL.

The mean disease burden by the 14 pathogens for the years 2017-2021 is presented in Figure 3 and in Table A.4 in Annex.
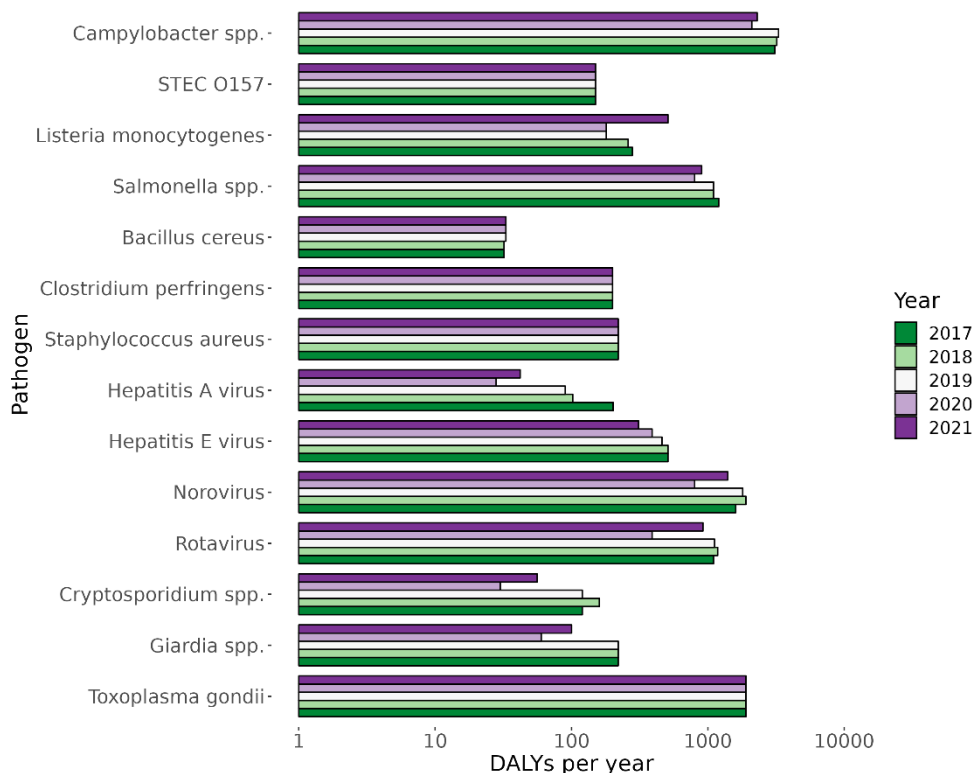
Figure 3 Comparison of disease burden (undiscounted DALYs) of food-related pathogens in 2017-2021

2.4   Cost-of-illness by pathogen

The total CoI in 2021 (363 M€; discounted at 4%) was higher than in 2020 (282 M€), but still lower than the years preceding the COVID-19

pandemic (Table 7, Figures 4-5, and Annex Table A.5). The four pathogens causing the largest CoI were norovirus (87 M€) , *Staphylococcus aureus* toxin (65 M€), rotavirus (57 M€) and *Campylobacter* (46 M€). The lowest contribution to the CoI was by hepatitis A virus (0.7 M€). The largest changes in CoI compared to 2020 were for norovirus (+35 M€) and rotavirus (+26 M€). The average cost per case was largest for perinatal *Listeria monocytogenes* infections (€214,000/case).

