Epidemiology

In this guide

At the time of the 1992 report, foodborne, infant and wound botulism were reported worldwide but foodborne botulism was by far the most common form reported in the UK. In contrast, currently in the UK, wound and infant botulism are more common forms than that associated with food.

There has been no significant change in the disease symptoms reported since 1992[25–27]. It remains the case that foodborne botulism is such a rare disease in the UK that misdiagnosis is a possibility due to the association of symptoms, by General Practitioners, with other more common diseases[27–29]. Misdiagnosis may result in delayed response to cases and outbreaks and may warrant increased awareness amongst the medical profession. The US Centers for Disease Control and Prevention (CDC) has issued clinical guidelines for the diagnosis and treatment of botulism[27].

Investigations into many outbreaks of botulism have focused on the determination of the toxin type, rather than on the identification of the organism and its phenotype, and this has led to the loss of valuable data for subsequent risk assessment.

In this chapter, cases and outbreaks of botulism are reviewed firstly with respect to their geography and then with respect to the type of organism and its associations and therefore some repetition of events is evident.

4.1 Botulism – the global picture

Botulism is regularly reported throughout the world and Table 2 summarises the cases of all types of botulism from selected countries where data are available. Foodborne botulism is responsible for most reports in many countries, but it is not universally the most prevalent form of botulism. For example, in the USA, infant botulism is the most common form of botulism with 1862 reported cases between 2001 and 2017, vastly exceeding 326 foodborne cases. In the UK wound botulism causes significantly more cases than infant and foodborne botulism combined but this may partly reflect the nature of clinical investigations and their capability.

4.1.1 UK

The UK has an extremely low number of outbreaks of foodborne botulism with only 10 reported outbreaks involving 13 cases since 1992 (data to 2019[8] are included in Table 3). There has been no increase in foodborne botulism in the UK in recent decades. There has been a noticeable change in the origin of foods associated with outbreaks; eight of the ten most recent outbreaks involved foods produced or illness acquired abroad. This highlights effectiveness of the safety controls applied by the UK food industry in relation to this organism. Food produced in the home caused the greatest number of outbreaks since 1992 and five of six outbreaks, where details of food storage were known, involved ambient storage. A single outbreak implicating chilled food was caused by temperature abuse. Where the cause or potential cause of an outbreak was identified the evidence indicates that established controls for *C. botulinum*, if applied correctly, would have prevented the incident.

4.1.2 Worldwide

A selection of outbreaks of foodborne botulism that have occurred globally since 1992 are detailed in Table 4[30]. There has been no significant change in the nature of foodborne botulism in recent decades with the exception of the identification of rare cases caused by neurotoxigenic *C. butyricum* and *C. baratii.* A few outbreak strains originally thought to be proteolytic *C. botulinum* are now recognised as *C. sporogenes* (details are included later in this chapter). The proportion of botulism outbreaks implicating commercial foods is weighted

towards chilled foods rather than ambient foods (details are included later in this chapter and in Table 4) and this may constitute a trend in relation to the food types causing outbreaks. However, it is possible that bias may have been introduced by supplementing the literature sources with review papers specifically on chilled foods. 42 of the 90 outbreaks reported involved non-commercially produced foods i.e. home produced, 40 involved commercially produced food and 8 were unclear. Temperature abuse was a contributory factor in 30 of 36 outbreaks where a cause was known or suspected. For commercially produced chilled foods (and one frozen food) where the cause was known or suspected 23 of 24 products were subject to some form of temperature abuse prior to the outbreak; the remaining product was consumed 3 days beyond the "Use By" date. Outbreaks implicating commercially produced products that were destined for ambient storage and where a cause was known or suspected occurred due to a variety of control failures including inadequate sterilisation, post-process contamination, inadequate formulation to prevent growth and toxin production and/or temperature abuse. In the case of both chilled and ambient storage of commercially produced foods, the established controls for *C. botulinum,* if appropriately applied, would have prevented these outbreaks. Novel food technologies are not a feature of reported botulism outbreaks which tend to implicate traditional technologies which have been widely employed for food production over many years e.g. canning.

4.1.2.1 France

France reported 402 outbreaks of human botulism between 1987 – 2016 consisting of 731 cases and 9 deaths[31]. Cooked ham from home-made preparation or from small scale producers was involved in 73.5% of the botulism outbreaks where the food source was identified. These outbreaks were mostly type B botulism; more specifically B4 (and non-proteolytic *C. botulinum*). The other sources of botulism were home-made canned vegetables or fruits (beans, asparagus, eggplant, spinach, pumpkin, chestnut), home-made meat or fish preparations and a small number of industrial foods (fish soup, chicken/beef sausage, chicken/enchiladas, ground meat, olives/dried tomatoes, fresh pasta carbonara). Most of the outbreaks with non-pork meat were type A botulism (and proteolytic *C. botulinum*). Two outbreaks of rare *C. baratii* neurotoxin type F (F7) botulism were observed in 2014 and 2015. Industrial ground meat prepared in a restaurant was identified as the source of one outbreak[32]. Previous cases of botulism attributed to *C. baratii* were generally associated with intestinal colonisation i.e. infant botulism or due to other predisposing conditions[33]. The

origin of the other *C. baratii* type F outbreak was not identified. *Clostridium butyricum* was implicated in a case of botulism in a 10-year-old boy with history of Meckel's diverticulum and chronic constipation, presenting dysarthria, dry mouth, hypotony, respiratory failure, and cardiac arrest in 2011. Stool analyses were positive for *C. butyricum* neurotoxin E5 by PCR and DNA sequencing up to 2 months after discharge. Botulism by intestinal colonisation with neurotoxigenic *C. butyricum* from undetermined origin was strongly suspected[34].

