Contents

Programme Monday March 13, Day 1  4
Programme Tuesday March 14, Day 2  5
Programme Wednesday March 15, Day 3  6
Programme Thursday March 16, Day 4  7
Programme Friday March 17, Day 5  8
Speakers  9
Structure of the poultry industry  71
Structure of the feed industry  73
# Programme

**MED VET NET-Workshop**  
Salmonella control in poultry from feed to farm, 13-17 March 2006 in Uppsala.

## Monday March 13, Day 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.00</td>
<td>Registration</td>
<td></td>
</tr>
<tr>
<td>09.30-09.40</td>
<td>Welcome address</td>
<td>Anders Engvall</td>
</tr>
<tr>
<td>09.40-09.50</td>
<td>MED VET NET; Developing scientific skills</td>
<td>Diane Newell and expertise</td>
</tr>
<tr>
<td>09.50-10.25</td>
<td>The Swedish Salmonella control in primary production – an overview of its background, strategy and development</td>
<td>Martin Wierup</td>
</tr>
<tr>
<td>10.25-10.50</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>10.50-11.30</td>
<td>The Swedish Salmonella control program in primary production – with special reference to poultry</td>
<td>Bengt Larsson</td>
</tr>
<tr>
<td>11.30-11.45</td>
<td>The significance of the Swedish Salmonella control programme in broilers</td>
<td>Lars Plym Forshell</td>
</tr>
<tr>
<td>11.45-12.00</td>
<td>The Swedish Zoonoses Center</td>
<td>Ivar Vågsholm</td>
</tr>
<tr>
<td>12.00-13.00</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>13.00-13.20</td>
<td>Salmonella control in the feed sector</td>
<td>Stig Widell</td>
</tr>
<tr>
<td>13.20-14.30</td>
<td>Salmonella control in the feed sector</td>
<td>Per Häggblom</td>
</tr>
<tr>
<td>14.30-15.00</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>15.00-15.30</td>
<td>Salmonella control of feed in the Swedish crushing industry</td>
<td>Per-Johan Herland</td>
</tr>
<tr>
<td>15.30-16.30</td>
<td>Experience from Salmonella control of feed in the UK</td>
<td>Robert Davies</td>
</tr>
<tr>
<td>16.30-17.00</td>
<td>Feed-borne outbreaks of Salmonella</td>
<td>Per Häggblom</td>
</tr>
<tr>
<td>17.00-17.30</td>
<td>Introduction to next day’s visit to feed plant</td>
<td>Per Häggblom</td>
</tr>
<tr>
<td>19.00</td>
<td>Dinner</td>
<td></td>
</tr>
</tbody>
</table>
Tuesday March 14, Day 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.00-10.00</td>
<td>Departure to feed mill</td>
<td></td>
</tr>
<tr>
<td>10.00-12.00</td>
<td>Visit at feed mill</td>
<td>Håkan Zetterström, Per Häggblom</td>
</tr>
<tr>
<td>12.30-13.30</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>14.00-15.00</td>
<td>Return to Uppsala</td>
<td></td>
</tr>
<tr>
<td>15.00-15.30</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>15.30-16.00</td>
<td>Summing up of Salmonella control in the feed sector</td>
<td>Per Häggblom</td>
</tr>
<tr>
<td>16.00-16.30</td>
<td>CRL-Salmonella Kirsten Mooijman</td>
<td></td>
</tr>
<tr>
<td>18.00-19.30</td>
<td>Dinner</td>
<td></td>
</tr>
<tr>
<td>Evening</td>
<td>Salmonella control in feed in participants own countries, what can be</td>
<td>Per Häggblom (Discussion leader)</td>
</tr>
<tr>
<td>exercise</td>
<td>learned? Discussion and free presentations.</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
<td>Speaker</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>09.00-10.15</td>
<td>Salmonella control in Swedish poultry</td>
<td>Björn Engström</td>
</tr>
<tr>
<td>10.15-10.45</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>10.45-11.15</td>
<td>Salmonella control in commercial egg production in Sweden</td>
<td>Björn Engström</td>
</tr>
<tr>
<td>11.15-12.00</td>
<td>Clean up procedures</td>
<td>Susanna Sternberg Lewerin</td>
</tr>
<tr>
<td>12.00-13.00</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>13.00-14.30</td>
<td>Salmonella control in the Danish egg production</td>
<td>Mogens Madsen</td>
</tr>
<tr>
<td></td>
<td>Salmonella control in the Danish broiler production</td>
<td>Mogens Madsen</td>
</tr>
<tr>
<td>14.30-15.00</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>15.00-16.00</td>
<td>UK experience with vaccination against Salmonella</td>
<td>Robert Davies</td>
</tr>
<tr>
<td>16.00-17.00</td>
<td>Salmonella control in poultry in participants’ own countries, what can be learned?</td>
<td>Susanna Sternberg Lewerin (Discussion leader)</td>
</tr>
<tr>
<td>18.00-19.30</td>
<td>Dinner</td>
<td></td>
</tr>
<tr>
<td>Evening</td>
<td>General discussion. How to implement Salmonella control in other countries?</td>
<td>Susanna Sternberg Lewerin (Discussion leader)</td>
</tr>
<tr>
<td>Exercise</td>
<td>Discussion and free presentations.</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>08.00-09.30</td>
<td>Salmonella control in meat producing poultry</td>
<td></td>
</tr>
<tr>
<td>09.45-12.15</td>
<td>Departure to poultry production unit, introduction on the bus:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salmonella control in broilers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Swedish experiences</td>
<td></td>
</tr>
<tr>
<td>12.30-13.30</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>13.30-15.00</td>
<td>Visit at broiler farm</td>
<td></td>
</tr>
<tr>
<td>15.00-16.00</td>
<td>Guided tour of Åkerö säteri</td>
<td></td>
</tr>
<tr>
<td>16.00-18.30</td>
<td>Departure to Uppsala</td>
<td></td>
</tr>
<tr>
<td>19.00-20.30</td>
<td>Dinner</td>
<td></td>
</tr>
<tr>
<td>Evening exercise</td>
<td>Continue discussions on Salmonella control in poultry in participants' own countries, what can be learned?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discussion and free presentations.</td>
<td></td>
</tr>
</tbody>
</table>

Björn Engström

Johan Lindblad

Susanna Sternberg Lewerin (Discussion leader)
<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.00-09.15</td>
<td>Costs and benefits of the Swedish Salmonella control programme</td>
<td>Anders Engvall</td>
<td>66</td>
</tr>
<tr>
<td>09.15-09.30</td>
<td>Economical aspects of the Salmonella control program in primary production</td>
<td>Bengt Larsson</td>
<td></td>
</tr>
<tr>
<td>09.30-09.45</td>
<td>Economical aspects of the Salmonella control program in feed</td>
<td>Per Häggblom</td>
<td></td>
</tr>
<tr>
<td>09.45-10.00</td>
<td>Economical aspects of the Salmonella control program in layers</td>
<td>Henrik Larsén</td>
<td>67</td>
</tr>
<tr>
<td>10.00-10.15</td>
<td>Economical aspects of the Salmonella control program in broilers</td>
<td>Johan Lindblad</td>
<td></td>
</tr>
<tr>
<td>10.15-10.45</td>
<td>Coffee break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.45-11.15</td>
<td>Salmonella in a country with a low incidence, human aspects</td>
<td>Yvonne Andersson</td>
<td>68</td>
</tr>
<tr>
<td>11.15-12.00</td>
<td>General discussion continued: How to implement Salmonella control in other countries?</td>
<td>Ivar Vågsholm (Discussion leader)</td>
<td></td>
</tr>
</tbody>
</table>

End of workshop and discussion on distance based learning or networking

12.00-13.00  Lunch
Speakers

Yvonne Andersson, Swedish Institute for Infectious Disease Control, Sweden
Robert Davies, Veterinary Laboratory Agency Weybridge, United Kingdom
Marianne Elvander, National Veterinary Institute, Sweden
Björn Engström, National Veterinary Institute, Sweden
Anders Engvall, National Veterinary Institute, Sweden
Per Johan Herland, Aarhus Karlshamn Sweden AB, Sweden
Per Häggblom, National Veterinary Institute, Sweden
Bengt Larsson, The Swedish Board of Agriculture, Sweden
Johan Lindblad, Swedish Poultry Meat Association, Sweden
Mogens Madsen, Danish Institute for Food and Veterinary Research, Denmark
Kirsten Mooijman, RIVM/MGB, The Netherlands
Diane Newell, Veterinary Laboratories Agency, United Kingdom
Lars Plym Forshell, National Food Administration, Sweden
Henrik Larsén, Swedish Egg and Poultry Association, Sweden
Susanna Sternberg Lewerin, National Veterinary Institute, Sweden
Stig Widell, The Swedish Board of Agriculture, Sweden
Ivar Vågsholm, National Veterinary Institute, Sweden
Martin Wierup, Swedish University of Agricultural Sciences, Sweden
From September 2004, the European Union (EU) 6th Framework Programme, within the ‘Quality and Safety of Food’ Priority Area, has provided five years of financial support for the development of Med-Vet-Net – a Network of Excellence for the Integrated Research on the Prevention and Control of Zoonoses. This network comprises 16 European partners including 8 public health and 7 veterinary institutes in 10 countries and utilises the expertise of over 300 scientists – including medical doctors, veterinarians, risk analysts, epidemiologists, microbiologists and molecular genetists.

The scope of our work is described on our website (www.medvetnet.org) and in particular we invite you to read our newsletters available there.

The overall aims of Med-Vet-Net are to:
- Improve the understanding, prevention and control of zoonotic diseases in Europe through strategic and integrated, high quality collaborative research across the food chain
- Raise awareness of zoonotic diseases in policymakers, the general public and other stakeholders
- Enhance the skills and knowledge base of European researchers in zoonotic diseases

The commitment of Med-Vet-Net to personal development is implemented within Workpackage 2 – Strategic Scientific Integration and delivered by a Training Sub-committee led by Prof Henrik Wagener (DFVF). This workshop in Salmonella Control is one of 4 training courses to be delivered in the first 18 month Joint Programme of Activities. In this workshop we have aimed to extend our activities outside of the network to European stakeholders including policymakers and other research scientists. The organisers of this workshop have worked hard to provide a unique opportunity for delegates to understand the processes currently available for the control of salmonella in poultry.

In its first year Med-Vet-Net has received a “Good-Excellent” rating from the external EC referee and the development of research skills and expertise was noted as a considerable strength of the network. I therefore hope that you enjoy the course and will maintain an interest in Med-Vet-Net activities in the future.
The Swedish salmonella control in primary production
- an overview of its background, strategy and development

Martin Wierup, Swedish University of Agricultural Sciences, 750 07 Uppsala, Sweden, www.slu.se

Severe epidemics initiated the control
Sweden faced severe Salmonella epidemics during 1953-54. The largest involved 9,000 people, of whom 90 died when S. Typhimurium was spread from an abattoir (Lundbeck et al., 1955). In another epidemic, 500 people were infected by S. Montevido, from meat imported from South America (Silverstolpe & Wranne, 1955). These epidemics demonstrated the need for a comprehensive control of salmonella infections in animals as a prevention of outbreaks in humans.

The development of the first control of salmonella
The above epidemics were controlled by the use of a legislation for epizootic diseases and later (1961) a special regulation for the control of salmonella were in place. Earlier a voluntary control of fowl typhoid (S. Gallinarium/ Pullorum) had been running since 1941. The outline of the control has since then been continuously revised. Statistics on Salmonella isolations from animals, feed and food products have continuously been published (DS Jo 1980:5). The first overall description of Salmonella control and its cost was presented by Wierup & Nordblom (1985) and Wierup et al. (1992) and of the current situation e.g in annual zoonoses reports (Anonymus 2004).

Concept of the control
Objective: Animal products delivered for human consumption shall be free from salmonella.
Strategies:
1. Prevent salmonella contamination of the whole production chain
2. Monitor at critical control points to detect if salmonella contamination occur
3. Undertake actions necessary to fulfill the objective of the control when salmonella infection/contamination is detected

The creation of a legal framework, motivations and incentives were found essential to ensure cooperation and compliance with the program. The control were continuously modified for possible improvement and cut of costs.

General Principals
Any finding of salmonella is notifiable. All isolations from index cases are sent to the National Veterinary Institute (NVI) for confirmation. In all suspected and confirmed Salmonella cases the Swedish Board of Agriculture (SBA) will instruct a veterinary officer to investigate the outbreak and supervise the clearance of the farm from the Salmonella infection or contamination.

In cattle and pigs, infected farms are subjected to restrictions which include ban on movement of animals, except for transport to “sanitary” slaughter. A veterinary officer supervising the clearance of a farm and give specific instructions e.g. to destroy carrier animals which may be long-term shedders of Salmonella. The restrictions remain in place until all animals are declared free from Salmonella following a bacteriological examination of two negative samples with a one-month interval from “all animals” was required before the herd is declared free from Salmonella. That was later limited to one negative sample for serotypes other than S. Typhimurium. However, in front of Sweden’s entry to the EU two negative samples is again required for all serotypes.

In poultry, in contrast to the case in cattle and swine, destruction of the infected flock has been the only alternative to clear Salmonella from an infected flock. Of basic importance for the control of Salmonella in food-producing animals is that meat products contaminated by any serovar of Salmonella are by law (Food Act. SFS 1971:511) declared unfit for human consumption.

Control in swine and cattle
In the 60ies around 50 outbreaks occurred annually
which later gradually decreased. In cattle epidemic cycles occurred. S. Dublin were most frequently isolated. During 1963 a larger epidemic occurred when cattle in at least 69 herds became infected with S. Dublin. The source of the epidemic was unpasteurized milk returning from a dairy and fed especially to calves. In addition 34 people were also infected (Nyström et al, 1964).

The surveillance in both swine and cattle was based on the clinical and laboratory (autopsy) control of the herds and on bacteriological examination of all animals sent to sanitary slaughter. During roughly 1974-89, three (0.008%) out of 33,899 sows and boars and 360 (0.7%) out of 50,109 fattening pigs were found to be Salmonella infected. For cattle, the corresponding figures for 1992 were 13 (0.1%) out of 19,999 cattle and four (0.4%) out of 954 calves (Wahlström et al, 1993). In front of Sweden’s entry to the EU in 1995 and due to a sharp decrease in the number of animals sent to sanitary slaughter specific controls on carcasses at normal slaughter were developed (test if intestinal lymph nodes). These controls for the first time selected on a statistical basis also verified a very low prevalence of Salmonella contamination; 0.8% of swine 0.1% of cattle sent to normal slaughter during 1990-92 (Wahlström et al., 1993). In addition sampling of carcasses and surveillance at cutting plants were at that time included in the surveillance (Wierup et al, 1992).