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, 2021

Pathogen	COI/year (M€)*		COI per 100,000 (k€)*		COI per case (€)*	
Discount rate	0%	4%	0%	4%	0%	4%
Bacteria − infectious						
Campylobacter spp.	49	46	280	260	970	900
STEC O157	12	6	69	34	5,500	2,700
Salmonella spp.	17	16	97	92	860	810
L. monocytogenes (perinatal)	7	3	41	15	602,000	214,000
L. monocytogenes (acquired)	2	2	14	13	30,000	28,000
L. monocytogenes (total)	10	5	55	28	103,000	52,000
Bacteria − toxin producing						
Bacillus cereus	12	12	69	69	230	230
Clostridium perfringens	31	31	180	180	180	180
Staphylococcus aureus	65	65	370	370	230	230
Viruses						
Norovirus	87	87	500	500	190	190
Rotavirus	57	57	330	330	330	330
Hepatitis A virus	0.7	0.7	4	4	1,700	1,700
Hepatitis E virus	4	4	22	22	4,900	4900
Protozoa						
Cryptosporidium spp.	9	9	50	50	270	270
Giardia spp.	8	8	45	45	210	210
Toxoplasma gondii (congenital)	47	15	270	86	138,000	44,000
Toxoplasma gondii (acquired)	1	1	7	7	3,000	2,900
Toxoplasma gondii (total)	48	16	280	93	62,000	21,000

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 23% of the total costs for the 14 pathogens, patient/family costs for 2% and costs in other sectors accounted for 74%. The distribution between the different cost categories varied between pathogens.
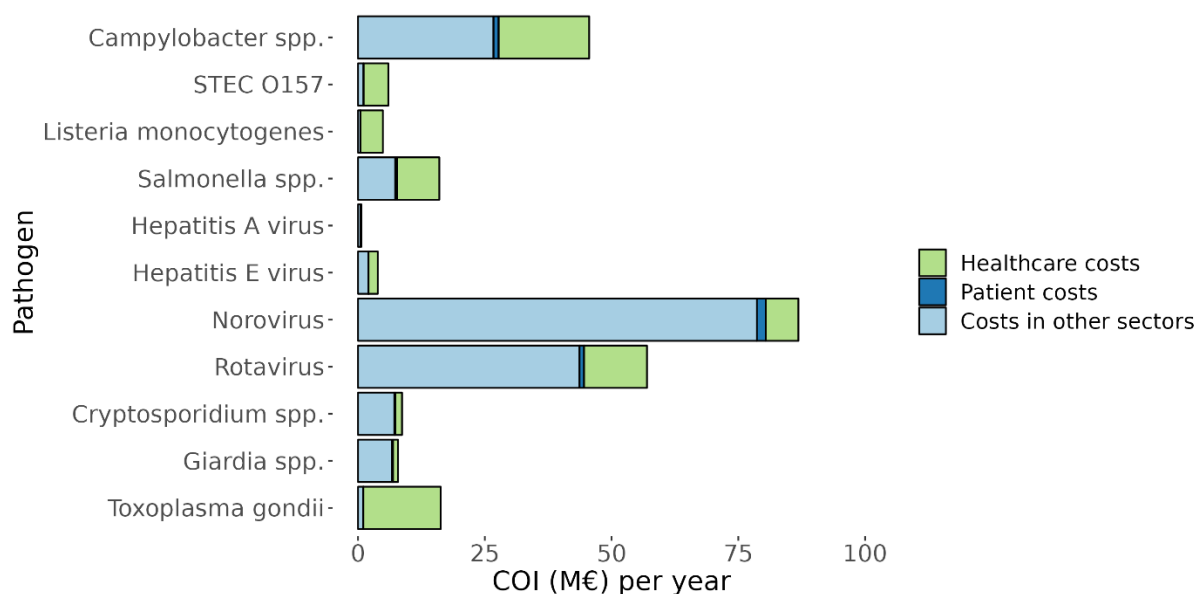
Figure 4 Mean cost-of-illness (discounted) per year of food-related pathogens in 2021, split up into healthcare costs, patient costs and costs in other sectors.

