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## REVIEW ARTICLE

# Salmonellosis associated with mass catering: a survey of European Union cases over a 15-year period

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### SUMMARY

*Salmonella* spp. is the causative agent of a foodborne disease called salmonellosis, which is the second most commonly reported gastrointestinal infection in the European Union (EU). Although over the years the annual number of cases of foodborne salmonellosis within the EU has decreased markedly, in 2014, a total of 88 715 confirmed cases were still reported by 28 EU Member States. The European Food Safety Authority reported that, after the household environment, the most frequent settings for the transmission of infection were catering services. As evidenced by the reviewed literature, which was published over the last 15 years (2000–2014), the most frequently reported causative agents were *Salmonella* Enteritidis and *Salmonella* Typhimurium serovars. These studies on outbreaks indicated the involvement of various facilities, including hospital restaurants, takeaways, ethnic restaurants, hotels, in-flight catering, one fast-food outlet and the restaurant of an amusement park. The most commonly reported sources of infection were eggs and/or egg-containing foods, followed by meat- and vegetable-based preparations. Epidemiological and microbiological studies allowed common risk factors to be identified, including the occurrence of cross-contamination between heat-treated foods and raw materials or improperly cleaned food-contact surfaces.

**Key words:** Food safety, foodborne outbreaks, HACCP, raw eggs, *Salmonella*.

### INTRODUCTION

This review focuses on the role of the catering industry in the spread of salmonellosis in Europe. First, the review describes the main features of the microorganisms belonging to the genus *Samonella* and of the associated human illness called salmonellosis. The most important issues and criticalities of mass catering

are then described. The subsequent overview of current European Union (EU) legislation on matters of food safety places particular emphasis on regulations concerning zoonoses, since salmonellosis is included in the list of zoonoses that have to be properly monitored. The main focus of this paper is the ‘case reports’ section that reports the information available in the current literature concerning the role of the catering industry in the spread of salmonellosis. In particular, the review reports published studies on the documented occurrence of salmonellosis outbreaks in the EU related to the catering sector between 2000 and 2014. Finally, considering once again the available

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literature, the authors analyse and discuss the possible risk factors that could have contributed to the presence of *Salmonella* in food preparations, and the achievable corrective actions, as well as the implementation of good manufacturing practices.

The genus *Salmonella*, which is included in the Enterobacteriaceae family, comprises only two species (*Salmonella enterica* and *S. bongori*) of Gram-negative, facultatively anaerobic, non-spore-forming rods (1–2 µm). The optimal growth temperature is about 38 °C (with a minimum of 5 °C). *Salmonella* is generally susceptible to low pH values, although an acid tolerance response has already been described for many *S. enterica* serovars [1].

*S. enterica* comprises the following six subspecies: *enterica* (I), *salamae* (II), *arizonae* (IIIa), *diarizonae* (IIIb), *houtenae* (IV), and *indica* (VI), whereas for *S. bongori* no subspecies have been identified [2]. For epidemiological purposes, *Salmonella* nomenclature is based on the use of over 2400 serovars which differ in their host range and the associated disease. The illness caused by *Salmonella* is called salmonellosis, which is one of the most frequently reported foodborne pathologies worldwide [3]. The causative agents of the invasive form of salmonellosis are *Salmonella enterica* serotypes Typhi or Paratyphi A and B, which cause enteric fever, and *S. Paratyphi* C, which causes septicaemia and metastatic purulent infections, or *S. Enteritidis* and *S. Typhimurium* serotypes which cause the invasive non-typhoidal illness [4]. The incubation period of salmonellosis, which is usually self-limiting in 4–7 days, varies between 12 h and 36 h; typical symptoms of salmonellosis include: diarrhoea, nausea, abdominal pain, bloody stool, mild fever and chills, vomiting, headache and malaise. Plasmids from 50 kb to 100 kb have been associated with the virulence of *Salmonella*, the infective dose of which can vary from 20 to 10<sup>6</sup> cells [3].

As reported by Sanchez-Vargas *et al.* [2], in cases of uncomplicated gastroenteritis, an antimicrobial therapy is usually not indicated since the disease is generally self-limiting. However, for patients aged >50 years, immunosuppressed individuals, and patients with vascular abnormalities or prosthetic valves, grafts or joints, an antimicrobial therapy should be considered, since these subjects can risk invasive disease. Antibiotic treatment normally includes the use of azithromycin, cephalosporins, trimethoprim-sulfamethoxazole, or ampicillin [2].

The intestinal tract of a wide range of domestic and wild animals is known to be the most common

reservoir of *Salmonella* which can be transferred to humans and foodstuffs [1].

