## REVIEW ARTICLE

# Egg-borne infections of humans with *Salmonella*: not only an Enteritidis problem

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None.

## Summary

The principal *Salmonella* serovar associated with infections linked to eggs and egg products in the UK, most European countries and North America is *Salmonella* Enteritidis. However, other serovars have also been implicated in a number of egg-associated outbreaks, most notably *S.* Typhimurium exhibiting a range of phage types. The present article reviews human egg-associated salmonellosis associated with non-*S.* Enteritidis serovars, predominantly in the European Union (EU) but also world-wide, using information from the published literature and epidemiological databases. There are also brief reviews of *S.* Enteritidis and of mechanisms leading to egg contamination by *Salmonella*.

The numbers of egg-associated infections caused by non-*S.* Enteritidis serovars are fairly substantial (for example 22 % of outbreaks and 11.5 % of more than 20,000 cases in the EU in 2008), and such infections have resulted in hospitalisations and deaths. Furthermore, in parts of the world where *S.* Enteritidis historically did not penetrate laying hen breeding flocks, egg-related salmonellosis is a problem associated specifically with non-Enteritidis serovars.

Control measures to limit the incidence of *S.* Enteritidis and *S.* Typhimurium in poultry flocks are vital. It is therefore important that close surveillance of *Salmonella* incidence and serovars in laying flocks is used to inform suitable biosecurity and vaccination programmes throughout EU Member States and elsewhere.

## Introduction

### Salmonellosis associated with eggs

In the European Union (EU), because of their relative frequency certain strains within two serovars (*Salmonella* Enteritidis and *S.* Typhimurium) are considered to be of public health significance. Together, they account for approximately 80% of all the human isolates to which typing has been applied (EFSA, 2009a, 2010a). Other serovars do not individually exceed 1% of the total, although this proportion may vary between and within individual Member States (MS) on a year-by-year basis. Non-*S.* Enteritidis serovars have contributed to over 20% of EU *Salmonella* case hospitalisations and have also resulted in fatalities over the last five years (EFSA, 2009a, 2010a). Attribution models from two EU MS and outbreak data from the EU (EFSA, 2010a) and elsewhere show that in relation to eggs from *Gallus gallus*, *S.* Enteritidis is by far the serovar most frequently associated with human illness. In comparison to *S.* Enteritidis the role of other serovars as causes of egg-borne infections is, in general, considered to be less important. In 2008, *S.* Enteritidis accounted for 88.5% of individual egg-associated cases and 77.2% of egg-associated outbreaks in the EU (EFSA, 2010a). In MS where *S.* Enteritidis is not endemic in the laying flocks, or has been reduced due to targeted control, the relative contribution from other serovars, including *S.* Typhimurium, may be higher. Additionally in some MS, outbreaks of non-*S.* Enteritidis serovars associated with eggs could have occurred, but because of the relatively low number of infections, may have gone undetected. Similarly, in parts of the world where *S.* Enteritidis does not appear to have penetrated the national poultry flocks to the same extent as in the EU, other serovars have caused infections associated with poultry and poultry products (Broughton *et al.*, 2010; OzFoodNet Working Group, 2009)

A review (EFSA, 2009b), of peer-reviewed scientific literature published in the period 1970 to 2008 reporting on *Salmonella* serovars involved in foodborne outbreaks linked to the consumption of eggs or egg products, indicated that *S.* Enteritidis was implicated in nearly 97% of such outbreaks, with *S.* Typhimurium implicated in 1.6%. Potential biases in these figures included differing standards of proof for attribution of infection source, the possibility of the same outbreak being reported more than once, and heavy representation of the USA and Europe compared with the rest of the world.

## Context of *Salmonella* Enteritidis

Since the mid-1980s, *S.* Enteritidis has been a major cause of human salmonellosis in Europe and North America (Baumler *et al.*, 2000; Hogue *et al.*, 1997; Velge *et al.*, 2005). *S.* Enteritidis is also the serovar most commonly isolated from humans globally (Herikstad *et al.*, 2002; Vieira, 2009; WHO, 2010). Nevertheless there are some major geographical areas where *S.* Enteritidis does not dominate in human infections. In North America *S.* Typhimurium has, for many years, been the principal serovar, although co-dominant with *S.* Enteritidis in some years (CDC, 2008; Vieira, 2009). In Australasia *S.* Enteritidis infections of humans are relatively uncommon (WHO, 2010) and are typically associated with foreign travel (OzFoodNet Working Group, 2009). There has been a steady decline in the incidence of isolates of *S.* Enteritidis from humans in the UK from a peak in the late 1990s, although *S.* Enteritidis remains the most common serovar isolated. Other serovars (notably *S.* Typhimurium) have not declined proportionately, so their relative importance has increased over the same period (HPA, 2011).

