Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) on the control strategies to reduce the burden of *Campylobacter* spp. in fresh poultry meat (broiler)

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Reference number: AESAN-2012-005

Report approved by the Scientific Committee on plenary session September 19th, 2012

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Abstract

Campylobacteriosis is a foodborne disease that affects humans mainly due to manipulation and consumption of broiler meat contaminated with different species of *Campylobacter*. Nevertheless the infection can also be acquired through contact with carriers and environmental exposure.

The main reservoir for *Campylobacter* spp. are birds, along with cattle, sheep, pigs, rodents, cats and dogs and wild mammals and birds. The reservoir spectrum varies according to the species: *C. jejuni* is widely spread whilst *C. coli* is more frequently isolated from pigs. Primary acquisition of *Campylobacter* spp. from animals occurs after birth and although it can be a cause of morbi-mortality in these animals, in most cases colonization leads to a state of permanent carrier (Humphrey and Jorgensen, 2006).

The last European Food Safety Authority report on zoonosis, zoonotic agents and foodborne outbreaks (EFSA, 2012) registered in 2010 shows that *Campylobacter* spp. is still the foodborne pathogen responsible for the largest number of cases (212,064). In the European Union (EU), the notification rate increased from 45.6 per 100,000 in 2009 to 48.6 per 100,000 in 2010. Remarkably the notification rate of confirmed campylobacteriosis has shown a growing trend in the last five years (2006-2010), especially since 2008.

Campylobacteriosis causes acute enterocolitis with discomfort, fever, severe abdominal pain and aqueous and/or bloody diarrhea. The incubation period varies from 1 to 11 days (usually 1-3 days). In most cases, the diarrhea is self-limiting. Bacteraemia occurs in less than 1% of the patients with enteritis and provoke after-effects like rheumatoid disorders or peripheral neuropathies (Guillain-Barré syndrome).

Translated from the original published in the journal: Revista del Comité Científico de la AESAN, 16, pp: 21-55

Control strategies to reduce the burden of *Campylobacter* spp. in broiler meat must be based on the strict implementation of Good Hygiene Practices (GHP) and the Hazard Analysis and Critical Control Points (HACCP) system along the whole food chain.

Key words

Campylobacter spp., broiler meat, Guillain-Barré syndrome, decontamination.

Introduction

The high incident rate of campylobacteriosis in the population, mainly due to the handling and consumption of undercooked chicken, has led the Executive Director of the Spanish Agency for Food Safety and Nutrition (AESAN) to request the Scientific Committee to prepare a report on the control measures which would permit the presence of *Campylobacter* spp. in fresh poultry meat (broilers) to be reduced.

The microorganisms identified as *Campylobacter* spp. are widespread in the natural environment, although the most common reservoir is the intestinal tract of mammals and birds, both domestic and wild. Carrier animals rarely develop the disease. *Campylobacter* spp. easily contaminates food, including meat and meat products, milk and milk products, fish and fish products, water, fruit and vegetables. However, the handling and consumption of poultry meat, and of unpasteurised milk and milk products and contaminated water, are the most common source by which humans acquire *Campylobacter* spp. The high incident rate of enteric infection with *Campylobacter* spp. and the possible existence of sequelae suggests the need to develop methodologies for the prevention and control of its presence in food (Rosenquist et al., 2003, 2006) (ELIKA, 2006).

In the European Union, between 2 and 20 million cases of infection with *Campylobacter* spp. are estimated to occur every year (EFSA, 2010). On a global level, the number of cases registered is estimated to be between 400 and 500 million (Ganan et al., 2012). The species most commonly associated with human infection are *C. jejuni* followed by *C. coli* and *C. lari*. These bacteria are widespread in the natural environment, although their most common reservoir is the intestinal tract of birds and mammals. Studies carried out in England, Scotland and New Zealand using Multilocus Sequence Typing (MLST) have identified broiler meat as the main source of transmission of *Campylobacter* spp. to humans (50-80% of all cases), demonstrating that the most isolated genotypes in humans are also the most isolated in broilers (Strachan and Forbes, 2010).

In humans, the incubation period of campylobacteriosis may range from between one and eleven days. Symptoms include acute diarrhoea which may be bloody, abdominal pain, fever, headaches and nausea. The infections are generally self-limiting and only last a few days. Complications are attributed to their gastrointestinal spread. Bacteraemia occur in <1% of patients with enteritis, and sequelae may occur in the form of rheumatic disorders or peripheral neuropathies.

Strategies for the control of *Campylobacter* spp. in broiler meat must be based on the strict application of Good Hygiene Practices and of the HACCP system throughout the food chain.

Risk assessment

The genus *Campylobacter* is considered to be responsible for human enteric infections (Friedman et al., 2000) (Doyle and Erickson, 2006), and therefore poses a major problem to public health. In the majority of industrialised companies, infections with *Campylobacter* spp. are more frequent than those due to *Salmonella* spp., *Shigella* spp., or *E. coli* O157:H7.

1. Hazard identification

The genus *Campylobacter* comprises 23 species and this number is constantly increasing due to the identification of new species. The majority of human cases are caused by *C. jejuni* (80%) and, to a lesser degree, by *C. coli* (10%). *C. jejuni* comprises two subspecies (*C. jejuni* subsp. *jejuni* and *C. jejuni* subsp. *doylei*). In humans the disease appears sporadically and outbreaks are less common. Other species including *C. upsaliensis*, *C. lari* and *C. fetus* have also been associated with diarrhoea in man.

The microorganisms of the genus *Campylobacter* are gram-negative, S-shaped or spiral shaped bacteria, moving with unipolar or bipolar flagella and are microaerophilic. Thermophilic *Campylobacter* spp. (optimum development at 42-43 ºC), and which include *C. jejuni*, *C. coli*, *C. lari*, *C. upsaliensis* and *C. helveticus*, are considered to be the most frequent source of gastroenteritis in humans.

Species of the genus *Campylobacter* are sensitive to factors such as low water activity, heat, irradiation ultraviolet light, salt, etc. In contrast to other food pathogens such as *Salmonella* spp., they do not multiply in food. However they can survive in the external environment if protected from dryness which is one of the major stresses for this organism. Many surface water sources are contaminated by animal manure containing *Campylobacter* spp. In slurries and in standing water they can survive for up to three months (Nicholson et al., 2005).

Species of the genus *Campylobacter* are found in the gastrointestinal tract of domestic and wild animals. The main reservoir of *Campylobacter* spp. is poultry (broilers, layers, ducks, turkeys, geese, quails, ostriches, etc.) (Wassenaar and Blaser, 1999) (Newel and Wagenaar, 2000) (Waldenstrom et al., 2002). Other reservoirs include cattle, sheep, pigs, rodents, dogs and cats and other mammals and wild birds. The spectrum of reservoirs varies with each species: *C. jejuni* is widespread, whereas *C. coli* is most frequently isolated in pigs. Primary acquisition of *Campylobacter* spp. by animals usually takes place soon after birth, and although it can be a cause of morbidity and mortality in these animals, most of the time colonisation leads to a permanent condition in the carrier.

The broad spectrum of animal reservoirs is probably the source of the majority of infections in humans. The most frequent path of infection is the consumption of meat from carrier animals or unpasteurised milk. Another less common path is contact with infected animals, either domestic pets or due to an occupational accident of those persons exposed to livestock. Many human serotypes have also been identified in animals.

Campylobacter spp. can survive in water for several weeks and persist in standing and waste water from a variety of sources, such as slaughterhouses or waste water treatment plants, eventually entering surface water sources, water reservoirs and drinking water. Thus, water treatment failure, the use of unchlorinated water or similar, or water drawn from wells may be the path used by the microorganism to reach animals and humans. In fact, the drinking of contaminated water has been responsible for some outbreaks of campylobacteriosis, which may also appear linked to leisure activities such as bathing in contaminated water. Fecal contamination of soil is also a source of infection in humans, mainly as a result of eating vegetables grown on contaminated land or irrigated with faecal water.

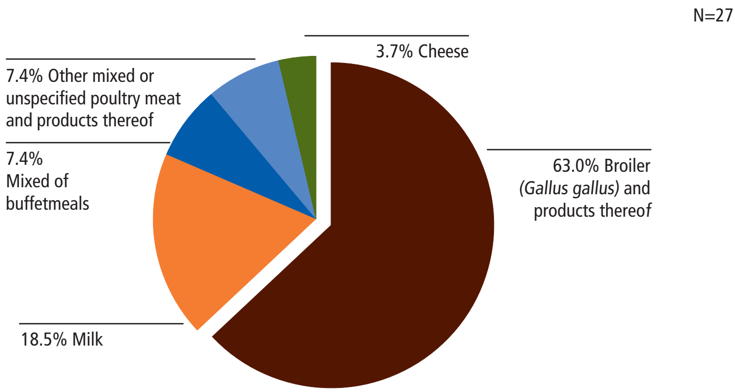
Insects such as flies in contact with faecal material, act as transmitters of *Campylobacter* spp. to the interior of animal farms, and may contaminate various sources.