In the 7-year period between 2008 and 2014, a constant declining trend of salmonellosis was observed in the EU/European Economic Area (EEA) [5]. The EU summary report on trends and sources of zoonoses, zoonotic agents and foodborne outbreaks in 2014 [5] reported a 15.3% increase in the EU notification rate compared to 2013. In 2014, a total of 88 715 (23.4 cases/100 000 population) confirmed salmonellosis cases were reported by 28 EU Member States (MSs) with a 0.15% case-fatality rate. In parallel, from 2008 to 2014 the total annual number of foodborne *Salmonella* outbreaks within the EU decreased markedly from 1888 to 1048. As reported by the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) [5], in 2014, *S. Enteritidis* and *S. Typhimurium* caused a total of 169 outbreaks with strong evidence (in various environments); *S. Enteritidis* was the prevalent causative agent of salmonellosis related to the consumption of eggs and egg products (46.1%), bakery products (17.0%), broiler meat and its products (6.4%), sweets and chocolate (5.0%), cheese (4.3%), buffet meals (3.5%), mixed food and other foodstuffs (17.7%). The presence of *S. Typhimurium* was the main cause of illnesses associated with pork and its products (48.1%), eggs and egg products (29.6%), bakery products (1.0%), cheese (1.0%) and other food and food products (crustaceans, molluscs, etc.). Although the number of outbreaks is declining, it should be noted that, after the household environment, the most frequently reported settings for foodborne salmonellosis are still represented by mass catering establishments such as restaurants, cafés, pubs, bars, hotels, and catering services in general (41 outbreaks) [5]. The reduction in cases of salmonellosis in humans is mainly the result of effective *Salmonella* control programmes in fowl (*Gallus gallus*) populations, which have led in particular to fewer contaminated eggs. This has been achieved through the combined efforts of food business operators, veterinary public health authorities and policy makers [6].

As regards foods, *Salmonella* is notifiable in 16 MSs (Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Romania, Slovakia, Slovenia, Spain, Sweden) and in two non-MSs (Norway and Iceland). Information is not available from Cyprus, Croatia, Greece, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal and Switzerland [5].

## MASS CATERING CONCERNS

The main objectives of catering systems are related to the production and serving of food products to defined groups of consumers. Such systems are normally characterized by a series of inputs, which include: (i) ready-to-eat or unprocessed foods; (ii) a number of adequately trained operators; (iii) suitable premises and equipment; (iv) availability of any necessary funds [7]. Catering systems are normally divided in two main sectors: the ‘cost sector’, which includes not-for-profit catering activities such as healthcare, education, business and industry, and public services and the ‘profit sector’ which includes all profit-orientated organizations such as cafés, fast-food outlets, hotels, leisure operations, pubs, restaurants, takeaways and travel organizations [7].

Most catering establishments adopt a ‘cook–serve’ method in which preparation and serving are almost simultaneous and can therefore be considered as a single operation. Catering services may also be differentiated as food-manufacturing systems, where the serving of food is separate from its production, or meal-assembly/food-delivery systems, where the main activities are just the assembly, regeneration, and serving of meals [7].

All things considered, it is clear that the catering industry is characterized by a complex series of operations aimed at obtaining high-quality finished food products, intended for a wide range of consumers, and hence it is imperative to ensure food safety at each stage along the production chain.

The most common risk factors that can lead to foodborne outbreaks of disease include: poor quality raw materials, inadequate cooking, improper holding temperatures, a lack of hygiene conditions and cross-contamination [8].

## THE EUROPEAN FOOD SAFETY APPROACH

In the EU, food safety procedures are established by Regulation (EC) No. 178/2002 [9], and, in 2005, the European Commission issued the so-called ‘Hygiene Package’ which brought together the following key provisions: Regulation (EC) No. 852/2004 [10], Regulation (EC) No. 853/2004 [11], Regulation (EC) No. 854/2004 [12], and Regulation (EC) No. 882/2004 [13]. The new integrated approach set by the ‘Hygiene Package’ aimed to clarify and simplify the European legislative framework, while maintaining a

high level of public health safety. This approach specifically regulates food hygiene and distinguishes the responsibility of food business operators from that of competent authorities and creates a framework to regulate animal health aspects. The new legal framework supersedes the laws of individual countries and establishes general rules for food hygiene in all foodstuffs as well as specific rules for certain food businesses.