4.1.2.2 Italy

Italy has one of the highest numbers of foodborne botulism cases in Europe with 1173 suspected foodborne cases between 1986 – 2015, of which 421 were laboratory-confirmed[25]. Homemade canned foods were implicated in 80.5% (95/118 incidents, involving 143 persons) of confirmed outbreaks including an outbreak caused by restaurant canned green olives. Vegetables canned in oil and in brine/water were associated with 43.2% and 28.8%, respectively, of laboratory-confirmed outbreaks. Other types of food implicated in confirmed outbreaks were home-bottled tuna (7.6%), ham (5.9%), home-bottled meat (5.9%), salami/sausages (4.2%), cheese (2.5%) and tofu and seitan (1.7%). Among vegetables, the most frequent products involved in cases or outbreaks were mushrooms in oil, olives and turnip tops. Regarding fish products, home-canned tuna was the most common food linked to confirmed incidents. Cheese or dairy products were seldom associated with confirmed incidents despite a large outbreak caused by mascarpone cheese[35]. Although not reported for foodborne botulism alone, 96% (316/330) of the laboratory confirmed incidents were due to toxin produced by proteolytic *C. botulinum* (neurotoxins Type B 79.1%, Type A 9.7%, Type F 0.3%, Type Ab 1.5% and Type Bf 0.6%). Of 36 cases of infant botulism in Italy from 1986 to 2015, *C. butyricum* neurotoxin type E was implicated in three cases. Botulism involving intestinal colonisation with *C. butyricum* neurotoxin type E was also found in two boys having a Meckel's diverticulum[36].

4.1.2.3 USA

There were 326 laboratory confirmed foodborne botulism cases in the USA between 2001 and 2017 of which 277 implicated a food or beverage (a food or beverage was a laboratory confirmed source of botulinum neurotoxin in 156 cases)[37]. 47% of cases implicated food prepared in the home excluding canned foods, 29% home canned foods, 10% commercially canned foods and 6% other commercially prepared foods (no food preparation method was available for 8%

of cases). Neurotoxin types A, E and B were responsible for most of the cases (65%, 25% and 7%, respectively). Outbreaks implicating commercial foods included a chilli meal, chilli sauce and nacho cheese sauce. A case of botulism implicating spaghetti with sauce/meat was attributed to *C. baratii* type F[38].

4.1.2.4 Turkey

A systematic review of botulism cases in Turkey from 1983 to 2017 identified 91 foodborne cases[39]. Not all cases or suspected foods were tested for botulinum neurotoxin but 10 of 19 tested were positive for type A toxin (proteolytic *C. botulinum*). The top-ranking food responsible for cases was canned green beans (30% and 28 reports). Other reported foods include strained yoghurt (x10), home-made local cheese (x24), canned purslane (x16), non-specific canned food, canned ferula communis or fennel (x4), canned peppers, scrambled eggs with garlic sausages, canned fried mushrooms (x5) and unknown.

4.1.2.5 Iran

A review of botulism cases in Iran in the period 2007 – 2017 identified 252 confirmed cases of foodborne botulism, 743 suspected foodborne cases and 48 fatalities[40]. The most commonly implicated foods, accounting for 34.1% of events, were home-prepared traditional processed fish (smoked fish, salted fish, ham, bacon, blood pudding, mosaic salami and sausage). Other implicated foods were commercially canned fish (28.6%), fish spawn (10.5%), dairy products (10.1%), vegetables and home-prepared legumes (9.7%), cottage cheese (5.9%) and canned fruits (1.1%).

4.1.2.6 Canada

There were 91 laboratory-confirmed outbreaks of foodborne botulism in Canada between 1985 and 2005 (205 cases and 11 deaths). Seventy-five outbreaks were associated with non-proteolytic *C. botulinum* type E; seven outbreaks associated with type A neurotoxin and five outbreaks with type B neurotoxin. The non-proteolytic *C. botulinum* neurotoxin type E outbreaks were attributed to consumption of traditionally prepared marine mammal and fish products by native communities (principally the Inuit of Nunavik in northern Quebec and the First Nations population of the Pacific coast of British Columbia). Two botulism outbreaks were attributed to commercial ready-to-eat meat products (pâté and cooked boneless pork) and three outbreaks to foods served in restaurants (chopped garlic in oil, bottled chanterelle mushrooms and baked potato). All

involved type A or type B toxin. A further eight outbreaks were attributed to non-native home-prepared foods[41]. A review of foodborne outbreaks in British Columbia in the period 2009 – 2013 identified 3 botulism outbreaks and 1 death[42]. Implicated foods include fruit and vegetables, seafood and sauces/condiments.