In industrialised countries, *Campylobacter* spp. is mainly transmitted to humans through the consumption of food of animal origin (particularly undercooked broiler meat), whereas in developing countries, the most frequent path of transmission is from the intake of food or water contaminated with excrement, or direct contact with sick animals or humans.

As is the case with other enteric infections, fecal-oral transmission between infected individuals is possible, in particular, among children living in conditions of poor hygiene. Transmission from asymptomatically infected persons handling the food is rare, but is greater when the infection is symptomatic. This justifies the exclusion of handlers from the work environment while they are infected.

The report from EFSA (2012) lists the principal foods involved in the outbreaks attributed to *Campylobacter* spp. As shown in Figure 1, 63% are attributed to the consumption of broiler meat, 18.5% to the intake of unpasteurised milk, 7.4% to ready-prepared meals, 7.4% to meat from animal species other than broilers and 3.7% from cheese.

Figure OUT17. Distribution of food vehicles in strong evidence *Campylobacter* outbreaks in the EU, 2010

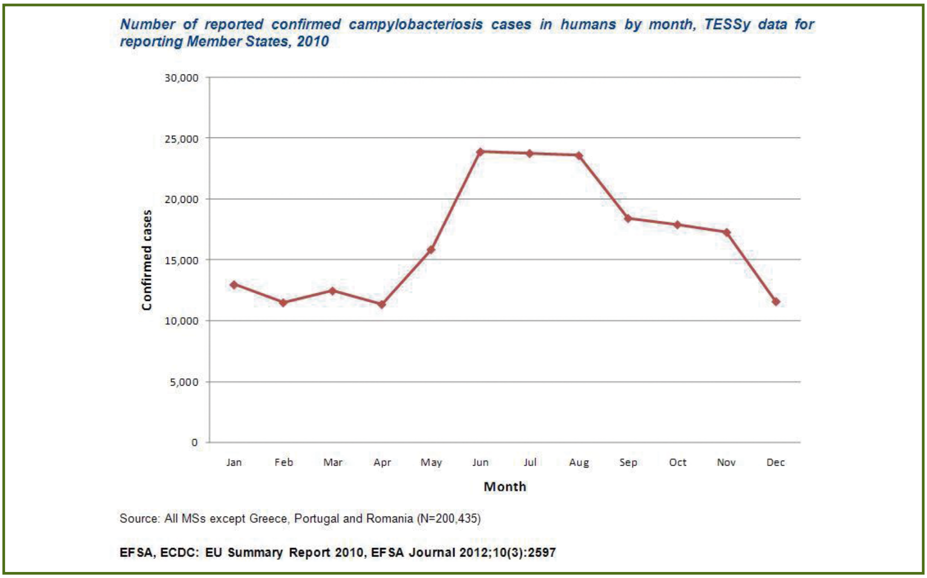


Note: Data from 27 outbreaks are included: Denmark (2), Finland (1), Germany (3), Ireland (1), Netherlands (2), Slovakia (2) and United Kingdom (16).

Figure 1. Distribution of food vehicles in strong evidence *Campylobacter* outbreaks in the EU, 2010. **Source:** (EFSA, 2012).

The association between the consumption of broiler meat and human campylobacteriosis is reflected in two food crises involving this animal species. In 1999, in Belgium, the detection of high concentrations of dioxins in feed intended for use on broiler farms led to the withdrawal from the market of the meat and eggs from this animal species, coincidently observing a 40% reduction in the human cases of campylobacteriosis. In May 2003, in Holland, as a consequence of an outbreak of avian influenza, a large number of broilers from different poultry farms were slaughtered, and this also contributed to a reduction of more than 40% of the cases of campylobacteriosis (EFSA, 2010).

All over the world, the number of cases of campylobacteriosis increases in the summer and early autumn, coinciding with the increase of ambient temperatures (Figure 2). The majority of *Campylobacter* spp. are sensitive to environmental conditions making their survival away from the host for any length of time unfeasible (Nachamkin, 1997). Factors impeding their multiplication in foods include: 1) an acid pH and dryness, 2) as they are microaerophiles, oxygen tension in the air inactivates them, 3) their growth at temperatures below 30 ºC is minimum, or even zero (in order to multiply they require temperatures of between 42 ºC and 45 ºC), and 4) they are sensitive to the majority of known disinfectants. Freezing has proven to be a good system for controlling *Campylobacter* spp. However, it has been demonstrated that some strains are able to survive for several months.



Note: The figures for cases in humans were collected at the European Centre for Disease Prevention and Control (ECDC) using the European Surveillance System (TESSy). TESSy is a computer platform which has been use since April 2008 and which collects data for 49 infectious diseases.

Figure 2. Number of reported confirmed campylobacteriosis cases in humans by month, TESSy data for reporting Member States, 2010. **Source:** (EFSA, 2012).

2. Hazard characterisation

Campylobacteriosis in human beings causes acute enterocolitis which is characterised by a feeling of sickness, fever, severe abdominal pain and watery or bloody diarrhoea. The incubation period ranges between 1-11 days (normally 1-3 days). In the majority of cases, the diarrhoea tends to cure itself. Complications derived from infection with *Campylobacter* spp. are attributed to its gastrointestinal spread and include cholecystitis, pancreatitis, peritonitis and gastrointestinal haemorrhages (Van Vlirt and Ketley, 2001). Bacteraemia occur in <1% of patients with enteritis due to *Campylobacter* spp. However, its invasive capacity is lower than that of other enteric pathogens. The mortality rate due to infection with *Campylobacter* spp. is 0.05 people per 1,000 affected.

C. jejuni and *C. coli* are recognised as the species responsible for the majority of gastrointestinal infections, with symptoms that are difficult to distinguish for both species. *C. upsaliensis, C. hyointestinalis, C. concisus* and *C. lari* have also been associated with gastrointestinal infection in humans. Several biovars of *C. sputorum* and *C. fetus* have also been linked to extraintestinal infections, whereas *C. mucosalis* has been isolated from patients with enteritis. *C. rectus, C. showae* and *C. gracilis* have also been isolated from periodontal infections (Nachamkin, 1997). In severe cases of the disease, the recommended treatment is with Erythromycin, although Fluoroquinolones, such as Ciprofloxacin and Norfloxacin may also be used.

Individuals exposed and colonised with *Campylobacter* spp. develop a humoral and cell-mediated immune response, which may provide protection in the event of successive exposure. In developed countries, the majority of infections are asymptomatic. In the United Kingdom and in Holland, only one out of 100 infections occurs with symptoms (EFSA, 2011).

Nevertheless, it should be noted that infections with *Campylobacter* spp. sometimes cause non-gastrointestinal sequelae, which are infrequent but severe (Smiyh, 1995). These infections include: 1) reactive arthritis, a non-infectious process affecting multiple articulations and associated to the phenotype HLA-B27, 2) the Guillain-Barré Syndrome (GBS), a demyelinating disorder of the nervous system with weakness, normally symmetric, of the eyelids and respiratory muscles, with a loss in reflexes and which may become chronic or mortal and 3), the Miller Fisher Syndrome (MFS), a variant of the GBS characterized by ophtalmoplegy, ataxia and arreflexia (Hadden and Gregson, 2001) (Nachamkin, 2002) (Schwerer, 2002) (Takahashi et al., 2005).

An analysis of the available bibliography shows that 20-50% of the cases of GBS originate from a previous infection with *Campylobacter* spp. and the incident rate of GBS in the population ranges from 0.6 to 1.9% (EFSA, 2010). In a study carried out in New Zealand (Baker et al., 2012) which analysed the cases of campylobacteriosis and of GBS for the period 1988-2010, the hospitalisations due to GBS were observed to be correlated to the notifications for campylobacteriosis. In patients admitted to hospital for campylobacteriosis, the risk of being hospitalised again due to GBS in the following 30 days was significantly higher. This study confirmed that following the adoption of measures aimed at reducing the contamination of broiler meat with *Campylobacter* spp., the number of notifications of cases of campylobacteriosis fell by 52% and the number of hospitalisations due to GBS by 13%. Therefore, the control measures for reducing campylobacteriosis are considered to have an additional effect, reducing the number of cases of GBS.

It has also been observed that 9% of those affected with the symptoms of enteritis went on to develop the infection with irritable bowel syndrome (IBS). In Holland, there are approximately 80,000 cases of campylobacteriosis per year, and the cost of the sequelae excluding IBS is estimated to be 21 million Euros per year. In Belgium, with 55,000 cases, the cost amounts to 27 million (EFSA, 2010).