Poultry products, especially undercooked and raw eggs, have been a major risk factor for human infection with *S.* Enteritidis (Coyle *et al.*, 1988; Doorduyn *et al.*, 2006; EFSA, 2010b; Hogue *et al.*, 1997; Kist and Freitag, 2000). Historically, vertical transmission of infection was important in the spread of *S.* Enteritidis within poultry breeding pyramids and by international trade in breeding stock (Baumler *et al.*, 2000; Laconcha *et al.*, 2000; Lister, 1988; Nakamura *et al.*, 1993), providing epidemiological evidence for transovarian infection of chicks by this serovar. Endemic infection of national flocks with *S.* Enteritidis has not occurred in some countries, notably Australia (Murray, 1994), where egg-associated human outbreaks are dominated by *S.* Typhimurium (OzFoodNet Working Group, 2009). In many countries improved biosecurity and hygiene in the poultry industry since the mid-1990s, plus legislative pressure and *Salmonella* vaccination (where permitted), have been followed by a reduction in reported incidents of *S.* Enteritidis in poultry and in humans (Defra, 2010; EFSA, 2010a; Marcus *et al.*, 2004; Mumma *et al.*, 2004; Wegener *et al.*, 2003). There remains a substantial reservoir of *S.* Enteritidis infection in commercial laying flocks in Europe and other *S.* Enteritidis-endemic regions (EFSA, 2010a; Garber *et al.*, 2003) and persistence of contamination on commercial laying farms is currently considered to be the predominant problem (Carrique-Mas *et al.*, 2008, 2009; Davies and Breslin, 2003; van de Giessen *et al.*, 1994).

## Egg infection by *Salmonella*

For consumers, the principal risk of *Salmonella* infection from layer flocks is *via* the consumption of contaminated eggs. The number of organisms within a fresh infected egg is typically low (less than 100 organisms), although occasionally greater than a thousand (Gast *et al.*, 2002; Humphrey *et al.*, 1991). Among eggs from infected flocks, the prevalence of internal or external *Salmonella* contamination appears to vary substantially in studies from the UK, the USA and elsewhere, from less than 0.03% to 1% of eggs overall (Davies and Breslin, 2004; De Buck *et al.*, 2004; Poppe *et al.*, 1998). Clustering can result in higher frequencies: for example seven out of a batch of 20 six-egg pools were positive in one UK outbreak investigation in 2002 (Anon., 2002). Table eggs collected from processing and at retail in 15 EU MS during 2008 showed that 0.5% of units (eggs or batches) were *Salmonella*-positive overall, but there was a wide range between results from individual MS, of 0% to 22.6% positive. A higher contamination frequency (1.1%) was found among egg products (Anon., 2002).

Systemic infections of hens with *Salmonella* can result in the infection of the reproductive tract, in both experimental and field studies (Barnhart *et al.*, 1991; Corkish *et al.*, 1994; Cox *et al.*, 2000; Hoop and Pospischil, 1993; Lister, 1988). Experimental inoculations by a variety of routes, including intravenous, conjunctival, cloacal and vaginal, have resulted in detectable *Salmonella* in the ovaries and oviduct of laying hens, thereby respectively providing routes for *in vivo* infections of yolk and albumen, (Cox *et al.*, 1973, 2000; Gantois *et al.*, 2008; Miyamoto *et al.*, 1997; Okamura *et al.*, 2001a, b). In an intravenous infection model (Okamura *et al.*, 2001a), *S.* Enteritidis colonised the caecum and reproductive organs in higher numbers and for longer periods than five other serovars (including *S.* Typhimurium), and was the only one found to have infected eggs internally. When the same serovars were administered vaginally, *S.* Enteritidis was again recovered more frequently and in higher numbers from reproductive organs and egg contents, than the other serovars although in this study *S.* Typhimurium also infected eggs (Okamura *et al.*, 2001b). In an oral inoculation study the serovars *S.* Typhimurium, *S.* Senftenberg and *S.* Thompson appeared to be poor internal colonisers of eggs (Cox *et al.*, 1973).