Control in broiler production
In 1970 the producers initiated a salmonella control of the fast growing broiler production following some severe outbreaks of human salmonellosis originating from chickens. Around 90% of the producers had joined the control and all its costs were paid by the State until 1984. When as a request from the industry the State made the control mandatory for all producers and also decided that the producer had to pay with the aid of an insurance programme. To obtain economic compensation in case of Salmonella contamination the insurance companies, as did the State before 1984, require that the chickens are delivered from hatcheries participating in the voluntary Salmonella control programme.

The primary objective is to stop Salmonella contaminated animals from entering the abattoir by preventing introduction of Salmonella through breeders, feed or the environment. Since 1984 all flocks of broilers and turkeys are tested by bacteriological sampling before slaughter to detect a prevalence of > 5% Salmonella contaminated animals in the flock. If any Salmonella, irrespective of serotype, is detected the flock is destroyed. During a ten-year period (1982-1991) flocks with a very low prevalence of salmonella could be slaughtered using special procedures (Wierup et al., 1989). However, flocks infected with S. typhimurium were always destroyed. This is however no longer an option.

Detailed rules for hygiene and management procedures in the different forms of productions is formulated and highest demands apply to the hatcheries. A veterinary officer is appointed by SBA to be in charge of the control for each farm.

All commercial poultry are imported as day-old grandparents and in quarantine tested extensively for Salmonella. If Salmonella is isolated, regardless of serotype, the birds are destroyed. The impact of this control was substantial. Altogether 12 out of 39 (30.8%) flocks of broiler-GP and 3 out of 38 (7.9%) flocks of layer-GP between 1982-1988 were found to be Salmonella contaminated. After that period the situation in imported grandparents has improved and 3 out of 47 (6.4%) grandparent chickens imported during 1989-1992. Those three flocks were destroyed. The prevention of introduction of Salmonella into the hatchery is based on the control of the breeders. During 1970-1992 Salmonella has only been isolated in hatcheries on one occasion, never found in GP flocks after release from quarantine, and only in two layer and one broiler parents flocks (1991).

From 1981 Competitive exclusion (CE)-culture was used to avoid re infection in a production unit found to be salmonella contaminated. During the period 1981-1990, CE-culture has been fed to 179 flocks including 3.82 million chickens. Only one of the flocks given CE-culture was found to be Salmonella contaminated. A contributory cause to the good results of the use of CE-culture is most likely that the hatcheries in Sweden can be claimed to be virtually Salmonella-free. An epidemiological study during a period when Salmonella was spread by contaminated feed, demonstrated that the CE-culture had a Salmonella-controlling effect also under field conditions (Wierup et al., 1988).

Control in layers
When the voluntary Salmonella control in poultry started in 1970 the majority of the parents flocks in
layer production also joined. Due to the cost and the fact that Salmonella contamination was virtually never found, most egg producers later left the control. The parent flocks were to some extent checked for Salmonella when sending birds for autopsy but the commercial layer producers were very seldom tested for Salmonella unless through plants producing pasteurized egg powder.

Due to the pandemic with S. Enteritidis (S.E) during 1980’s comprehensive studies were during 1988-1989 undertaken to verify the Salmonella situation and to improve the control of Salmonella in layers (Wierup et al., 1993). These studies indicated that S.E was not disseminated among egg producing layers but also that the commercial layers to some extent were contaminated by other serovars of Salmonella. Accordingly, further actions were taken to control Salmonella during the production period. Up to June 1993 a control before slaughter detected 44 flocks to be Salmonella contaminated. The dominating serotype found was S. Livingstone. Due to actions taken by authorities the frequency of the Salmonella contaminated flocks decreased. It was 5% in 1991, 2% in 1992 and 1% during the first half of 1993. During the last years only sporadic cases has occurred (Anonymous, 2004). S.E were up till then isolated from five flocks and all layers and eggs were destroyed. (Wierup et al., 1993). Before joining the EU, clean and whole eggs from layers infected with non-invasive serotypes could be put on the market. However at present this is not allowed. Later an mandatory and improved control have been implemented.

Method for diagnostic and eradication

Only bacteriological methods have been used to identify salmonella although other methods like a skin for use in cattle have been tried (Robertsson, 1985). Antibiotics have not been used to prevent shedding of salmonella. When tetracyclin could be given continuously to calves in sub therapeutic doses, both experimentally and epidemiologically, studies indicated that its negative effect on the Salmonella situation (Wierup, 1983). Before the Swedish ban of antibiotic growth promoters registration of a drug to be mixed in poultry feed required documentation that it did not increase the poultry’s susceptibility to Salmonella infection.

Costs

The cost for the total Salmonella control programme was presented by Wierup and Nordblom (1985). SBA (1993) has presented a balance sheet for the national costs for preventive control and eradication split up in costs paid by the state and by the farmers. The farmers paid the majority of the cost for preventive (97%) and roughly half (48 %) of the costs for eradication. A more detailed evaluation of the economics of the Swedish Salmonella control is presented by Engvall and Andersson (1993).

Control of feed

Monitoring and control of Salmonella in feed has been carried out since 1940’s directed to imported feed (Thal et al 1957). In 1960 a voluntary control programme in 1992 involved all 16 feed factories producing feed for farm animals. The strategy emphasized in early 1990’s was to detect, as early as possible in the production chain, when Salmonella contaminated raw material has entered the factory. The primary objective is that Salmonella-contaminated feed must not leave the factory. Actions taken when Salmonella is isolated in different parts of the production is described by Häggbom (1993). All costs for the Salmonella control must to be paid by the producers and also for interventions as a result of Salmonella positive samples.

References


Swedish Board of Agriculture: Control of Salmonella infections in Sweden 1993. www.sjv.se

Thal, E Rutqvist L and H Holmquist: Salmonella isolated from animals in Sweden during the years 1949-1956 Nord.Vet Med. 1957, 9, 822-830


The Swedish salmonella control program and its success is the result of cooperation between authorities and industry where all parts of the food chain are involved from feed to food. Continuous discussions over time at various levels, from high political level to level of farmers and farmers organizations and actions taken have lead to the target, that is to minimize the human exposure to salmonella.

Legal provisions
The zoonoses act (1999:658) issued by the parliament states that if a veterinarian has grounds for suspecting a case of zoonoses (i.e. Salmonella), he/she shall immediately perform an examination in order to establish the nature of the disease or infectious agent and take any action that be necessary to prevent the spread of infection. The person who has the animals in his care shall accept any intrusion, submit to any measures and provide any assistance that may be necessary. The veterinarian shall notify the Swedish Board of Agriculture (SBA) and the county administrative board as soon as possibly. If a case of zoonoses has been detected, the county administrative board shall notify the National Veterinary Institute, the National Food Administration, the Swedish Institute for Infectious Disease Control, the physician responsible for infection control, the municipal committee or committees that are responsible for environmental health and the district veterinarian as soon as possible. The authority appointed by the government (i.e. SBA) may for the purpose of preventing or controlling zoonoses, issue roles or, in individual case, decisions concerning the slaughter or killing of animals by other means; the destruction of dead animals, animal products and associated waste and other material that can spread infection; disinfection; vaccination and other preventive treatment of animals; examination of animals and animal products for control purposes; livestock management; restrictions or other conditions relating to handling of animals, animal products and other products or to contacts between animals and humans; the transportation of animals and goods; the keeping records concerning animals, animal products and animal transports; the destruction of pests that spread infection; sampling and analysis methods and reporting procedures to be applied by persons in charge of laboratories with regard to analyses performed; and any other necessary measures.

The zoonoses ordinance (1999:660) states that the SBA is responsible for the control of zoonoses. It also states that, in poultry, the state compensate up to 50 % for value of animals or animal products, cleaning and disinfection and production losses. If the owner is participating in voluntary programme to prevent infection the compensation can be 70 %. However, compensation rate is not given for broiler production if the production exceeds 5000 broilers per year or for breeding of more than 50 000 day-old poultry per year.

The zoonoses regulation (SJVFS 1999:101), issued by the SBA states that salmonella is govern by the zoonoses act.

Regulation SJVFS 1994:92, latest edition SJVFS 2000:117 gives the rules for the obligatory sampling of poultry regarding salmonella and regulation SJVFS 1995:79, latest edition SJVFS 2000:118 for a voluntary programme in order to prevent salmonella infection. All poultry establishments approved within the voluntary and preventive Salmonella control programme are registered and officially supervised. This includes all poultry for slaughter, all breeding establishments and approx 80% of the laying hens population. This programme includes: rules for feed production and transport (heat treatment, hygiene control); hygienic rules to protect the birds from Salmonella infection from the surroundings (restrictions for visitor, rodent control, hygiene barriers, bird- and rodent proof houses etc); Salmonella free newly hatched chickens are delivered from the hatcheries; precaution to stop spread of...
Salmonella from an infected flock, and all in - all out principle in all categories of poultry production.

The competent authorities
The Swedish Board of Agriculture (SBA) is the competent authority responsible for the agriculture sector and is responsible for the control of zoonoses according to the zoonoses act and ordinance. SBA issues regulations with defined rules and is the supervising authority for the Salmonella control programme in live poultry. The board takes active part and leads combating salmonella in farms.

The National Food Administration (NFA) is the competent authority for the purposes of Community and National legislation on food hygiene. The NFA is responsible for the official meat inspection in Sweden and for the border inspection of food. The NFA has the overall responsibility for investigating food borne outbreaks in Sweden and is contact point for RASFF for food.

The County Board Administration is the regional supervising authority in each of the 21 counties in Sweden. The board takes active part in combating salmonella in farms, reports in accordance with the zoonoses act and reports to the SBA about the progress of the obligatory control programme. There are 289 municipalities in Sweden which has supervising functions in small food producing establishments and restaurants.

Laboratories
The laboratories involved in the control programme are designated by the competent authorities and apply quality assurance systems that conform to the requirements of the current EN/ISO standard (ISO standard 17025). They are participating in collaborative testing organized or coordinated by the national reference laboratory.

The National Veterinary Institute, SVA, is a Swedish Government authority under the Ministry of Agriculture. SVA aims to promote animal health by preventing, diagnosing and controlling infectious diseases in animals. SVA is the largest and only official laboratory in veterinary medicine in Sweden. SVA supports in decision-making and assists the Ministry of Agriculture, Board of Agriculture, other authorities, organisations, veterinarians and the general public in the prevention and control of epizootic diseases and zoonoses. A zoonoses centre is located at SVA. The centre has a leading role in the zoonoses council, in which organizations/authorities from both human and animal side is represented.

Description of the poultry programme
Nation-wide official control programmes for Salmonella were launched in 1995. The programme covers both live animals (cattle, swine, and poultry) and meat (cattle, swine, sheep, and poultry) and are similar to the Norwegian and Finnish Salmonella control programmes. The programme for live poultry comprises analyses of faeces, meconium and/or organs. Sampling of breeder flocks of poultry have been carried out in accordance with the programme as laid down in Annex III of Council Directive 92/117/EEC. All slaughtered meat-producing flocks of poultry are sampled 1-2 weeks prior to slaughter, and all commercial layer flocks are sampled at least 3 times during egg production.

The control programme for fresh poultry meat comprises analyses of neck skin samples from poultry carcasses. Neck skin samples are sampled from all slaughtered flocks and a total sample size sufficient to detect Salmonella at a prevalence level of 0.1% (with 95% confidence level) are collected.

The results show that poultry meat produced in Sweden is virtually free from Salmonella. Since the start of the programme in 1995 between 2778 and 4358 neck skin samples have been analyzed each year. From 1995 to 2004 38,762 neck skin samples have been analyzed and 12 (0,03%) have been found positive. Sampling within the control programme show that only a few flocks/holdings are infected with Salmonella each year. In the years 2000 - 2004, between one and three broiler flocks and two to four layer flocks were infected with Salmonella each year. Sampling in broiler flocks became mandatory in 1984 and, since then, there has been a steady decline in the number of infected flocks each year. In the years 2000 - 2004, between one and three broiler flocks and two to four layer flocks were infected with Salmonella. Salmonella Enteritidis has not been isolated in broilers since Sweden joined the EU in 1995.

The new programme:

Even though the Regulation only requires the control programme for breeder flocks of Gallus gallus to be submitted for approval by the end of December 2005, the Nordic countries decided to design a control programme covering the whole poultry production. This is to make the transition from the change from our old programme to the new one as easy as possible. The control of Salmonella in different poultry subpopulations are interconnected, and changes in sampling plans and analytical methods due to the new EU regulation are preferably introduced in all the programmes covering the poultry sector simultaneously.

The aim of the programmes both the old and the new one is to minimize the human exposure to Salmonella spp. from poultry and poultry products. Thus, the target of the program is to keep the annual prevalence of Salmonella spp. (all serotypes) in each poultry production category of Gallus gallus (breeders, layers, broilers), turkey, ducks, geese and ratites less than 1 %. The programme is implemented nation-wide. It does however not apply to primary production leading to the direct supply of small quantities of primary products, by the food business operator producing them, to the final consumer or to local shops.

Neither the use of live or inactivated vaccines against Salmonella, nor the use of antimicrobials as a specific method to control Salmonella in animals are not allowed in Sweden.

The control strategy is to prevent, detect, and adequately control Salmonella spp. at the level of primary production before any threat to human health arises and further spread to other animal populations and environment occur. The focus of the risk management is, therefore, mainly the poultry primary production and intermediary products used in the primary production of poultry (feed).

In breeder flocks, samples are taken at hatchery, then at an age of 4 weeks, 2 weeks before being moved and then every second week. Laying hens are sampled as day-old at hatchery/holding, 2 weeks before being moved and then every 15th week. Broiler flocks and other poultry for meat production are tested 1-2 weeks before slaughter. For poultry meat, 10 neck skins per day and slaughterhouse are sampled and tested.

An official veterinarian visits every breeding establishment and takes the official samples in accordance with Regulation (EC) No 1003/2005. In commercial egg laying (table egg production) and meat production establishments an official veterinarian visits at least once a year and takes the official samples. On these occasions the official veterinarian scrutinizes the obligatory records showing the production, health status and results of laboratory investigations and inspects the hygienic measures and management practices.