The EFSA report (2006) underlines that a relatively high proportion of strains of *Campylobacter* spp. from animals and food are resistant to the antibiotics normally used in the treatment of human diseases. This is so, particularly in the case of the resistance to Fluoroquinones shown by strains of *Campylobacter* spp. from poultry, of which up to 94% were resistant to Ciprofloxacin.

In spite of the role of *Campylobacter* spp. as the cause of infection in humans, doubts remain about the biological mechanisms of their pathogenic activity (Haddad, 2010) (Silva et al., 2012). Nevertheless, it is known that the different isolations of *C. jejuni* are extraordinarily varied, in terms of phenotype and genetically, thus conditioning the characteristics of their potential virulence factors. These differences may be due to genomic plasticity, derived from the observation that the order, location and presence of genes is different in the different isolations assessed (Parkhill et al., 2000) (Fouts et al., 2005) (ELIKA, 2006) (Hofreuter et al., 2006).

Among the virulence factors associated with *Campylobacter* spp. the polar flagella play an active role in their mobility along the intestinal tract, adherence, invasion of human epithelial cells, and immunity. Another of the potential virulence mechanisms is the production of toxins, enterotoxins and cytotoxins, of which up to six were recognised and for which only the gene responsible for the synthesis of one of these (cdt) was found in its genome. It is also known that *Campylobacter* spp. invades the human epithelial cells using adhesion phenomena and cell invasion resulting in cell damage, loss of functionality and diarrhoea (Hernández, 2010). In addition, as is the case with other Gram negative bacteria, lipid A of the lipopolysaccharides (LPS) of the cell wall of *C. jejuni* has an endotoxic activity. Therefore a systemic infection may cause sepsis and shock, presumably as a result of the release of LPS. *C. jejuni* displays a varied antigenic structure derived from its lipopolysaccharides (LPS) or lipooligosaccharides (LOS). Interest in the role of the LPS/LOS in the pathogenicity of *C. jejuni* is the result of the recognition that these structures display homology with the neuronal gangliosides, which may contribute to the development of the *Guillain-Barré* Syndrome (Duim et al., 2000). *C. jejuni* also has two plasmids (pVir and pTet) which are possibly involved in its virulence.

The age distribution of the cases of infection with *Campylobacter* spp. is similar to other enteric pathogens in humans (EFSA, 2007). In industrialised countries, two peaks of activity have been observed: in children under 4 years of age and in young people aged between 15 and 24 (Figure 3). There is increasing evidence that the immunity acquired as a consequence of successive exposure to *Campylobacter* spp., may play a major role in providing protection against the disease (Cawthraw et al., 2000).

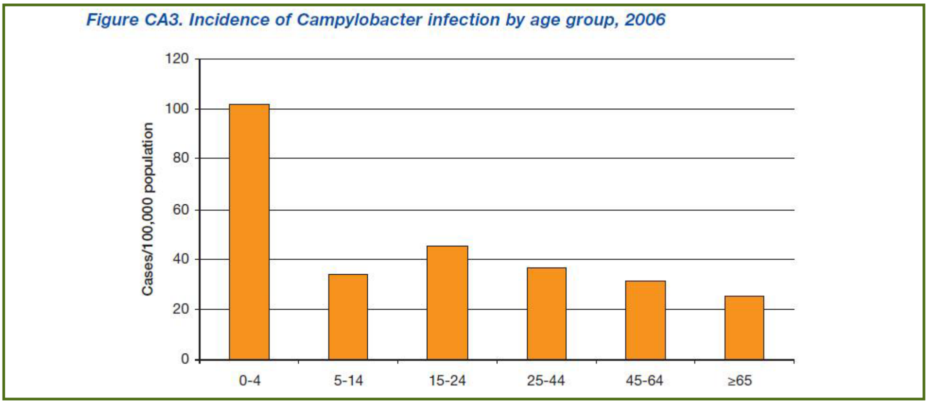


Figure 3. Incidence of *Campylobacter* infection by age group. **Source:** (EFSA, 2007)

Species of the *Campylobacter* genus are sensitive to low pH levels and, therefore, conditions in the gastrointestinal tract should be adequate for eliminating or reducing the majority of strains of *C. jejuni* that pass through it (Allos, 2001). However, paradoxically, infective doses of less than 1,000 cells of *C. jejuni* are able to start the disease (Haddad et al., 2010).

The latest report from EFSA (2012) on zoonoses, zoonotic agents and foodborne outbreaks recorded in 2010 shows that *Campylobacter* spp. continues to be the foodborne pathogen responsible for the greatest number of cases (212,064) (Figure 4).

Figure SU1. Reported notification rates of zoonoses in confirmed human cases in the EU, 2010

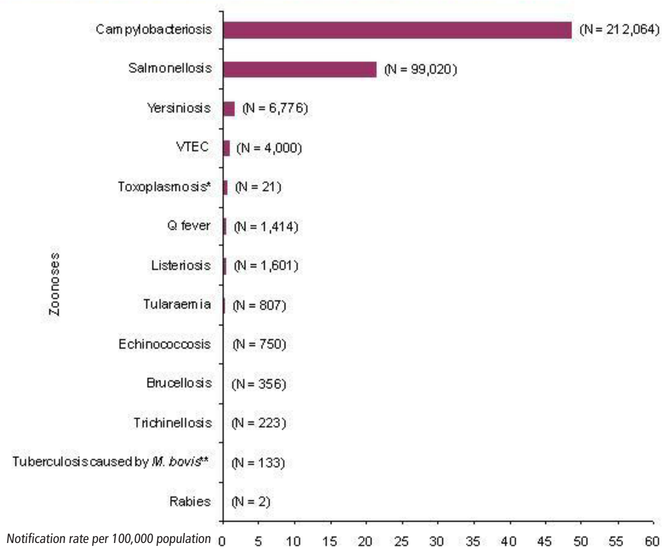


Figure 4. Reported notification rates of zoonoses in confirmed human cases in the EU, 2010. **Source:** (EFSA, 2012).

In the European Union, the number of confirmed cases of campylobacteriosis in humans increased by 6.7% in 2010 with respect to 2009. In Spain 6,340 cases were confirmed (Figure 5).

Figure 5. Reported campylobacteriosis cases in humans 2006-2010 and notifications rates for 2010.
Source: (EFSA, 2012)

		2010			2009	2008	2007	2006
Country	**Report type[1]**	**Cases**	**Confirmed**	**Confirmed cases/100,000**	**Confirmed cases**			
Austria	C	4,405	4,405	52.60	1,516	4,280,	5,822	5,020
Belgium	C	3,031	3,031	27.96	5,697	5,111	5,895	5,771
Bulgaria	A	6	6	0.8	26	19	38	75
Cyprus	C	55	55	6.85	37	23	17	2
Czech Republic	C	21,164	21,075	200.58	20,259	20,067	24,137	22,571
Denmark	C	4,037	4,037	72.94	3,353	3,470	3,868	3,239
Estonia	C	197	197	14.70	170	154	114	124
Finland	C	3,944	3,944	73.70	4,050	4,453	4,107	3,439
France	C	4,324	4,324	6.68	3,956	3,424	3,058	2,675
Germany	C	65,713	65,110	79.59	62,787	64,731	66,107	52,035
Greece	-[4]	-	-	-	-	-	-	-
Hungary	C	7,201	7,201	71.91	6,579	5,516	5,809	6,807
Ireland	C	1,662	1,660	37.15	1,810	1,752	1,885	1,812
Italy	C	457	457	0.76	531	265	676	801
Latvia	C	1	1	0.04	0	0	0	0
Lithuania	C	1,095	1,095	32.89	812	762	564	624
Luxembourg	C	600	600	119.51	523	439	345	285
Malta	C	204	204	49.40	132	77	91	54
Netherlands[2]	C	4,322	3,983	46.21	3,739	3,341	3,289	3,186
Poland	C	375	367	0.96	359	270	192	157
Portugal	-[4]	-	-	-	-	-	-	-
Romania	C	179	175	0.82	254	2	-	-
Slovakia	C	4,578	4,476	82.51	3,813	3,064	3,380	2,718
Slovenia	C	1,022	1,022	49.93	952	898	1,127	944
Spain[3]	C	6,340	6,340	55.14	5,106	5,160	5,331	5,889
Sweden	C	8,001	8,001	85.66	7,178	7,692	7,106	6,078
United Kingdom	C	70,298	70,298	113.37	65,043	55,609	57,849	52,134
EU Total		**213,211**	**212,064**	**48.56**	**198,682**	**190,579**	**200,807**	**176,440**
Iceland	C	55	55	17.32	74	98	93	117
Liechtenstein	-	-	-	-	-	2	0	10
Norway	C	2,682	2,682	55.21	2,848	2,875	2,836	2,588
Switzerland[5]	C	6,604	6,604	85.05	7,795	7,552	5,834	5,240

[1]A: aggregated data report; C: case-based report; no report.