In more detail, as a part of the ‘Hygiene Package’, European Regulation (EC) No. 852/2004 [10] set obligations for food businesses in relation to food hygiene, establishing their responsibilities for the safety of foodstuffs. With this type of approach, food business operators are required to both decide and monitor measures for controlling any risk to public health. One of the basic obligations provided for by Regulation (EC) No. 852/2004 [10] is that food businesses have to implement permanent procedures based on Hazard Analysis and Critical Control Point (HACCP) principles in order to ensure the safety of foods.

Moreover, Regulation (EC) No. 853/2004 [11], which establishes rules for the organization of official controls on products of animal origin intended for human consumption, specifies that the official veterinarian is to impose the conditions in which animals are to be dealt with, under a specific scheme for the eradication or control of certain diseases, such as brucellosis or tuberculosis, or zoonotic agents such as *Salmonella*, under his/her direct supervision (chapter III, Decisions concerning live animals).

Among the Regulations contained in the ‘Hygiene Package’, Regulation (EC) No. 882/2004 [13] on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules, states that any more specific pre-existing rules in the areas of feed and food, and of animal health and animal welfare controls, must be applied. Regulation (EC) No. 882/2004 [13] also established community reference laboratories for the analysis and testing of zoonoses (*Salmonella*).

Moreover, from 1 January 2006, Regulation (EC) No. 2073/2005 [14], as amended by Regulation (EC) No. 1441/2007 [15], indicates microbiological criteria for foodborne bacteria (*Salmonella* spp., *Listeria monocytogenes* and *Enterobacter sakazakii*), microbial toxins (i.e. staphylococcal enterotoxins) and metabolites (i.e. histamine). Such criteria provide points of reference for the evaluation of the HACCP system by food business operators.

Most European legislation is aimed at protecting human health against diseases and infections which are transmissible directly or indirectly between animals and humans (zoonoses) since these foodborne infections may be the cause of severe social concern and economic losses.

The EU system for the monitoring and collection of information on zoonoses is based on the Zoonoses Directive 2003/99/EC [16] on the monitoring of zoonoses and zoonotic agents, which amended Council Decision 90/424/EEC [17] and repealed Council Directive 92/117/EEC [18]; in particular, Directive 2003/99/EC [16] identified *Salmonella* spp., *Campylobacter* spp., verotoxigenic *Escherichia coli* (VTEC), *L. monocytogenes*, *Cryptosporidium* spp., *Echinococcus granulosus/multilocularis* and *Trichinella spiralis* as public health priorities. In this context EU MSs are responsible for collecting data via their monitoring systems and for the epidemiological investigation of outbreaks. The European Commission also promotes the cooperation and exchange of information and evaluates trends at European level. The collection of data on human diseases from MSs is carried out in accordance with Decision 1082/2013/EU [19] on serious cross-border threats to health, which replaced Decision 2119/98/EC [20] on setting up a network for the epidemiological surveillance and control of communicable diseases in the EU. National zoonoses reports are used as the basis for the EU Summary Reports on Trends and Sources of Zoonoses, zoonotic agents, antimicrobial resistance and foodborne outbreaks in the EU, drawn up each year by the EFSA and the ECDC.

## CASE REPORTS

Despite great progress in the field of food safety, meals produced and served by the catering sector continue to be one of the major causes of foodborne infections and poisoning, with serious social and economic consequences, especially when vulnerable consumers are involved [21]. As reported by Møller and colleagues [22], it is estimated that 70% of worldwide foodborne illnesses are related to food prepared at food service establishments.

Inadequate application of good manufacturing practices (GMPs) by the staff involved in the preparation of meals at catering facilities and, in particular, the incorrect heat treatment of foods, can be pivotal factors which contribute to outbreaks of foodborne illnesses. The studies described below, emphasise the importance of the proper management of foods, also in

relation to the risk associated with the presence of *Salmonella*.

In 2000, an outbreak of salmonellosis, caused by *S. Enteritidis* phage types 5c and 6a, occurred across Scotland [23]. A total of 70 cases, probably related to the consumption of chicken dishes from Chinese restaurants or takeaways, were recorded. Unfortunately, environmental analyses did not identify the source of chicken contamination.

Following a series of gastrointestinal symptoms affecting consumers who had eaten a meal in a Chinese restaurant in Suffolk (UK) in 2002 [24], an outbreak control team carried out epidemiological, microbiological and environmental investigations. The cohort study found 38 consumers who met the case definition of salmonellosis, of whom two were hospitalized; *S. Enteritidis* phage type 34a was found in 31 stool specimens subjected to microbiological analyses. The study identified significantly high attack rates related to egg and chicken fried rice; the chef confirmed that the egg mixture used for egg-fried rice was subjected to temperature abuse before serving. Moreover, the environmental inspection highlighted deficiencies in good hygiene practice (i.e. inadequate hand-washing facilities). From the analysis of data, Badrinath and colleagues [24] suspected that dishes containing eggs were the most likely source of the outbreak, suggesting that the use of pasteurized eggs and the correct application of GMPs would have prevented the outbreak.