4.1.2.7 Poland

Reviews identified that 54 of 109 botulism cases in Poland between 2014 and 2017 were due to home-produced foods and 55 due to commercial foods. Canned foods accounted for the vast majority of cases (84) with canned meat (other than pork) being the most frequently implicated food followed by canned fish, sausages and cured meat, canned pork, canned meat and vegetables and canned mushrooms, fruits and vegetables[43–46].

4.1.2.8 China

A review of botulism in China between 2004 and 2020 identified a total of 80 foodborne outbreaks with 386 illnesses and 55 deaths[29]. The most common foods implicated were home-prepared traditional processed stinky tofu and dried beef, accounting for 51.2% of outbreaks. Contributory factors causing the outbreaks included improper processing and improper storage (77.5% of outbreaks). Initial misdiagnosis of illness occurred in 27.5% of cases. In an overview of type E botulism[47], 11 outbreaks between 1965 and 2005 implicated soy bean milk, fermented bean curd, raw dried beef, dried mackerel and blood sausage. The bacteria involved were either non-proteolytic *C. botulinum* type E or *C. butyricum* type E.

4.2 Association of clostridia and non-clostridia with foodborne botulism

4.2.1 Proteolytic *C. botulinum* and *C. sporogenes*

The vast majority of botulism cases associated with foods are caused by proteolytic *C. botulinum* neurotoxin types A and B. Rare cases implicating foods have been reported involving toxin type F.

It is widely recognised that proteolytic *C. botulinum* and *C. sporogenes* are closely related species. Recent genomic studies have highlighted that a number of strains of proteolytic *C. botulinum* should actually be classed as strains of *C. sporogenes* and *vice versa*, and that neurotoxigenic and non-neurotoxigenic

strains of proteolytic *C. botulinum* and *C. sporogenes* exist[8] (details of Taxonomy are included in Chapter 2 of this report). Four outbreaks of foodborne botulism have been attributed to *C. sporogenes* type B, including one case in the UK, along with rare cases of infant and wound botulism. As the historical identification of proteolytic *C. botulinum* associated with cases or outbreaks of botulism was based on the neurotoxin type this does not strongly affect the data presented in this chapter; neurotoxigenic *C. sporogenes* would have been incorrectly assigned to proteolytic *C. botulinum.* Moving forward it may be necessary to redefine historical data on botulism.

Proteolytic *C. botulinum* and neurotoxigenic *C. sporogenes* are far more resistant to adverse conditions than other *C. botulinum* groups, requiring stronger heat processes to destroy spores and lower pH and water activity to prevent growth in food. Foodborne outbreaks associated with proteolytic *C. botulinum* have not shown any significant change in pattern, in recent decades, that would indicate an increased risk to foods. The controls that have been in place to manage the survival, population growth and toxin production by proteolytic *C. botulinum* for many years appear robust and do not need modification (details of the Occurrence, Growth and Survival of *C. botulinum* are included in Chapter 5 of this report).

4.2.2 Non-proteolytic *C. botulinum*

Non-proteolytic *C. botulinum* neurotoxin types B and E (and very occasionally toxin type F) are associated with foodborne outbreaks of botulism, but generally to a lesser extent than proteolytic *C. botulinum* neurotoxin types A and B, although this does vary by country.

Non-proteolytic *C. botulinum* is much less resistant to processing used in the food industry than proteolytic *C. botulinum*. The spores are more readily destroyed by heat and growth is more readily controlled by pH or water activity than for proteolytic *C. botulinum*. However, non-proteolytic *C. botulinum* is able to grow at much lower temperatures than proteolytic *C. botulinum;* this includes growth at refrigeration temperature*s* (details of the Occurrence, Growth and Survival of *C. botulinum* are included in Chapter 5 of this report). This presents a risk in chilled, minimally processed, extended shelf-life foods and this led to the provision of FSA guidelines for manufacture and sale of chilled foods in the UK[2] (details of the FSA guidelines are included in Chapter 1 of this report).

Despite the risk presented by non-proteolytic *C. botulinum* in chilled foods there have been no reported outbreaks of botulism involving chilled foods from any

commercial product where the food has been stored at the recommended chilled temperature and consumed within its designated shelf life. In a review of global botulism outbreaks[48] caused by chilled foods, in the period 1985 to 2015, 16 of 26 outbreaks identified (Table 5) were caused by proteolytic *C. botulinum*, one by *C. baratii* and four by non-proteolytic *C. botulinum* (all type E in vacuum packed fish). Five outbreaks did not identify the organism and three of these involved toxin type B (it is unknown whether proteolytic *C. botulinum* or non-proteolytic *C. botulinum* were causal). Temperature abuse was identified as the cause or most likely cause in 25 of the 26 outbreaks and consumption of the product beyond its "Use By" date was the reported cause of the remaining outbreak. In a review of botulism outbreaks in the USA between 1994 and 2021 that involved commercially produced foods intended to be stored chilled, 11 events were due to unrefrigerated storage by the consumer at home and the other two were due to unrefrigerated storage by the retailer prior to sale[49]. In three of the events refrigeration instructions were deemed to be inadequate and contributory to the outbreak. In the 10 events where a toxin type was determined, all involved proteolytic *C. botulinum* (nine type A and one type Bf).

