Epidemiology and control of egg-associated *Salmonella* Enteritidis in the United States of America


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Summary

The isolation rate for *Salmonella enterica* serotype Enteritidis (SE) in humans in the United States of America (USA) increased from 1,207 sporadic isolates identified in 1976 (0.6 isolates/100,000 population) to 10,201 identified in 1995 (4.0/100,000 population). The proportion of reported *Salmonella* isolates which were SE increased from 5% to 25% during the same time period. In 1990, 1994, and 1995, SE was the most commonly reported *Salmonella* serotype in the USA. Much of this increase has been associated with the consumption of contaminated shell eggs. An examination of the results of a United States Department of Agriculture (USDA) survey of spent hens at slaughter and unpasteurised liquid egg at breaker plants (liquid egg processors) in 1991 and 1995 reveals an increase in the prevalence of SE isolates overall and in most regions of the USA.

SE phage type 4 (pt 4), the predominant SE phage type in other parts of the world, has emerged in the egg industry in the western USA concurrent with a sharp increase in the number of sporadic human SE pt 4 isolates in California and Utah. Research on the molecular structure and virulence of SE pt 4 isolates from the USA as compared with isolates from other parts of the world (human and poultry) should be a priority. A comparison of DNA from pt 4 isolates from the USA and Europe may provide information about the potential threat to public health and poultry in the USA from this phage type.

Some regional success in the reduction of human illness as a result of SE control efforts is apparent. The Pennsylvania Egg Quality Assurance Program has shown progress in reducing SE infection in participating flocks. At a national level, however, neither the incidence of human illness due to SE nor the prevalence of
SE in flocks and unpasteurised liquid eggs have decreased significantly, despite the implementation of the USDA 'trace back' regulation from 1990 to 1995, and intensified efforts to educate food handlers and to enforce safe food handling practices.

More effort is needed to control SE at every stage of the egg continuum, from production through to consumption. A risk-reduction approach, with barriers to the introduction and multiplication of the pathogen throughout the farm-to-table continuum, is the most practical method for reducing human illness from SE in shell eggs at present. An effective long-term solution will require interdisciplinary efforts involving government, industry, consumers, and academics. Interventions should be developed and evaluated in compliance with the potential for reducing the risk to human health and cost-effectiveness.

Keywords

Introduction
This paper provides a summary of the epidemiology and measures for control of *Salmonella enterica* serotype Enteritidis (SE) infection in humans and in egg-laying poultry in the United States of America (USA). Information from recently completed surveys of unpasteurised liquid eggs, spent hens at slaughter and the environment of flocks participating in the Pennsylvania Egg Quality Assurance Program (PEQAP) has been integrated with data on human isolates and outbreaks of SE infection. Recommendations for risk-reduction strategies in this paper focus on the egg production level of the continuum, but consideration should be given to controls at all stages, from production through to consumption.

History of United States Department of Agriculture controls for *Salmonella enterica* serotype Enteritidis

The three areas in which the United States Department of Agriculture (USDA) is involved in the reduction of SE infection in poultry and resulting human illness associated with shell eggs are as follows:

a) a regulation requiring 'trace back' of eggs to source flocks and diversion of eggs from SE positive flocks, when eggs were determined to be the source of illness in human SE outbreaks

b) a producer-driven, co-operative, quality assurance programme in Pennsylvania

c) a programme to eliminate SE from primary and multiplier breeding flocks.

The USDA SE regulation (27) was initiated in February 1990 as an emergency response to the sharply rising incidence of SE cases and outbreaks in humans, particularly in the north-eastern USA. Many of these outbreaks were attributed to the consumption of foods made with fresh eggs (22). When the SE regulation was proposed in 1989, there was a lack of data on the prevalence of SE infection in poultry flocks. The involvement of a limited number of SE-infected flocks was assumed, since only a small number of flocks had been implicated in human SE outbreaks on repeated occasions during the previous three to four years. The USDA regulation was designed to perform the following functions:

- to trace egg-implicated human SE outbreaks back to the flock of origin
- to test the flock serologically and microbiologically for the presence of SE
- to divert eggs from the SE-positive flock to pasteurisation or hard-cooking processes.