The mean CoI estimates per pathogen for the years 2017-2021 is presented in Figure 5 and in Table A.5 in Annex.
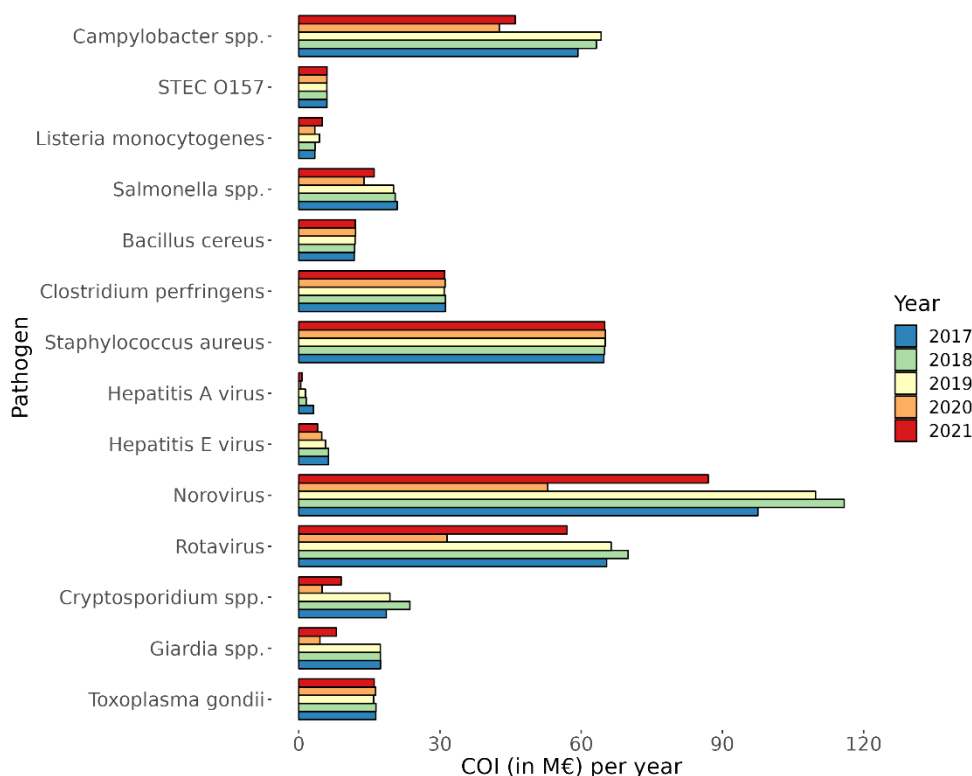
Figure 5 Comparison of cost-of-illness (M€, discounted at 4% and expressed in 2020 euros) of food-related pathogens in 2017-2021.
Attribution
The attribution results for the DALYs and CoI in 2021 are presented in Table 8 for the main pathways and in Table 9 for the different food

groups. More details can be found in the Tables A.6–A.13 of the Annex. Foodborne disease burden accounted for 46% of the total burden (i.e. 4,200 DALYs of the total burden of 9,100 DALYs per year), and 47% of the total CoI (i.e. 172 M€ of the 363 M€). About 56% of the foodborne burden was associated with meat (i.e. poultry, pork, beef & lamb). These foods were estimated to cause 45% 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. [7]. 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 [8]. 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 and in 2021 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 2021 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 2021. 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 2021 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 2017-2021 are presented in Tables 10-13. The foodborne disease burden increased by 600 DALYs from 3,600 DALYs in 2020 to 4,200 DALYs in 2021. The CoI increased by 19M€ from 153 M€ in 2020 to 172 M€ in 2021 .

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, 2021

Main pathway	Food	Environment	Human	Animal	Travel	Total
Number of incident cases (per year)[b]	606,000	139,000	394,000	57,000	91,000	1,287,000
Number of fatal cases (per year)[b]	82	32	58	16	16	200
Disease burden (DALY, undiscounted)[b]	4200	1800	1800	710	610	9100
Disease burden (DALY, discounted (1.5%))[b]	3300	1300	1600	610	500	7400
Cost of illness (M€, undiscounted)[c]	199	62	98	24	27	410
Cost of illness (M€, discounted (4%))[c]	172	48	97	21	25	363

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, 2021

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]	109,000	42,000	50,000	18,000	51,000	46,000	32,000	14,000	38,000	118,000	88,000	606,000
Number of fatal cases (per year) [b]	12	10	15	4	7	6	8	2	3	5	11	82
Disease burden (DALY, undiscounted) [b]	720	780	860	130	300	270	320	73	100	200	430	4200
Disease burden (DALY, discounted (1.5%)) [b]	570	530	730	110	230	220	240	63	91	170	370	3,300
Cost of illness (M€, undiscounted) [c]	36	26	25	6	16	13	12	4	9	28	24	199
Cost of illness (M€, discounted (4%)) [c]	29	16	22	5	14	12	10	4	9	27	22	172