A buffet consisting of meat, potatoes, pasta, and raw vegetables, was found to be the origin of an outbreak of salmonellosis in Denmark in 2003 [25]. The restaurant involved was part of a catering system of 35 facilities located in an amusement park near Copenhagen. Due to the high number of visitors, 67 cases were confirmed, while a total of 390 cases were estimated as the real number of people infected. Epidemiological and microbiological studies indicated that the contamination of foods was probably caused by an assistant chef who was found to excrete the epidemic strain of *S. Typhimurium* phage type DT104. A non-functional staff toilet, meaning that staff and customers had to use the same toilet facilities, was considered the most probable risk factor.

Following a significant change in the epidemiology of *S. Enteritidis* in England and Wales which was probably due to the use of raw shell eggs, in 2002, the UK Health Protection Agency launched an investigation to determine the contamination and the origin of the eggs used by the catering plants involved in the

outbreaks. The use of eggs produced in Spain was identified as a risk factor in many of the outbreaks, hence raw shell eggs were prohibited in catering facilities and hospitals. Sixteen phage types were identified in some isolates of *S. Enteritidis* from Spanish eggs [26].

Prior to the 2004 Athens Olympic Games, an integrated environmental health surveillance programme was implemented. During the surveillance activity, in August 2003, an outbreak of salmonellosis occurred, linked to a hotel restaurant which accommodated athletes during a test event. The hotel involved had already been ranked by environmental health surveillance officers as having the most unsatisfactory results even before the outbreak occurred [27].

Irvine and colleagues reported a large outbreak of *S. Newport* that occurred in Northern Ireland during September and October 2004 with 130 reported cases [28]. The statistical analysis carried out on control cases associated the outbreak with the consumption of lettuce (probably iceberg lettuce) in meals produced in fast-food premises (American-style hamburger outlets and fish-and-chip shops); this exposure was reported in 57% of cases. Unfortunately, no samples of contaminated salads were available for microbiological analyses.

Heissenhuber and colleagues [29] reported a contaminated pudding which was probably responsible for an outbreak of *S. Enteritidis* in hospitals and nursing homes in 2004 in Germany.

In the same year, roast chicken served at a hospital restaurant in Greece was identified as the cause of an outbreak of salmonellosis in 133 patients, visitors and hospital employees [30]. Despite the fact that epidemiological and microbiological investigations indicated *S. Enteritidis* as the causative agent of the outbreak, the source of contamination remained speculative. However, the main risk factors associated with the outbreak could be attributed to a lack of GMPs, including: non-systematic use of gloves and gowns, the use of common surfaces for raw materials and ready-to-eat foods, improper sanitation procedures, inadequate temperature control, and/or inadequate cooking.

Although infection originating in fast-food premises has been rarely described, in 2005, one of the largest outbreaks of enteric infection occurred in a fast-food outlet located in London (UK) [31]. *S. Enteritidis* was isolated from both stool samples and 14 out of 40 food samples examined. Moreover, an environmental health inspection of the premises highlighted deficiencies in food preparation (i.e. time-temperature

abuse in sauce storage) and hygiene. The most serious cases were related to the consumption of chips and salads produced in the same plant.

In the same year *carpaccio* was identified as the probable source of an outbreak that occurred in an Italian restaurant in Denmark [32, 33]. Eleven customers who had eaten at the restaurant were hospitalized; all the infections were laboratory-confirmed.

In 2008, iceberg lettuce was the most probable source of an infection caused by both *S. Newport* and *S. Reading* in Finland [34]. The ready-chopped lettuce was prepared by institutional kitchens and served in different catering plants; a total of 107 confirmed cases of salmonellosis were reported, and two patients died. Epidemiological and microbiological investigations allowed the source of contamination to be traced back to the lettuce but did not reveal the risk factor.

Janmohamed and colleagues [35] reported the results of an epidemiological investigation after a national outbreak of *S. Enteritidis* phage type 14b that occurred in England in 2009. Sixty-three cases were studied; the study revealed that eating foods from restaurants serving Chinese or Thai cuisine was significantly associated with the illness. Fortunately, no deaths were reported in the cases studied. The source of contamination was found to be eggs originating from Spain used for the preparation of egg meals and vegetarian foods containing eggs. Microbiological analyses on eggs collected from food-service premises and egg production establishments, revealed the presence of *Salmonella* in both plants.