Epidemiological data concur with experimental evidence of the exceptional capacity of *S.* Enteritidis to infect eggs. In a systematic survey of EU laying flock premises only around 50% of *Salmonella* isolates were *S.* Enteritidis (EFSA, 2007b). Nevertheless, in the EU Enteritidis remains the pre-eminent serovar in isolates from eggs and egg products (90.3% and 66.5% of reported serovars in 2006 and 2007, respectively) (EFSA, 2007a, b) and among egg-associated outbreaks of salmonellosis (88.5% of cases in 2008) (EFSA, 2010a).

Furthermore, the original dissemination of *S.* Enteritidis through the breeding pyramids suggests a substantial capacity for the internal infection of eggs.

Current epidemiological and experimental findings, reviewed recently (Wales and Davies, 2011) do not provide a coherent picture of the mechanisms that underlie the difference in behaviour between *S.* Enteritidis and other common serovars in respect of egg infection. Some evidence points to transovarian transmission, but events in the reproductive tract may be significant modifiers or originators of internal infection. Data presented by Keller *et al.* (1995) supported a hypothesis that although *S.* Enteritidis infects many forming eggs *via* the albumen, most of this does not survive through to the laid egg. Thus much *S.* Enteritidis infection of laid eggs may be acquired from the lower reproductive tract and/or cloaca, being drawn in through the shell as the egg cools.

Evidence of this nature has led some investigators to consider that a significant proportion of internal infection of eggs may be acquired across the shell after lay (Cox *et al.*, 2000; Guan *et al.*, 2006). The penetration of freshly-laid eggs by *S.* Typhimurium, with infection to the point of hatching, was very successful regardless of whether it was applied by spray or by contact with dry, contaminated litter (Padron, 1990). This suggests that systemic infection of hens is not an absolute pre-condition for eggs to become internally infected by *Salmonella*, provided that the organism comes into contact with the surface of freshly-laid eggs, whether via faecal, vaginal or environmental contamination, and the strain is one that can survive once it has penetrated the eggshell.

In addition to the internal infection of eggs, *Salmonella* may present a hazard as a contaminant confined to the surface of soiled eggshells. It appears to be difficult to reliably differentiate internal egg infection from eggshell contamination (Messens *et al.*, 2005) and survey estimates of the ratio of externally to internally contaminated eggs vary considerably, in the range of 4:1 to 20:1 in large-sample surveys that tested shells and contents separately

(FSA, 2004). In a study of eggshell contamination linked to farms in France, serovars found on eggshells included many non-*S.* Enteritidis isolates and reflected those found on the source farm in environmental and faeces samples (Chemaly *et al.*, 2009). It is considered by many investigators in areas where *S.* Enteritidis is not endemic that most egg contamination is via soiled eggshells and does not always relate to any single dominating serovar (EFSA, 2010b; Greig and Ravel, 2009).

Eggs that have visible external soiling by faeces or other extraneous matter were significantly more likely to yield *Salmonella* than were clean eggs in one UK survey of catering eggs (Little *et al.*, 2008). A Canadian study found a significantly elevated frequency of *Salmonella* contamination among eggs that were dirty but only if they were also cracked (Poppe *et al.*, 1992). Soiling may introduce, but will also protect, *Salmonella* on the egg surface (Braun *et al.*, 2002), and it disqualifies an egg from the European 'Grade A' class, used for retail and catering supplies (Anon., 2003).

## Non-*S.* Enteritidis outbreaks

For the purposes of this review, information on non-*S.* Enteritidis egg-related salmonellosis is divided into reports of egg-associated outbreaks of non-*S.* Enteritidis serovars from England and Wales, the rest of Europe, countries outside Europe other than Australia, and finally, Australia.

### England and Wales

In the 26-year period 1984 – 2010, 18 outbreaks of infection linked to eggs and involving non-*S.* Enteritidis serovars were identified, including five possibly related outbreaks in the north of England during 1984 and 1985 (Table 1). Over 950 persons have been affected, with at least 51 hospitalisations and seven deaths. Seven serovars have been implicated: *S.* Typhimurium (12 outbreaks), *S.* Panama, *S.* Hadar, *S.* Montevideo, *S.* Indiana, *S.* Bareilly and *S.* Anatum. Within *S.* Typhimurium six phage types were identified - definitive phage types (DTs) 4, 49, 141, 193 and phage type (PT) U320. In five of the outbreaks over 100 persons were affected and in all outbreaks epidemiological investigations implicated eggs or egg products as the vehicle of infection.