All examinations take place in laboratories approved by the competent authority. All serotypes of Salmonella in animals and animal feeding stuffs are notifiable (LSFS 1982:30 and SJVFS 1993:177) according to provisions issued by the SBA. Salmonella is notified when the bacteriological diagnose Salmonella spp is ready. This obligation is directed to the veterinarian responsible for the diagnosis. The veterinary laboratory in question shall immediately notify SBA and the regional veterinary authority when Salmonella has been diagnosed. All Salmonella findings must be sent to the National Veterinary Institute for confirmation and typing. The obligation to notify all Salmonella findings has been in force since 1961. All findings of Salmonella in food are also to be notified.

If Salmonella spp. has been detected in a flock all poultry are slaughtered/destroyed. Sanitary measures enforced will be: thorough cleaning and disinfection of houses and equipment, safe disposal of culled bird, manure, residual feed etc (moulding, composting, rendering, incineration in some extreme cases) and official approval, including negative bacteriological testing of the in-house environment, before restocking.

There will also be official investigations into the probable source of contamination and the possibility of further spread of Salmonella spp. from this source. Also, the possible further spread of Salmonella spp. from the holding will be investigated. There will also be a review of the hygienic barriers/bio-security at the holding, and corrective actions will be taken if necessary.

Products on the market derived form positive flocks will be traced and withdrawn. If the products are aimed for the international market, RASSF notification will be made.
Actors in salmonella control
Salmonella in broilers and broiler products
The results from the Salmonella control programme in broilers have, since the start of the programme, clearly demonstrated an extremely low prevalence of Salmonella contaminated birds after slaughter (table 1).

Table 1: Results from the Swedish Salmonella Control in slaughterhouses and cutting plants 1995-2004. (National Food Administration).

<table>
<thead>
<tr>
<th>Year</th>
<th>Samples</th>
<th>Positive samples (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>2778</td>
<td>2 (0.07)</td>
</tr>
<tr>
<td>1996</td>
<td>4503</td>
<td>2 (0.04)</td>
</tr>
<tr>
<td>1997</td>
<td>4958</td>
<td>0</td>
</tr>
<tr>
<td>1998</td>
<td>5148</td>
<td>1 (0.02)</td>
</tr>
<tr>
<td>1999</td>
<td>4607</td>
<td>2 (0.04)</td>
</tr>
<tr>
<td>2000</td>
<td>4956</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>5364</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>5558</td>
<td>3 (0.05)</td>
</tr>
<tr>
<td>2003</td>
<td>5339</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>5499</td>
<td>0</td>
</tr>
<tr>
<td>1995-2004</td>
<td>48710</td>
<td>10 (0.02)</td>
</tr>
</tbody>
</table>

Salmonella guarantees
When joining the EU in 1995 it was considered to

primary production a zero-tolerance for Salmonella since long has been applied and that all Salmonella-positive flock are destroyed. Between 3200 - 3500 flocks have been raised in Sweden each year since the middle of the 90’s and of these 0 to 4 flocks per year have been found infected with Salmonella.

Salmonella guarantees
When joining the EU in 1995 it was considered to be an imperative necessity, after years of target-oriented and successful efforts to reduce Salmonella in the food-chain, to get special Salmonella guarantees on meat and meat-products produced in the other member-states. This was of course based on the fact that Salmonella-contaminated meat and meat-products were more common in the other member-states and thus it was considered that trade with these products could be a threat to the public health in Sweden unless some guarantee concerning freedom from Salmonella was granted.

Salmonella-guarantees implying that each consignment should be certified to be free of Salmonella spp. were after long discussions granted. Consignments destined to direct heat-treatment were excepted.

The adherence to the guarantees has been studied in projects in 1997 and 2000. In 1997 35 % of poultry consignments with a certificate stating freedom from Salmonella were found positive. In 2000 the same figure was 14%. Disappointing results were found also in pork consignments.

In 2002 meat-preparations, which are not covered by any guarantees, were studied. 26% of the analysed consignments were positive for Salmonella. Samples taken by the local authorities in Sweden have also some years clearly demonstrated a prevalence of contaminated broilers and broiler products on the market that is much higher than the prevalence demonstrated by the Salmonella control programme. The conclusion must be that these contaminated products are of foreign origin. These results together with a substantial increase in imported products since 1995 give cause for worry.

Public health effects
Conclusions concerning the effect on public health caused by this increase in Salmonella contaminated products on the market in Sweden must be cautious since no dramatic increase in domestic cases of human salmonellosis has been observed since joining the EU.
making it reasonable to suggest that, not only would the actual number of cases these years have been lower but also that a trend towards a decrease would have been observed had contaminated products not reached the market.

Another aspect of this question is that due to the Salmonella- guarantees the concentration of Salmonella on the contaminated products in most cases perhaps is quite low which could explain why an increasing effect on domestic cases has not been observed so far. We conclude that the Salmonella- guarantees are important in protecting public health as is the Salmonella control programme giving justification for these guarantees.

Final remark
Considering the dramatic increase in imported products that has taken place in the last decade and which is expected to continue, the National Food Administration is pleased with the ambition to decrease the prevalence of infected poultry that is expressed in the Regulation (EC) No 2160/2003 on the control of Salmonella and we see this as a commitment for further efforts towards still lower prevalences in the future.
The Swedish Zoonoses Centre

Ivar Vågsholm, Swedish Zoonoses Centre, National Veterinary Institute,
Uppsala S 751 89. Sweden. tel 46-18-674000, fax 46-18674445, e-mail Ivar.Vagsholm@sva.se

Monday, March 13, 11.45-12.00

The aim of the zoonoses centre is to produce information enabling an efficient zoonoses control, during the last 10 years with an emphasis on food borne zoonoses. The task vested with the zoonoses centre include producing the annual zoonosis report according to the revised zoonoses reporting Directive 2003/99 updating and replacing the previous directive 92/117/EEC. However, new challenges such as the emergence of the avian flu pandemic necessitate a flexible approach ahead.

The work of the zoonoses center is guided by the zoonoses council, that consists of:
- National Food Administration,
- Swedish Board of Agriculture,
- Swedish Institute of Infectious Disease Control
- National Board of Health and Welfare
- National Veterinary Institute (SVA)
- Swedish Agricultural University
- Swedish Association of Local Authorities
- Swedish medical association of epidemic disease control (smittskyddsläkar föreningen)
- Swedish association of county veterinary officers
- Swedish work environment authority

An important element in the collaboration is that veterinary, food safety, occupational and public health agencies meet four times a year for discussing zoonoses control in the zoonoses council. This creates a possibility to build a consensus on important issues that thereafter enable quick action if needed.

An example of this process is the forthcoming review of salmonella control policy in Sweden. This review must have regard to the objectives of keeping the same acceptable level of protection (ALOP) for public health, to include the new EU legislation, to update the policy to the changed structure of the Swedish primary (e.g., poultry) production and new scientific knowledge, if base the review on the new concepts of risk assessment and management such as food safety and performance objectives, and to reduce the costs of the salmonella control in the primary production.
Salmonella control in the feed sector

Per Häggblom, National Veterinary Institute, Uppsala, Sweden

Introduction

Animal feed is at the beginning of the food chain in the "farm- to- fork" model. The emergence of Creutzfeldt-Jakob disease has raised the awareness of the importance of contaminated animal feed but less attention has so far been paid to the role of bacterial contamination of animal feed in human foodborne illness. In the recently introduced EG- legislation the control of feed is important in order to stop introduction of pathogens or toxic compounds into the food chain. Although tracing salmonella contamination to its ultimate source is difficult several large outbreaks have been traced back to contaminated animal feed (Crump et al., 2002). One contributing factor is that the extent of salmonella contamination of feed is substantially underestimated, because of the difficulties in obtaining representative samples, when monitoring ingredients or finished feed (Davies, 2000; Durand et al., 1990; Schluter et al., 1994).

The most well known example of feed involved in the spreading of salmonella, is in 1970 when S. Agona emerged as a public health problem in several countries due to contaminated fish meal. In the United States a rapid increase of human infections with S. Agona occurred from 1968 to 1972. Human cases occurred primarily in states with poultry operations that used feed with fishmeal imported from Peru (Clark et al., 1973). Epidemiological investigations were able to show that human cases occurred as a result of consumption of chicken where the poultry feed contained fishmeal (Clark et al., 1973). Similarly, human infections with S. Agona occurred simultaneously in European countries. Since then, S. Agona is among the most prevalent serotypes in humans in the USA and it is estimated that the serotype has caused more that one million human illnesses only in the USA since it was introduced in the food chain (Crump et al., 2002).

How did the Swedish salmonella control of feed start?

In the Swedish salmonella control programme for food producing animals the control of animal feed has proved to be very important. In accordance with the present feed legislation animal feed must be salmonella negative. The salmonella control of feed is focused on several steps in the feed chain.

Surveillance and control of salmonella in feed have been carried out by the feed industry since the late 40's (Thal et al., 1957). The reason for this early interest to control salmonella in the feed sector was not the salmonella per se, but the finding of Bacillus anthracis in imported meat-meal intended as ingredient for pig feed. From this particular consignment of meat- meal twelve different salmonella serotypes were isolated as well. In experiments using heat pelleting, carried out in the middle of the 50's, attempts were made to control salmonella in feed ingredients (Swahn and Rutqvist, 1957). The need to develop procedures to control salmonella in feed production became the primary objective for an industry association, Stiftelsen Veterinär Foderkontroll, founded in 1958, comprising most of the Swedish feed producers. Several of the early guidelines on how to control salmonella, particularly in broiler feed, were developed as industry recommendations in collaboration with government experts at the National Veterinary Institute. Since 1972, broiler feed is heat treated at temperatures above 75°C. In 1991, a HACCP approach was implemented in the salmonella control of feed mills based on a risk analysis, with critical control points in the processing line being monitored weekly.

Structure of feed industry

The total volume of commercial feed for food producing animals in Sweden in 2003 was approximately 2.2 million (metric) tons of which 177.000 tons were for broilers and 205.000 tons for layers. Fifteen ma-
Major feed mills produce approximately 95% of the feed. About 70% of the feed mills are farmers' cooperatives, integrated feed and animal production is not present in Sweden.

Salmonella control of poultry feed

According to Swedish experience broilers and layers appear to be particularly sensitive to salmonella present in the feed. There are several examples of poultry flocks which were infected from salmonella in the feed, such as: S. Infantis, S. Kentucky, S. Mbandaka, S. Newington, S. Liverpool, S. Livingston, S. Tennessee and S. Senftenberg (Sandstedt et al., 1980; Mårtensson et al., 1984; Eld et al., 1991; Häggblom and Aspan, 1997).

Recently, new (i.e. not previously isolated in Sweden) serotypes have been detected in feed ingredients of plant origin. Salmonella Yoruba was isolated in imported soybean meal in 1997. Since then, S. Yoruba was frequently isolated from soybean meal and also caused outbreaks in domestic pig and poultry operations (Östergberg et al., 2001). Data indicate a decreased sensitivity to high temperatures in this serotype (Häggblom et al., 2002), which might explain the survival of the organism during pelleting.

The on-farm feeding of whole wheat to broilers was introduced in 1995. Control strategies and restrictions on the use of whole wheat to broilers, at the farm, were introduced simultaneously. Epidemiological data indicates that under Swedish conditions the feeding of whole wheat, as a complement to commercial feed, does not present an increased risk for salmonella infection in broilers.

The control of salmonella in commercial poultry feed is based on several strategies. An important point of the control programme is the HACCP-based process control in the feed mills where the most important hazards are identified in the processing line. The aim is to make sure that the processing line for poultry feed is not contaminated with salmonella.

The most important risk factors in the production of poultry feed are feed raw materials. Previously, raw materials of animal origin were the greatest risk factors but presently ingredients of plant origin are more important. Quarantine and control of feed raw materials must be applied before ingredients are incorporated into compounded feed, including both domestic and imported products of animal as well as plant origin.

Domestic products are monitored at the supplier. All imported commodities are investigated for salmonella before or at the point of entry. The sampling protocol for feed raw materials is designed to detect salmonella with 99% probability assuming that salmonella bacteria are evenly distributed in the commodity.

Salmonella in ingredients

Soybean meal is often contaminated and approximately 30% of the consignments imported to Sweden are positive for salmonella. Other ingredients often contaminated are rapeseed meal, corn gluten meal, fishmeal and imported meat meal. Most serotypes detected in raw materials are "exotic" serotypes, i.e. not the types normally isolated from animals. Salmonella Typhimurium and S. Enteritidis are rarely isolated from feed ingredients.

Salmonella positive consignments of animal origin are rejected. Raw materials of plant origin contaminated with salmonella are treated with organic acids, such as formic acid, before pelleting. The acid (1-2%) is thoroughly mixed with the contaminated ingredient in a mixer separated from feed processing. After 48 h the treated commodity has to be retested for salmonella and if negative it will be used in compound feed.

All poultry feed must be heat treated for > 30s at a minimum of 75°C resulting in a reduction of salmonella by approximately 1000-fold. Inappropriate heat treatment during pelleting, condensation of free water in coolers, transportation systems or storage bins of the feed mill due to insufficient cooling of the feed are important risk factors. Recontamination of the feed after the heat treatment may easily occur due to poor cleaning of the premises, foot traffic or accumulation of wet material but also during transport or storage at the farm.

Monitoring and disinfection of feed mills

Five weekly samples are collected from feed mills producing poultry feed and analysed for salmonella. The samples are collected from the following points of the processing line: a) the unloading pit for raw materials, b) the aspiration filter, c) the top of the pellet cooler, d) the area surrounding the pellet cooler and e) the top of bin for finished feed. The samples collected are "dust samples " or scrapings often less than 25 g. End point testing of finished feed is not carried out in the monitoring programme. Positive samples are most fre-
quently isolated from sampling points a) and b) while salmonella is rarely isolated after the heat treatment. In 2003, a total of 9,548 samples were taken in the HACCP control of feed plants, 78 yielding salmonella (National Veterinary Institute, 2004).

Action is always taken when salmonella is detected in any of the samples in the monitoring programme. Approximately 30 samples (dust samples or scrapings) will then be collected from the processing line mostly after the heat treatment step and analysed for salmonella. If all samples are negative, indicating that salmonella is not present in the processing line, the investigation is finalised. If salmonella is detected in the top of the pellet cooler there will be an immediate stop of production on that production line and no delivery of feed is allowed. A careful dry cleaning followed by disinfection of processing equipment and premises is used when salmonella is detected in the feed mill. Ineffective disinfection may accentuate salmonella problems in feed mills. According to Swedish experiences feed mills rarely carry endemic salmonella infections in contrast to crushing mills, which may be contaminated persistently.