In 2014, Zenner and colleagues [36] published the results of a large *S. Enteritidis* outbreak which occurred in a north west London (UK) takeaway restaurant during September 2009. The study was carried out using a new approach based on the analysis of till receipts to assess associations between sales and illness. Analysis of stool samples, from the initial patients with enteric illness, identified *S. Enteritidis*; subsequently, a number of patients went to hospital with symptoms of diarrhoea and vomiting. The epidemiological investigation allowed 66 individuals to be identified, which fulfilled the definition of a probable or confirmed outbreak of salmonellosis. Of these, 31 were classified as confirmed cases by microbiological analyses on stool samples. The data obtained from epidemiological and microbiological analyses and till receipt collection indicated a correlation between the consumption of rotisserie chicken and illness. Cross-contamination between raw and cooked foods, and insufficient recording of temperature control were noted as risk factors.



In 2010, a retrospective cohort study was conducted to identify the food item(s) most likely to be associated with an outbreak of *S. Enteritidis* phage type 4 that occurred during a soccer camp in Austria [37]. Among the 143 participants, 34 were found to be affected by salmonellosis with an attack rate of 23.8%. Epidemiological and microbiological analyses revealed that eggs used as ingredients for spaetzle (homemade noodles) and hamburgers, produced in the hotel that accommodated the soccer camp participants, were considered to be the most probable vehicle of the outbreak strain. The public health authorities which carried out hygiene inspections in the kitchen of the hotel found a lack of food safety practices related to unclean food contact surfaces (including ovens, grills and stoves), improper storage conditions, and inadequate training of kitchen staff.

In the same year (2010) an outbreak of *S. Enteritidis* occurred in a hospital located in Germany [38]. After the epidemiological investigation, the authors identified cheesecake, served by two different cafeterias located in the hospital, as the source of infection. Since neither of the cafeterias prepared the cheesecake, the authorities contacted the bakery which supplied both the catering plants. The bakery was ordered to stop using raw eggs. At the same time the stool of one member of the staff was found positive for the presence of *S. Enteritidis*. The authors suspected that the relatively low cooking temperature of the cheesecake allowed the survival of the pathogens already present in the inner part of the cake.

The consumption of salad leaves at restaurants and/or purchased from commercial catering organisations was significantly associated with a large outbreak of *S. Java* in the UK in 2010 [39]. The probable cross-contamination between meat products and salads during food preparation in the catering plants was found to be the risk factor.

In 2011, a group of Irish travellers contracted salmonellosis caused by *S. Heidelberg* during their return flight from Tanzania; the symptoms included diarrhoea, abdominal pain, fever, nausea, vomiting and bloody diarrhoea. Rebolledo and colleagues [40] conducted a case-control study in order to establish the source of infection. The study identified milk tart and egg dishes served on board as significantly associated with the outbreak, hence, the producer of the meals, located in Tanzania, was contacted and asked to provide documentation on food preparation procedures. Other passengers from The Netherlands, Norway, USA, and Canada, travelling from Tanzania

in the same period, were also contacted. Some of them were found to be positive to the infection; this information contributed to better defining the source of infection (in-flight catering), although the risk factors which contributed to the contamination of foods remained unclear.

After the largest *S. Newport* outbreak, which occurred in Germany in 2011 [41], an analytical epidemiological and microbiological investigation was carried out. The outbreak involved 106 individuals in Germany and 20 associated cases in The Netherlands; the study, which was carried out in parallel in the two countries, traced the contamination of *S. Newport* to mung bean sprouts sampled from both the producer of the sprouts, located in The Netherlands, and the distributor in Germany. Sprouts were served at a clinic salad bar and Asian restaurants in Germany, and in a hospital in The Netherlands. The authors concluded that raw or insufficiently cooked sprouts, which were already naturally contaminated, were the source of the infection.

Recently, Chironna and colleagues [42] reported the results of an investigation carried out after an outbreak of acute gastroenteritis in people who had eaten at an inexpensive restaurant in southern Italy. Laboratory analyses confirmed infection caused by *Salmonella* which was isolated from a stool sample. A total of 23 cases of gastroenteritis (two of which were hospitalized) were notified. All cases reported symptoms of diarrhoea, fever, abdominal cramps, vomiting and nausea. The kitchen facility in the inexpensive restaurant was subjected to microbiological analyses carried out on the work surfaces including: the porchetta cutting board, the tray table, knife, mincer, handle of freezer and handle of the staff toilet. Porchetta (a typical central Italy speciality) and stool samples were also analysed. Environmental analyses revealed *S. Infantis* on the porchetta cutting board, in the four tested pieces of porchetta and in the stool samples. The stools collected from staff members were also positive for the same pathogen, despite the absence of symptoms.