**Table 1: Documented and identified outbreaks of infectious intestinal disease caused by non-Salmonella Enteritidis serovars and linked to eggs in England and Wales: 1984 2009**

| Serovar / phage type | Year | No. affected | Hospital-isations (deaths) | Egg-related food vehicle(s) | Reference(s)* |
|---|---|---|---|---|---|
| *S.* Typhimurium DT141 | 1984/85 (5 outbreaks) | 59+ | NS (0) | Icing sugar, vanilla slices, quiche, meringue | Chapman *et al.*, 1988 |
| *S.* Typhimurium DT49 | 1988 | 120 | NS (0) | Egg mayonnaise | Mitchell *et al.*, 1989; Threlfall *et al.*, 1990 |
| *S.* Typhimurium DT4 | 1989 | 89 | 2 (0) | Egg mayonnaise | Ortega-Benito and Langridge, 1992 |
| *S.* Typhimurium PT U313 | 1996 | 36 | 7 (0) | Eggs | |
| *S.* Panama | 1997 | 14 | 2 (0) | Egg mayonnaise | |
| *S.* Hadar | 1997 | 14 | 0 (0) | Egg sandwiches | |
| *S.* Typhimurium DT141 | 1998 | 224 | 14 (0) | Egg white | |
| *S.* Montevideo | 1999 | 25 | 0 (0) | Egg rolls | |
| *S.* Indiana | 2000 | 17 | 0 (0) | Egg mayonnaise sandwiches | Mason *et al.*, 2001 |
| *S.* Bareilly | 2003 | 128 | 0 (0) | Egg sandwiches | |
| *S.* Anatum | 2007 | 102 | 12 (5) | Egg & cress sandwiches | |
| *S.* Typhimurium DT49 | 2007 | 4 | 1 (1) | Eggs | |
| *S.* Typhimurium DT193 | 2008 | 16 | 0 (0) | Egg mayonnaise sandwiches | |
| *S.* Typhimurium PT U320 | 2008 | 174 | 13 (1) | Egg & cress sandwiches | |
| **Totals** | | **953+** | **51** (7) | | |

NS: Not stated.
*Outbreaks from 1990 – 2009: Health Protection Agency Centre for Infections, Gastrointestinal, Emerging and Zoonotic Infections. eFOSS April 2010. Outbreaks pre-1990: PubMed

In a series of studies in the UK of contamination of shell eggs with *Salmonella*, involving both UK-produced and non-UK produced eggs, 12 non-*S.* Enteritidis serovars were identified in eggs originating from the UK, France, Poland and Spain. The serovars identified are summarised in Table 2.

**Table 2: Non-*Salmonella* Enteritidis serovars identified in UK studies of contamination of shell eggs with *Salmonella*, involving both UK-produced and non-UK produced eggs**

| Source of eggs | Serovars/phage types | Reference(s) |
|---|---|---|
| UK | *S.* Altona, *S.* Bredeney, *S.* Infantis, *S.* Ohio, *S.* Livingstone, *S.* Typhimurium DT7, *S.* Mbandaka | Little *et al.*, 2007a, 2008 |
| France | *S.* Mbandaka, *S.* Rissen | Little *et al.*, 2007b |
| Poland | *S.* Braenderup, *S.* Infantis, *S.* Mbandaka, *S.* Panama, *S.* Rissen, *S.* Weltevreden | Little *et al.*, 2007b |
| Spain | Unnamed *Salmonella* | Little *et al.*, 2007b |

**Outbreaks outside the UK**

Details of non-*S.* Enteritidis egg-associated outbreaks outside the UK are summarised in Table 3. In an egg sandwich-related *Salmonella* outbreak in Finland in 1986, 226 people were infected with *S.* Infantis as a result of cross-contamination in a premises supplying food for railway and airline passengers (Hatakka, 1992). Eggs were implicated in an extensive outbreak of salmonellosis in the Castellón outbreak of Spain in 1992 (Arnedo *et al.*, 1998). In this outbreak 545 persons were exposed, 100 were symptomatic and 16 were hospitalised. Both *S.* Enteritidis and *S.* Typhimurium were isolated from eggs taken from the farm supplying the food distribution outlets involved in the outbreak. It should be noted that the information provided was insufficiently detailed to link a particular serovar with overt infection. In contrast, in an outbreak of *S.* Typhimurium among pupils in a school in France in 1992, a combination of phenotypic and molecular typing techniques linked isolates of

*S.* Typhimurium from cases with isolates from a variety of egg products, including egg mayonnaise, and also with the farm supplying the eggs (Carramiñana *et al.*, 1997).