---------------------------------------
References


The Swedish crushing industry
In Sweden there is one crushing plant situated in Karlshamn on the south Baltic coast. The plant has an extraction capacity of 300 kton of rapeseed and produce 120 kton of rapeseed oil and 180 kton of rapeseed meal per year. All the extracted rapeseed meal is further heat treated in the ExPro-Process to improve the protein value for ruminants and eliminate bacteria in the meal.

Feed customers
The rapeseed meal is delivered to feed industries in Sweden, Norway and Finland and is mainly used in feed for cattle.

Salmonella tolerance of feed materials
In the Nordic countries, Sweden, Norway, Finland and Iceland all feed materials must be analysed for salmonella and found negative before delivered.
In the EU-25 there is today no majority for a mandatory feed control of salmonella. Probably, all member states in near time will accept minimum requirement and recommendations.

Control program for salmonella in Crushing Industry in Sweden
The official salmonella-monitoring program for the crushing plant is built on the principle of HACCP. Sampling and analyses are as follows:

Sampling (scrapings)
- From production-areas, drier-cooling-system, 7 samples/week
- From weighing units, and feed silo bins, 7 samples/week
- From outdoor environment, 6 samples/month
- From meal produced (automatic meal-samples, every 15 min) 4-10 samples/24 h

Method of analyses
As official method NMKL-71(5) 1999 is used. To get results before meal delivery, the faster PCR-method is used. The laboratories and methods used are approved by the Swedish Board of Agriculture.

Voluntary GMP-program - VFK Feed Safety Standards
The aim of the Association for Safe Feed Materials - VFK is to work proactively to achieve safe feed materials for production of safe animal feed, and thereby contribute to ensure the safety of food for human consumption. The Feed Safety Standards are based on EC and national legislation, the principle of precaution and HACCP. These far-reaching laws and principles have been interpreted by VFK in consultation with the National Veterinary Institute and formulated in 16 paragraphs that describe the VFK Feed Safety Standard. Feed materials producers certified according to the VFK Feed Safety Standard have a decreased risk of chemical, microbiological and physical risk disorders.

Results of salmonella analyses 2004-2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of scraping samples in production plant and silo</th>
<th>Where of positive</th>
<th>Number of scrapings in outdoor environment</th>
<th>Where of positive</th>
<th>Number of meal samples from production</th>
<th>Where of positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>757</td>
<td>9</td>
<td>72</td>
<td>25</td>
<td>1328</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>672</td>
<td>7</td>
<td>72</td>
<td>19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Actions when salmonella is detected
In production plant
Stop of production
Cleaning
Disinfection
Follow up sampling and analyses

In feed silo bins
Stop use of the bin
Cleaning
Disinfection of bin and meal
Follow up sampling and analysing of bin and meal
Outdoor environment
Cleaning
Disinfection
Follow up sampling and analysing

In finished meal
Stop deliveries-inform customers and authorities
Extra sampling of production plant, transport line and silo bins
Cleaning
Disinfection of meal and silo bins
Follow up sampling and analyses must be salmonella negative to start delivery

Cost of the salmonella program at AarhusKarlshamn Sweden AB
The Swedish feed law does not except delivery of feed materials contaminated with salmonella.
For the Swedish crushing industry it is obvious to have a well designed process, trained personal and an efficient salmonella program to avoid salmonella in the meal.

The costs of the salmonella program are as follows: 

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Year (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyses</td>
<td>700 000</td>
</tr>
<tr>
<td>Laboratory work</td>
<td>500 000</td>
</tr>
<tr>
<td>GMP-program</td>
<td>50 000</td>
</tr>
<tr>
<td>Cleaning</td>
<td>200 000</td>
</tr>
<tr>
<td>Sampling BCC</td>
<td>240 000</td>
</tr>
<tr>
<td>Insurance</td>
<td>600 000</td>
</tr>
<tr>
<td>Total cost</td>
<td>2290 000 or 245 000 Euro</td>
</tr>
</tbody>
</table>

Cost per ton of delivered meal 13 sek/ton or 1.4 Euro/ton. These costs do not include the special process design or the marketing side to sell meal with a salmonella guarantee.

Identified salmonella problems
For a period of more than twenty years AarhusKarlshamn, Sweden AB have been monitoring salmonella in the production of rapeseed meal.

The following is a list of identified problems and actions in the production of rapeseed meal.
1. Too high temperature in the produced meal after cooling
2. Too low capacity of the meal drier/cooler
3. Condensation of water in the transport systems and tops of bins
4. Contaminated particles introduced into the cooling system from air intake.
5. Contamination of the process equipment by maintenance workers
6. The method of analyses takes to long to keep all produced meal in quarantine.

Actions
1+2. New well designed meal drier/cooler with higher capacity
3. New pneumatic transport system for meal from process plant to silos
4. New air intake to drier/cooler with effective filters
5. Improved training and management system
6. New faster method of analyses based on PCR-technology which take 24 hours.

Added value of salmonella free meal
These calculated added value of protein meal free of salmonella are based on cost for the Swedish feed compound industry to eliminate salmonella in contaminated meal:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Ton (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost for external heat treatment of protein-meal</td>
<td>250</td>
</tr>
<tr>
<td>Cost for acid treatment of protein-meal</td>
<td>150</td>
</tr>
</tbody>
</table>

Approximately 25% of all imported protein meal by the Swedish feed industry is contaminated with salmonella which gives a calculated cost for salmonella decontamination of 38 sek/ton or 4 Euro/ton. The marginal cost can be 150 sek/ton or 16 Euro/ton when they have to change the feed recipes when there is lack of salmonella free feed materials.
Introduction
It is well recognised that Salmonella is able to survive, and in some cases proliferate, outside the living host in the natural environment. Most strains are relatively resistant to desiccation and so may persist for years in dry dusty environments. According to situation and serotype there may be extensive subclinical carriage of infection in domestic and wild animals and, to a lesser extent, in humans. Even this subclinical carriage may involve excretion of large numbers of organisms but when there is clinical disease extremely large numbers of Salmonella bacteria may be excreted and the faecal waste from infected animals is a potent potential source of contamination of the surrounding environment. This includes water, crops, equipment and whatever wildlife which may move through the contaminated environment. Salmonella therefore possesses the ideal properties for a feed contaminating pathogen and it is therefore fitting that it should form the focus of controls on feed contamination in many countries.

Relevance of feed contamination in animal Salmonellosis
In many countries the predominant serovars of Salmonella seen in domestic livestock do not correlate well with serovars found regularly in feed. This is because in these cases another route of dissemination of infection is predominant, for example vertical ovarian transmission of S. Enteritidis in chickens or spread of S. Typhimurium in cattle and pigs through live animal movements and in some cases selection by the use of antimicrobials. This selection does not mean that feed contamination was not an issue at some point in the epidemiology of the early stages of dissemination. In the case of S. Enteritidis PT 4/8 and related egg transmitting strains there would have been an increased chance of spread of infection via feed before these strains became recognised as a special problem and control measures increased. The fact that meat and egg laying birds managed completely separately were equally affected also suggests a common source such as feed. Similarly, in the period around the beginning of the penta-resistant S. Typhimurium DT 104 epidemic in cattle there were several isolates of this strain reported from feed, surprisingly the number reduced during the further development of the epidemic but it would have been possible for the initial spread to involve feed contamination.

The majority of Salmonella serotypes associated with feed contamination can also be found in broilers, which in the UK at least are less likely to be influenced by other sources. The most important exception to this being persistent contamination of the hatchery. Salmonella serovars may be linked with certain ingredients or certain suppliers or feed mills and this contamination may persist for many years. This gives rise to ‘company specific’ serotypes which can be consistently isolated both from the feedmill and broiler flocks. Similar principles also apply in the case of turkeys and ducks but in these species the occurrence of problems with breeding flocks, hatcheries and persistent farm contamination is greater so the influence of feed as a source is diluted. Similarly, integrated pig companies may also suffer from infections with Salmonella strains such as S. Kedougou which are regularly found in feed and individual cattle herds may suffer transient infections, normally subclinically, with Salmonella found in ‘straight’ vegetable protein oil extraction residue meals such as palm kernel or rapeseed which are increasingly fed as part of total mixed rations. In the case of commercial laying flocks feed related serovars appear to be relatively uncommon compared with S. Enteritidis and often appear transiently, appearing and disappearing within the life of the flock and sometimes being present against a background of ongoing S. Enteritidis infection.

Relevance of feed contamination in human Salmonella infection
There is generally little commonality between the
Salmonella serotypes commonly found in feed and those which are predominant in human disease, which in most countries are normally S. Enteritidis and S. Typhimurium. In some cases there may be some apparent commonality with less frequently reported serovars, such as S. Agona but this needs to be investigated in more detail by molecular genetic methods. Although the major human Salmonella serovars are rarely isolated from feed in most years there are a small number of isolates of these reported. Since sampling of feed ingredients and finished feed is relatively insensitive because of the large volume of material to be sampled and the difficulty of obtaining a truly representative subsample the actual occurrence of serovars of public health significance is likely to be significantly higher. Each contamination incident offers an opportunity for establishment of infection somewhere in the food chain. If the strain involved is one with ‘epidemic’ potential then one incident affecting a primary poultry or pig breeding company at the time when monitoring was more limited could have resulted in widespread dissemination of infection. Better long-term archiving of Salmonella isolates is required so that retrospective genetic analysis of suspected sources of epidemic strains can be carried out in future.

Routes of contamination of feed ingredients

(a) Primary production
In the UK many feed ingredients, particularly vegetable proteins and fish meal, but also some cereals and their by-products are imported. Some ingredients such as rice may be grown in conditions where contaminated irrigation water is a problem. Feed ingredients from warm countries may be contaminated with unusual Salmonella serovars commonly found in reptiles. Feed ingredients may become contaminated at any stage between ripening and arrival at the feed mill. In various studies carried out in UK contamination of grain and protein ingredients such as rapeseed and linseed has been observed following contamination by faeces of wildlife or domestic pets, particularly cats, which like to use stored feed as litter. This may be an issue on large outdoor pig farms which are sited next to grain flat-stores or on cattle farms which produce grain. In such cases wildlife may gain access to stores whilst doors are left open or poorly cleaned cattle yards may be used for short-term storage of grain prior to drying. There may also be some contamination of lodged grain in the field. This commonly involves Salmonella serovars found in badgers. Equipment and vehicles used for handling ingredients on farm may also be associated with contamination.

(b) Processing
A low level of contamination present in feed ingredients may lead to more serious problems by causing contamination of processing equipment which may then be responsible for more extensive dissemination of infection. This may occur in grain drying equipment but there is limited multiplication of Salmonella here because of reduced moisture. The organism can however often be found at a relatively high frequency in dust from drying equipment auger systems.

The most significant problem relates to the oil extraction process for oil seed products such as soya beans, rapeseed and linseed. Following the cooking process which releases the oil it is necessary to cool the product to reduce heat and moisture before storage. This provides a warm, moist environment in which Salmonella can multiply and colonise the fatty deposits which form within the cooler. The origin of this contamination is residual contamination of material which may have failed to reach a satisfactory temperature for long enough, typically at the start of a production run, or entry of contaminated air from the general mill environment. This contamination may be transient or in some cases can lead to establishment of a resident Salmonella population which may persist indefinitely unless strong remedial action is taken. Ingredients may also be contaminated after processing, by cross-contamination during storage and transport.

Routes of contamination of finished feeds
The primary source of contamination of finished feeds is the use of contaminated ingredients, in which contamination may survive into the final ration unless remedial action is taken. Many rations for adult pigs, ruminants and horses are only lightly heat treated. Rations for commercial layers are normally meals which have no antibacterial treatment. Feed for breeding birds and commercial meat birds is normally heat treated but whole grain which has not been heat treated may also be fed to broilers. In most cases this is treated with organic acids, but not always successfully, so could represent an occasional means of introduction of Salmonella into flocks. Where heat treatment has been carried out successfully there is still a danger that recontamination may occur as a result of cooler conta-
mination as described for ingredient production. This problem most commonly affects mills serving poultry integrations which are not able to shut down production long enough to fully decontaminate. Some small independent mills may also be in a similar position as production cannot be switched to an alternative mill during decontamination. It is possible to find Salmonella serotypes associated with resident mill contamination in broilers and poultry processing samples from affected companies over many years. If there is a focus of contamination in a mill then cross contamination can occur in bins and auger systems, particularly when reworked material is used. Contaminated dust is also produced which may disseminate to various parts of the mill.

Control of Salmonella contamination in feed production

Ingredients
Good segregation of feed ingredient storage and handling facilities and equipment as well as proofing against and control of rodents, wild birds and access by domestic animals is fundamental. Faecal waste should not be spread on land adjacent to that growing crops close to harvesting. Equipment used for handling should ideally not be used for other purposes but it is difficult to comply with this on small farms so good cleaning and disinfection between operations is essential. These procedures should be HACCP based and are described in DEFRA, Agricultural Industries Confederation (AIC), and Universal Feed Assurance Scheme (UFAS) Codes of Practice and manuals, which covers the production and delivery of compound feeds and the supply of feed materials to the farm. Many livestock industry assurance schemes such as the British Egg Industry Council (BEIC) Lion Code for egg production also require farms to source feed from UFAS assured feed mills.

The Feed Materials Assurance Scheme (FEMAS) covers the sourcing and production of feed materials right back to the country where they are grown and the Trade Assurance Scheme for Combinable Crops deals with grains and pulses after leaving the farm. Auditors for AIC schemes are accredited under the European Standard EN45011. In the oil crushing industry contamination due to resident Salmonella in cooling systems is often dealt with by treating products with formaldehyde and organic acid mixtures and this may help to suppress Salmonella most of the time but some organisms do survive and this becomes more apparent with time as the bacteriostatic effect of the additives wear off. Also, if there are problems with application then there may be spikes of contamination as these may be noted as part of nationwide surveillance of ingredients by compound feed mills and later in monitoring of poultry flocks, particularly where intensive faecal monitoring is carried out. Total decontamination of large cooling systems involved in ingredient processing is difficult because of access but it is possible for infection to be cleared by continuous use of additives combined with good general hygiene management.

