The effects, costs and benefits of *Salmonella* surveillance in the Danish table-egg sector


**1** Danish Institute for Food and Veterinary Research; **2** Danish Veterinary and Food Administration.

**Abstract**

A public plan for eradicating *Salmonella* in the Danish table-egg production was implemented in 1997. The program is based on the principle of top-down eradication and has regularly been revised to meet a higher level of food-safety. Monitoring is based on a combination of serologic and bacteriologic testing of all breeder and table-egg layer flocks. The sampling frequency and sample material depend on the production stage and the age of the birds. Infected breeder and pullet-rearing flocks are removed from production. Table eggs from positive layer flocks are pasteurised. By the end of 2002, the public financing ended and the poultry industry took over the administrative and total financial responsibility of the programme. The food authorities continue to supervise the surveillance and set targets for further improvement.

The public-health impact of the plan has been quite remarkable. In 1997, 5,015 cases of human salmonellosis were reported. Of these, 55-65% was estimated to be associated with eggs. In 2004, these figures were reduced to 1,538 and 5-8%, respectively.

Based on an assessment of the number of human cases attributable to table eggs and saved due to control, we estimated the saved societal costs including direct health costs and costs of lost labour, and compared these with the costs of control. It was assumed that between 5% and 20% of cases were reported. The results showed a continuous decreasing cost-benefit ratio reaching well below one in 2002, indicating that the control efforts have been a good investment for the society.

**Introduction**

Salmonellosis is a common cause of foodborne diarrhoeal disease worldwide. The majority of infections are transmitted from healthy carrier animals to humans via contaminated food. The main reservoir of zoonotic *Salmonella* is food-producing animals and the main sources of infections in industrialised countries are animal derived products, notably fresh meat and poultry products. Table eggs are the most important food source of human salmonellosis in Denmark (Hald *et al.* 2004a).

The *Salmonella* control program in the table-egg production was implemented in Denmark in 1997 and has been revised regularly. The objective is the complete freedom of *Salmonella enterica* in the top of the breeding pyramid of layers and in all shell eggs from commercial layer flocks. The program is based on the principle of top-down eradication. Monitoring is based on a combination of serologic and bacteriologic testing of all flocks. The sampling frequency and sample material depend on the production stage and the age of the birds. Infected breeder flocks and rearing flocks of pullets are removed from production. Table eggs from positive layer flocks are pasteurised. The reduction of *Salmonella* in table-eggs layers is achieved primarily by eradication of infected breeder flocks, but also by increased hygiene and bio-security measures at hatcheries and in layer farms (Hald *et al.* 2004a).

The proportion of layer flocks infected with *Salmonella*, notably S. Enteritidis, has been markedly reduced since the initiation of the program (Wegener *et al.* 2003). Likewise, major reductions on the incidence of foodborne human salmonellosis have been reported (Anonymous 2005). In this paper, we describe the effects, costs and benefits of control of *Salmonella* in the Danish table-egg production.
Materials and Methods

To estimate the effects, costs and benefits of the control program, the following questions need to be answered:

1. How many human Salmonella cases are egg-associated?
2. How many egg-associated cases have been saved due to control?
3. What are the societal costs of human salmonellosis?
4. What are the (public) costs of control?

Estimating the Number of Egg-Associated Cases

In order to estimate the number of human Salmonella infections attributable to the various food animal sources, a stochastic model has been developed. The principle is to compare the reported number of human cases caused by different subtypes (serotypes and phage types) with the distribution of the same subtypes isolated from the different animal reservoirs or food sources. It is a pre-requisite that some of the dominant subtypes are found almost exclusively in a single source. Such subtypes are regarded as indicators for the human health impact of that particular source, assuming that all human infections with these subtypes originate only from that source. Human infections caused by subtypes found in several sources are then distributed relative to the prevalence of the indicators. This approach requires and integrated surveillance of Salmonella in most major food animals, food (including imported food) and humans, providing a collection of representative isolates from the farm-to-fork chain, followed by the use of appropriate discriminatory typing methods. The model has been described in detail by Hald et al. (2004).