Depopulation of the infected flock was not stipulated, but cleaning and disinfection of poultry houses was required before the SE-positive flock could be released from restriction. Funding for this USDA SE regulation was discontinued by Congress in October 1995. As a result, the United States Food and Drug Administration (FDA) became responsible for enforcement of the regulation using the protocol outlined in the 1993 USDA proposed rule (a revision of the 1991 regulation concerning chicken infection caused by SE) (26).

The continued occurrence of outbreaks of SE infection in humans in the north-eastern USA after implementation of the trace back regulation helped spur development and implementation of a producer-driven quality assurance
programme, the SE Pilot Project (SEPP). The USDA, in collaboration with Pennsylvania egg producers, the Pennsylvania Department of Agriculture, the University of Pennsylvania, Pennsylvania State University, and the Pennsylvania Poultry Federation, began the SEPP in 1992.

Egg producers who volunteered to participate in the SEPP agreed to test their flocks for SE and to implement a series of measures designed to prevent SE introduction or to eliminate SE from their flocks. These measures included microbiological testing of layer houses for the presence of SE, implementation of stringent rodent control procedures, cleaning and disinfection of layer houses between flocks, and implementation of effective biosecurity measures. If SE was isolated from the layer house environment, eggs from the flock were cultured. If SE was isolated from the internal contents of eggs, eggs from the flock were sent to pasteurisation plants.

The SEPP evolved into the current Pennsylvania Egg Quality Assurance Program (PEQAP) which commenced in February 1994. This programme uses many of the control measures and testing procedures identified in the SEPP. There are now more than 200 flocks (1.5 million layers) participating in the PEQAP, which represent more than 80% of the layers in Pennsylvania. Responsibility for the PEQAP was transferred from the USDA to producers and the State Department of Agriculture in Pennsylvania in June 1996.

As transovarian transmission of SE has been shown to occur (with possible passage of infection from breeding flocks to replacement pullets to commercial layer flocks), the National Poultry Improvement Plan (NPIP) of the USDA was expanded on 1 July 1989 to include voluntary SE testing for all egg-layer breeding flocks (28). The plan was designed to reduce the prevalence of SE in hatching eggs and chicks through an extensive testing and sanitation programme on breeder farms and hatcheries. In February 1990, the USDA issued a regulation that all hatching eggs and newly-hatched chicks from egg-type chicken breeding flocks which move between States should originate from flocks certified free of SE. If SE were to be detected at any time, the flock would lose SE-free classification, and would be depopulated. All of the hatching eggs from the flock would be destroyed and pullet flocks hatched since the last negative test would be traced forward and tested for SE.

![Fig. 1](image_url)

Isolation rate (per 100,000 population) for Salmonella Enteritidis by Region, United States of America, 1976-1995

Source: Centers for Disease Control National Salmonella Surveillance System
Human illness from *Salmonella enterica* serotype Enteritidis

From 1976 to 1995, the occurrence of SE in humans increased from 1,207 isolates identified in 1976 (0.6 isolates/100,000 population) to 10,201 in 1995 (4.0/100,000 population) (2) (Fig. 1). SE was the most commonly reported *Salmonella* serotype in the USA in 1990, 1994 and 1995, accounting for 26% of all *Salmonella* isolates in 1994 and 25% in 1995 (Centers for Disease Control, unpublished data) (Fig. 2).

Outbreaks and sporadic cases of SE infections continue to show an association with the consumption of raw or undercooked shell eggs, a source which was first identified by St Louis et al. in 1988 (10, 17, 22). A vehicle was implicated in 45% of the human outbreaks of SE: shell eggs constituted 82% of this group (38% of total outbreaks) between 1985 and 1991 (16).