The lack of evidence for outbreaks caused by non-proteolytic *C. botulinum* in correctly stored chilled foods in the UK, both before and after the introduction of recommendations following the 1992 report, together with a similar lack of evidence from other countries throughout the world, provides some useful context regarding the magnitude of the risk and consequent need for controls in chilled foods. However, this review has not extensively examined the potential for under-ascertainment of botulism cases and outbreaks in other countries nor the legislative or industrial controls applied to foods globally. Currently it is not possible to use this insight in revising the risk from non-proteolytic *C. botulinum* in vacuum and modified atmosphere packaged chilled foods. Further study of these factors may provide more conclusive evidence that could indicate a lower risk to chilled foods from this organism that might, in turn, merit reduced controls or a focus on foods where the risk is greatest due to the known frequency of contamination and the associations with outbreaks i.e. vacuum packaged fish and seafood.

4.2.3 *C. botulinum* Group III

C. botulinum Group III (toxin types C and D) is often associated with animal botulism but has been implicated in human disease on rare occasions. In a recent review of all nine of the type C and D botulism outbreaks cited in literature, eight implicated foods; one was associated with infant botulism[26]. Of the food

outbreaks five had food vehicles suspected or confirmed as pâté (x2), smoked chicken, diseased chicken and home-made ham. The vast majority (seven) of these outbreaks were reported before 1992 when methods of identification and typing were less well advanced. Sporadic increases in animal botulism especially in farmed animals such as cows, cattle and chicken have raised concern regarding the potential for increased risk of transmission to humans. However, the ACMSF has reviewed such matters on a number of occasions and has considered the risk to humans to be low and supported the adequacy of current controls[50,51]. There is no evidence that *C. botulinum* Group III presents any new or increased risk in relation to human foodborne botulism.

4.3 Other neurotoxin-producing clostridia

4.3.1 *Clostridium butyricum*

Neurotoxigenic *C. butyricum* type E has been reported in a small number of cases of infant botulism[33], adult intestinal botulism[36] and foodborne botulism in India[52], China[53] and Italy[54]. In the Indian incident clinical samples were not analysed and, despite the organism being isolated from a crisp made from gram flour, it was not possible to definitively confirm foodborne botulism. In a Chinese outbreak that occurred in 1994 implicating salted and fermented paste made of soybeans and wax gourds[55] six cases were clinically diagnosed with neurotoxin type E botulism that was also confirmed in the food although *C. butyricum* type E was only isolated from the food following further studies several years later[53]. Retrospective analysis has also indicated an association of *C. butyricum* type E with other historical outbreaks of foodborne botulism in China[47,56]. Type E botulism in China is most commonly associated with fermented grain/beans and raw meat and is frequently reported far from the sea (e.g. in Qinghai-Tibet plateau at an altitude of approximately 4-5 km). Canederli (bread dumplings) were the suspected food in a case of foodborne botulism in Italy in 1999 involving *C. butyricum* neurotoxin type E. Neurotoxigenic *C. butyricum* type E is a relatively newly identified hazard. No foodborne outbreaks of this type have been reported in the UK. Low numbers of confirmed outbreaks in other countries indicates that the risk presented by this organism has not substantially changed.

4.3.2 *Clostridium baratii*

Clostridium baratii producing botulinum neurotoxin type F has been associated with several foodborne outbreaks of illness although it was first isolated in an infant botulism case in the USA[57] and has subsequently been associated with a number of further cases of infant botulism[38,58] and adult intestinal botulism[59,60]. Foodborne outbreaks have been reported in Spain, implicating individual meat pit pies[61] and in France, where the food source was not identified although the only common item consumed by the two cases was an alcopop (which tested negative for growth and toxin[62]) that reportedly contained 5% alcohol and had pH = 3.5. An outbreak in France implicated frozen and defrosted ground beef used for the production of spaghetti Bolognese at a restaurant where temperature abuse was again suspected as the underlying cause[32,63]. Spaghetti and sauce mixture was implicated in a case of botulism caused by *C. baratii* type F in the USA in 2001[38]. Raw deer meat was associated with an outbreak of foodborne botulism in Thailand in 2006, and a strain of *C. baratii* type F was isolated and its genome sequenced[64,65].

Neurotoxigenic *C. baratii* is a relatively newly identified hazard. No foodborne outbreaks of this type have been reported in the UK. Low numbers of confirmed outbreaks in other countries indicates that the risk presented by this organism has not substantially changed.

4.3.3 *Clostridium argentinense*

Clostridium argentinense was originally isolated from soil samples in Argentina in the 1960s and despite being capable of producing botulinum neurotoxin type G, there are no cases of botulism that have been associated with this bacterium[65]. *C. argentinense* is not covered further in this report.

4.3.4 Other bacteria with potential botulinum neurotoxin genes

The advent of genomics has allowed the identification of potential botulinum neurotoxin genes in a number of bacteria outside of the *Clostridium* genus (more details are included in Chapter 2 of this report). The presence of botulinum neurotoxin genes is of potential concern but none of these bacteria have been shown to be capable of forming botulinum neurotoxin in foods and there are no known cases or outbreaks of botulism associated with bacteria outside the genus *Clostridium*.