Estimating (Guessimating) the Number of Saved Cases due to Control

Assuming that the number of human Salmonella cases had remained at the same level as in 1997, if no control program had been implemented, the number of saved cases was estimated by subtracting the annual number of egg-associated cases (as estimated as described above) from the number of egg-associated cases in 1997. The expected number of reported cases without surveillance was modelled using the estimated number of egg-related cases in 1997, assuming a range of +/- 20%. The number of saved cases was estimated for the reported cases and for the total number cases assuming that 5%, 10% or 20% of the cases were reported.

Estimating the Societal Costs of Human Salmonellosis

The societal costs due to zoonotic Salmonella infection in 2001 have been estimated by Korsgaard et al. (2005). The costs were estimated for seven different patient groups: Hospitalised cases that underwent surgery (grp. 1), with invasive infections (grp. 2) or without complications (grp. 3). Cases diagnosed at a general physician (GP) (grp. 4), cases with a false-negative diagnose at a GP (grp. 5), cases with no diagnose at a GP (grp. 6) and cases that stayed at home (grp. 7). Patient group 5-7 constitute the non-reported cases.

The expected 2001 health-care costs estimated by these authors included: costs for patients hospitalised with gastroenteritis without complications (€2,658,-), undergoing surgery (€10,193,-) and with invasive infections (€5,470,-), the cost of laboratory analysis per diagnosed case (€120,-) and per case with a false negative diagnose (€77,-) and the cost of a consultation at a GP (€13,-). The health-care costs were modelled assuming +/- 10% uncertainty.

The costs of lost labour were estimated by assuming the following number of days of illness for each patient group: hospitalized: 14-21 days of illness; cases tested at a GP: 10-14 days of illness; cases not tested at a GP or that stayed at home: 1-4 days of illness. The assumptions were based on a review of different studies and statistical material. The salary per hour were modelled by estimating min and max parameters using reported salary lower-quartile, median and upper-quartiles for persons employed in the private sector, the state and in the municipal sector each year. A weighted salary per day was calculated, based on the proportion of jobs in each sector assuming a
7.5-hour workday. The proportions of cases with lost production per year were assumed to be the proportion of adults (over 18 years) with employment, thus assuming that adults stayed home to take care of the sick children. Data regarding employment and salary was obtained from Statistics Denmark.

We applied the cost model for the “saved” egg-associated cases assuming that these infections were distributed on the different patient groups proportionally to the total number of infections. The average health-care cost per case was estimated, assuming a 2% rate of inflation per year.

**The Public Costs of Salmonella Control**

From the Danish Veterinary and Food Administration, we received a statement of the costs used for control in the period from 1997 to 2002. The costs were divided on costs used for surveillance (sampling and testing) and costs used to compensate farmers that had to buy replacement stock due to *Salmonella* infection (Table 1). Fifty percent of the costs of replacement of breeding flocks are reimbursed by the EU. Unfortunately, the costs regarding surveillance in the broiler and table-egg sector were accounted together since 1999, meaning that we did not have the exact surveillance costs related only to the table-egg production. Consequently, we estimated this proportion based on the costs for 1998. Since 2001, the routine sampling costs have been assumed by the industry, which lead to a significant decrease in the overall public costs in 2001 and 2002. Rightfully, these costs should be included in the cost estimates, but we did not have access to these figures.

<table>
<thead>
<tr>
<th>Table 1 Public costs of the Danish <em>Salmonella</em> control program in the table-egg production from 1997-2002 (in 1.000 Euro).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance costs¹</td>
</tr>
<tr>
<td>Replacement costs²</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

1) From 1999, the surveillance costs for the broiler and table-egg sector were accounted together. The costs for the table-egg production were estimated based on the proportion observed for 1998.

2) EU reimburses 50% of the costs due to replacement stock in breeding flocks.