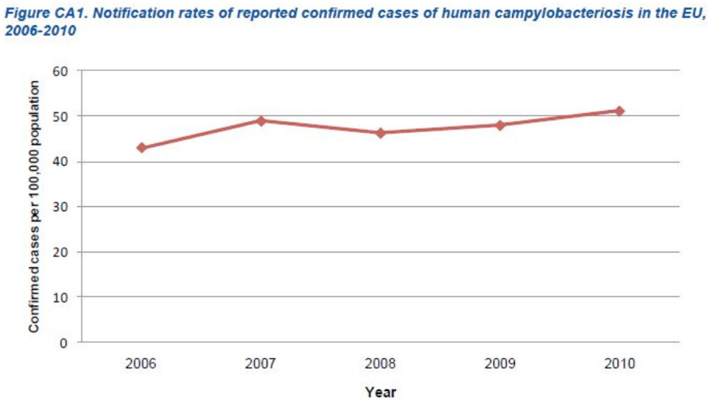
[2]Sentinel system; notification rates calculated on estimated coverage of 52%.

[3]Surveillance system; notification rates calculated on estimated coverage of 25%.

[4]No surveillance system exists.

[5]Switzerland provided data directly to EFSA.

In the EU, the notification rate went from 45.6 cases per 100,000 inhabitants in 2009 to 48.6 in 2010 (Figure 6).



Source (for EU trend): Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuana, Luxembourg, Malta, Netherlands, Poland, Slovakia, Slovenia, Spain, Sweden, and United Kingdom.

Figure 6. Notification rates of reported confirmed cases of human campylobacteriosis in the EU, 2006-2010. **Source:** (EFSA, 2012).

The number of deaths attributed to this pathogen was 266. As in previous years, children under five had the highest rate of notification (126.8 per 100,000 inhabitants). In general, the notification rates went up in all the population groups, although the mortality rate was relatively low (0.22%). It is important to note that the reporting of cases of campylobacteriosis is voluntary in some countries, including Spain (Figure 7). Therefore, in the European Union, between 2 and 20 million clinical cases of campylobacteriosis in humans are estimated to occur (EFSA, 2010, 2011).

Figure 7. Notification on Campylobacter in humans (V=Voluntary, O= Other), animals and food 2010. **Source:** (EFSA, 2012)

Country	Notifiable in humans since	Notifiable in animals since	Notifiable in food since
Austria	1947	no	1975
Belgium	2000 V	1998	2004
Bulgaria	yes	-	-
Cyprus	2005	-	-
Czech Republic	yes	no	yes
Denmark	1979	no	no
Estonia	1988	2000	yes[1]
Finland	1995	2004[2]	no[3]
France	2002 V	-	-
Germany	no	yes[4]	yes
Greece	-	no	no
Hungary	1998	no	no
Ireland	2004	1992	no
Italy	1990 V	no	1962
Latvia	1999	yes	2004
Lithuania	1990	>30 years	-
Luxembourg	yes	no	-
Malta	yes	-	-
Netherlands	yes V	yes	yes
Poland	2004	-	-
Portugal	no	no	-
Romania	yes	no	-
Slovakia	1980's	no	2000
Slovenia	1987	no	2003
Spain	1989 V	1994	1994
Sweden	1989	no	no
United Kingdom	no 0	no	no
Iceland	yes	-	-
Liechtenstein	yes	-	-
Norway	1991	yes[5]	yes[5]
Switzerland	yes	1966	no

[1]In Estonia, only *C. jejuni*.

[2]In Finland, *Campylobacter* notifiable in *Gallus gallus* only.

[3]In Finland, food business operator has to notify to the competent authority, but there is no central notification system.

[4]In Germany, *Campylobacter* is notifiable in cattle (veneric infection).

[5]In Norway, only positive samples from *Gallus gallus* detected in the national control programme.

According to the report from the EFSA (2012), the species of *Campylobacter* identified in 2010 were *C. jejuni* (35.7%), *C. coli* (2.3%), *C. lari* (0.22%) and *C. upsaliensis* (0.006%). In 2010, 51.8% of the 212,063 cases attributed to *Campylobacter* spp. were not classified at species level.

The incidence of outbreaks associated with direct contact either with carrier animals or as a result of the intake of contaminated food or water is not known precisely. Nevertheless, the report from the EFSA (2012) recorded a total of 470 outbreaks, of which strong evidence of the food involved was only available in 27 cases (Figure 8).

Figure 8. Strong and weak evidence food-borne outbreaks caused by Campylobacter (excluding strong evi dence outbreaks), 2010. **Source:** (EFSA, 2012)

	Total Outbreaks		Strong evidence outbreaks				Weak evidence outbreaks			
		Reporting rate		Human cases				Human cases		
Country	**N**	**per 100,000**	**N**	**Cases**	**Hospitalised**	**Deaths**	**N**	**Cases**	**Hospitalised**	**Deaths**
Austria	82	0.98					82	185	27	0
Belgium	2	0.02					2	4	0	0
Czech Republic	3	0.03					3	26	0	0
Denmark	3	0.09	2	46	1	0	1	2	1	0
Estonia	6	0.45					6	13	0	0
Finland	3	0.06	1	3	0	0	2	10	4	0
France	20	0.03					20	168	9	0
Germany	149	0.18	3	42	0	0	146	381	24	0
Hungary	29	0.29					29	66	11	0
Ireland	1	0.02	1	5	1	0	0	0	0	0
Italy	6	0.01					6	12		
Lithuania	1	0.03					1	2	2	0
Malta	19	4.59					19	48		0
Netherlands	17	0.10	2	24	0	0	15	43	3	0
Poland	5	00.1					5	20	4	0
Slovakia	98	1.81	2	20	1	0	96	289	28	0
Spain	2	<0.01	0	0	0	0	2	5	0	0
Sweden	6	0.06					6	25	5	0
United Kingdom	18	0.03	16	258	7	0	2	92	4	0
EU Total	**470**	**0.10**	**27**	**398**	**10**	**0**	**443**	**1,391**	**122**	**0**
Norway	5	0.10					5	18	0	0
Switzerland	1	0.01					1	3	0	0

Unlike other food-borne bacteria, the majority of cases of campylobacteriosis are sporadic, and the appearance of outbreaks affecting several individuals is infrequent.

As regards the triggering causes of the outbreak, 20 cases (74.1%) were attributed to inadequate hygiene practices in restaurants, cafés and hotels (Figure 9). The handling of raw broiler meat and cross contamination during the preparation of food in a domestic or restaurant environment is a critical point of control in the reduction of human campylobacteriosis (Riedel et al., 2009).

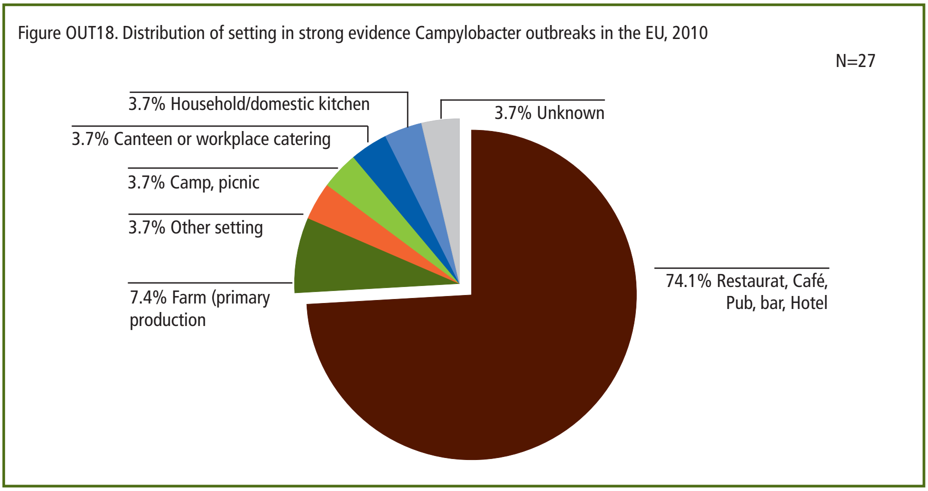


Figure 9. Distributions of settings in strong evidence *Campylobacter* outbreaks in the EU, 2010. **Source:** (EFSA, 2012).

3. Evaluation of exposure

To assess the presence of *Campylobacter* spp. in poultry meat (broilers) the prevalence of the microorganism on poultry farms, at slaughter houses and in subsequent stages of commercialisation should be considered.