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 2017-2021, total and by pathogen

Pathogen	Incidence/year				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	38,000	40,000	41,000	28,000	30,000
STEC O157	790	780	770	850	870
Salmonella spp.	13,000	12,000	12,000	8,700	10,000
Listeria monocytogenes	91	61	92	77	76
Bacillus cereus	47,000	47,000	48,000	48,000	48,000
Clostridium perfringens	155,000	155,000	157,000	157,000	157,000
Staphylococcus aureus	251,000	251,000	252,000	252,000	252,000
Norovirus	86,000	103,000	98,000	44,000	76,000
Rotavirus	27,000	29,000	27,000	10,000	22,000
Hepatitis A virus	55	69	75	62	89
Hepatitis E virus	180	180	160	140	110
Cryptosporidium spp.	8,200	10,900	8,600	2,200	3,900
Giardia spp.	11,000	11,000	11,000	2,800	4,900
Toxoplasma gondii	430	430	430	430	430
Total	**636,000**	**660,000**	**655,000**	**553,000**	**606,000**

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 2017-2021, total and by pathogen

Pathogen	Number of fatal cases/year				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	28	26	30	21	22
STEC O157	1	1	1	2	2
Salmonella spp.	16	12	11	12	15
Listeria monocytogenes	9	5	13	15	12
Bacillus cereus	0	0	0	0	0
Clostridium perfringens	4	4	4	4	4
Staphylococcus aureus	6	6	6	6	6
Norovirus	9	11	11	5	9
Rotavirus	5	5	5	2	4
Hepatitis A virus	0.2	0.2	0.3	0.2	0.3
Hepatitis E virus	2	2	2	2	1
Cryptosporidium spp.	1	1	1	0	0.2
Giardia spp.	0.3	0.3	0.3	0.1	0.1
Toxoplasma gondii	7	7	7	7	7
Total	**88**	**81**	**90**	**76**	**82**

Table 12 Attribution of mean disease burden (DALY per year, undiscounted) to food in the Netherlands for 2017-2021, total and by pathogen

Pathogen	DALY (undiscounted)/year				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	1,700	1,800	1,800	1,300	1,400
STEC O157	56	56	56	59	61
Salmonella spp.	570	520	510	400	470
Listeria monocytogenes	220	210	140	140	410
Bacillus cereus	29	29	29	29	29
Clostridium perfringens	180	180	180	180	180
Staphylococcus aureus	190	190	190	190	190
Norovirus	270	320	310	140	240
Rotavirus	140	150	150	50	120
Hepatitis A virus	6	8	8	6	10
Hepatitis E virus	70	71	63	54	43
Cryptosporidium spp.	14	19	15	4	7
Giardia spp.	29	28	29	7	13
Toxoplasma gondii	1,100	1,100	1,000	1,100	1,100
Total	**4,600**	**4,600**	**4,600**	**3,600**	**4,200**

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 2017-2021, total and by pathogen

Pathogen	COI per year (4%)/year (Million €)				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	31	33	35	25	27
STEC O157	2	2	2	2	2
Salmonella spp.	9	9	9	7	8
Listeria monocytogenes	3	3	3	3	4
Bacillus cereus	10	10	10	11	11
Clostridium perfringens	26	27	27	27	28
Staphylococcus aureus	52	53	55	55	57
Norovirus	15	18	18	9	15
Rotavirus	8	9	8	4	7
Hepatitis A virus	0.1	0.1	0.1	0.1	0.2
Hepatitis E virus	0.8	0.8	0.8	0.7	0.5
Cryptosporidium spp.	2	3	2	1	1
Giardia spp.	2	2	2	1	1
Toxoplasma gondii	9	9	9	9	9
Total	**169**	**178**	**181**	**153**	**172**

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 the foodborne pathogens when using burden of disease metrics is different compared to the ranking based on disease incidence. We observed an increase in the number of incident cases for some of the 14 enteric food-related pathogens, especially for norovirus, rotavirus, hepatitis A and perinatal listeriosis compared to the year 2020.