In an outbreak of *S.* Newport among students in Ethiopia in 1991 /1992, there was an epidemiological linkage between the consumption of undercooked eggs and illness (Aseffa *et al.*, 1994). In this outbreak there were no isolations of the causative organism from food samples. An outbreak of nine cases of *S.* Infantis in Japan in 1996 was linked to eggs from which the same serovar was isolated. Spent hens from the originating farm also yielded *S.* Infantis (Otomo *et al.*, 2007). In an outbreak of *S.* Typhimurium food poisoning in Mauritius in 2008, involving at least 53 persons, laboratory and epidemiological investigations implicated raw eggs used to prepare a dish of marlin mousse, which was consumed by all affected patients (Issack *et al.*, 2009).

In the USA, between 1973 and 2001 a total of 101 outbreaks of *S.* Heidelberg were associated with food vehicles; eggs were implicated in three and egg-containing products in a further 17 outbreaks (Chittick *et al.*, 2006). During that 28-year period, the annual proportion of Salmonella outbreaks involving this serovar did not change significantly, nor did the proportion of *S.* Heidelberg outbreaks that were associated with poultry, eggs or egg products. Although not proven, invasion of the egg contents through the shell was considered a possibility. More recently a population-based case-control study has been conducted to investigate an upsurge in sporadic *S.* Heidelberg infection in the early 2000s (Chittick *et al.*, 2006). Out-of-home egg consumption was identified as the principal risk factor and recommendations to avoid eating undercooked eggs were disseminated. In 1982 eggs produced locally and used in the preparation of homemade ice cream were implicated in an outbreak of *S.* Typhimurium affecting eight persons on a farm in Wyoming (Taylor *et al.*, 1984). One child died and his mother and four siblings were treated in intensive care units. The causative organism was isolated from patients, the food and the hens from which the eggs were sourced. In 2003 pre-prepared egg salad was implicated in an outbreak of

*S.* Typhimurium involving 18 individuals in Oregon and Washington states (Keene *et al.*, 2004).

In Australia, *S.* Enteritidis is not endemic in the egg laying flocks, presumably due to a different breeding stock (great-grand and grand-parents) population, and sporadic *S.* Enteritidis infections are almost all travel related (OzFoodNet Working Group, 2007). Furthermore, both *Salmonella* and specifically egg-related *Salmonella* outbreaks are not only less predominant than in Europe but also most often implicate *S.* Typhimurium (Greig and Ravel, 2009). There have been several outbreaks reported involving different phage types of *S.* Typhimurium: DT9 (Ward *et al.*, 2002), DT44 (Dyda *et al.*, 2009), DT135 (Hall, 2002; Sarna *et al.*, 2002; Stephens *et al.*, 2007; Tribe *et al.*, 2002), and DT197 (Slinko *et al.*, 2009). These phage types are in general uncommon in cases of infection in Europe. Aggregated data additionally includes egg-associated outbreaks involving *S.* Typhimurium DTs 26var, 102, 126, 135a, 144, 170, 197 and PT U302, plus *S.* Potsdam, *S.* Hadar and *S.* Heidelberg (OzFoodNet Working Group, 2002, 2003, 2006, 2008, 2009). Over 500 cases of non-*S.* Enteritidis egg-associated salmonellosis have been reported since 2000. To a certain extent Australian investigators have related these outbreaks to eggshell contamination, i.e. soiled eggshells, but the consumption of raw shell eggs has been recorded as a causative factor in at least two substantive outbreaks in that country in 2002 (Hall, 2002; Sarna *et al.*, 2002; Tribe *et al.*, 2002) and in recurrent outbreaks in Tasmania in 2005 (Stephens *et al.*, 2007).