The colonisation of the intestinal tract of poultry with *Campylobacter* spp. depends on the efficiency of the introduction of biosecurity programmes on poultry farms, as there is no vertical transfer to the egg, and the chicks are born free of *Campylobacter* spp. (FAO/WHO, 2001, 2002, 2003). A study carried out in the European Union on the prevalence of *Campylobacter* spp. in fecal droppings of the broilers, revealed 82.2% of positive samples compared to 59.6% in 2009 in Spain (Figure 10).

Figure 10. Campylobacter in broilers, 2008-2010. **Source:** (EFSA, 2012)

	2010		2009		2008	
Country	**N**	**% pos**	**N**	**% pos**	**N**	**% pos**
Broilers (animal-based data)						
Czech Republic	-	-	-	-	422	69.9
France	196	78.1	191	80.6	-	-
Hungary[2]	439	66.5	713	78.0	325	54.2
Romania	51	100	104	100	-	-
Total animal-based (3 MSs in 2010)	**686**	**72.3**	**1,008**	**80.8**	**747**	**63.1**
Broilers (flock-based data)						
Austria[1]	394	46.7	326	55.5	-	-
Czech Republic[1]	134	72.4	-	-	422	61.1
Denmark[10]	3,132	16.5	4,591	29.4	4,912	25.9
Estonia[1]	47	0	48	0	-	-
Finland[1.6]	338	1.8	-	-	-	-
Finland[1.7]	1,409	6.0	1,720	4.8	1,276	6.5
Germany[2.4]	-	-	149	15.4	345	32.2
Germany[2.5]	-	-	332	10.2	-	-
Lithuania	-	-	-	-	374	42.0
Poland	-	-	-	-	420	79.0
Slovenia[1.8]	100	88.0	157	73.2	-	-
Slovenia[1.9]	99	92.9	149	83.9	-	-
Spain[1]	202	82.2	198	59.6	-	-
Sweden[1]	3,357	13.2	3,219	12.0	2,398	12.4
United Kingdom[1]	-	-	400	77.5	-	-
Total flock-based (8 MSs in 2010)	**9,212**	**18.2**	**11,289**	**24.1**	**10,147**	**24.7**
Norway[2.3]	2,170	5.1	1,924	6.1	4,675	4.1
Switzerland	400	33.0	442	44.3	-	-

Note: Data are presented only for sample sizes $\geqslant$ 25. Clinical investigations not included.

[1]Slaughter batch-based data.

[2]At farm, Germany (2009). Hungary (2009) and Norway (2008-2010). For Norway (2008-2010), flocks sampled maximun four days before slaughter.

[3]Data from Norway 2009 and 2010 cover only the peak season, 1 May to 31 October.

[4]In Germany, surveillance in 2009.

[5]In Germany, monitoring in 2009.

[6]In Finland, sampling in January-May and November-December in 2010.

[7]In Finland, sampling between June and October in 2010.

[8]In Slovenia, caecum samples in 2010.

[9]In Solvenia, neck skin samples in 2010.

[10]Data from Denmark in 2010 are not comparable with previous years owing to a change in sampling strategy from cloacal swabs at slaughter to boot swabs 7-10 days prior to slaughter.

In Sweden, almost all poultry in the slaughterhouse are subject to an analytical control to detect *Campylobacter* spp. In a study carried out from July 2001 to June 2002, 17% of samples taken from cloacal swabs were found to be positive. In addition, it was noted that 8% of negative samples from cloacal swabs gave positive results in the skin analyses, indicating contamination by the operators and processing equipment. In the same study, the isolations obtained after the cooling process were compared using DNA restriction profile analysis. The isolations from the carcasses were also compared to those from the cloacal swabs and from the skin and neck. The results of this work showed that 1/3 of the positive carcasses contained more than one genotype. These results are in line with those of other authors, who state that all the carcasses are contaminated with the predominant genotype during the butchering of groups of positive poultry with *Campylobacter* spp. (Lindmark et al., 2006).

Studies on the colonisation of the intestinal tract of poultry (EFSA, 2010) reveal that this starts ten days after hatching; therefore age has been identified as a risk factor. Initial protection is believed to be due to the presence of protective maternal antibodies (Wassenar, 2011). Once *Campylobacter* spp. has colonised in the first birds through the drinking water, rodents, insects, operators, etc., it spreads rapidly to all the flock that become positive within a week. There are many studies which reveal the presence of *Campylobacter* spp. inside the different protozoa present in the birds' drinking water (Snelling et al., 2008). The higher level of resistance of the protozoa to the action of agents used in the disinfection of the water increases the capacity of *Campylobacter* spp. to colonise in the birds. In addition, colonisation is greater in the summer. This is attributed to the temperature and the increase in the number of flies which may act as vectors of transmission. Moreover, in summer ventilation and water consumption are increased due to the high temperatures. Another handling practice that increases colonisation of the intestinal tract of poultry is that related to the reduction in the density of birds in the flocks, supposing a stress for the birds. This practice requires time, personnel and equipment which may act as a source of transmission of the microorganism to the birds. Farm workers and other operators visiting the farm may also act as sources of contamination.

Birds that are positive with *Campylobacter* spp. eliminate concentrations of between 10^5 and 10^6 cfu/g in their droppings (Lindmark et al., 2006). The concentration in the cloacal content is normally high and may reach levels of 10^{10}cfu/g in birds which are only a few weeks old. Such high excretion levels determine the ease with which all the flock become positive with *Campylobacter* spp. and guarantee the easy spread of the microorganism to the materials and equipment with which the birds are in contact, not only on the farm but also during transportation and slaughtering at the slaughterhouse. At the slaughterhouse, the carcasses may be contaminated at different stages in the processing chain, particularly in the scalding, defeathering, evisceration stages and in the cooling tanks.

Figure 11 lists the data for the presence of *Campylobacter* spp. in samples of broiler meat taken at the slaughterhouse, processing plant and retail establishment. In 2010, 16 countries from the European Union submitted data to the Commission, and the proportion of positive samples amounted to 29.6% (with a prevalence ranging from 3.1% to 90.0%). In Spain, the percentage of positive samples taken at the slaughterhouse was 44.6%, at processing plants it amounted to 74.7% and in retail establishments it was 25.4%. With respect to the presence of *Campylobacter* spp. in meat from birds other than broilers, the incidence of positive samples submitted by Spain was 23.9%, but these figures did not specify to which species they belonged.

Figure 11. *Campylobacter* in fresh broiler meat, 2008-2010. **Source:** (EFSA, 2012)

			2010		2009		2008	
Country	**Sample unit**	**Sample weight**	**N**	**% pos**	**N**	**% pos**	**N**	**% pos**
At slaughter								
Belgium	Single	1 g	388	37.9	261	32.2	185	33.0
Denmark	Single	10 g/15 g	1,177	10.4	986	12.4	484	14.7
Estonia	Batch	1 g	47	8.5	48	6.3	-	-
Hungary	Single	25 g	170	54.1	-	-	-	-
Greece	Single	25 g	-	-	47	70.2	-	-
Ireland[4]	Single	Various	202	63.4	273	59.3	-	-
Italy	Batch	Not indicated	30	26.7	-	-	-	-
Poland	Single	400 cm^2	451	58.8	-	-	-	-
Romania[7]	Batch	1 g	225	40.4	266	34.2	-	-
Spain	Single	25 g	139	44.6	72	95.8	420	86.2
At processing plants								
Austria	Single	25 g	30	90.0	-	-	-	-
Belgium[1]	Batch	1 g	358	8.9	1,007	9.0	523	7.3
Germany	Single	25 g	107	47.7	45	35.6	78	33.3
Hungary	Single	25 g	77	29.9	291	26.8	-	-
Poland[6]	Single	10 g	118	89.0	-	-	-	-
Portugal	Single	25 g	108	19.4	-	-	-	-
Slovenia[8]	Single	1 g	100	79.0	101	67.3	-	-
Spain	Single	25 g	178	74.7	99	70.7	50	58.0
At retail								
Austria	Single	25 g	324	3.1	37	24.3	138	8.0
Belgium	Batch	1 g	439	12.1	199	12.1	-	-
Czech Republic	Single	25 g/27 g	-	-	120	75.0	-	-
Denmark[2]	Single	10 g/15 g	767	46.2	702	32.5	1,057	36.6
France	Single	1 g	-	-	120	90.0	-	-
	Single[9]	1 g	-	-	241	69.3	-	-
Germany[3]	Single[10]	25 g	681	28.5	633	28.6	887	36.4
	Single[11]	10 g	-	-	413	47.0	-	-
Hungary	Single	25 g	30	43.3	64	17.2	-	-
Latvia[5]	Single	25 g	50	10.0	-	-	205	9.8
Luxembourg	Single	10 g	68	58.8	84	79.8	122	49.2
Netherlands	Single	25 g	1,023	9.9	657	10.8	1,421	14.1
Slovenia	Single	25 g	-	-	106	78.3	315	74.6
Spain	Single	25 g	126	25.4	273	49.5	165	13.3
Sampling level not staded								
Italy	Batch	Not indicated	-	-	59	16.9	66	3.0
	Single	Not indicated	-	-	108	0	26	7.7
Total (16MSs in 2010)			**7,413**	**29.6**	**7,312**	**31.0**	**6,142**	**30.1**

4. Classification of the risk and control measures

According to the reports from ELIKA (2006,) EFSA (2008a), EFSA (2010), EFSA (2011), EFSA (2012), FSA (2010) and Vose Consulting (2011), there is a direct relationship between the prevalence of *Campylobacter* spp. in broiler carcasses and the disease in humans.