Centers for Disease Control and Prevention (CDC) data on SE outbreaks in the USA do not indicate a discernable trend in recent years. Human outbreaks of SE declined from 70 in 1990 to 44 in 1994. A total of 56 outbreaks were reported in 1995 and 49 in 1996 (Centers for Disease Control, unpublished data). Outbreaks alone are not adequate indicators of the occurrence of human infection with SE: laboratory-confirmed isolates and active surveillance for SE infections should also be considered.

Salmonella enterica* serotype Enteritidis in poultry and eggs

An examination of the results of a USDA survey of spent hens at slaughter and unpasteurised liquid eggs at breaker plants in 1991 and 1995 reveals an increase in the prevalence of SE isolates overall and in most regions of the USA (13) (Figs 3 and 4). These survey data are consistent with human isolate data in that neither poultry nor human data shows a decline in SE since 1991. However, there is no apparent correlation between SE in humans, layer flocks, and unpasteurised liquid egg across regional areas of the USA.

![Fig. 2](Salmonella Enteritidis, Typhimurium and Heidelberg isolates reported to the Centers of Disease Control (CDC) 1976-1996)

Source: CDC National *Salmonella* Surveillance System

![Fig. 3](Salmonella Enteritidis in unpasteurised liquid eggs: 1991 and 1995 (13))
Salmonella Enteritidis phage type 4

SE phage type 4 (pt 4) has emerged in the egg industry in the western USA concurrent with a sharp increase in the number of sporadic human pt 4 isolates in California and Utah. A poultry outbreak of SE pt 4 infection on a southern California egg farm was reported by APHIS on 13 June 1994, although no human SE infections were known to be associated with that flock. From April to July 1994, 496 cases of SE infection were reported in Los Angeles County, nearly five times the number reported from April to July 1993 (17). In 1994, 24% of all SE isolates in the USA were from California. Of 16 randomly selected case-isolates, 15 (94%) were phage type 4 (17). As of June 1996, SE pt 4 has caused a significant number of human illnesses in California, Utah, Nevada and Arizona. A human outbreak of SE pt 4 infection occurred in Utah in 1995 and the rate of sporadic human isolates increased at the same time. Utah reported 129 SE isolates in 1995, compared with 43 laboratory-confirmed SE isolates in 1994 and a mean of 34 SE isolates per year during the period from 1990 to 1994 (21). An investigation of the 1995 Utah SE outbreak determined that ill persons were more likely to have eaten in a restaurant which pooled eggs (21).

In a 1995 survey of unpasteurised liquid egg, SE pt 4 was the predominant phage type found in the Western APHIS Region of the USA (13) (Fig. 6). A survey of spent hens at slaughter also found SE pt 4 to be one of the predominant phage types in the Western Region (13) (Fig. 6). Except for one liquid egg sample from the South-east Region, all pt 4 isolates found in both surveys were from the Western Region. In contrast, SE pt 4 was not detected in the 1991 spent hen or liquid egg surveys (13).