Finished feed
In commercial feed mills it is important to effectively monitor ingredients and report positive results back to suppliers, avoiding suppliers which regularly provide contaminated material. Compounders who are known to be carrying out effective testing are also less likely to be supplied with contaminated ingredients. Unfortunately monitoring by individual mills may be insufficient to detect contamination trends but results from other premises are confidential. It would be advantageous to collate and publish these results more openly. General mill hygiene as described in DEFRA and UFAS codes of practice is important, especially good segregation between storage materials of different risk categories, clearance of bins before refilling, dust, humidity and pest control and good control of conditioning times and temperatures, especially for the first rations produced after a shut-down period. Recommended conditions for heat treatment of pellets or heat treated meals are 80°C + for two minutes but often the time used is less than this so high levels of contamination in protective fatty ingredients may not be completely eliminated. Higher temperatures for shorter periods may be achieved by extrusion, which is often combined with subsequent pelleting to improve pellet quality. Feed intended for use for chicken breeding flocks is often treated with both heat and organic acids. Research has shown that liquid acid products with the highest level of free acids are more effective than granular acid salts but these are more corrosive for milling equipment so granular products are more often used. Acid products are also normally used for grains which will be fed whole.

Cooler contamination is avoided by maintaining suitable conditioning conditions and air cleanliness in the cooler area to minimise intake of contaminated dust.
Ideally the cooler should be situated in a separate air-space from other milling operations or receive filtered air. Regular production of acid treated finished feeds can also help protect against establishment of infection and ideally these should be evenly spaced throughout the production period. Some mills will pass through the system wheatfeed treated with higher levels of formaldehyde products or organic acid products regularly. If a cooler does become persistently contaminated it is not easy to eliminate this and very thorough cleaning of the whole mill, and in particular the cooler interior, combined with intensive chemical decontamination ideally using formaldehyde over a prolonged period, is required. Sometimes it is necessary to cut sections out of contaminated coolers to facilitate adequate cleaning. Production of acidified rations for a period after decontamination is also recommended. Half-hearted attempts at decontamination are usually unsuccessful and specialist assistance should be sought. In some cases it is not possible to shut down production long enough to thoroughly decontaminate coolers and suppression by regular use of formaldehyde products is usual. If this is combined with good humidity and temperature control this can substantially reduce the level of contamination of feed but spikes may occur when there are management failures or repairs are carried out which may dislodge old contaminated material. Cross contamination subsequent to cooling may occur and is controlled by good auger and bin hygiene. In some mills there is an accumulation of feed dust and wild birds in outloading gantries and this should be discouraged by good hygiene and appropriate bird control. Feed lorries should be kept clean and dry. Ineffective liquid disinfection may make contamination worse by supplying moisture.

Monitoring for Salmonella
Ingredient Processors and Compound Feed Mills are required to carry out a minimum level of testing of aggregate samples of ingredients and finished feeds. Subsamples which contribute to the aggregate samples are retained and investigated individually in the case of positive aggregate samples so that epidemiological tracing can be carried out. Monitoring of finished feed and ingredients in this way has limited sensitivity because of the non-uniform distribution of what is normally fairly low levels of contamination so only highly contaminated rations or chance sampling of a ‘hot-spot’ in the batch is likely to lead to a positive result.

A better way to determine the Salmonella status of the mill throughput as a whole is process and ‘environmental’ monitoring. This gathers accumulated material at key points in the production system and may involve taking scrapings of fatty deposits with milling equipment such as coolers or auger systems, start-up rations taken after a shut-down period when contamination of equipment is likely to be at its highest or collection of local accumulations of spillage and dust from specific items of equipment. Most Salmonella is concentrated on medium sized particles of dust which do not travel far from the contaminated area so collecting this dust is a good way of defining the location of contamination. Prime areas for sampling in this way are ingredient intake pits, ingredient auger systems, grinder discharge and dust emanating from weighers and mixers. This gives a good indication of the range of Salmonella serotypes entering the mill in ingredients. Monitoring the process between heat treatment and cooling is not always practical but can indicate the success of the heat treatment. It is normally easy to obtain deposits from within coolers and emanating dust and the potential for contamination of finished products can be assessed by samples from pellet sieves, finished product bin augers and the outloading gantry or bagging plant. Dust taken from air filters on equipment can also be useful. It would not be unexpected in the UK to get an occasional Salmonella isolate from these locations but a consistent pattern of contamination requires further investigation.

Official controls on Salmonella in feedingstuffs
The Zoonoses Order 1989 requires notification of all Salmonella isolates from livestock, their environment or feedingstuffs to be notified to Defra. If S. Enteritidis or S. Typhimurium is isolated from finished feed in a compound feed mill then a nominated officer of Defra will visit the mill to ensure that proper investigations and control measures have been taken and may take additional environmental samples to ensure that the process is not still contaminated. Under the terms of the EC Feed Hygiene Regulation 183/2005 feed businesses must be approved or registered with their local authority. The regulation covers ingredients and finished feeds as well as feed stores, transporters and industries related to use of co-products for use in livestock or companion animal feed. Approval requires an inspection visit. Larger farms growing or using crops for livestock feed for their own use or onward sale are also included. The Animal By-Products Regulation 2005 requires operators of rendering plants to test for Salmonella samples of rendered animal protein that
is intended for use in feed. Under the terms of the TSE Regulations 2002 the only allowed animal protein is fish meal for poultry and companion animals but most poultry rations do not use this and are soya-based. The Food Standards Agency is responsible for enforcement of legal requirements for feed, in collaboration with Defra, SVS and VLA, and a new comprehensive code of practice on feed law enforcement has been drafted.

Test results
The table below summarises results of testing of feed carried out in 1994 and 2004. Data from the feed industry is particularly valuable as unlike the livestock industry data from all tests is provided, not just positive results, so accurate denominator and prevalence data is available. The data shows an improved situation compared with 10 years previously with oilseed residues and imported fish meal resulting in the greatest contamination levels.

Conclusions
The UK feed industry has worked hard to achieve a high level of Salmonella control. Improvements have also been made on farms and in storage. Now that the prevalence is low it would be advantageous to include more process monitoring to identify problems more accurately and so to identify areas for further improvement. It is debatable whether most of the feed-related Salmonella serotypes have much public health significance but as a point of entry of infection into livestock production networks it is important that standards, particularly relating to imported feedingstuffs which may be contaminated with future epidemic strains, are continually upgraded to minimise such risks.

<table>
<thead>
<tr>
<th>Product</th>
<th>No of tests</th>
<th>1994</th>
<th>Percent positive</th>
<th>No of tests</th>
<th>2004</th>
<th>Percent positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processed animal protein at a GB protein processing premises</td>
<td>10203</td>
<td>220</td>
<td>2.2</td>
<td>3576</td>
<td>32</td>
<td>0.9</td>
</tr>
<tr>
<td>GB and imported processed animal protein arriving for feedingstuffs use</td>
<td>6137</td>
<td>254</td>
<td>4.1</td>
<td>1153</td>
<td>36</td>
<td>3.1</td>
</tr>
<tr>
<td>Oilseed meals and products for feedingstuffs use</td>
<td>15169</td>
<td>743</td>
<td>4.9</td>
<td>10364</td>
<td>337</td>
<td>3.3</td>
</tr>
<tr>
<td>Non-oilseed meal vegetable products</td>
<td>14422</td>
<td>289</td>
<td>2.0</td>
<td>8845</td>
<td>35</td>
<td>0.4</td>
</tr>
<tr>
<td>Ruminant concentrates</td>
<td>3235</td>
<td>111</td>
<td>3.4</td>
<td>1982</td>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>Pig extrusions</td>
<td>6598 (+meal)</td>
<td>239</td>
<td>3.6</td>
<td>1591</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>Pig and poultry meals</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3069</td>
<td>25</td>
<td>0.8</td>
</tr>
<tr>
<td>Poultry extrusions (+meal)</td>
<td>14256</td>
<td>389</td>
<td>2.7</td>
<td>5299</td>
<td>12</td>
<td>0.2</td>
</tr>
<tr>
<td>Protein concentrate</td>
<td>1724</td>
<td>64</td>
<td>3.7</td>
<td>511</td>
<td>6</td>
<td>1.2</td>
</tr>
<tr>
<td>Minerals/other</td>
<td>949</td>
<td>5</td>
<td>0.5</td>
<td>380</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Feed borne outbreaks of Salmonella

Per Häggblom, National Veterinary Institute, Uppsala, Sweden

Background
A look into historical data of broiler flocks becoming infected with salmonella in Sweden clearly show that “exotic” salmonella serotypes have caused infections in a large number of flocks. Data from 1968-2004 (National Veterinary Institute), where the number of notified cases of infected broilers flocks are summarized, correlate well with the more stringent feed control introduced in 1991 and resulted in considerably fewer salmonella cases than previously. The greatest difference was for “exotic” salmonella with approx. 80% reduction in the number notified cases. For S. Typhimurium the decline was around 50%. The large variation between different years in the number of salmonella cases notified was considerably reduced after 1991. Interestingly, the heat pelleting for broiler feed, introduced in 1972, had no obvious effect per se on the number of infected flocks. Outbreaks in broiler flocks could very often be traced back to persistent infection in coolers.

Examples of feed borne outbreaks
In the autumn of 1998 several positive samples of S. Mbandaka were detected in a feed mill producing poultry feed. For about two months S. Mbandaka was isolated from the section of raw materials in the feed mill. During the same period a broiler flock was tested positive for S. M bandaka and it was found out that the contaminated mill was the feed supplier. Pulsed Field Gel Electrophoresis (PFGE) was used trace the origin of salmonella in the broilers. The results showed that all isolates of S. M bandaka from the feed mill had identical PFGE-types and the same subtype was also found in the broiler flock. Epidemiological data supported the results from the subtyping investigation. Interestingly, S. M bandaka was never isolated from the finished feed (Häggblom and Aspan, 2002).

In 1999 S. Yoruba was detected for the first time in the Swedish salmonella control programme in imported soybean meal. In 1999 and 2000 two poultry flocks were found positive for S. Yoruba and the serotype was not detected in any of the heat-treated feed samples investigated. Several pulsotypes of S. Yoruba were isolated from the soybean meal and one of the types was present in both poultry flocks (Häggblom et al., 2002).

In a large outbreak of feedborne salmonellosis (S. Cubana) in pigs in 2003 details of the feed mill involved were carefully investigated. The investigation showed that contamination of a cooler was the most likely reason why the feed was infected after heat-treatment. Condensation of free water in coolers, followed by persistent infections with salmonella, is an important factor why heat-treated feed may easily become infected with salmonella according to Swedish experiences.

References

The first official Salmonella control programme for poultry started in 1951 with serological screening of all breeder flocks for Salmonella Gallinarum (fowl typhoid) and Pullorum. (Efforts to control these diseases started already in the 1920ies.) It was first a voluntary programme supported by the government. It was very successful and in 1961 it became a mandatory programme. Fowl typhoid and pullorum disease was soon eradicated in commercial poultry (1962) and in 1971 the official support for the programme ended and no case in commercial poultry has been reported ever since.

General outline of the Swedish Salmonella control programme
In Sweden, a pre-harvest salmonella control programme for poultry has been in place since 1970 covering all parts of the poultry production chain — from feed to meat and egg.

In the beginning there was a strong economical support from the government. All laboratory costs for sampling and bacteriological examination were paid by official means. If the flock had to be destroyed due to a Salmonella infection the state paid 90% of the value of the birds, and 100% of the costs for extra cleaning and disinfection of the house and for costs due to interruption of the production.

Since 1984 the state stopped paying for the laboratory costs and provides no compensation for the costs due to salmonella infection in broiler flocks. Private insurance covers such losses today. The insurance companies demand that flocks have to participate in the voluntary programme in order to be insured. For other poultry the state pays 70% of the losses due to salmonella outbreaks if affiliated to the voluntary programme, otherwise only 50%.

The programme today covers laying hens, broilers, turkeys, duck and geese from grandparent flocks to commercial stock. The programme consists of a mandatory and a voluntary part. The mandatory part covers surveillance of all flocks, reporting of all salmonella isolations and that eradication is undertaken when positive flocks are detected. The voluntary part mainly consists of prophylactic measures. The voluntary control programme has been revised several times since the start to adapt to new knowledge and changes in modern poultry production. During each revision, the industry has been involved in discussions with the authorities on which improvements in biosecurity that must be introduced and practically implemented at any level of the production chain. The close cooperation with the industry is considered very important for the success of the programme.

The objective of the Swedish salmonella control programme today is to deliver salmonella-free poultry meat and eggs of Swedish origin to the consumers. All serotypes of Salmonella enterica are regarded as undesirable and all positive flocks are destroyed. This policy is based on the fact that all serotypes of Salmonella enterica with zoonotic potential are pathogenic for humans although certain serotypes are more common (Wray and Wray, 2002). The policy of including all serotypes in the control programme has so far prevented the introduction and spread of new, emerging and potentially more pathogenic or invasive serotypes. For example, the global pandemics of S. Enteritidis and S. Typhimurium DT 104 have not been established in Swedish poultry production. The low prevalence of salmonella in poultry and other domestic animals in Sweden makes the inclusion of all serotypes in the programme feasible.

The use of live or inactivated vaccines against Salmonella is not allowed and the use of antimicrobials is not allowed as a specific method to control Salmonella in animals, including poultry.

The voluntary control programme
The voluntary control programme gives detailed instructions regarding hygienic and feed control measu-
res and control of breeder flocks. Before a poultry farm may be affiliated to the voluntary control programme it must fulfil certain standards in the house, equipment, management and hygiene. Official veterinarians visit all affiliated flocks twice a year. In this way, the three main ways for introduction of salmonella to the birds – infected breeding stock, contaminated feed and contaminated environments – are controlled. Sternberg et al., (2005) has recently described the Swedish control programme in more detail.

Measures to prevent introduction of salmonella into a poultry house
The basic principle is to introduce salmonella-free poultry into salmonella-free poultry houses and to ensure that the flocks will remain salmonella-free by preventing horizontal infection from feed, water and the environment. A system of all-in-all-out within each separate poultry house with thorough cleaning and disinfection between each batch of birds is of basic importance.

On a farm site affiliated to the control programme there must not be any uncontrolled poultry present.

The houses should not be situated too close to each other in order to avoid spread of salmonella between houses. Each room/compartment in a house may be considered an epidemiological unit if there are separate ventilation systems and there are no openings between the rooms. The poultry house should be constructed to facilitate cleaning and disinfection, and all materials used in the house must have smooth surfaces that are easy to clean. All drains and other outlets must be constructed to ensure that no backflow of water, sewage, slurry or other material may occur.