The reduction in the number of cases of infection with *Campylobacter* spp. in humans can be achieved with greater control of the breeding, transport, slaughtering at the slaughterhouse, processing and commercialisation of poultry carcasses intended for human consumption (Ross and Sumner, 2002) (Rosenquist et al., 2003) (Sears et al., 2011) (Wassenaar, 2011) (Silva et al., 2012). The reports from ELIKA (2006) and EFSA (2011) recommend the following control measures:

Biosecurity programmes on poultry farms

Biosecurity programmes on poultry farms must include:

- Training of farm workers in the importance of minimising the transmission of *Campylobacter* spp. and other pathogens through shoes, clothing, hands, etc. Therefore, they should have clothing and shoes exclusively for use on the farm, in addition to adequate facilities for personal hygiene.
- Control of personnel not working on the farm but who may visit the farm. Use of disposable shoes and clothing protection.
- Disinfection of vehicles entering the farm.
- Inclusion of suitable cleaning, disinfection, desinsectation and deratisation programmes.
- The installation of mosquito nets on the windows will prevent the entrance of insects inside the building, and therefore reduce this path of transmission, especially in summer when the number of positive animals increases. In primary production, the use of mosquito nets reduces the risk of campylobacteriosis in humans by between 50-90%.
- Avoid the use of water drawn from untreated or inadequately treated wells, as this increases the number of birds positive with *Campylobacter* spp. in the flock. Water must be treated by chlorinating, ozonation, ultraviolet radiation, etc. Sometimes the presence of *Campylobacter* spp. has been observed inside protozoa in the water or on the ground, thus increasing its resistance to the action of the chlorine.
- *Campylobacter* spp., as with other emerging zoonotic pathogens, is found in animal reservoirs. Therefore its presence can be reduced by incorporating probiotics, prebiotics, bacteriophages, antimicrobial peptides or bacteriocins in the feed (Loc Carrilo et al., 2005) (Stern et al., 2006) together with additives (caprylic acid, potassium sorbate, propionic acid, etc.). The administration of bacteriocins or bacteriophages to broilers two or three days before slaughter reduces the intestinal colonisation of the birds with *Campylobacter* spp. by three $\log_{10}$. A reduction of three $\log_{10}$ in the intestine of the poultry to be slaughtered would reduce the risk to humans by 90%.
- Stopping thinning is expected to reduce the risk of human campylobacteriosis by up to 25%.
- The reduction in the age of slaughter has also been identified as a risk factor. The prevalence of positive flocks is directly linked to the age of slaughter. The risk could be reduced by 50%, if the age of slaughter is reduced to a maximum of 28 days. In Sweden, where the birds are slaughtered at

33-35 days old, it has been observed that if the age is raised to 42-44 days, the number of positive birds doubles and if increased to between 48-61 days, it quadruples. An EFSA study in 2010 shows that the risk of colonisation of the birds with *Campylobacter* spp. doubles every ten days of age (EFSA, 2010).

- Development of genetic selection programmes. The objective of this is to obtain breeders resistant to colonisation with *Campylobacter* spp.
- The use of rapid microbiological techniques to identify flocks of positive birds prior to slaughter at the slaughterhouse and to be able to perform this at the end of the day (Krause et al., 2006).

Figure 12 summarises the control strategies at level of the animal farms.

Figure 12. Overall summary of effects of interventions. **Source:** (EFSA, 2011)

	Efficacy for *Campylobacter* reduction at the point of application	**Modelled**	**References**
Hygiene/biosecurity	At 21 days: from 20.0% to 7.7% between-flock prevalence (BFP)	Yes	Gibbens et al., 2001
	At 28 days: from 32.0% to 12.0% BFP		
	At 35 days: from 40.0% to 30.8% BFP		
	At 42 days: from 70.8% to 38.5% BFP		
	Implemented in model as the beta coefficient that corresponds to a bazard ratio of 0.40, (0.15, 1.09) p = 0.06		
Fly screens	At 21 days: from 11.4% to 5.8% BFP	Yes	Hald et al., 2007
	At 28 days: from 28.6 to 5.8% BFP		
	At 35 dats: from 45.5% to 7.7% BFP		
	Implemented in model as a slaughter age-weighted k-factor or 0.47 (21 days of slaughter age) 0.15 (28 days of slaughter age) and 0.10 (35 days of slaughter age)		
Discontinued thinning	BFP estimate OR = 1.74, implemented in model as regression coefficient (0.5521)	Yes	EFSA, 2010a
Slaughter age	BFP estimate OR = 1.98 per 10 days increase, implemented in model as regression coefficient (0.06742)	Yes	EFSA, 2010a
Vaccination	2 log_{10} reduction in caecal contents	No	de Zoete et al., 2007
Bacteriocins	5.1-5.9 log_{10} reduction in caecal contents	No	Svetoch et al., 2008
Bacteriophages	3 log_{10} reduction in caecal contents	No	Wagenaar et al., 2005
Drinking water treatment with organic acids	0.5-2 log_{10} reduction in caecal contents	No	Chaveerach et al., 2004
Feed additives	No effect to complete inhibition	No	Hilmarsson et al., 2006 Solis de los Santos et al., 2010 Skanseng et al., 2010

Animal transport

Compliance to regulations regarding animal welfare during transport helps to reduce the number of animals colonised with *Campylobacter* spp. The stress suffered by the animals must be minimised, by reducing the time and distances to the place of slaughter. In addition, the application of strict cleaning and disinfection programme in the cages and vehicles used for transport is essential (Figure 13).

Slaughterhouse

In the slaughterhouse, the correct introduction of the HACCP system is essential for reducing the number of *Campylobacter* spp. in carcasses. It is important to minimise cross contamination from processing equipment, tools used in butchering, operators, etc. The defeathering systems and cooling tanks require special attention (Figure 13).

Scheduled slaughters permit the identification of batches *Campylobacter* spp. positive birds prior to slaughter, enabling control methods to be adopted.

In accordance with the results of various risk analysis studies, the most effective control measures for reducing the risk of campylobacteriosis in humans consist in the application of decontamination or hygienisation of the carcasses after slaughter at the slaughterhouse. After slaughter, it is possible to achieve a 100% reduction with the application of irradiation or heat treatment, as long as recontamination is avoided. Washing the carcass with hot water, lactic acid, acidified sodium chlorite or trisodium phosphate permit reductions in the risk of 50-90%. Merely washing with hot water (80 ºC for 20 seconds) reduces the risk by 50-90%.

A $\log_{10}$ reduction in the number of *Campylobacter* spp. in the carcasses would reduce the risk by 40-90%. A reduction by more than two $\log_{10}$ would reduce the risk to humans by more than 90%.

In some countries, such as Denmark, negative carcasses are sold fresh and positive carcasses are frozen. Freezing reduces the number of viable microorganisms, but some may survive. However, the demand for fresh meat is far higher than the demand for frozen meat. A reduction of over 90% can be obtained if the carcasses are frozen for a period of 2-3 weeks and of 50-90% for periods of 2-3 days.

With respect to the establishment of microbiological criteria, reductions of >50% or up to 90% might be obtained if the poultry meat which is sold fresh has maximum levels of 1000 or 500 cfu per gram or cm^2 on the skin of the neck and breast.

Regulation (EC) 853/2004 of the European Parliament and the Council, of 29 April 2004 laying down specific hygiene rules for food of animal origin (EU, 2004), establishes in article 3.2 that food business operators shall not use any substance other than potable water, or when Regulation (EC) 852/2004 or 853/2004 permits its use, clean water, to remove surface contamination from products of animal origin, unless use of the substance has been approved in accordance with the procedure referred to in section 2 of Article 12.