Recently, Inns and colleagues [43], reported a multi-country outbreak of *S. Enteritidis* phage type 14B in the UK; the food chain investigation allowed the illness to be associated with eggs from a German producer. A total of 287 cases were recorded, of which *Salmonella* infection was considered to be a contributory factor in the death of one patient. Epidemiological and environmental investigations allowed the pathogen to be sampled from a catering

trolley in one of the wards of a hospital. Cooked chicken, pork and egg-containing vegetarian noodles sampled in restaurants were also found positive for the presence of *Salmonella*. Interestingly, the pathogen whole genome sequencing carried out in this study, discovered a link between the isolates from patients, eggs and environmental samples collected in premises and clusters of cases in an outbreak that occurred in several EU MSs.

## DISCUSSION

Although a decreasing trend in the number of cases of salmonellosis has been observed in the EU, *Salmonella* is still the causative agent of most of the reported foodborne outbreaks in the EU, and in fact salmonellosis is the second most commonly reported gastrointestinal infection in the EU/EEA [44].

The analysis of the reviewed literature, described in detail in the previous section and summarized in Table 1, highlighted the prevalence of the *S. Enteritidis* serovar as the causative agent of the outbreaks, followed by *S. Typhimurium* (found in the cases that occurred in Denmark) and, to a lesser extent, by *S. Java*, *S. Infantis*, *S. Heidelberg* and, *S. Newport*. These findings are in agreement with the data published by the ECDC which reported that, in 2012, the five most commonly reported serotypes of *Salmonella* belonged to *S. Enteritidis*, *S. Typhimurium*, monophasic *S. Typhimurium*, *S. Infantis*, and *S. Stanley* [44]. As stated by Regulation (EC) No. 2073/2005 [14], it has been demonstrated that the implementation of control programmes can markedly contribute to a reduction in the prevalence of *Salmonella* in production animals and products thereof. Moreover, Annex I of the same EU Regulation (chapter 1) specified the absence of *Salmonella* in 25 g of product placed on the market during shelf-life, except for minced meat and meat preparations made from species other than poultry which are intended to be eaten cooked, and for mechanically separated meat for which the absence of *Salmonella* in 10 g of product is required.

As regards the infection environments, the reported outbreaks, which were widespread in several EU countries, showed the involvement of various facilities, including: hospital restaurants, takeaways, ethnic restaurants, hotels, in-flight catering, one fast-food outlet and the restaurant of an amusement park. To the best of the authors' knowledge no *Salmonella* infections in school catering plants were reported in the considered period. The case studies published

over a 15-year period, showed the involvement of about 1300 users, although with a low mortality rate (eight cases). It is worth underlining that each catering environment is characterized by different peculiarities, especially as regards the type of consumer. Among the most critical settings, hospital restaurants can cause outbreaks with the highest mortality rates; as clearly shown in Table 1, 5/8 reported deaths occurred in such facilities. This finding is not surprising, since hospitalized patients can be considered as high-risk consumers.

Regarding the sources of the outbreaks, the traceability system, the implementation of which is guaranteed by the application of Regulation (EC) No. 178/2002 [9], has played a key role in tracing the foods (and/or the producers) which caused the outbreaks. Of the 18 reviewed salmonellosis outbreaks (from 2000 to 2014), about one third were related to the consumption of eggs and/or egg containing foods (i.e. egg-fried rice, vegetarian food containing eggs, cheese-cake, raw eggs, etc.). This finding is confirmed by the EFSA and ECDC EU Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Foodborne Outbreaks [5] which reported that, in 2014, the most important sources of foodborne *Salmonella* outbreaks were eggs and egg products. In 2010 the Food Safety Authority of Ireland (FSAI) issued Fact Sheet No. 1 [45] which included guidelines for caterers in order to reduce the risk represented by the use of fresh shell eggs and products made from fresh eggs. The reported high-risk dishes include tiramisu, scrambled egg, omelette, quiche, some pastry products, mousse, homemade mayonnaise, homemade ice-cream, hollandaise or similar sauces. Recently, the ECDC and the EFSA [46] have reported a multi-country outbreak of *S. Enteritidis* infection associated with the consumption of eggs from Germany. The ECDC and EFSA also warn that *S. Enteritidis*-contaminated eggs have been able to reach the market, despite the strict regulations applying to table eggs for human consumption, and the success in reducing human and animal infections in recent years within the EU. Hence it is necessary to continue a close monitoring of the occurrence of human cases through the Epidemic Intelligence Information System for Food- and Waterborne Diseases and Zoonoses (EPIS-FWD) and MS surveillance.