The overall BoD of the 14 food-related pathogens in 2021 (9,100 DALYs) was higher than in 2020 (+25%), but still lower than in the years preceding the COVID-19 pandemic. The burden attributable specifically to foodborne transmission also increased compared to 2020 (from 3,600 DALYs to 4,200 DALYs; +17%), albeit proportionally less than the overall BoD. Also, the overall CoI and the foodborne related CoI increased in 2021 as compared to 2020 (+29% and +12%, respectively).

For four pathogens (*Salmonella*, *Campylobacter*, STEC, *Listeria monocytogenes*), 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 2021 attribution estimates for the BoD and CoI in comparison with the years preceding the COVID-19 pandemic, are due to the COVID-19 pandemic and not to the attribution method.

Some pathogens, such as the three toxin-producing bacteria (*Bacillus cereus, Clostridium perfringens, Staphylococcus aureus*), 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 the lack of up-to-date surveillance data. This means that the related DALYs and COI likely 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 and 2021. 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*. However, incidence data from these three peripheral diagnostic laboratories was not available for 2021. Therefore, we assumed the same increase from 2020 to 2021 for *Giardia* and *Cryptosporidium* as was observed for *Salmonella*.

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 experience or develop long-term complication due to the parasite. The percentage of infected children that later in life experience health problems, and the severity thereof 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.

References

1. Havelaar, A.H., et al., *Disease burden of foodborne pathogens in the Netherlands, 2009.* Int J Food Microbiol, 2012. **156**(3): p. 231-8.
2. Mangen, M.J.J., *Disease burden of food-related pathogens in the Netherlands, 2015*, in *RIVM Letter report 2017-0060*. 2017, National Institute for Public Health and the Environment: Bilthoven. p. 42.
3. Mangen, M.J.J., *Disease burden of food-related pathogens in the Netherlands, 2017*, in *RIVM Letter report 2018-0037*. 2018, National Institute for Public Health and the Environment: Bilthoven. p. 52.
4. Pijnacker, R., *Disease burden of food-related pathogens in the Netherlands, 2018*, in *RIVM Letter report 2019-0086*. 2019, National Institute for Public Health and the Environment: Bilthoven. p. 50.
5. Lagerweij, G.R., et al., *Disease burden of food-related pathogens in the Netherlands, 2019*, in *RIVM Letter report 2020-0117*. 2020. p. 51.
6. Benincà, E., et al., *Disease burden of food-related pathogens in the Netherlands, 2020*. 2021. p. 50.
7. Havelaar, A.H., et al., *Attribution of foodborne pathogens using structured expert elicitation.* Foodborne Pathog Dis, 2008. **5**(5): p. 649-59.
8. Mughini-Gras, L., et al., *A statistical modelling approach for source attribution meta-analysis of sporadic infection with foodborne pathogens.* Zoonoses and Public Health, 2022.

Annex: Detailed results

Table A.1 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 1999-2021

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
2021	**24**	**6**	**4**	**13**	**19 [c]**	**82**	**11**	**12**	**4**	**55**	**22**	**78**	**23 [q]**	**1**

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; q) known for 76/78 cases.

Table A.2 Mean number of incident cases by pathogen in the Netherlands, 2017-2021

Pathogen	**Estimated mean number of incident cases/year**				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	67,000	71,000	73,000	47,000	51,000
STEC O157	2,100	2,100	2,100	2,200	2,200
Salmonella spp.	27,000	27,000	26,000	17,000	20,000
Listeria monocytogenes	115	78	120	96	94
B. cereus toxin	53,000	53,000	53,000	53,000	54,000
C. perfringens toxin	171,000	171,000	173,000	174,000	174,000
S. aureus toxin	287,000	288,000	289,000	289,000	289,000
Norovirus	515,000	615,000	585,000	265,000	453,000
Rotavirus	209,000	224,000	211,000	74,000	173,000
Hepatitis A virus	1,800	900	700	200	380
Hepatitis E virus	1,300	1,300	1,200	1,000	790
Cryptosporidium spp.	69,000	91,000	72,000	19,000	32,000
Giardia spp.	83,000	82,000	83,000	22,000	38,000
Toxoplasma gondii	770	770	760	770	780
Total	**1,490,000**	**1,630,000**	**1,570,000**	**963,000**	**1,287,000**