Article 13 of Regulation (EC) 853/2004 also establishes that the Commission shall consult the European Food Safety Authority on any matter falling that could have a significant impact on public health. In this respect, the European Food Safety Authority has considered in various reports that the treatment of chicken carcasses with solutions of trisodium phosphate, sodium dichloride, chlorine dioxide or peracetic acid, does not imply a risk for the consumer. In addition it recommends that these solutions are applied with a spray rather than using dipping treatments (EFSA, 2005, 2008b). However, the Council of the European Union has rejected the use of antimicrobial substances to eliminate microbial contamination from the carcasses of poultry pending further scientific information to permit a more exhaustive risk assessment regarding the possibility that the approval of these substances might lead to an increase in resistance to antimicrobials that affect human beings, and therefore no decontaminating substances are authorised for use in the European Union (EU, 2009). Other alternatives include irradiation, high pressure, electric pulses, etc. (Liu et al., 2012).

Figura 13. Control measures in the transport and slaughter at the slaughterhouse to reduce campylobacteriosisin humans. **Source:** (EFSA, 2011

	Efficacy for *Campylobacter* reduction at the point of application	Modelled	References
Interventions during transport and before slaughter			
Feed withdrawal	Various results and various outcomes	No	
Crate treatment	7.5 log_{10} per crate compartment; 5.5 log per crate surface, 40-60% reduction of crate positivity	No	Berrang et al., 2004a Allen et al., 2008a Slader et al., 2002
Interventions at slaughter			
Prevention of leakage of intestinal contents	0.9 log_{10} CFU reduction on carcass	No	Boysen and Rosenquist, 2009
Detection/re-processing of highly (faecally) contaminated carcasses	1.75 log_{10} CFU on carcass	No	Kemp et al., 2001
Cloacal plugging	0.53-1.7 log_{10} CFU reduction	No	Musgrove et al., 1997 Berrang et al., 2001 Buhr et al., 2003
Scheduled slaughter (positive batches are scheduled to a risk reducing procedure such as freezing or heat treatment)	Depends on risk reducing procedure	Yes (not directly in model, but included by using baseline results and assuming a 100% effective treatment on scheduled batches	Hofshagen et al., 2008 EFSA, 2010a
Logistic slaughter (the slaughter of negative batches before the positive)	Very little effect	No	Havelaar et al., 2007
Interventions post slaughter			
Chemical decontamination of carcasses			
Lactic acid (2%)	0.47 log_{10} reduction (through inside-outside bird washer (IOBW) 0.74 log_{10} reduction (inoculated skin)	Yes	Bolder, 2007 Riedel et al., 2009

Figure 13. Control measures in the transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

	Efficacy for *Campylobacter* reduction at the point of application	Modelled	References
Chemical decontamination of carcasses			
Acidified sodium chlorite (1,200 mg/l)	1.26-1.75 log_{10} reduction (sprayed after IOBW)	Yes	Bashor et al., 2004
	1.75 log_{10} reduction (sprayed after IOBW)		Kemp et al., 2001
	0.5 log_{10} cycles (in IOBW)		Bolder, 2007
	0.5-1 log_{10} when sprayed at 1,000 ppm		Corry et al., 2008
Chlorine dioxide (50-100 mg/l)	0.49 log_{10} reduction (4.25 ppm in IOBW)	No	Bolder, 2007
	0.99-1.21 log_{10} reduction (50 or 100 ppm, dip-inoculated)		Hong et al., 2008
Trisodium phosphate (10-12%, pH 12)	1.03 log_{10} reduction (spray)	Yes	Bashor et al., 2004
	1.2 log_{10} reduction (dipping at 50 ºC)		Slavik et al., 1994
	No effect of dipping at 20 ºC		Whyte et al., 2001b
	0.5 log_{10} when sprayed at 12%		Corry et al., 2008
Acidified electrolysed oxidising water (immersion)	1.07 log_{10} reduction	No	Kim et al., 2005
Peracetic (peroxyacetic) acid	43% reduction of positive carcases	No	Bauermeister et al., 2008a
Physical decontamination of carcasses			
Freezing for few days	0.91-1.44 log_{10} reduction	Yes	Sandberg et al., 2005 Georgsson et al., 2006a Rosenquist et al., 2006
Freezing for 3 weeks	1.77-2.18 log_{10} reduction	Yes	Sandberg et al., 2005 Georgsson et al., 2006a
Hot water immersion	1.25 log_{10} reduction	Yes	Corry et al., 2006
Irradiation	6 log_{10} reduction	Yes	Farkas, 1998 or expert opinion
Cooking	6 log_{10} reduction	Yes	Whyte et al., 2006
Crust-freezing	0.42 log_{10} reduction	No	Boysen and Rosenquist, 2009
Steam	0.46 log_{10} reduction	No	Whyte et al., 2003
Steam ultrasound	1.3-2.51 log_{10} reduction	No	Boysen and Rosenquist, 2009

The advantages and disadvantages of the above control measures are summarised in Figure 14.

Figure 14. Advantages and disadvantages of the control measures applied in primary production, transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

Advantages, disadvantages and availability of interventions			
	Advantages in addition to a possible *Campylobacter* reducing effect	**Disadvantages**	**Availability**
Interventions in primary production			
Hygiene/biosecurity	Excludes other infectious (animal) diseases as well, some of economic importance	Complex mixture of factors, difficult to define and audit	Immediately available, but migh need modification of poultry houses
	Reduces environmental contamination and indirect transmission to humans	Very stringent implementation needed. Farmer compliance required. Only fully appicable to indoor rearing	General principles are well known but needs to be evaluated under local conditions. Only one intervention experiment in UK avalilable
Fly screens	Reminds the farmers of need for hygiene	Only fully applicable to indoor rearing	Rapidly available in theory
	Effective against seasonal peak in birds	Applicability depends on construction of poultry houses	Only tested in Denmark and Iceland
	Reduces environmental contamination and indirect transmission to humans	Needs maintenance for keeping efficiency	
Discontinued thinning	Avoids stress at thinning	Interferes with current industrial practices	Immediately available, in theory
	Increased animal welfare	Productivity and flexibility of industrial production will be altered	
Reduction of slaughter age	Potentially increased animal welfare	Interferes with current industrial practices Productivity and flexibility of industrial production will be altered For the organic and traditional free range chickens, the slaughter age must not be ower than 81 days	Immediately available, in theory
Vaccination	Applicable to both indoor and outdoor rearing	Most studies have been poorly reproducible	Vaccines are still in the development phase
	Multiple vaccines are often applied at same time and systems for the mass application of vaccines are available		
Bacteriocins	Applicable to both indoor and outdoor rearing	Scale-up of bacteriocin production and purification remains to be further elaborated	Preparations have been described, and patents have been applied for

Figure 14. Advantages and disadvantages of the control measures applied in primary production, transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

Advantages, disadvantages and availability of interventions			
	Advantages in addition to a possible *Campylobacter* reducing effect	**Disadvantages**	**Availability**
		Small-scale studies from only one research groups, its reproducibility remains to be confirmed Sustainability to be confirmed and take into account the variety of *Campylobacter* species, genotypes and the species' genetic variability Safety aspects for use to be confirmed	Not yet tested on large scale
Bacteriophages	Applicable to booth indoor and outdoor rearing	Emergence of phage-resisten *Campylobacter* strains needs to be further evaluated under field conditions Multiple phage populations will be required taking nto account the variety of *Campylobacter* species, genotypes and the species' genetic variability Sustainability to be confirmed	Only tested in small scale experiments
Drinking water treatment with organic acids		Biofilms on drinkers may be a challenge Low pH to control biofilm build-up could lead to welfare issues Palatability for birds	Conflicting evidence on effectiveness Not yet tested on large scale
Feed additives		In some studies a reduced growth rate was observed	Not yet tested on large scale
Interventions during transport and before slaughter			
Feed withdrawal	Current guidelines based ond animal welfare considerations appear to be optimal for control of *Campylobacter* contamination as well	Inadequate available data, complex variables and confounding factors involved make it difficult to assess any beneficial effect of feed withdrawal or good hygiene practiques during transportation and holding before slaughter. Not yet tested on a large scale	Immediately available
Crate treatment	Limits spreading of faeces	Inadequate available data, complex variables and confounding factors	Not yet tested on a large scale

Figure 14. Advantages and disadvantages of the control measures applied in primary production, transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

Advantages, disadvantages and availability of interventions			
	Advantages in addition to a possible *Campylobacter* reducing effect	**Disadvantages**	**Availability**
		involved make it difficult to assess any beneficial effect of crate treatment	
Interventions at slaughter			
Prevention of faecal leakage	Can be applied to colonized flocks	Interferes with current industrial practices using high-throughput slaugthering and processing lines Effect post-chill needs to be investigated	Equipment not commercially available
Detection/re-processing of highly faecal-contaminated carcasses	Eliminates high level contaminated carcasses	Effect on-line has not been demonstrated	Immediately available
Cloacal plugging	Can be applied to colonized flocks	Complex methodology	Equipment not commercially available
Scheduled slaughter (positive batches are scheduled to a risk reducing procedure such as freezing or heat treatment)	Reduces the number of flocks to be subjected to further treatment, if considered	Particularly effective in low prevalence countries Need of reliable and sensitive testing methods for *Campylobacter* spp.	Immediately available No internationally standardized PCR-method available
Logistic slaughter (the slaughter of negative batches before the positive)		Impractical if high between-flock prevalence Need of reliable and sensitive testing methods for *Campylobacter* spp. Testing must be done as close to slaughter as possible May also need to consider *Salmonella* carriage Not effective for public health as numbers of *Campylobacters* on negative batches processed after positive ones are very low	Immediately available
Interventions post slaughter			
Chemical decontamination of carcasses			
All chemicals		Risk of residues and by-products Issues of waste water management	Available in the short term Currently no chemicals are approved in the EU