All buildings should be constructed to prevent rodents and wild birds from gaining access. The preventive work includes the sealing of holes and cracks where rodents might enter the house, putting nets in front of windows and ventilation apertures, and keeping an area of land within two meters from the house free from objects and vegetation. Spillage of feed around the silo that may attract wild birds and rodents should be avoided and, if occurring, immediately cleaned up. At each farm a professional rodent control programme must be set up. No other animals like cats and dogs are allowed into the house. To prevent introduction of dust and dirt by shoes into the houses an area outside the doors must be hardened and easy to keep clean. In poultry house there must be an anteroom with facilities to wash hands and change footwear and clothes. The anteroom must be divided in two parts by a physical hygiene barrier where everybody has to change footwear and put on protective clothes. According to Swedish experience the use of footbath is insufficient for decontamination purposes and, therefore, change of footwear is required. The outer part of the anteroom that is closest to the outer environment is considered as the potentially contaminated part and the part closest to the birds as the clean part. In grandparents and parents houses the hygiene barrier should preferably be combined with a shower.

If there are several pens in a house with one anteroom in common there should be a second barrier outside each door leading to a pen where footwear must be changed again. The ambition is to avoid spread of salmonella between the pens within a house.

Poultry that are housed outdoors without strict biosecurity cannot be affiliated to the programme.

Man can be an important transmitter of salmonella. The keeper has to be trained and motivated to follow the hygiene rules. Visitors should not be allowed to enter the poultry pen if it is not really necessary. The keeper of the birds has to be tested for salmonella if he/she has been abroad or has had symptoms of salmonella infection. He or she is not allowed to be in direct contact with the birds if he/she is found infected as long as he/she is shedding salmonella.

Equipment can easily spread salmonella. In each pen, equipment often used must stay in the pen all the time and equipment introduced from elsewhere must be disinfected before brought into the pen. Repairmen who have to visit a poultry pen with birds represent a great risk as some of their tools may be difficult to disinfect. Most technical equipment should be placed in the anteroom in order to limit visits in the pen. The crates or containers in which the birds are transported to the processing plant can be an important carrier of salmonella between poultry pens especially if the birds in the pen are sent for slaughter at several different occasions and the crates are brought into the pen. The crates are difficult to clean and seldom disinfected in a proper way. For example, Hansson et al., 2005 found that transport crates were a risk factor for campylobacter contamination in broilers at slaughter. More over, harvesting machinery is common today and very difficult to disinfect as well.
In houses for caged layers there may be holes in the walls for transport of eggs and manure between the houses and pens. Egg transport belts between houses constitute a risk for airborne transmission of salmonella and culverts for transport of manure may be an open door for rodents.

Litter may be contaminated with salmonella on its way to the poultry house. Wooden shavings are used as litter in Sweden. The litter must be stored in a separate storage with low risk of contamination.

Feed is the most important route of transmitting salmonella to the birds and all feed has to be heat-treated. Farmers may get special permission to mix the heat-treated feed from the feed mill with home produced whole wheat. Control of the feed in the feed factory is described elsewhere. On the way to the farm the feed must be transported in containers that are used for transport of heat-treated feed only. On the farm the silos must be in good condition and possible to clean properly.

On the farm it is allowed to mix the feed from the factory with whole wheat after permission from the Swedish board of agriculture. The use of whole wheat is most common in the broiler production.

If silos are placed outdoors it is important to keep the ground free from spilled feed to avoid attracting birds and rodents. The feed tubes into the pens must be possible to dismount and clean and disinfect if salmonella is found. The principle of handling feed on the farm is to prevent recontamination, and to have equipment that is easy to clean and disinfect if salmonella is found.

Water has to come from a good well and the hygiene standard must be frequently controlled i.e., be of potable quality (drinking water). The drinking water may be contaminated with salmonella and transmit it to the birds. Frequent cleaning and disinfecting of the water systems is necessary. Big bell drinkers are especially difficult to keep clean but they are rare today in Sweden. If the water cups are contaminated with faeces containing salmonella the high temperature in the pen favours the growth of bacteria in the cups. This can be the starting point of a rapid spread of salmonella in a flock. On the other hand, drinking nipples are not contaminated in the same way and easier to keep clean.

Control of breeders and hatcheries

One infected parent or grandparent bird can be the origin of thousand infected production birds in the worst-case scenarios. Hence, the breeders and hatcheries are kept in strict isolation and the general hygiene rules in the control programme should be applied very rigorously. The risks of becoming infected with salmonella are the same for breeders as for other types of poultry. However, as breeders are more valuable and may transmit the salmonella to their progeny, more strict control measures are applied for breeders than for production animals. The handling of hatching eggs is critical as surface contamination of the eggs may result in infected day-old birds.

Import control

All grandparent- and a limited number of parent flocks are imported to Sweden and kept in quarantine. Before they are released from quarantine they have been sampled frequently and found free from salmonella and a number of other pathogens. All imported flocks found infected are destroyed irrespective of serotype. This strict control of imported grandparents has stopped the spread of imported salmonella infection to the following generations.

This stamping out policy has minimised the introduction of new salmonella infections in the production chain from imported breeders.

Very few flocks of parents have been infected with salmonella and only one has been infected via the egg. All breeders are killed if any serotype of salmonella is found in a flock.

Special hygiene rules for breeders and hatcheries

In breeder flocks and hatcheries it is very important to keep a very good hygiene and sanitise the eggs to obtain a good hatching result. If Escherichia coli, Pseudomonas aeruginosa, Proteus spp and other bacteria enter the eggs the embryos may become infected and die during incubation or as chicks during the first week of life.

Disinfection of eggs is also an important measure to prevent spread of contagious diseases by contaminated eggs. Consequently the hygiene rules in our programme concerning handling of eggs are not stricter than general good management practice in breeder houses and hatcheries.

Egg handling in breeder houses

Most salmonella bacteria do not enter the egg before the egg is laid. If faeces in the nest soil the egg, the
bacteria in the faeces can penetrate the shell and infect the egg. Rollaway nests are most hygienic as the eggs roll away when the hen has laid the egg and left the nest and the risk of contamination is small. Dirty eggs should not be used for hatching. Slightly dirty egg may be used preferably after washing. It is important to collect the eggs as soon after laying as possible.

The eggs should be disinfected with a good disinfectant immediately after collection in a special room or in the storage room. The eggs are packed only in racks coming from a hatchery affiliated to the control programme. The personnel transporting the eggs to the hatchery is not allowed to enter the anteroom, only the storage room for eggs. A record must be kept for each breeder flock with details of the egg production, health of the birds and the delivery of eggs to the hatchery in order to trace eggs if salmonella infection in the flock is diagnosed.

Hatcheries
All eggs shall be sanitised at arrival to the hatchery, in the incubators when they are first set and the day before hatching with a disinfectant with a good bactericidal effect. Incubators and the equipment have to be thoroughly cleaned and disinfected after each hatch and all the incubators in a room has to be empty at the same time at least twice a year in order to make a complete disinfection of the room.

Return of transport crates or containers from the chicken farm always constitutes a risk for introducing infection into the hatchery. Disposable crates are best but too expensive. The crates should be cleaned and disinfected in a separate room of the hatchery before they are introduced into the hatchery room. Many types of crates are difficult to clean properly as faecal droppings get stuck in corners and holes.

It is important to keep the hygiene routines on a high level and act as if salmonella may have been introduced in the hatchery without being found in order to avoid the spread of salmonella to other parts of the hatchery and to farms. A record must be kept of the delivery of birds to the farms to make it possible to trace salmonella infection in both directions.

Measures to prevent salmonella from staying in a poultry pen between batches of birds
We always apply the "all in - all out" principle with depopulation of the whole house before new birds arrive. Although no salmonella has been found in a previous flock the house always must be cleaned and disinfected very thoroughly. The used litter is usually removed the same day or the day after the birds have left the house.

The details of cleaning and disinfection will be presented elsewhere. Without a proper cleaning it is impossible to disinfect.

The high standard of the routine of cleaning and disinfecting can be illustrated by the low prevalence of several viral diseases in Sweden. Infectious bursal disease (IBD) is usually permanently present in poultry pens, but in Swedish broiler flocks it is very rare. All houses, so far, have been possible to sanitise by our standard cleaning and disinfections procedures. Chicken anaemia virus (CAV) infection has also appeared in a different way in Sweden compared to other countries possibly due to the hygiene programme. CAV spreads from breeders to their progeny if the breeders are infected when they are producing eggs for hatching. The progeny will show sign of disease and experience high mortality. In most countries the breeders are usually infected with CAV already during the rearing period, and CAV is not spread to the progeny. In Sweden however, the isolated breeders can stay free from CAV until they start producing egg and the progeny become infected. Today we vaccinate the breeders during the rearing period.

Before a new batch of chicken arrives, the pen and all equipment have been the properly cleaned and disinfected. Nevertheless, a small number of salmonella bacteria may survive routine cleaning and disinfection if salmonella was present in the previous flock.

Sampling
Within the Swedish mandatory salmonella control programme, regular sampling of all poultry flocks is done at all stages in the production chain, from the grand parents to the broiler chickens and commercial layers. Sampling is performed with different frequencies depending on the level in the production chain, and on the impact an undetected infection would have on the end product. The sampling regimes are designed to detect a Salmonella prevalence of 5% or more with a 95% confidence limit at each sampling occasion (Table 1). Breeding animals are sampled every month throughout their lives and every batch of hatched chickens is sampled in the hatchery. Hens for commercial egg production are sampled once during
the rearing period, three times during the laying period including just before slaughter. Broilers, ratites, turkeys, ducks and geese are sampled at least once before slaughter, at the end of the rearing period.

Actions taken when salmonella is diagnosed
If salmonella is detected in any part of the production chain, the result is notified to the authorities. Restrictions are laid upon the farm to stop transmission from the farm and an investigation is carried out to try to find the source of the infection and any potential spread from the farm. Initially the restrictions enforced include all houses in a holding. If the official investigation can show that different houses within a holding can be regarded as separate epidemiological units, the restrictions can be limited to just include the houses were the infection has been diagnosed. All poultry in the infected flock(s) are destroyed. Restrictions are released when the sanitation is successfully finished.

---

Table 1 Mandatory Salmonella sampling scheme in poultry.
Total number of sampling occasions in different categories of poultry.

<table>
<thead>
<tr>
<th>Category of poultry</th>
<th>Rearing</th>
<th>Eggproduction</th>
<th>Hatchery</th>
<th>Sampling prior to slaughter</th>
<th>Slaughter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand parents</td>
<td>5 a)</td>
<td>~10 b,c)</td>
<td>~20 b,d)</td>
<td>yes</td>
<td>e)</td>
</tr>
<tr>
<td>Parents</td>
<td>3 a)</td>
<td>~10 b,c)</td>
<td>~20 b,d)</td>
<td>yes</td>
<td>e)</td>
</tr>
<tr>
<td>Layers</td>
<td>1</td>
<td>3</td>
<td>n.r.</td>
<td>yes</td>
<td>e)</td>
</tr>
<tr>
<td>Meat producing poultry f)</td>
<td>n.r.</td>
<td>n.r.</td>
<td>n.r.</td>
<td>yes</td>
<td>e)</td>
</tr>
<tr>
<td>Ratites, breeders</td>
<td>4 sampling occasions per year</td>
<td>n.r.</td>
<td>n.r.</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Quails, (eggproducing)</td>
<td>n.s.</td>
<td>2 sampling occasions per year</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

a Extended sampling compared to the former zoonosis directive (92/117/EEC)
b Sampling according to the former zoonosis directive
c One sampling per month
d One sampling in every flock
e Monitoring at slaughter. Annually about 4000 neck skin samples are collected from poultry. From ratites faecal samples are collected
f Broilers, turkeys, ducks, geese, ratites
n.r. not relevant
n.s. no sampling

References


Swedish egg production

Since the 1960s, conventional battery cages have been the predominant housing system for egg producing laying hens in Sweden. As a consequence of animal welfare concerns, new legislation was introduced in 1988. By this legislation cages for laying hens were banned from 1999 with a long transition period. In 1988, the level of knowledge concerning alternative housing systems was insufficient. Research was initiated early on, and different types of aviary housing systems were evaluated on a limited number of trial farms. In 1996, the evaluation had produced disappointing results i.e. the mortality rates were high in these aviary systems. The same year, minimum housing requirements were laid out for laying hens, which included a nest area, and access to dust bathing and perches. Through this change, enriched cages became an option.

The Swedish laying hen industry has gradually replaced conventional battery cages with alternative housing systems. The main change has taken place since 2001. From August 2000, farmers could apply for exemption to use conventional battery cages, but this possibility was discontinued in August 2002.

During the last 20 years, the Swedish laying hen population has varied between 5 and 6.5 million birds. As a direct consequence of the change from conventional cages to alternative housing systems the population dropped but recovered soon again. The number of birds kept in different systems November 2005 is shown in table 1.

<table>
<thead>
<tr>
<th>System</th>
<th>Number of hens (1000)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>365</td>
<td>6</td>
</tr>
<tr>
<td>Floor indoor</td>
<td>1 740</td>
<td>28.5</td>
</tr>
<tr>
<td>Multi-tier indoor</td>
<td>1 560</td>
<td>25.5</td>
</tr>
<tr>
<td>Enriched cages</td>
<td>2 227</td>
<td>36</td>
</tr>
<tr>
<td>Old cages</td>
<td>223</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>6 115</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. Number of laying hens in different systems, November 2005

As in other countries the majority of eggs are produced in a few large farms, 91% of all produced eggs are produced in 204 (0.4%) of the farms. These large farms have between 10,000-500,000 hens. Each farm usually has between 1 and 15 flocks/epidemiological units. Each flock/epidemiological unit can vary between 10,000 and 40,000 hens.