Although not clearly defined, the potential threat of SE pt 4 to both human health and the poultry industry may be greater than that of other phage types. SE pt 4 has become a problem in the broiler industry in the United Kingdom (UK), where the phage type contributes to human illness from the consumption of contaminated poultry meat (3, 4, 19). SE pt 4 has shown the ability to invade deep muscle tissue (14). In the SE pandemic which has affected Europe and the UK since 1980, the rate of human salmonellosis has increased and pt 4 has become the predominant phage type. The current situation in the USA appears to be following a similar epidemidic pattern.
Antimicrobial resistance survey in monitoring and surveillance of human illness associated with phage-typing. From the cooperative CDC/USDA/FDA active surveillance isolates for phage-typing to the CDC. In addition, phage-typed and used as a baseline for comparison. For isolates collected from spent hen and broiler slaughter plants, surveillance could include population and in layer and broiler flocks in the USA should increase in ongoing surveillance. CDC. Sporadic outbreaks of human infection proposed by the CDC. Currently, isolates from SE outbreaks of human infection are phage-typed by the CDC. Sporadic SE isolates submitted as part of a nationwide surveillance programme. Comparison of deoxyribonucleic acid (DNA) from pt4 isolates from Europe and the USA may provide information on the potential threat of this phage type to public health in the USA. Recent evidence suggests that the European pandemic may have resulted from the efficient spread of one bacterial clone of SE pt4. However, regardless of phage type, all SE isolates from Europe and the USA differ in the heterogeneity which exists among other serogroup D1 isolates (as defined by slide agglutination reaction), not all DNA-based molecular typing methods are discriminating enough to provide useful epidemiological information. Comparison of chromosomal heterogeneity between pt4 isolates from Europe and the USA would be greatly facilitated if genetic fingerprints common to all countries were available as a point of reference. A surveillance programme should include a notification system to inform State Departments of Public Health and Agriculture regarding the status of SE and SE phage types in human and poultry populations. Surveillance would serve as an early warning system for States which do not currently have SE pt4. If SE pt4 is found to be spreading, public and animal health departments of other, vulnerable States would be notified and measures to identify the source of infections and prevent further spread would be encouraged. In addition, actions – to be taken if predetermined levels for SE and SE phage type 4 in layer and broiler populations and humans in the USA are exceeded – should be defined as part of a plan for a comprehensive SE surveillance programme.

Deoxyribonucleic acid comparison of Salmonella Enteritidis phage type 4 isolates in the United States of America and Europe

Carcass studies in broilers in the USA have not shown an increase in SE following the detection of SE pt4 in this country (29). The frequent appearance of SE in European broilers, but not American broilers, may be related to differences in management practices or to genetic predisposition of stock, as well as to bacterial virulence properties. However, SE pt 4 was detected in the USA for the first time in 1994, and may yet become established in broilers in this country.

Based on historical and current patterns, there is a significant risk that, in the absence of new effective control measures, SE pt 4 will spread in the commercial layer industry throughout the USA and may spill over into broilers, as was the case in the UK and Europe. Due to this potential threat to human health and the commercial poultry industry, surveillance designed to track the spread of SE and SE phage types in the human population and in layer and broiler flocks in the USA should be conducted. Poultry surveillance could include Salmonella isolates collected from spent hen and broiler slaughter plants for pathogen reduction and hazard analysis and critical control point (HACCP) monitoring.

Surveillance for SE and SE phage types in the commercial egg and broiler industry would complement the intensified monitoring and surveillance of human illness associated with SE infection proposed by the CDC. Currently, isolates from SE outbreaks of human infection are phage-typed by the CDC. Sporadic SE isolates submitted as part of a nationwide antimicrobial resistance survey in 1994 and 1995 will be phage-typed and used as a baseline for comparison. For ongoing surveillance, 14 to 20 States will submit sporadic SE isolates for phage-typing to the CDC. In addition, SE isolates from the cooperative CDC/USDA/FDA active surveillance network will also be phage-typed.

Research on the molecular structure and virulence of SE pt4 isolates in the USA compared with isolates from other parts of the world (human and poultry) should receive priority. A comparison of deoxyribonucleic acid (DNA) from pt4 isolates from Europe and the USA may provide information on the potential threat of this phage type to public health in the USA. As a result of the homogeneity which exists among SE and among other serogroup D1 isolates (as defined by slide agglutination reaction), not all DNA-based molecular typing methods are discriminating enough to provide useful epidemiological information. Comparison of chromosomal heterogeneity between pt4 isolates from Europe and the USA would be greatly facilitated if genetic fingerprints common to all countries were available as a point of reference.