4.4 Conclusions

4.4.1 Outbreak identification and clinical diagnosis

Foodborne botulism in the UK is extremely rare but consequently this may result in delayed responses due to unfamiliarity in the diagnosis of cases and delays in reporting.

4.4.2 Organisms responsible for botulism

There has been no significant change in the nature of foodborne botulism in recent decades with the exception of the identification of rare cases caused by neurotoxigenic *C. butyricum*, *C. baratii* and *C. sporogenes*. Other clostridia and non-clostridia have been identified with botulinum neurotoxin genes but have not been implicated in cases of foodborne botulism in the UK or elsewhere.

4.4.3 Foodborne botulism trends

There has been a noticeable change in the nature of foods that are associated with outbreaks of foodborne botulism in the UK. Eight of the ten outbreaks in the last 30 years involved foods produced or illness acquired abroad and the majority of these involved home-production.

Botulism outbreaks implicating commercially produced chilled foods appear more prevalent than in previous decades although bias in ascertainment of evidence may have affected this conclusion. The vast majority of botulism outbreaks, for both chilled or ambient stored foods, are identified with proteolytic *C. botulinum,* i.e. those organisms that do not grow under chilled conditions, and temperature abuse is the single most common cause identified for foodborne outbreaks. In relation to outbreaks in the last 30 years, in the UK and worldwide where a cause can be identified, there is evidence to believe that known controls for the organism, combined with the correct storage of the foods, if applied correctly, would have prevented the incident. Novel food technologies are not a feature of botulism outbreaks and most implicate traditional technologies, such as canning, employed for food production.

4.4.4 Vacuum packaged, extended shelf-life chilled foods

There have been no reported outbreaks of botulism globally in chilled foods from any commercial product where the food has been stored at the recommended chilled temperature and consumed within its designated shelf life. There has not been an extensive review of the potential for under-ascertainment of botulism cases and outbreaks in other countries nor the legislative or industrial controls

applied to foods globally. However, further study of these factors may provide evidence that could indicate a lower risk to chilled foods that might, in turn, merit reduced or more focused controls. Nevertheless, the evidence indicates that where chilled foods are associated with outbreaks of botulism this is almost exclusively due to temperature abuse and in most cases is caused by proteolytic *C. botulinum*.

Table 2

Botulism cases in selected countries

Country	**Period**	**Foodborne cases**	**Infant botulism**	**Wound botulism (confirmed only)**	**Adult intestinal botulism**	**Inhalation**	**Iatrogenic**	**Oth**
UK	1992 - 2019	13 (A, B, Bf)	16 (A, B, Bf, E– *C. butyricum*)	112 (A, B, AB)	1 (NT)			
France	1992-2016	574 (A, B, AB, E, F - *C. baratii*)		1 (B)	1 (E – *C. butyricum*)	2 (B)		
France	2004 - 2016		17 (A, B, AB, Bf)					

Italy	1986 - 2015	421 (Not reported)	36 (A, B, Ab, Bf, E – *C. butyricum*)	6 (B)	3 (A, E – *C. butyricum*)		
USA	2001 - 2017	326 (A, B, E, F)	1862 (A, B, Ab, Ba, Bf, E, F, F - *C. baratii*)	372 (A, B, AB)	10 (A, F)	7 (A, B)	5 F – *bar*

Table 3

Summary of botulism cases recorded in the UK since the publication of the 1992 ACMSF Report on Vacuum Packaged Foods and underlying causes (Adapted from Brunt et al., 2020[8]).

Year	Cases	Organism (toxin type)[a]	Toxin subtype	Food	Country of origin	Storage (cause)	Reference
1998	2	Prot (B)	B2	Home produced bottled mushrooms	Italy	Ambient (Inadequate controlling factors)	McLauchlin et al., 2006[67]
2003	1	Cspo (B)	B1	Home produced Sausage	Poland	Unknown (Inadequate controlling factors likely)	McLauchlin et al., 2006[67]

2004 1	Un (un)	nt[b]	Commercial Hummus	UK	Chilled (Temperature abuse)	McLauchlin et al., 2006[67]
2004 1	Prot (A)	nt	Unknown	Georgia	Unknown	McLauchlin et al., 2006[67]
2005 1	NP (B)	B4	Home preserved pork	Poland	Ambient (Inadequate controlling factors)	McLauchlin et al., 2006[67]
2010 1	Un (B)	nt	Unknown	Algeria	Unknown	Brunt et al., 2020[8]
2011 3	Prot (A)	A1	Commercial korma sauce	UK	Ambient (Unknown cause)	Browning et al., 2011[18]
2012 1	Prot (B)	B2	Commercial olives	Italy	Ambient (Unknown but inadequate controlling factors likely)	Brunt et al., 2020[8]
2013 1	Un (un)	nt	Home produced Mushrooms	Poland	Ambient (Inadequate controlling factors)	Brunt et al., 2020[8]; Brola et al 2013[68]

2016	1	Un (B)	nt	Tuna??	Italy	Unknown storage and controlling factors	Brunt et al., 2020[8]

aProt: proteolytic *C. botulinum*, NP: non-proteolytic *C. botulinum*, Cspo: *C. sporogenes*, un, unknown.

b not tested in the present study.