Moreover, meat-based products were also considered as an important source of infection. As evidence of the constant efforts made by the scientific

Table 1. Reported cases of salmonellosis outbreaks related to catering services in the European Union (2000–2014)

Year	EU country	Catering service involved	Food involved	<i>S. enterica</i> serovars	Cases	Hospitalized patients	No. of deaths	Risk factors	Reference
2000	UK	Chinese food businesses	Chicken dishes	<i>S. Enteritidis</i>	70	n.r.	1	n.r.	Cowden <i>et al.</i> 2003 [23]
2002	UK	Chinese restaurant	Egg-fried rice	<i>S. Enteritidis</i>	38	2	0	Cleaning and maintenance issues, improper maintenance temperature of egg rice mixture	Badrinath <i>et al.</i> 2004 [24]
2003	Denmark	Restaurant at an amusement park	Food buffet	<i>S. Typhimurium</i>	77	n.r.	0	Assistant chef who excreted the epidemic strain, non-functional staff toilet	Ethelberg <i>et al.</i> 2004 [25]
2003	Greece	Hotel restaurant	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	Hadjichristodoulou <i>et al.</i> 2006 [27]
2004	Northern Ireland	Fast-food premises	Lettuce	<i>S. Newport</i>	130	25	0	n.r.	Irvine <i>et al.</i> 2009 [28]
2004	Germany	Hospital catering	Pudding	<i>S. Enteritidis</i>	n.r.	n.r.	2	n.r.	Heissenhuber <i>et al.</i> 2005 [29]
2005	Greece	Hospital catering	Roast chicken	<i>S. Enteritidis</i>	133	n.r.	2	Cross-contamination, inadequate temperature control and/or inadequate cooking	Gikas <i>et al.</i> 2007 [30]
2005	UK	Fast food	Chips, salad, chilli sauce, chicken, mint yogurt sauce	<i>S. Enteritidis</i>	81	n.r.	0	Inadequate heat treatment practices, time temperature abuse, cross-contamination of raw and cooked ingredients, a lack of hygiene	Giraudon <i>et al.</i> 2009 [31]
2005	Denmark	Restaurant	Carpaccio (thinly sliced, raw fillet of beef)	<i>S. Typhimurium</i>	40	11	0	Contaminated raw meat	Ethelberg, 2005 [32]; Ethelberg <i>et al.</i> 2005 [33]
2008	Finland	Institutional kitchens	Ready-chopped iceberg lettuce	<i>S. Newport</i> , <i>S. Reading</i>	107	n.r.	2	Uncertain	Lieneman <i>et al.</i> 2011 [34]



Table 1 (cont.)

Year	EU country	Catering service involved	Food involved	<i>S. enterica</i> serovars	Cases	Hospitalized patients	No. of deaths	Risk factors	Reference
2009	UK	Takeaway restaurant	Rotisserie chicken	<i>S. Enteritidis</i>	66	22	0	Cross-contamination between raw and cooked foods, insufficient recording of temperature control	Zenner <i>et al.</i> 2014 [36]
2009	UK	Restaurants serving Chinese or Thai cuisine	Eggs, vegetarian food (containing eggs)	<i>S. Enteritidis</i>	63	12	0	Contamination of laying flocks of eggs production establishment	Janmohamed <i>et al.</i> 2011 [35]
2010	Germany	Local pastry supplier	Cheesecake	<i>S. Enteritidis</i>	7	4	0	Cross-contamination, insufficient cooking temperature of the cheesecake	Poetter <i>et al.</i> 2014 [38]
2010	Austria	Hotel	Spaetzle (homemade noodles), hamburger	<i>S. Enteritidis</i>	34	n.r.	0	A lack of food safety practices	Liu <i>et al.</i> 2012 [37]
2011	UK	Commercial catering settings	Salad vegetables	<i>S. Java</i>	136	n.r.	0	Probable cross-contamination from meat products during food preparation in catering establishments	Gobin <i>et al.</i> 2011 [39]
2011	Italy	Hash house	Porchetta	<i>S. Infantis</i>	23	2	0	Uncertain	Chironna <i>et al.</i> 2014 [42]
2011	Ireland	In-flight catering	Milk tart and egg dish	<i>S. Heidelberg</i>	25	5	0	Uncertain	Rebolledo <i>et al.</i> 2014 [40]
2011	Germany, The Netherlands	Clinic and Asian restaurants in Germany, hospital in The Netherlands	Mung bean sprouts	<i>S. Newport</i>	126	38	0	Insufficient heat treatment of undercooked sprouts	Bayer <i>et al.</i> 2014 [41]
2014	UK	Hospital canteen, three restaurants	Eggs from a German producer	<i>S. Enteritidis</i>	287	78	1	Not reported, probably undercooked food	Inns <i>et al.</i> 2015 [43]

n.r., Not reported.