The assessment of plasmid DNA fingerprints is an important epidemiological evaluation of a common source of extrachromosomal DNA heterogeneity, and pt4 isolates harbour several plasmids. An important question is whether or not pt4 isolates from Europe and the USA differ in the types of plasmids which they carry. DNA sequencing of either entire plasmids or polymerase chain reaction (PCR)-amplified fragments or regions within large plasmids, is the method of analysis least likely to produce technical complications. Some plasmids are 'serotype-specific' and are involved in virulence (9, 12, 30).
A comparison of pt 4 isolates from Europe and the USA using virulence-associated phenotypic patterns may be helpful in understanding the virulence of SE in humans. Phage type 4 isolates from the UK vary greatly in their virulence potential in mice and laying hens, as measured by virulence-associated phenotypic patterns (tolerance to heat, acid, hydrogen peroxide and the ability to survive on surfaces) (15). A tissue culture invasion assay indicated that a pt 4 strain from the USA was not as invasive and did not persist in HeLa cells for as long as strains from Europe (1). This suggests that pt 4 strains from the USA may be neither the same as, nor as virulent as, SE pt 4 isolates from Europe.

Experimental studies have also shown significant differences in virulence for chicks within a set of European pt 4 isolates, as well as within the set of isolates of other phage types (3). In addition, the rank-order of virulence for various SE strains differed between breeds of birds (5). The virulence capabilities of phage types can be assessed by monitoring changes in the structure of outer membrane molecules, and alternative methods to phage-typing which use commercially available diagnostic reagents have been developed (7). The most reliable indicator to date of virulence in birds and rodents has been the structure of lipopolysaccharide (LPS). Production of LPS similar to that produced by the human pathogen Salmonella Typhi is a characteristic of orally invasive and egg-contaminating SE of prevailing phage types, including pt 4 (18). However, the outer membrane of pt 4 is significantly different from all other phage types in that the LPS molecule bears an additional modification (J. Guard-Petter, unpublished data). Pt 4 seems to be the phage type most likely to express expected immunogenicity associated with hyper-production of H1 flagella in response to environmental conditions (6). New LPS characterisation methods were used to produce a statistical model of how field isolates of non-pt 4 SE are composed of three distinct cell sub-populations which vary in ability to invade organs of mice and chicks (8). Thus, determination of the relative ratios of cell sub-populations within pt 4 isolates from both Europe and the USA may be useful, especially if only one of these sub-populations routinely produces an LPS structure which can be historically associated with adaptation to people.

Information available from research to date has not identified any pt 4 characteristics or capabilities which clearly and definitively indicate pt 4 isolates as a uniquely dangerous threat. Some, but not all, pt 4 strains possess heightened virulence properties in three-day-old chicks, suggesting a contribution to virulence specifically related to phage type. On the other hand, phage type does not appear to be the principal determinant of virulent behaviour.

If research eventually determines that pt 4 strains have some defined, unique ability to spread and infect chickens, and perhaps even to contaminate eggs and cause human illness, this may not lead to any immediate or major changes in the nature of control efforts. Current quality assurance strategies for Salmonella in the USA employ many of the best available ideas. Comprehension of the differences between phage types is important, but control strategies which are effective against a wide range of phage types and serotypes will still be needed.

**Pennsylvania Egg Quality Assurance Program**

The SEPP collected samples and data from more than 130 flocks and cultured more than 750,000 eggs. Flocks with SE in the environment produced 2.75 SE positive eggs per 10,000 (20). This incidence of contamination was considerably lower than estimates; contamination of as many as 50 positive eggs per 10,000 from flocks in an SE-contaminated environment had been estimated. The project made efforts to identify specific management practices associated with SE infections in flocks. Although some practices, including the quality of biosecurity, molting, aging flocks, and the presence of mice in the hen house, were associated with the presence of SE, no definitive control measures were identified (20).