Table 4

Reported outbreaks of botulism in foods occurring since the publication of the 1992 ACMSF Report on Vacuum Packaged Foods
(for UK, see Table 3).

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
1990	United States	3	B	Point	Unclear	Confirmed	Surgeon fish (palani)	-
1991	Egypt	97	E	Point	Commercial	Confirmed	Uneviscerated gray mullet fish (faseikh) – not reported	Te ab pr
1992	United States	4	E	Point	Non-commercial: other	Confirmed	Uneviscerated fish (moloha) – not reported	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
1993	United States	8	A	Intermittent common	Commercial	Confirmed	Cheese sauce - ambient	Co an ter ab
1993	Italy	7	B	Intermittent common	Commercial	Suspected	Canned eggplant in oil - ambient	Ina co fac
1994	United States	30	A	Intermittent common	Commercial	Confirmed	Baked potato dip - ambient	Te ab
1994	United States	1	A	Point	Commercial	Confirmed	Black bean dip - chilled	Te ab pro ref
1994	United States	2	A	Point	Commercial	Confirmed	Clam chowder - chilled	Te ab pro ref
1995	Canada	3	E	Point	Non-commercial: other	Confirmed	Fermented seal meat	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
1995	Canada	5	E	Point	Non-commercial: other	Confirmed	Fermented walrus meat	-
1995	Canada	2	B	Point	Commercial: other	Confirmed	Country style pâté– chilled	Te ab pro ref
1996	Italy	8	A	Intermittent common	Commercial	Confirmed	Mascarpone cheese – chilled	Te ab
1996	India	34	Unknown	Point	Unclear	Suspected	Sevu (gram flour crisp)	-
1996*	Spain	2	Unknown	Point	Non-commercial: other	Suspected	Green beans	-
1997	United States	1	Bf	Point	Commercial	Suspected	Burrito – chilled	Te ab
1997	Thailand	6	Unknown	Unclear	Non-commercial: home-canned	Suspected	Canned bamboo shoots	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
1997	Germany	2	E	Point	Commercial	Confirmed	Hot-smoked whitefish VP – chilled	Un Te ab
1998	Argentina	9	A	Intermittent common	Non-commercial: other	Suspected	Matambre meat roll	-
1998	Thailand	13	A	Point	Non-commercial: home-canned	Confirmed	Canned bamboo shoots	-
1998*	United States	3	B	Point	Non-commercial: other	Confirmed	Peyote	-
1999	Canada	4	B	Point	Non-commercial: home-canned	Suspected	Canned tomatoes	-
1999*	Turkey	4	Unknown	Point	Non-commercial: home-canned	Suspected	Uncooked canned vegetables	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
1999	France	1	A	Point	Commercial	Suspected	Fish soup – chilled	Te ab ho
2000	France	9	B	Point	Non-commercial: home-canned	Suspected	Canned asparagus	-
2001	United States	14	E	Point	Non-commercial: other	Suspected	Fermented beaver tail and paw	-
2001	United States	16	A	Intermittent common	Commercial	Confirmed	Frozen chili	Te ab
2001	Iran	2	Unknown	Point	Unclear	Suspected	Salted fish	-
2001	Canada	2	E	Point	Non-commercial: home-canned	Confirmed	Jar of salmon roe	-
2001	Canada	2	E	Point	Non-commercial: other	Confirmed	Stink eggs	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2001	Canada	1	A	Point	Commercial	Confirmed	Cooked boneless pork product - chilled	Te ab pro ref
2001	United States	1	F – *C. baratii*	Point	Non-commercial: other	Confirmed	Spaghetti noodles and meat sauce	-
2002	United States	8	E	Intermittent common	Non-commercial: other	Confirmed	Raw beached whale (muktuk)	-
2003	United States	1	A	Point	Commercial	Confirmed	Clam chowder	Te ab
2004	United States	4	A	Point	Non-commercial: other	Suspected	Pruno	-
2004	Germany	1	E	Point	Commercial	Suspected	Vacuum packed smoked salmon	Co aft da
2004	Italy	28	B	Intermittent common	Commercial	Suspected	Green olives - ambient	Im pre

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2004*	India	2	Unknown	Point	Non-commercial: other	Suspected	Canned meat, preserved curd	-
2005	Turkey	10	A	Point	Non-commercial: other	Confirmed	Suzme yoghurt buried in soil	-
2005	United States	5	E	Intermittent common	Non-commercial: other	Confirmed	Salted fish	-
2005*	Turkey	5	Unknown	Point	Non-commercial: home-canned	Suspected	Canned mushrooms	-
2006	United States, Canada	6	A	Intermittent common	Commercial	Confirmed	Carrot juice - refrigerated	Te ab
2006	Austria	5	Unknown	Point	Non-commercial: other	Suspected	Barbequed pork	-
2006	Finland	2	E	Point	Commercial	Suspected	Smoked whitefish - chilled	Te ab