Generally, Swedish laying hens are reared in cages or non-cage systems to the age of approximately 16 weeks, when they are transferred to the egg-producing farms. During the rearing period, the pullets are vaccinated against Marek’s disease, avian encephalomyelitis and infectious bronchitis. Floor-reared pullets are also vaccinated against coccidiosis. During the production period the hens are regularly vaccinated against infectious bronchitis. All-in-all-out management is practiced on flock level by a majority of farmers. However, multi-age farms are common. In enriched cages, the minimum available space per bird shall be 600 cm², plus a shared 200 cm² nest and 200 cm² dust bathing area. The group size is usually eight to ten hens (at most 16). In floor systems, the hens have access to a litter area, slats, nests, and on most farms, perches. Depending on the bodyweight of the hen a maximum of 7.5 to 9 hens per m² usable area are allowed. In multi-tier aviary systems, 20 hens per m² usable area are allowed. For organic laying hens additional requirements for housing, feed and management are set out in the standards of the Swedish association for organic farming ‘kontrollföreningen för ekologisk odling’ (KRAV) (http://arkiv.krav.se/arkiv/regler/Standards2005EditionJuly.pdf), which meet the International Federation of Organic Agricultural Movements (IFOAM) Basic Standards and the European Union regulations (91/2092/EEC) for organic animal production. According to these regulations, the stocking density in for organic hens is maximized to six hens per m² floor (1667 cm² per laying hen). During the warm season, they have access to pasture (4 m² per bird). The flock...
size in organic egg production is maximized to 3,000 birds.
The change in housing system for egg production between 2001 and 2005 is shown in fig. 1. Note that the egg production in % does not equal number of hens in various housing systems as the production is higher in conventional and enriched cages than in free range systems.

Introduction of Salmonella control programme in egg production

When the voluntary Salmonella control programme started 1970 many commercial layer farms became affiliated. As no salmonella were found in layers and the risk for spread to the eggs was considered to be small, all laying farms left the programme. Only one out of five breeder companies for layers were affiliated to the salmonella control programme in 1988. However, all poultry including layers sent to laboratories for autopsy in Sweden were tested for salmonella and only few cases of salmonella in layers were reported during 1970-1988 (fig. 2).

In 1988 Salmonella Enteritidis became an important problem for the egg production in Europe. An increasing number of people became infected after eating eggs. A new variant of the bacteria (PT 4) had been introduced and spread to many countries throughout Europe, mainly by movement of live poultry. Prior to this outbreak it was conventional wisdom that eggs could not be infected with salmonella inside the shell. This shows the importance of continuously updating salmonella control programmes as knowledge increases.

Due to the S. Enteritidis outbreak in Europe, a survey of the Swedish egg production was performed in 1988. Samples were collected from parent flocks (faecal samples), hatcheries (meconium samples) and from all four egg-processing plants (egg powder production). No salmonella were found in the parent flocks or hatcheries but from samples from egg processing plants, four different serotypes of salmonella were found in egg mixture (18/381 samples). However, no S. Enteritidis was found.

As both the mandatory and voluntary control programmes were not adapted to the egg production these programmes were revised by the Swedish board of agriculture in cooperation with SVA and the industry. In meanwhile, the poultry meat industry imposed a requirement that layer flocks sent for slaughter had to be tested for salmonella two weeks in advance. This testing started in 1990 and became mandatory in 1991.

In December 1993, both the mandatory and voluntary salmonella control programmes were finalised. Affiliation of layers to the voluntary programme was slow in the start as the biosecurity in many farms was poor and improvements to fulfil the requirements of the program expensive. With the change from old cages to new systems most of the houses had to be refurbished and many new houses were built. This change made it easier to fulfil the demand of the programme.

Today all breeding flocks producing layers are affiliated to the voluntary programme and 85% of commercial layers. After the implementation of the salmonella control programme governmental reimbursement in case of salmonella were differentiated. In commercial
layer and breeder flocks if affiliated to the voluntary programme, the state pays 70% of the losses due to salmonella outbreaks otherwise only 50%.

Import control
Between 1982 and 1988 three layer breeder flocks were euthanised due to salmonella infection. Since 1989 five imported flocks were found infected and culled in quarantine. Most of the flocks were imported from North America. No salmonella was spread to the next generation.

Incidence of Salmonella in egg production
Two flocks were tested positive in 1990 and thirty in 1991 (fig 2). Three of these 32 cases were S. Enteritidis but only one of them caused outbreaks in humans. As seen in fig.2 there was no dramatic increase in number of salmonella infected flocks after the mandatory control programme was introduced in December 1993. Only one flock with S. Enteritidis, already mentioned, could be traced to outbreaks in humans and none of these flocks could be traced to infected parent flocks. No layer parent flock was found infected with salmonella. S. Livingstone has been the most common serotype in layers in Sweden (fig.2). Elimination of S Livingstone from the laying egg production has been successful (Fig 2). However, in several farms the infection has been found again after cleaning and disinfection of the farms. As seen in fig. 3, S. Livingstone did reoccur in thirteen farms up three times. In some farms it disappeared for several years but reappeared again. S. Livingstone was probably introduced, at least the first time, to the farms with feed as this serotype was found in feed factories at several occasions. However, the reoccurrence probably reflects the problem with cleaning and disinfection of layer farms. S. Livingstone is an uncommon serotype in humans in Sweden, which indicate that there has not been any transmission by egg with this serotype to the consumers.

Critical points in the voluntary programme in layers
Before 1990 feed for layers was not heat-treated. Heart treatment of the feed was the first mandatory regulation for control of salmonella in the egg production. Biosecurity, which is an important part of the salmonella control, was more difficult to establish in houses with egg production compared to broilers. The risk of spreading salmonella in cage systems where the birds are kept above the floor is smaller than in floor systems where salmonella can be spread by movement of people (shoes).
During the rearing period it is generally easier to keep up the biosecurity as there is less contact with other parts of the production chain. The adult laying hens stay from 16 weeks of age up to slaughter in the house and produce eggs and manure in large quantity, which both have to be removed regularly. In many large farms with many units with flocks there are often ducts and conveyor belts transporting manure and eggs passing through several houses before they reach the egg collection room or central manure pit. It is difficult to stop entrance of for instance rodents into these transport systems.

Poultry housed outdoors present a problem, as it is difficult to maintaining adequate hygienic barriers if the surrounding environmental is contaminated with salmonella. In Sweden, outdoor environments are not generally considered to be contaminated by salmonella. However contamination may occur for example by small passerine birds. By careful planning of location and husbandry practices, the risk for infection may be decreased, albeit not eliminated. Contacts with rodents and wild birds can be avoided to some extent by designing feeding systems that minimise spilling and prevent the access of vermin to feed troughs. So far we have not had any salmonella in organic farms.

In Sweden a system for outdoor keeping of commercial layers was designed that could be affiliated to the voluntary control programme, but it was not accepted to be organic for several reasons. The outdoor area was smaller than for organic farms but never overcrowded. The floor was made of concrete with sand on top. There was a roof and instead of walls netting that did not allow flies to enter. It kept out rodents and insects. The outdoor area was possible to clean and disinfect.

### Cleaning and disinfection of layer farms

Before 1990 cleaning of houses for layers was not properly performed and disinfection were seldom used as disease problem seldom occurred. Most farmers only vacuum cleaned the house but refused to use water for cleaning. The equipment did not stand water for different reasons. In the 1990ies, when salmonella was found in many farms (Fig 2) it was very difficult to sanitise and eliminate salmonella from houses. The cage systems had and still have so many hidden spaces where salmonella can hide and appear again. The new housing systems are possible to wash but are unfortunately not always constructed to allowed proper cleaning and disinfection. The reoccurrence of S Livingstone was probably due to the problem with cleaning and keeping good biosecurity standards.
Cleaning and disinfection
A thorough cleaning and disinfection of poultry houses and all other possibly contaminated areas is essential for preventing salmonella infection of subsequent flocks (Larsen et al, 1994, van de Giessen et al, 1994, Davies & Wray, 1996, Rose et al, 1999, Bailey et al, 2002). Salmonella has been isolated from various sites in establishments housing infected poultry flocks (Jones et al, 1995, Davies & Wray, 1996, Hoover et al, 1997, Davies & Breslin, 2001). Effective cleaning and disinfection measures require scientific knowledge on critical points for pathogen survival as well as systems to ensure that the work is performed according to instructions. This includes both the cleaning and disinfection procedures as well as carcass removal and destruction.

Clean up procedures in Swedish poultry flocks
The Swedish salmonella control programme includes a stamping-out policy of all infected poultry flocks irrespective of serotype found. In the following, the cleaning and disinfection routines as employed for poultry farms in the national Swedish salmonella control programme are described. More detailed descriptions have been given by Engvall (1993) and Svedberg (1993 and 1994).

After the culling of the flock, carcasses are destroyed, usually by transporting them to a destruction plant. Carcass removal and transport from the buildings must be done with as little spillage as possible and in leak-proof transport vehicles, in order to avoid environmental contamination. Intensified rodent control should be instigated immediately (prior to depopulation), so as to avoid rodent migration to other animal operations, spreading the infection. Moreover, the presence of rodents has been shown to be a risk factor for salmonella persistence on a farm (Jones et al, 1991, Davies, 1995, Davies & Breslin, 2001, Liebana et al, 2003).

All litter is removed and either buried, composted or spread and immediately ploughed into arable land. Spreading on pasture or grassland is not allowed. Composting should ensure adequate temperature levels inside the dung heap. This requires both proper mixing of the material and an adequate holding time. Possibly contaminated areas outside the buildings, e.g. where spillage from carcass and litter removal operations may have occurred, are disinfected with slaked lime or some other suitable disinfectant, after the removal of all visible spillage. In cases of heavy contamination, the surface layer is removed and replaced by new gravel. Remaining feed is removed from the buildings and destroyed.

The first step in the cleaning process involves dismantling of all removable equipment and dry cleaning (shovelling, sweeping, vacuum cleaning) of all areas, including all equipment (as well as feeding and watering systems), roof and ventilation canals. This step may take several days, or weeks, depending on the building. Salmonella has been shown to be transmitted via air and dust (among others, Holt et al, 1998, Davies & Breslin, 2001) and it is important that not only visible dirt but also dust is removed. Old or damaged equipment, from materials that are difficult to clean, is discarded. Older buildings are generally more difficult to clean and in some instances it has been more economical to tear down an old poultry house and building a new one, especially in the case of old-fashion layer houses.

When dry cleaning is completed, soaking, washing and rinsing is performed. Hot or warm water is preferred and detergents are useful as well as pressure spraying. However, when using high-pressure spraying, care should be taken not to create aerosols that could spread salmonella. All work is done from top to bottom, with the avoiding of re-contamination of already cleaned areas.
After completing the wet cleaning stage and ensuring that all visible dirt has been removed, repairs to ensure even surfaces, as well as filling cracks and holes where rodents might enter the building are undertaken.

When all repair work is done and the building and all equipment are visibly clean, disinfection, either by spraying or fogging, is performed.

The disinfectant is left to dry and, after this, environmental samples are taken at critical control points for salmonella culture. Swabs are taken in cracks and corners where soil and organic material may be difficult to remove. The number of environmental samples varies between different houses, both due to size and construction. All samples must be negative before restrictions on the farm are lifted. In case of positive environmental samples, the entire house has to be re-cleaned and disinfected.

During the entire cleaning and disinfection procedure, hygiene barriers between areas in different stages of the process, as well as around the entire farm, have to be maintained. All personnel involved should have adequate information about salmonella contamination risks and how to avoid them, as well as how to ensure personal safety and prevent infection while working on the premises.

Disinfectants

Disinfectants used should have a documented effect against salmonella and be handled according to the manufacturer’s instructions. Improper mixing or application of disinfectants has been associated with failure to remove salmonella from poultry houses (Davies & Wray, 1996), and inadequate ambient temperatures is well known to be detrimental for the effect of disinfectants. During the cold season in Sweden, special care must be taken to ensure adequate indoor temperature for the disinfectant to be effective, e.g. by using extra fans or adjusting existing heating and ventilation systems.

At the moment, in Sweden, there is no formal system for approving disinfectants for use against salmonella. According to Council Directive 98/8/EC, concerning the placing of biocidal products on the market, the competent authority should approve biocids for use based on documentation on both safety and efficacy. In Sweden, two authorities are concerned in this issue, the Board of Agriculture (deciding on how to handle salmonella infected farms) and the Chemicals Inspectorate (assessing safety of chemicals as regards human health and environment). So far, if a product is regarded safe, it’s been up to the producer to provide detailed documentation on efficacy so that the National Veterinary Institute can advise the Board of Agriculture on whether it has effect against salmonella. Documentation on environmental effects as well as detrimental effects on certain materials are also taken into account.

However, even though all products with proven efficacy are mentioned in discussions on disinfectants, farmers and veterinarians usually prefer products that they normally use. A more formal procedure, with detailed requirements for documentation of efficacy testing and approval for use against salmonella has been discussed.

In all cleanup procedures it must be emphasized that no disinfectant are effective on dirty surfaces and that mechanical cleaning is the most important step, no matter what disinfectant is used.

Specific problems in different production systems

Adequate cleanup is usually more complicated in layer systems than in broiler systems. Nests, egg collection systems, packing machines, etc. all contain parts or materials that are difficult to clean. Some modern housing systems are also difficult to dismantle, with large sections installed as “one piece”.

Ecological production presents a particular problem with systems that allow the birds outdoors. In this case, outdoor areas where salmonella contamination is suspected should be treated as described above for heavily contaminated areas around poultry houses. No case of salmonella has been found in ecological production in Sweden, but some cases in other production systems with partly outdoor housing (such as ostrich farming) have been found. In these cases, outdoor pens have been treated by removing the surface layer, treating the area with slaked lime and covering it with new material. However, the main problem with outdoor housing is not the handling of the contaminated pens but the difficulties in upholding the biosecurity barrier in such systems. Thus, there might be an increased risk of introducing salmonella infection into systems with outdoor housing of the birds.
References


Introduction

Salmonellosis is one of the most common causes of foodborne diarrheal disease worldwide. Most of these infections are zoonotic and are transmitted from infected carrier animals to humans through contaminated food. The main reservoir of zoonotic Salmonella is food animals; consequently, the main sources of infections in industrialized countries are animal-derived products, notably fresh meat products and eggs.

The incidence of human salmonellosis increased in most industrialized countries in the 1980s and 1990s. Rapid spread of a limited number of successful Salmonella clones in different sectors of food animal production (swine, broiler chickens, and particularly layer hens) has been suggested as the most important cause of this increase (1).

Despite much research and many national and international attempts to implement control strategies, the incidence of human salmonellosis in most countries remains high. Notable exceptions within the EU are Sweden and Finland, which remain essentially free from the Salmonella problems typical for most other industrialized countries, and maintain additional guarantees on imports from other Member state countries in order to protect their status. In the European Union, the Zoonosis Directive (2) was an attempt to initiate a European Union-wide control effort against foodborne zoonoses, particularly Salmonella in broiler chickens and layer hens. Most European Union countries found that they either could not or would not implement the directive, which did not permit use of vaccines, antimicrobial drugs, or both as elements in the control program of Salmonella in broiler chickens or layer hens. This constraint was seen as an obstacle by some countries. Recently a new directive has been formulated (3), and a regulation specifically describes measures to be taken against Salmonella in poultry production at the EU level (4).