There is evidence that PEQAP has shown progress in reducing SE infections in Pennsylvania flocks (31). An environmental survey conducted in 1995 showed a reduction of SE infections in flocks from those poultry houses which had been in the pathogen reduction programme since 1992 (31). The PEQAP did not eliminate SE from all participating flocks, but the percentage of positive flocks decreased from about 40% to less than 15% (based on manure drag swab sampling).

Risk-reduction interventions in the PEQAP target a reduction of SE in eggs as well as in flocks. Flocks identified as SE-positive by environmental sampling are required to submit eggs for bacteriological culture. If any egg cultures are SE-positive by environmental sampling are required to submit eggs for bacteriological culture. If any egg cultures are SE-positive, the producer must divert eggs from that flock to pasteurisation or hard boiling. The effectiveness of PEQAP controls in reducing SE contamination of eggs has been estimated but not measured.

During the period when the SE Pilot Project and PEQAP were in operation (1992-1995), there was a concomitant reduction in human SE isolation rates in the Mid Atlantic Region (New York, New Jersey and Pennsylvania States) which constitutes the market for Pennsylvania eggs (Fig. 1). The authors believe that the combined efforts of egg producers, retail marketers and food handlers have had a positive impact on public health in the Mid Atlantic Region.

Results of the spent hen and liquid egg surveys showed an increase in the percentage of SE-positive samples between
1991 and 1995 in the Northern Region (Figs 3 and 4). These findings, however, are not a direct measure of the effect of the PEQAP, since shell egg producers in the Northern Region who are not on quality assurance programmes are included. In addition, there is selective diversion of SE-positive eggs to pasteurisation, based on the testing programme in the PEQAP.

The environmental study of PEQAP flocks did not provide information on the relative importance of the interventions used. The results only showed that, used together, the PEQAP interventions were effective in reducing the number of houses infected. Additional field epidemiological studies and research will help identify and verify the most appropriate and effective management practices which should be used in SE risk-reduction programmes. The PEQAP can serve as a prototype for the development of egg quality assurance programmes in the egg industry, and the industry should adopt quality assurance programmes based on the interventions developed in the SE Pilot Project and used in the PEQAP.

According to PEQAP results, egg quality assurance programmes should include testing for the determination of flock infection status for SE and the impact of control strategies. If the flock infection status is known, producers can make informed management decisions about the marketing of eggs from the flocks and the need for cleaning and disinfection between flocks. Data obtained from flock testing is also essential for accurate assessment of the effectiveness of quality assurance practices and programmes.

Goals for quality assurance

Industry has developed quality assurance programmes for use in several States in the USA besides Pennsylvania. These programmes include the United Egg Producers (UEP) Five Star Program, the California Egg Quality Assurance Program and the Maine SE Risk Reduction Program. These programmes generally rely on good production practices to reduce the risk of SE, but there is some variation in the recommendations and requirements of the different programmes. In 1995, the United States Animal Health Association reactivated an SE Task Force to develop standards for egg quality assurance programmes. This effort should help to focus interest and research on the identification of effective interventions in egg production.

The definitive answers on how SE enters flocks and how to eradicate SE once the bacterium becomes established in flocks are not yet available. Fortunately, there are measurable indicators which industry can use to evaluate progress in reducing risk of human illness from shell eggs, namely:

a) Demonstration of reduced levels of SE in flocks participating in quality assurance programmes compared to flocks not participating in quality assurance programmes.

b) Participation of an increasing percentage of producers in quality assurance programmes and adherence to the requirements of these programmes.

c) Demonstration of an increase in eggs giving negative results to tests for SE.

The egg industry bears a significant responsibility in ensuring the safety of eggs and egg products. Industry is more likely to develop effective and efficient quality assurance programmes if those programmes are producer-initiated and performance-based.