**Results**

Table 2 shows the estimated number of human cases of salmonellosis attributable to the consumption of eggs between 1997 and 2002. The decreasing tendency in the total number of cases, as well as on the number of cases attributable to table eggs, is significant. In 1997, 5,015 cases of human salmonellosis were reported. Of these, 3,030 (95% C.I.: 2,758-3,260) were estimated to be associated with eggs. In 2002, 608 (95% C.I.: 580-642) of the total 2,071 cases were related with the consumption of eggs.

<table>
<thead>
<tr>
<th>Table 2 The mean number of human cases of <em>Salmonella</em> infection assessed to be attributable to the consumption of table-eggs and the total number of reported cases in the period from 1997-2002.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated no. of cases attributable to table eggs</td>
</tr>
<tr>
<td>Total no of reported cases</td>
</tr>
</tbody>
</table>

It was estimated that during the period 1998-2003, the surveillance program have most likely saved 12,700 (95% C.I.: 11,638-13,800) reported cases. Figure 1 show the estimated number of saved cases per year if only 10% were reported and assuming that the number of egg-related cases without the *Salmonella* surveillance program had remained at the 1997–level of approximately 3,030 reported cases. Including the uncertainty related to the degree of underestimation the most
likely total number of saved cases during 1998-2003 was estimated to be between 63,700 and 254,900.

The cost model estimated that during the period 1998-2003, the surveillance programmed have most likely reduced the societal costs to health care and lost production with mill. €19.5 (95% C.I.: 17.3-21.7) for the reported cases. Figure 2 show the estimated societal costs per year when assuming that only 10% of the cases were reported. Including the uncertainty related to the degree of underestimation the most likely saved societal costs during 1998-2003 were estimated to be between mill. €26.3 - 49.5.

Finally, based on the public costs of control and the estimated saved societal costs due to control, the cost-benefit ratio per year was calculated (Figure 3). The results showed a continuous decreasing cost-benefit ratio reaching well below one in 2002, indicating that the control efforts have been a good investment.

Figure 1 Estimated most likely number of saved cases per year, assuming a reporting fraction of 10% and that the number of egg-related had remained at the 1997–level in case of no control. Error-bars indicate CI95%.

Figure 2 Estimated most likely saved societal costs per year (mill. €) for reported and non-reported cases, assuming a reporting fraction of 10%. Error-bars indicate CI95%.

Figure 3 Annual ratios of the public costs of control and the estimated saved societal costs. A cost-benefit ratio below 1 indicates that the net-benefit is positive.
Discussion

We assumed that if no control program had been implemented, the number of human salmonellosis cases attributable to Danish eggs would have remained at the 1997-level. This is probably a very unlikely scenario. Some would probably argue that the prevalence of *Salmonella* among egg-layers, and consequently the human incidence, would have continued increasing. On the other hand, the human incidence in other countries appeared to decline towards the end of the 90ies suggesting an overall decreasing trend. Still, no countries experienced such a rapid decrease as the one observed in Denmark (Anonymous 2006). Based on this, we chose the pre-control level.

The estimate of the saved societal costs must be considered a minimum. Costs to medicine and non-medical cost such, as transportation has not been included. Additionally, and more importantly, the cost of sequelae, premature death and other complications requiring special care were not included, as these costs could not be determined.

Rightfully, the costs of control in 2001 and 2002 should have included the costs of routine sampling. However, these costs were assumed by the industry at this time and we did not have access to them. Still, judging from Figure 3, the cost-benefit ratios had most likely not exceeded 0.4 in 2001 and 2002 even if the costs of routine sampling had been included.

By the end of 2002, the public financing ended and the poultry industry took over the administrative and financial responsibility of the program. Therefore, we did not obtain any cost data for 2003, but the estimated saved costs (Figure 2) suggest that the cost-benefit ratio has continued to decrease, which is a logical effect of the continuing reduction of infected table-egg layer flocks.

Conclusion

The Danish *Salmonella* control efforts in the table-eggs production have been successful in achieving their main objective: reducing the number of egg-associated human salmonellosis. From a societal point of view, the results presented here also indicate that the control efforts have been a good investment. Table-eggs are, however, still one of the most important domestic sources of human salmonellosis in Denmark. The aim must therefore be a continuing reduction.

References