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, 2017-2021

Pathogen	Estimated mean number of fatal cases/year				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	49	47	53	36	37
STEC O157	4	4	4	4	4
Salmonella spp.	34	25	24	23	28
Listeria monocytogenes	12	6	16	19	15
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	56	69	66	30	52
Rotavirus	35	38	36	12	31
Hepatitis A virus	6	3	3	1	1
Hepatitis E virus	15	15	13	13	9
Cryptosporidium spp.	4	6	4	1	2
Giardia spp.	2	2	2	1	1
Toxoplasma gondii	12	12	12	12	12
Total	**240**	**238**	**245**	**163**	**200**

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 2017- 2021, total and by pathogen

Pathogen	2017	2018	2019	2020	2021
Campylobacter spp.	3,100	3,200	3,300	2,100	2,300
STEC O157	150	150	150	150	150
Salmonella spp.	1,200	1,100	1,100	800	900
Listeria monocytogenes	280	260	180	180	510
B. cereus toxin	32	32	33	33	33
C. perfringens toxin	200	200	200	200	200
S. aureus toxin	220	220	220	220	220
Norovirus	1,600	1,900	1,800	800	1,400
Rotavirus	1,100	1,200	1,100	390	920
Hepatitis A virus	200	100	90	28	42
Hepatitis E virus	510	510	460	390	310
Cryptosporidium spp.	120	160	120	30	56
Giardia spp.	220	220	220	60	100
Toxoplasma gondii	1,900	1,900	1,900	1,900	1,900
Total	**11,000**	**11,000**	**11,000**	**7,300**	**9,100**

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 2017-2021, total and by pathogen

Pathogen	COI per year (4%)/year (Million €, expressed in 2020 euros)				
	2017	**2018**	**2019**	**2020**	**2021**
Campylobacter spp.	56	60	62	42	46
STEC O157	6	6	6	6	6
Salmonella spp.	20	19	19	14	16
Listeria monocytogenes	3	3	4	3	5
B. cereus toxin	11	11	12	12	12
C. perfringens toxin	29	29	30	30	31
S. aureus toxin	61	61	63	64	65
Norovirus	92	109	106	52	87
Rotavirus	62	66	64	31	57
Hepatitis A virus	3	1	1	0.4	0.7
Hepatitis E virus	6	6	5	5	4
Cryptosporidium spp.	17	22	19	5	9
Giardia spp.	16	16	17	4	8
Toxoplasma gondii	15	15	15	16	16
Total	**397**	**426**	**423**	**282**	**363**

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, 2021

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	30,000	9,000	3,200	7,000	1,400	51,000
STEC O157	870	400	280	480	150	2,200
Salmonella spp.	10,000	2,200	3,400	2,700	1,100	20,000
Listeria monocytogenes	76	7	6	6	0	94
B. cereus toxin	48,000	590	640	590	3,900	54,000
C. perfringens toxin	157,000	3,800	3,700	3,700	5,600	174,000
S. aureus toxin	252,000	10,000	9,200	6,400	11,000	289,000
Norovirus	76,000	64,000	251,000	23,000	39,000	453,000
Rotavirus	22,000	29,000	101,000	5,200	15,000	173,000
Hepatitis A virus	89	89	120	0	88	380
Hepatitis E virus	110	200	60	85	340	790
Cryptosporidium spp.	3,900	9,000	8,900	4,400	6,400	32,000
Giardia spp.	4,900	9,000	13,000	4,000	6,700	38,000
Toxoplasma gondii	430	280	7	19	36	780
Total	**606,000**	**139,000**	**394,000**	**57,000**	**91,000**	**1,287,000**