community to reduce the risk of *Salmonella* in foods, recently Møller and colleagues [22] carried out a risk assessment of *Salmonella* in Danish meatballs produced in the catering sector. These authors determined that a temperature of  $\sim 70$  °C at the core of the meatballs, using oven heating, significantly reduced the risk of *Salmonella*. The authors also found that the risk was low even with pan-frying provided that the meatballs were not exposed to conditions that allow the growth of the pathogen. As evidenced by the analysis of the scientific literature, the quality of raw materials can also be identified as a parameter of fundamental importance, especially when raw meats are consumed without cooking (e.g. carpaccio). Recently, Zweifel & Stephan [47] shed light on the contribution of spices and herbs in *Salmonella*-related foodborne diseases. Usually, these ingredients are used either for the production of cured raw meat products not subjected to heating or for the seasoning of ready-to-eat products. The authors found frequencies of *Salmonella*-positive samples ranging from 0% to 8.4%. Zweifel & Stephan [47] suggested that the microbiological status of spices and herbs should be carefully monitored by food business operators since these ingredients might constitute a threat for the contamination of end products.

As far as risk factors are concerned, some common elements were represented by the occurrence of cross-contaminations between heat-treated foods and raw materials (eggs and raw meat) or the inadequate application of GMPs. Moreover, a combination of factors such as structural deficiencies of the producing plant (e.g. the non-functional staff toilet) and infected members of staff was an acknowledged cause of risk. Despite epidemiological and microbiological investigations, in some of the reported cases it was not possible to discover the risk factors that contributed to the spread of *Salmonella* infections.

Since structural deficiencies can usually only be resolved by the allocation of considerable funds, one way to improve the hygiene conditions of catering facilities is to optimize the application of GMPs and act decisively on staff training.

It is well-known that, in food production environments, *Salmonella* can be particularly insidious, since it can persist thanks to its ability to adhere to several food contact surfaces, forming biofilms. Srey and colleagues [48] reported that *Salmonella* can produce biofilms on plastic surfaces used in the food industry. Moreover, it has also been found that this pathogen could demonstrate a different degree of

adhesiveness to Teflon, stainless steel, glass, and polyurethane. In order to obtain safer foods Lianou & Sofos [49], pointed out that structured training programmes for staff are essential. It is common knowledge that the contamination of foods (as well as cross-contamination) can be reduced by washing hands, the use of gloves, the separation of raw materials from end products, the sanitation and disinfection of equipment and food contact surfaces. Moreover, as reported by Luning and colleagues [50], the observation of food handlers with direct intervention to change incorrect behaviour can be useful for developing a greater food safety awareness.

On this subject, Powell and colleagues [51] reported that training programmes are often ineffective and their knowledge evaluation does not reflect real improvements in practices; on the contrary, Gormley and colleagues [52] state that trained staff have a greater knowledge of food safety than non-trained personnel.

The WHO Fact Sheet No. 139 [53] established a set of hygiene rules for food preparation addressed to food businesses. Among these, the WHO document states that professional food handlers who suffer from fever, diarrhoea, vomiting or visibly infected skin lesions should report these symptoms to their employer immediately. The WHO also set the following so-called 'Five Keys to Safer Food' as the basis for educational training programmes: keep clean, separate raw and cooked, cook thoroughly, keep food at safe temperatures, use safe water and raw materials. Although these recommendations may appear somewhat simple or obvious, an incorrect application of one or more of them, can lead to the failure of the entire prevention system.

## CONCLUSIONS

The efforts made over the years by the European Legislative Bodies, by the EFSA and the ECDC and by the National Food Safety Authorities of EU MSs, have led to a progressive and significant reduction in salmonellosis cases related to catering and, more in general, to the food industry. These achievements should not underestimate the risk that *Salmonella* can still represent, since, even in recent years, there have been cases of salmonellosis related to the catering sector, hence, epidemiological and microbiological studies remain pivotal in order to trace the sources of contamination. In addition, the application of preventive measures based on the

adoption of GMPs and the proper training of the staff continue to play a key role in ensuring the safety of foods.

## DECLARATION OF INTEREST

None

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