Épidémiologie et prophylaxie de l’infection humaine à Salmonella Enteritidis aux États-Unis d’Amérique due à la consommation d’œufs


Résumé

Aux États-Unis d’Amérique, le taux d’isolement de Salmonella enterica sérotype Enteritidis (SE) chez l’homme est passé de 1207 isolats sporadiques en 1976 (0,6 isolat/100 000 habitants) à 10 201 en 1995 (4,0/100 000 habitants). La part de SE

**Mots-clés**
Épidémiologie — États-Unis d’Amérique — Salmonella Enteritidis — Santé publique — Sécurité alimentaire — Volailles.
Epidemiología y control de la salmonelosis por *Salmonella Enteritidis* debida al consumo de huevos en Estados Unidos de América


**Resumen**

En Estados Unidos de América la tasa de aislamiento en el ser humano de *Salmonella enterica* serotipo Enteritidis (SE) pasó de los 1.207 casos de 1976 (0,6 aislamientos/100.000 personas) a los 10.201 casos de 1995 (4,0 aislamientos/100.000 personas). Durante aquel mismo período, la proporción de cepas de *Salmonella* que se revelaron pertenecientes al serotipo SE creció desde un 5% hasta un 25%. En los años 1990, 1994 y 1995, el SE fue el serotipo de *Salmonella* aislado con mayor frecuencia en Estados Unidos de América. Gran parte de este incremento se atribuye al consumo de huevos contaminados. Los resultados de estudios realizados en 1991 y 1995 por el Departamento de Agricultura de Estados Unidos de América (USDA), a partir de gallinas descartadas en mataderos y de huevos de consumo no pasteurizados en plantas fracturadoras (procesamiento de huevos de consumo), ponen de relieve el incremento de los casos de aislamiento de SE, tanto a nivel nacional como en la mayoría de regiones del país.

La industria huevera del oeste de Estados Unidos ha asistido a la aparición del fago tipo 4 del SE, el tipo predominante en otras partes del mundo; al mismo tiempo se observaba un acusado incremento del número de aislamientos esporádicos del fago tipo 4 de SE en el ser humano en los Estados de California y Utah. Sería necesario otorgar prioridad a las investigaciones sobre la estructura molecular y la virulencia de las cepas del fago tipo 4 de SE descubiertas en Estados Unidos y compararlas con las cepas aisladas (en humanos y aves de corral) en otras partes del mundo. La comparación entre el ADN de las cepas del fago tipo 4 norteamericanas y europeas podría suministrar información sobre su potencial amenaza para la salud pública y la sanidad aviar en Estados Unidos.

No puede negarse la consecución a escala regional de algunos éxitos en la reducción de las intoxicaciones alimentarias, fruto de los esfuerzos realizados para el control de SE. El Programa de garantía de calidad de los huevos, implementado por el Estado de Pennsylvania, ha deparado progresos en la reducción del número de infecciones por SE en las bandadas que participaron en él. A escala nacional, sin embargo, ni la incidencia de enfermedades del hombre causadas por SE ni la prevalencia de SE en las bandadas y en los huevos de consumo no pasteurizados muestran descenso significativo, pese a la entrada en vigor, entre 1990 y 1995, del reglamento del USDA destinado a marcar el origen de los productos y a los intensos esfuerzos realizados para formar el personal encargado de manipular alimentos e imponer la aplicación de métodos seguros al respecto.

Es preciso redoblar esfuerzos para controlar la presencia de SE en cada eslabón de la cadena que va desde la producción de los huevos hasta su consumo. En la actualidad, el método más práctico para reducir las enfermedades humanas por SE asociadas al consumo de huevos contaminados consiste en aplicar procedimientos de reducción de riesgos, con barreras contra la penetración y multiplicación del microorganismo a lo largo de toda la cadena desde la producción hasta el consumo. Para dar con una solución eficaz y duradera, serán necesarias iniciativas interdisciplinarias en las que participen instancias del sector público, los productores, los consumidores y las universidades. Será
necesario concebir y ensayar posibles formas de intervención, sin perder de vista tanto su rendimiento económico como su potencial para reducir los riesgos para la salud humana.

**Palabras clave**

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**References**