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2006	United States	2	A	Point	Non-commercial: other	Confirmed	Fermented tofu	-
2006	Taiwan	5	B	Unclear	Non-commercial: other	Confirmed	Fermented raw goat meat (cinkrugan)	-
2006*	Italy	2	Unknown	Point	Non-commercial: other	Suspected	Preserved asparagus	-
2007	United States	8	A	Intermittent common	Commercial	Confirmed	Canned chili sauce - ambient	Pro fai
2007	China	66	A	Intermittent common	Commercial	Suspected	Sausage – not reported	Te ab
2008	Turkey	8	B	Point	Commercial	Suspected	Unprocessed black olives - ambient	Un

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2008	France	2	A	Point	Commerical	Confirmed	Chicken enchiladas - chilled	Te ab pro ref an co da By
2008	Uganda	3	A	Point	Non-commercial: other	Suspected	Oil-based condiment	-
2008	United States	6	A	Point	Non-commercial: home-canned	Confirmed	Canned carrots and green beans	-
2009	France	3	E	Point	Commercial	Suspected	Vacuum packed hot-smoked whitefish (VP) - chilled	Te ab
2009	United States	3	A	Point	Non-commercial: home-canned	Confirmed	Canned green beans	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2009	United States	3	A	Point	Non-commercial: home-canned	Confirmed	Canned asparagus	-
2010	France	5	A	Point	Unclear	Confirmed	Canned green beans or pork chops	-
2011	United States	8	A	Point	Non-commercial: other	Suspected	Pruno	-
2011	United States	1	A	Point	Commercial	Suspected	Potato soup - chilled	Te ab
2011	United States	1	A	Point	Commercial	Suspected	Potato soup - chilled	Te ab
2011	Spain	5	F – *C. baratii*	Point	Unclear	Suspected	Indeterminate	-
2011	France	9	A	Intermittent common	Commercial	Confirmed	Green olive paste - ambient	Inc ste

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2011	Finland	2	B	Intermittent common	Commercial	Confirmed	Jar of olives - ambient	Po co
2011*	Turkey	4	Unknown	Point	Non-commercial: home-canned	Suspected	Canned red peppers	-
2012	Canada	3	E	Point	Commercial	Confirmed	Salt-cured fish (fesikh) – unknown need paper	Un ne
2012	United States	8	A	Point	Non-commercial: other	Confirmed	Pruno	-
2012	Japan	2	A	Point	Commercial	Confirmed	Adzuki batto (bean soup) (VP) – not reported	Te ab
2012	United States	2	Unknown	Point	Commercial	Suspected	Broccoli soup - chilled	Te ab
2012	Thailand	2	B	Point	Unclear	Confirmed	Fermented crab	-

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2013	China	12	A	Point	Commercial	Confirmed	Smoked ribs (restaurant) – chilled	Te ab
2013	Green-land	5	E	Unclear	Non-commercial: other	Suspected	Eider fowl	-
2013	Iran	5	Unknown	Unclear	Non-commercial: home-canned	Suspected	Canned cheese (kupeh)	-
2014	France	2	F – *C. baratii*	Point	Commercial	Suspected	Alcopop?	Un
2014	Spain	3	Unknown	Point	Non-commercial: other	Confirmed	Stew	-
2014	USA	2	B	Intermittent common	Commercial	Confirmed	Jar of pesto - ambient	Un pre ina pro
2015	Slovakia	1	A	Intermittent common	Commercial	Confirmed	Hummus (pouches) Chilled	Te ab

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2015	USA	29	A	Point	Non-commercial: home-canned	Confirmed	Canned potatoes	-
2015	France	3	F – *C. baratii*	Point	Non-commercial: other	Suspected	Meat (ground) frozen used in sauce by Restaurant	Te ab
2015*	New Zealand	1	Unknown	Point	Commercial	Suspected	Risotto - Chilled	Te ab
2016	United States	1	A	Point	Commercial	Confirmed	Grain and vegetable product - chilled	Te ab
2017*	Spain	2	Unknown	Point	Commercial	Confirmed	Canned beans - ambient	No
2017	USA	2	A	Point	Commercial	Suspected	Prepackaged Pouches of Liquid Herbal Tea -Chilled	Co an ter ab

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2017	USA	10	A	Intermittent common	Commercial	Confirmed	Nacho cheese sauce (Pouch) - Ambient	Co an ter ab
2018	Nigeria	3	Unknown	Point	Non-commercial: other	Suspected	Fish pepper soup	-
2018	USA	3	A	Point	Non-commercial: home-canned	Confirmed	Canned peas	-
2019	United States	4	A	Point	Commercial	Suspected	Potato product - chilled	Te ab
2019	China	4	A, B, E	Point	Commercial	Suspected	Fish and ham (VP) – not reported	No
2020	Italy	35	Unknown	Point	Unknown	Suspected	Salad	Un
2020*	Portugal	1	Unknown	Point	Unknown	Suspected	Unknown	Un

Year	Location	Cases	Toxin type	Exposure source	Food vehicle	Laboratory-confirmed or suspected[a]	Implicated/ suspected Food – typical storage	Ca
2021	United States	1	A	Point	Commercial	Confirmed	Clam chowder - chilled	Te ab

a Laboratory-confirmed or suspected food

b Likely cause but not definitive

* Outbreak year not reported, publication year used instead

Table 5

Examples of foodborne botulism outbreaks involving commercial foods intended to be stored chilled (Peck et al., 202048).