**Table 3: Non-*Salmonella* Enteritidis egg-associated outbreaks outside the UK, 1973 - 2010**

| Year | Country | Serovar / phage type | No. affected (deaths) | Egg-related food vehicle(s) | Reference(s) |
|---|---|---|---|---|---|
| 1973-2000 | USA | *S.* Heidelberg | NS* (NS) | Eggs (3 outbreaks) Egg-containing products (17 outbreaks) | Chittick *et al.*, 2006 |
| 1982 | USA | *S.* Typhimurium | 8 (1) | Ice-cream | Taylor *et al.*, 1984 |
| 1986 | Finland | *S.* Infantis | 226 (0) | Egg sandwiches | Hatakka, 1992 |
| 1998-9 | Australia | *S.* Typhimurium DT9 | 54 (0) | Custard cake | Ward *et al.*, 2002 |
| 1991- 2 | Ethiopia | *S.* Newport | 79 (0) | Undercooked eggs | Aseffa *et al.*, 1994 |
| 1992 | Spain | *S.* Typhimurium* | 100 (0) | Omelette, soufflé, Russian salad | Arnedo *et al.*, 1998 |
| 1992 | France | *S.* Typhimurium | NS (0) | Egg mayonnaise | Carramiñana *et al.*, 1997 |
| 1992-6 | Japan | *S.* Infantis | 9 (0) | Eggs | Otomo *et al.*, 2007 |
| 2001-2 | USA | *S.* Heidelberg | NS (NS) | Out-of-home egg consumption | Hennessy *et al.*, 2004 |
| 2001 | Australia | *S.* Typhimurium DT135 | 53 (0) | Ice cream dessert | Hall, 2002; Sarna *et al.*, 2002 |
| 2002 | Australia | *S.* Typhimurium DT 135 | >20 (0) | Tiramisu, rice pudding, various products | Sarna *et al.*, 2002; Tribe *et al.*, 2002 |
| 2003 | USA | *S.* Typhimurium | 18 (0) | Egg salad | Keene *et al.*, 2004 |
| 2007-8 | Australia | *S.* Typhimurium DT135 | 125 (0) | Cakes | Stephens *et al.*, 2007; Stephens *et al.*, 2008 |
| 2008 | Mauritius | *S.* Typhimurium | 53 (0) | Marlin mousse | Issack *et al.*, 2009 |
| 2008 | Australia | *S.* Typhimurium DT44 | 22 (0) | Hollandaise sauce | Dyda *et al.*, 2009 |
| 2008-9 | Australia | *S.* Typhimurium DT197 | >20 (0) | Eggs used in a variety of dishes | Slinko *et al.*, 2009 |

NS, not stated. * 20 outbreaks

## Conclusions

Although *S.* Enteritidis is without doubt the serovar most commonly implicated in egg-associated outbreaks of salmonellosis in the UK, Europe and North America from 1986 to 2009, other serovars have also been implicated in a number of outbreaks, most notably *S.* Typhimurium belonging to a range of phage types. The numbers of infections caused by such serovars, although small compared to *S.* Enteritidis, are nevertheless quite substantial and on occasion have resulted in hospitalisations and deaths.

There is no evidence to suggest that these serovars have either been established for long periods or transmitted vertically in poultry flocks by the transovarian infection route, although certain strains within some serovars, e.g., *S.* Heidelberg, has been shown to have the capacity for ovarian infection. Furthermore, in most outbreaks with non-*S.* Enteritidis serovars, including *S.* Typhimurium, the possible role of egg shell contamination in terms of direct infection of people handing eggs, contamination of the egg contents when eggs are cracked, contamination of the kitchen environment or trans-shell contamination of contents, has not been fully explored.

In Australasia a different situation exists as *S.* Enteritidis does not appear to have become established in poultry flocks. Consequently there have been no known food-borne outbreaks of infection with *S.* Enteritidis, although outbreaks of *S.* Typhimurium associated with undercooked or raw eggs have been recorded.

In the EU, *S.* Enteritidis (as well as *S.* Typhimurium) in laying hens is now subject to harmonised monitoring and control. This is likely to result in a substantial reduction in the prevalence of *S.* Enteritidis in humans in most MS. There are, however, fears that another strain may increase to fill this niche (Foley *et al.*, 2011) and one group of strains that is rapidly increasing in food animals and humans worldwide is the monophasic group B cluster within *S.* Typhimurium DTs 193 and 120, i.e. *S.* 4,5,12:i:- and *S.* 4,12:i:- strains. In addition, different serovars may have different sources, for example feed, breeding stock, rodent pests or persistent environmental contamination. Consequently, differing strategies may need to be developed for control or elimination. It is therefore important that surveillance trends in laying flocks are closely monitored and that suitable biosecurity and vaccination programmes are in place to minimise the risk of incursion of new zoonotic serovars into the egg industry .

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## Declarations of Interest

None.

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