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, 2021

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	22	7	2	5	1	37
STEC O157	2	0.7	0.5	0.9	0.3	4
Salmonella spp.	15	3	5	4	2	28
Listeria monocytogenes	12	1	0.9	0.9	0	15
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	9	7	29	3	5	52
Rotavirus	4	5	18	0.9	3	31
Hepatitis A virus	0.3	0.3	0.4	0	0.3	1
Hepatitis E virus	1	2	0.7	1	4	9
Cryptosporidium spp.	0.2	0.6	0.5	0.3	0.4	2
Giardia spp.	0.1	0.2	0.4	0.1	0.2	1
Toxoplasma gondii	7	4	0.1	0.3	0.6	12
Total	**82**	**32**	**58**	**16**	**16**	**200**

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, 2021

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	1,400	410	150.0	320	62	2,300
STEC O157	61	28	20.0	33	11	150
Salmonella spp.	470	100	150.0	120	49	900
Listeria monocytogenes	410	37	31.0	32	0	510
B. cereus toxin	29	0.4	0.4	0.4	2	33
C. perfringens toxin	180	4	4.0	4	6	200
S. aureus toxin	190	8	7.0	5	8	220
Norovirus	240	200	800.0	72	130	1,400
Rotavirus	120	160	540.0	28	82	920
Hepatitis A virus	10	10	13.0	0	10	42
Hepatitis E virus	43	78	24.0	34	130	310
Cryptosporidium spp.	7	16	15.0	8	11	56
Giardia spp.	13	24	35.0	11	18	100
Toxoplasma gondii	1,100	690	17.0	48	87	1,900
Total	**4,200**	**1,800**	**1,800.0**	**710**	**610**	**9,100**

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, 2021

Main pathway	Food	Environment	Human	Animal	Travel	Total
Campylobacter spp.	27	8	3	6	1	46
STEC O157	2	1	0.8	1	0.4	6
Salmonella spp.	8	2	3	2	0.9	16
Listeria monocytogenes	4	0.3	0.3	0.3	0	5
B. cereus toxin	11	0.1	0.1	0.1	0.9	12
C. perfringens toxin	28	0.7	0.7	0.7	1	31
S. aureus toxin	57	2	2	1	2	65
Norovirus	15	12	48	4	8	87
Rotavirus	7	10	33	2	5	57
Hepatitis A virus	0.2	0.2	0.2	0	0.2	0.7
Hepatitis E virus	0.5	1	0.3	0.4	2	4
Cryptosporidium spp.	1	2	2	1	2	9
Giardia spp.	1	2	3	0.8	1	8
Toxoplasma gondii	9	6	0.1	0.4	0.8	16
Total	**172**	**48**	**97**	**21**	**25**	**363**

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, 2021

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Campylobacter spp.	5,800	930	15,000	690	1,200	2,100	930	540	540	540	2,100	30,000
STEC O157	570	80	20	16	31	20	31	23	19	23	45	870
Salmonella spp.	770	2,300	1,400	1,600	720	430	610	320	430	600	1,300	10,000
Listeria monocytogenes	5	4	8	2	22	4	22	2	2	2	2	76
B. cereus toxin	3,500	1,700	770	1,700	2,800	960	960	820	8,100	26,000	1,200	48,000
C. perfringens toxin	75,000	13,000	11,000	4,400	6,500	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	75,000	30,000	252,000
Norovirus	2,400	2,300	2,200	1,400	1,500	12,000	5,500	2,300	3,900	3,800	38,000	76,000
Rotavirus	0	630	0	0	380	4,400	5,400	990	1,700	1,000	8,100	22,000
Hepatitis A virus	0	0	0	0	0	12	12	4	4	3	56	89
Hepatitis E virus	0	81	0	0	0	5	8	4	0	0	11	110
Cryptosporidium spp.	1,000	170	110	100	360	840	800	120	0	120	240	3,900
Giardia spp.	960	230	150	0	380	630	1,600	160	0	160	600	4,900
Toxoplasma gondii	99	220	21	0	20	16	25	0	0	10	25	430
Total	**109,000**	**42,000**	**50,000**	**18,000**	**51,000**	**46,000**	**32,000**	**14,000**	**38,000**	**118,000**	**88,000**	**606,000**