Country (year)	Product	Organism (toxin type)	Cases (deaths)	Factors contributing to outbreak	References
Canada (1985)	Garlic-in-oil	Prot (B)	36	No preservatives; temperature abuse	St. Louis et al. (1988)[151]
UK (1989)	Hazelnut yoghurt	Prot (B)	27(1)	Toxin added with canned hazelnut conserve to correctly chilled yoghurt	O'Mahony et al. (1990)[152]

Country (year)	Product	Organism (toxin type)	Cases (deaths)	Factors contributing to outbreak	References
USA (1989)	Chopped garlic-in-oil	Prot (A)	3	Temperature abuse (product not refrigerated)	Morse et al. (1990)[153]
USA (1990)	Grilled fresh Palani (surgeon fish)	NR (B)	3	Temperature abuse	CDC (1991)[154]
USA (1993)	Canned cheese sauce (restaurant)	Prot (A)	8(1)	Contamination of canned cheese sauce after opening, then temperature abuse (opened tin not refrigerated)	Townes et al. (1996)[73]
USA (1994)	Potato dip (‘‘skordalia’’) and aubergine dip (‘‘meligianoslata’’) (restaurant)	Prot (A)	30	Toxin added with temperature-abused baked potatoes to correctly chilled yoghurt dishes	Angulo et al. (1998)[76]
USA (1994)	Clam chowder	Prot (A)	2	Temperature abuse (product not refrigerated)	Sobel et al. (2004)[77]
USA (1994)	Black bean dip	Prot (A)	1	Temperature abuse (product not refrigerated)	Sobel et al. (2004) [77]

Country (year)	Product	Organism (toxin type)	Cases (deaths)	Factors contributing to outbreak	References
Canada (1995)	Country-style pâté	NR (B)	2	Temperature abuse (product not refrigerated)	Leclair et al. (2013)[41]
Italy (1996)	Mascarpone cheese	Prot (A)	8(1)	Temperature abuse; pH > 6	Aureli et al. (2000)[35]
Germany (1997)	Hot-smoked, vacuum-packed fish	NP (E)	2	Suspected temperature abuse	Korkeala et al. (1998)[82]
Argentina (1998)	Meat roll (“matambre”)	Prot (A)	9	Insufficient cooking, lack of preservatives, vacuum-packed in heat-shrunk plastic, & inadequate refrigeration	Villar et al. (1999)[83]
France (1999)	Fish soup	Prot (A)	1	Temperature abuse at home	Carlier et al. (2001)[89]
Canada (2001)	Cooked boneless pork product	Prot (A)	1	Temperature abuse (product not refrigerated)	Leclair et al. (2013)[41]
Germany (2004)	Vacuum-packed smoked salmon	NP (E)	1	Consumed 3 days after ‘Use By date’	Dressler (2005)[99]

Country (year)	Product	Organism (toxin type)	Cases (deaths)	Factors contributing to outbreak	References
UK (2004)	Organic hummus	NR	1	Time/temperature abuse	McLauchlin et al. (2006)[67]
Canada/USA (2006)	Refrigerated carrot juice	Prot (A)	6	Temperature abuse; product pH between 6 and 7	Sheth et al. (2008)[107]
Finland (2006)	Vacuum-packed smoked whitefish	NP (E)	1	Suspected temperature abuse	Lindström et al. (2006)[110]
China (2007)	Sausages	Prot (A)	66	Temperature abuse (product not refrigerated)	Zhang et al. (2010)[116]
France (2008)	Chicken enchiladas	Prot (A)	2	Time/temperature abuse (product not refrigerated); consumed 1 day after 'Use By date'	King & the French Multidisciplinary Outbreak Investigation Team (2008)[118]
France (2009)	Vacuum packed hot-smoked whitefish	NP (E)	3	Suspected temperature abuse during travel and home storage	King et al. (2009)[121]

Country (year)	Product	Organism (toxin type)	Cases (deaths)	Factors contributing to outbreak	References
Italy (2010)	Cream of vegetable soup	NR (B)	1	Temperature abuse (product not refrigerated); long shelf-life	Daminelli et al. (2011)[155]
USA (2011)	Potato soup	Prot (A)	2	Temperature abuse (product not refrigerated)	CDC (2011)[125]
New Zealand (2015)	Chilled, ready-to-eat risotto	NR	1	Time/temperature abuse (product not refrigerated; consumed several months past best-before date)	Smyth et al. (2015)[141]
Slovakia (2015)	Hummus spread	Prot (A)	1	Suspected temperature abuse	Mad'arova et al. (2017)[139]
France (2015)	Frozen minced beef used in restaurant Bolognese sauce	*C. baratii* (F)	3	Time/temperature abuse (sauce prepared ≥24 h in advance, left at room temperature for several hours)	Mazuet et al. (2017) [32]

Prot: proteolytic C. botulinum, NP: non-proteolytic C. botulinum, NR: not reported