Figure 14. Advantages and disadvantages of the control measures applied in primary production, transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

Advantages, disadvantages and availability of interventions			
	Advantages in addition to a possible *Campylobacter* reducing effect	**Disadvantages**	**Availability**
Lactic acid	Occurs naturally in meat No organoleptic effect when used at low concentrations, e.g. 2%	Carcass discoloration might occur at high Concentrations 2% lactic acid would not significantly affect carcass colour	Available in the short term Currently not approved in the EU
Acidified sodium chlorite	Effective as a dip or spray	Unpleasant for operatives Has to be prepared on-site	Available in the short term Currently not approved in the EU
Chlorine dioxide	Better effect can be expected post-washing	Conflicting results Unstable and has to be prepared on-site Effect will depend on presence of organic substances	Available in the short term Currently not approved in the UE
Trisodum phosphate	Effective as a dip or spray	Negative environmental impact of phosphates Unpleasant for operatives	Available in the medium term Currently not approved in the EU
Acidified electrolysed oxidising water (immersion)	Could be used during water chilling	Not tested on-line or on naturally contaminated carcases	Available in the short term Currently not approved in the EU
Peracetic (peroxyacetic) acid		Not tested on-line or on naturally contaminated carcasses	Available in the short term Currently not approved in the EU
Physical decontamination of carcasses			
All physical treatments	No residues	Energy consuming	Can be used in without specific authorisation all EU countries (except irradiation)
Freezing for few days/ 3 weeks	Proven on production scale. Effective and implemented in some countries	Thawing causes drip, which may caused cross-contamination	Available in the short term
Hot water immersion	Product still fresh	Reduced product quality (appearance affected in some studies) No on-line equipment available	Available in the medium term
Irradiation	Product still fresh Eliminates *Campylobacters* inside the muscle and liver	Not feasible for whole carcasses unless x-rays or gamma radiation from isotopes used	Available in the medium term Not authorised for use in all EU countries

Figure 14. Advantages and disadvantages of the control measures applied in primary production, transport and slaughter at the slaughterhouse to reduce campylobacteriosis in humans. **Source:** (EFSA, 2011)

Advantages, disadvantages and availability of interventions

	Advantages in addition to a possible *Campylobacter* reducing effect	Disadvantages	Availability
Cooking	No residues	Not fresh meat anymore May only be possible to apply to a small proportion of products Variability in survival depending upon the product, the strain and the procedure for heat treatment (pan-frying, oven heating, etc) May not be popular with consumers	Immediately available, in theory
Crust-freezing	Product still fresh	Only proven on-line for breast fillets, not feasible for whole carcasses	Available in the short term
Steam	Product still fresh In-line equipment could be designed and installed easily on existing lines No issue with waste disposal	Reduced product quality (appearance affected in some studies) Slight shrinkage of skin which becomes less pronounced after storage No on-line equipment available	Available in the medium term
Steam ultrasound	No residues Product still fresh	Slightly boiled appearance of skin using proof-of-concept apparatus (highest efficacy) Product quality maintained using on-line equipment (lower efficacy)	Available in the short term

Figure 15. Results of the application of different control measures in the reduction of the presence of *Campylobacter* spp. in broiler meat. **Source:** (EFSA, 2011)

Examples of reported risk reductions as a consequence of reduction on *Campylobacter* concentrations due to the application of control options along the broiler meat processing chain

Reference of QMRA	Point of the chain	Target parameter	Effect (log_{10} reduction)	Risk reduction (% of human incidence)
Rosenquist et al., 2003 • generic reduction of concentration on carcasses			–2	97%
Lake et al., 2007 • generic reduction of concentration on carcasses			–1 –2	71% 88%
Brynestad et al., 2008 • generic reduction of concentration on carcasses	Processing plant	Log_{10} number (CFU) of *Campylobacter* on carcass	–0.2	30%
Linqvist and Lindblad, 2008 • generic reduction of concentration on carcasses			–2	92%-97%[1]
FAO/WHO, 2009b • generic reduction of concentration on carcasses			–0.25	11%-82%[2]
Nauta et al., 2005b and Havelaar et al., 2007[3] Phage therapy	Farm	Log_{10} number (CFU) of *Campylobacter* in faeces	–1/–2/–2	74.4%
Reduction of faecal leakage	Processing plant	Log_{10} number (CFU) of *Campylobacter* in faeces	0/–6/–∞	77.1%
Decontamination in the scalding tank: • by adding lactase • by adding TSP (trisodium phosphate)	Processing plant	Log_{10} number (CFU) of *Campylobacter* on carcass	–0.3/–0.8/–2 –1.03/–1.24/–1.5	12.4% 18%
Decontamination before chilling: • using lactic acid • using TSP (trisodium phosphate)	Processing plant	Log_{10} number (CFU) of *Campylobacter* on carcass	–0.3/–1.3/–2 –1.03/–1.24/–1.5	86.9% 90.6%
Other decontamination measures: • only dipping • dipping and spraying • crust freezing • irradiation • freezing of products	Processing plant	Log_{10} number (CFU) of *Campylobacter* on carcass	–0.3/–1.3/–2 3[2](–0.27/–0.6/–0.83) –0.4/–1.1/–1.7 –4.7/–10.5/–20.8 –0.9/–1.7/–3.2	77% 80% 82.8% 100% 94.9%

Figure 15. Results of the application of different control measures in the reduction of the presence of *Campylobacter* spp. in broiler meat. **Source:** (EFSA, 2011)

Examples of reported risk reductions as a consequence of reduction on *Campylobacter* concentrations due to the application of control options along the broiler meat processing chain

Reference of QMRA	**Point of the chain**	**Target parameter**	**Effect (log_{10} reduction)**	**Risk reduction (% of human incidence)**
Gellynck et al., 2008[3]				
Phage therapy	Farm	Log_{10} number (CFU) of *Campylobacter* in faeces	–1/–2/–3 (–1 on external)	53/-76%-82%
Carcass decontamination	Processing plant	Log_{10} number (CFU) of *Campylobacter* on carcass		
• crust freezing			–0.4/–1.1/–1.7	32%-61%-82%
• lactic acid[4]			–0.3/–1.3/–2	0%-38%-72%
• electrolyzed oxidizing water[4]			–1.1/–2.3/–3	28%-80%-91%
• irradiation			–4.7/–10.5/–20.8	99.8%-100%-100%

[1]If fresh or frozen chicken respectively are considered.

[2]Depeding on the initial concentration equal to 6 log CFU and 2 log CFU respectively.

[3]Based on three different levels of efficacy (pesimistic, most likely, optimistic) of each measure. The outcomes are expressed as mean risk reduction values.

[4]Used to replace carcass washing.

Processing, distribution and culinary preparation in catering or domestic environments

The HACCP system must be correctly applied to the processing industries. In addition, it would be interesting if the products which are sold raw included an informative label indicating or advising that although the meat comes from animals which have passed the veterinary inspection at the slaughterhouse, it may contain pathogens that involve the need for correct hygienic handling together with the correct heat treatment. The handling of raw broiler meat and cross contamination during the preparation of food in a domestic or catering establishment is a critical point of control in the reduction of campylobacteriosis in humans. The training and education of the consumers is essential if we wish to reduce the incidence of food-borne diseases that have a microbial aetiology. In addition, special attention should be given to pets, particularly cats as these are a source of transmission of *Campylobacter* spp. and may contaminate surfaces and food.

Conclusions of the Scientific Committee

The strategies for the control of *Campylobacter* spp. in broiler meat must be based on the strict application of the Good Hygiene Practices (GHP) and the Hazard Analysis and Critical Control Points System (HACCP) by the food business operators. The proposed measures include: 1) introduction of biosecurity programmes on poultry farms to reduce the colonisation of the birds, 2) minimisation of cross contamination in the slaughterhouse, 3) introduction of authorised techniques for the hygienisation of carcasses, 4) correct hygienic handling and heat treatment in the culinary preparation of food prior to consumption, and 5) training of consumers as active agents in the prevention of food-borne diseases.

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