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, 2021

Food groups	Beef& lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans& animals	Total
Campylobacter spp.	4	0.7	11	0.5	0.9	2	0.7	0.4	0.4	0.4	2	22
STEC O157	1	0.1	0.04	0.03	0.06	0.04	0.06	0.04	0.04	0.04	0.08	2
Salmonella spp.	1	3	2	2	1	0.6	0.9	0.5	0.6	0.9	2	15
Listeria monocytogenes	0.7	0.7	1	0.3	3	0.7	3	0.3	0.4	0.4	0.4	12
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	0.3	0.3	0.3	0.2	0.2	1	0.6	0.3	0.5	0.4	4	9
Rotavirus	0	0.1	0	0	0.07	0.8	0.9	0.2	0.3	0.2	1	4
Hepatitis A virus	0	0	0	0	0	0.04	0.04	0.01	0.01	0.008	0.2	0.3
Hepatitis E virus	0	0.9	0	0	0	0.06	0.09	0.04	0	0	0.1	1
Cryptosporidium spp.	0.06	0.01	0.007	0.006	0.02	0.05	0.05	0.007	0	0.007	0.01	0.2
Giardia spp.	0.03	0.006	0.004	0	0.01	0.02	0.04	0.004	0	0.004	0.02	0.1
Toxoplasma gondii	2	3	0.3	0	0.3	0.2	0.4	0	0	0.2	0.4	7
Total	12	10	15	4	7	6	8	2	3	5	11	82

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, 2021

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Campylobacter spp.	260	42	660	31	55	93	42	24	24	24	93	1400
STEC O157	40	6	1	1	2	1	2	2	1	2	3	61
Salmonella spp.	35	100	62	72	32	19	28	15	19	27	58	470
Listeria monocytogenes	26	23	46	10	120	24	120	9	13	13	12	410
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	5	5	14	6	180
S. aureus toxin	14	15	15	6	28	11	4	3	14	56	23	190
Norovirus	8	7	7	5	5	37	18	7	13	12	120	240
Rotavirus	0	3	0	0	2	23	29	5	9	5	43	120
Hepatitis A virus	0	0	0	0	0	1	1	0.4	0.4	0.3	6	10
Hepatitis E virus	0	32	0	0	0	2	3	2	0	0	4	43
Cryptosporidium spp.	2	0.3	0.2	0.2	0.6	1	1	0.2	0	0.2	0.4	7
Giardia spp.	3	0.6	0.4	0	1	2	4	0.4	0	0.4	2	13
Toxoplasma gondii	240	530	51	0	49	39	62	0	0	24	60	1100
Total	720	780	860	130	300	270	320	73	100	200	430	4200

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, 2021

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Campylobacter spp.	5	0.8	13	0.6	1	2	0.8	0.5	0.5	0.5	2	27
STEC O157	2	0.2	0.06	0.04	0.08	0.06	0.08	0.06	0.05	0.06	0.1	2
Salmonella spp.	0.6	2	1	1	0.6	0.3	0.5	0.3	0.3	0.5	1	8
Listeria monocytogenes	0.2	0.2	0.4	0.1	1	0.2	1	0.09	0.1	0.1	0.1	4
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	14	2	2	0.8	1	2	2	0.7	0.7	2	1	28
S. aureus toxin	4	5	4	2	8	3	1	1	4	17	7	57
Norovirus	0.5	0.4	0.4	0.3	0.3	2	1	0.4	0.8	0.7	7	15
Rotavirus	0	0.2	0	0	0.1	1	2	0.3	0.6	0.3	3	7
Hepatitis A virus	0	0	0	0	0	0.02	0.02	0.01	0.01	0	0.1	0.2
Hepatitis E virus	0	0.4	0	0	0	0.03	0.04	0.02	0	0	0.06	0.5
Cryptosporidium spp.	0.3	0.04	0.03	0.03	0.1	0.2	0.2	0.03	0	0.03	0.06	1
Giardia spp.	0.2	0.05	0.03	0	0.08	0.10	0.30	0.03	0	0.03	0.1	1
Toxoplasma gondii	2.0	5.00	0.40	0	0.40	0.30	0.50	0	0	0.2	0.5	9
Total	29	16	22	5	14	12	10	4	9	27	22	172

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).

RIVM
Committed to *health and sustainability*