In Denmark, the incidence in human salmonellosis increased rapidly in the second half of the 1980s because of the spread of Salmonella in broiler chickens. This increase led to the initiation of a targeted national control program. Subsequent spread of Salmonella in layer hens in the latter half of the 1990s also led to increases in human disease incidence and subsequently to the development and implementation of targeted control efforts (5).

In this presentation, Denmark’s Salmonella control program in broilers is presented, and the effects on Salmonella in broilers, broiler meat and humans are discussed.

Control of Salmonella in Broiler Chickens

Objectives, Program, and Effects

The initial aim of the program was that <5% of broiler flocks would be infected with Salmonella. The program was successful and was gradually revised towards assurance of complete freedom from Salmonella in broiler production. The program is based on the principle of top-down eradication, ensuring freedom from Salmonella from the top of the broiler-breeding pyramid down. Infected flocks of breeding animals are destroyed, and infected birds are processed for slaughter. The testing program has developed gradually to adjust to higher food safety objectives. As progress stalled, more intensive serologic and bacteriologic testing was developed and applied. The current testing scheme is shown in Table 1. Birds from infected flocks are slaughtered on separate slaughter lines or late in the day to avoid cross-contamination. Farmers get a better price for birds from Salmonella-free flocks, and slaughterhouses can use the label “Salmonella-free” for birds that meet criteria determined by the authorities. No decontaminants, such as organic acids or chlorine, are used during carcass processing.
The proportion of Salmonella-infected broiler flocks has been markedly reduced since the initiation of the control program. Almost 70% of broiler flocks tested positive for Salmonella during the first year of the program (1989) while the level has remained stably below 2% infected since the turn of the century. This decrease in Salmonella has also led to a concomitant reduction in the proportion of infected broiler carcasses after slaughter and at retail (Figure 1).

The Danish government and the European Union equally compensate owners of destroyed breeding stock for their losses. In 1993, a major Danish retailer (COOP-Denmark) stopped the marketing of broiler chicken, which exceeded a 5% target. Danish chicken could not meet this target at that time, so producers suffered severe losses because they had to export their chicken to lower priced markets. Salmonella can be effectively reduced (nearly eliminated) from broiler chickens by intensive flock-level testing and top-down eradication. Essential to success is a sufficiently sensitive testing program in the breeding and rearing flocks as well as in the hatcheries, i.e., one that involves intensive sampling and a combination of serologic and bacteriologic testing methods (Table 1). Bacteriologic testing alone is not sufficiently sensitive to achieve control, especially if S. Enteritidis infections are present.

Removal of all organic material, thorough cleaning and disinfection of the poultry house, and an empty resting period of 10–14 days between flocks can ef-

---

Table 1: Sampling programme for the parent segment of Danish broilers

<table>
<thead>
<tr>
<th>CENTRAL REARING FLOCKS</th>
<th>Central rearing flocks</th>
<th>Breeding segment, central rearing flocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Sample-taking</td>
<td>Material</td>
</tr>
<tr>
<td>Day-old</td>
<td>Per delivery</td>
<td>10 crates and 20 chicks (ZD)*</td>
</tr>
<tr>
<td>1st week</td>
<td>Per unit</td>
<td>40 chicks</td>
</tr>
<tr>
<td>2nd week</td>
<td>Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
</tr>
<tr>
<td>4th week</td>
<td>Per unit</td>
<td>60 samples of fresh faeces (ZD)*</td>
</tr>
<tr>
<td>8th week</td>
<td>Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
</tr>
<tr>
<td>2 weeks before being</td>
<td>Per unit</td>
<td>60 samples of fresh faeces (ZD*) and 60 blood samples</td>
</tr>
<tr>
<td>moved</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HATCHING-EGG PRODUCTION</th>
<th>Hatchling egg production</th>
<th>Breeding segment, hatchling egg production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every two weeks</td>
<td>Per flock</td>
<td>250 meconium samples or 50 dead-chick samples taken from the hatchery (ZD)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regional Veterinary and Food Control Authority (RVFCA) takes samples every 8 weeks (ZD)*</td>
</tr>
<tr>
<td>Every week</td>
<td>Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RVFCA is in charge of sample-taking once every quarter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HATCHERY</th>
<th></th>
<th>At least 25 grams of wet dust per hatchling</th>
<th>At least 25 grams of wet dust per hatchling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every hatchling, every</td>
<td>Up to 4 hatchlings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hatchling</td>
<td>can be pooled</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Compulsory samples pursuant to the Zoonous Directive.

Table 1: Sample-taking programme for the parent segment.
fectively eliminate residual infections. In Denmark, most infections appear to be vertically transmitted (nearly always traceable to an infected hatchery or parent flock), whereas horizontal transmission from the environment and wild fauna appear to play a minor role. Competitive exclusion cultures, vaccines, or antibiotics have not been used in the Danish control program.

The fraction of human Salmonella infections attributable to broiler meat has been very low for a number of years; in 2004 it was estimated to comprise only 3-6% of the total number of laboratory-confirmed cases in Denmark (6).

References


Salmonella control in the Danish egg production

Mogens Madsen, DVM, PhD, Head, Department of Poultry, Fish and Fur Animals
Danish Institute for Food and Veterinary Research, 2 Hangoevej, DK-8200 Aarhus N, DENMARK

Introduction
Salmonellosis is one of the most common causes of foodborne diarrheal disease worldwide. Most of these infections are zoonotic and are transmitted from infected carrier animals to humans through contaminated food. The main reservoir of zoonotic Salmonella is food animals; consequently the main sources of infections in industrialized countries are animal-derived products, notably fresh meat products and eggs.

The incidence of human salmonellosis increased in most industrialized countries in the 1980s and 1990s. Rapid spread of a limited number of successful Salmonella clones in different sectors of food animal production (swine, broiler chickens, and particularly layer hens) has been suggested as the most important cause of this increase (1).

Despite much research and many national and international attempts to implement control strategies, the incidence of human salmonellosis in most countries remains high. Notable exceptions within the EU are Sweden and Finland, which remain essentially free from the Salmonella problems typical for most other industrialized countries, and maintain additional guarantees on imports from other Member state countries in order to protect their status. In the European Union, the Zoonosis Directive (2) was an attempt to initiate a European Union-wide control effort against foodborne zoonoses, particularly Salmonella in broiler chickens and layer hens. Most European Union countries found that they either could not or would not implement the directive, which did not permit use of vaccines, antimicrobial drugs, or both as elements in the control program of Salmonella in broiler chickens or layer hens. This constraint was seen as an obstacle by some countries. Recently a new directive has been formulated (3), and a regulation specifically describes measures to be taken against Salmonella in poultry production at the EU level (4).

In Denmark, the incidence in human salmonellosis increased rapidly in the second half of the 1980s because of the spread of Salmonella in broiler chickens. This increase led to the initiation of a targeted national control program. Subsequent spread of Salmonella in layer hens in the latter half of the 1990's also led to increases in human disease incidence and subsequently to the development and implementation of targeted control efforts (5).

In this presentation, Denmark's Salmonella control program in layer hens is presented, and the effects on Salmonella in layer hens and humans are discussed.

Control of Salmonella in Layer Hens

Objectives, Program, and Effects
All shell eggs from commercial layer flocks should be free from all serovars of Salmonella enterica (5).

Control of layer breeders in Denmark is essentially identical to the control program for broiler breeders (Table 1). Blood and fecal samples of rearing flocks are tested, and infected flocks are destroyed. All commercial flocks of layer hens in production are tested routinely every 9 weeks by a combination of serologic testing of egg yolk and bacteriologic testing of environmental samples (Table 2). All eggs from suspect or confirmed-positive layer flocks are pasteurized. All shell eggs are distributed in a cold chain (not exceeding 12°C) and kept refrigerated at retail; eggs are generally refrigerated in private homes. The government and the European Union equally compensate owners of destroyed breeding stock for their losses.

The proportion of layer flocks infected with Salmonella, notably S. Enteritidis, has been markedly reduced since the initiation of the control program. Figure 1 shows that >7% of layer flocks tested positive for Salmonella in the first year of the program, 1998, versus
<2% in 2003. The level of Salmonella-contaminated shell eggs has not been measured from the initiation of the control program. However, a year before the program began, a study of 13,000 eggs from different types of production determined the level to be 1 per 1,000 eggs (20% of the contaminated eggs harbored S. Enteritidis). Top-down eradication of S. Enteritidis has effectively reduced the level of Salmonella, notably S. Enteritidis, in Danish commercial layer flocks. The program has been effective in free range, deep litter, organic, and caged birds. Frequent testing by a combination of serologic and bacteriologic testing methods is essential to achieve adequate sensitivity in the monitoring program. Control of residual infections in poultry houses can be conducted with a success rate of nearly 70% by thorough cleansing and disinfection of the depopulated house (removal of all organic material, disinfection of surfaces, and resting of the empty house for 2 weeks). Competitive exclusion cultures and vaccination are not used in the Danish program.

Table 1. Sampling programme for the parent segment of Danish layer hens

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample-taking</th>
<th>Material</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-old Per delivery</td>
<td>10 crates and 20 chicks (ZD)*</td>
<td>10 crates and 20 chicks (ZD)*</td>
<td></td>
</tr>
<tr>
<td>1st week Per unit</td>
<td>40 chicks</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2nd week Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4th week Per unit</td>
<td>60 samples of fresh faeces (ZD)*</td>
<td>60 samples of fresh faeces (ZD)*</td>
<td></td>
</tr>
<tr>
<td>8th week Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
<td>2 pairs of sock samples</td>
<td>-</td>
</tr>
<tr>
<td>2 weeks before being moved Per unit</td>
<td>60 samples of fresh faeces (ZD)* and 60 blood samples</td>
<td>60 samples of fresh faeces (ZD)*</td>
<td></td>
</tr>
</tbody>
</table>

HATCHING-EGG PRODUCTION

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample-taking</th>
<th>Material</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every two weeks Per flock</td>
<td>250 meconium samples or 50 dead-chick samples taken from the hatchery (ZD)*</td>
<td>250 meconium samples or 50 dead-chick samples taken from the hatchery (ZD)*</td>
<td></td>
</tr>
<tr>
<td>Regional Veterinary and Food Control Authority (RVFCA) takes samples every 8 weeks (ZD)*</td>
<td>RVFCA takes samples every 8 weeks (ZD)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every week Per unit</td>
<td>2 pairs of sock samples (in one bag)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RVFCA is in charge of sample-taking once every quarter</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HATCHERY

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample-taking</th>
<th>Material</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every hatching, every hatching</td>
<td>Up to 4 hatchlings can be pooled</td>
<td>At least 25 grams of wet dust per hatching</td>
<td>At least 25 grams of wet dust per hatching</td>
</tr>
</tbody>
</table>

*Compulsory samples pursuant to the Zoonosis Directive.

Table 3: Sample-taking programme for the parent segment.
Table 2. Sampling programme for the rearing and table-egg producing segment of Danish layer hens

### REARING STOCK

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample-taking</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-old</td>
<td>Per delivery</td>
<td>10 crates and 20 chicks</td>
</tr>
<tr>
<td>Week 3</td>
<td>Per flock</td>
<td>5 pairs of sock samples (in 5 bags) or 300 samples of fresh faeces (in 5 bags), if the taking of sock samples is not possible. Flocks of less than 200 birds: only 2 pairs of sock samples (in one bag) or 60 samples of fresh faeces (in one bag).</td>
</tr>
<tr>
<td>Week 12</td>
<td>Per flock</td>
<td>Flocks of 500 and more: 60 blood samples and 5 pairs of sock samples (in 5 bags) or 300 samples of fresh faeces (in 5 bags) if the taking of sock samples is not possible. Flocks of 200-499: 55 blood samples and 5 pairs of sock samples (in 5 bags). Flocks of less than 200 birds: blood samples, cf. Table 1 of govt. order, as well as 2 pairs of sock samples (in one bag) or 60 samples of fresh faeces (in one bag).</td>
</tr>
</tbody>
</table>

### TABLE EGG PRODUCTION FOR CERTIFIED EGG PACKING STATIONS

| Every 9 weeks | Per flock | A number of eggs per Table 1 of govt. order 44 and 2 pairs of sock samples (in one bag) or samples of fresh faeces (in one bag) equaling the number of eggs where it is not possible to take sock samples. |

### FARM-GATE FLOCKS AND BARNYARD FLOCKS

| 3 times a year | Per flock | A number of eggs pursuant to Table 1 of the govt. order. |

*The regional veterinary and food control authority is in charge of taking and sending in the samples indicated.

Vaccination cannot, at present, be used in combination with serologic testing because of problems of cross-reaction.

The control programme in layer hens has led to a marked reduction both in the total number of human salmonellosis cases (Figure 2), and to the fraction attributable to table eggs that in 2004 was estimated to comprise only 5-8% of the total number of laboratory-confirmed cases in Denmark (6).
Figure 1. Development in Salmonella-suspected and confirmed Salmonella-infected table egg laying flocks in Denmark 1998-2003.

Figure 2. Development in human cases of Salmonellosis in Denmark 1980-2005
References


Introduction
Salmonella is typically an intestinal organism and most cases in poultry are asymptomatic. In this situation it could be imagined that there is little potential benefit from vaccination since it is difficult to artificially stimulate local intestinal immunity. In practice, vaccination used as part of an overall management, hygiene and biosecurity package can make a valuable contribution to reduction of infection, both in terms of eradication of infection from individual flocks or holdings or, where this is not possible, reduction in within flock prevalence, shedding and contamination of the farm environment and food products originating from the farm. Historically both live and killed Salmonella vaccines have been used in cattle and pigs; for example a live rough variant of Salmonella Dublin Strain S1 was used in the twentieth century to control Salmonella Dublin and Typhimurium in calves and a S.Choleraesuis vaccine was used to control clinical Salmonellosis in pigs. Interestingly, S.Choleraesuis has spontaneously virtually disappeared from pig production in several countries including the UK. Autogenous or ‘Emergency herd vaccines’, based on adjuvanted bacterins prepared from killed cultures of Salmonella organisms found on the holding have also been used both in the UK and USA but reliable data as to their effectiveness is lacking. Commercial vaccines intended for one species have also been used in other species. For example, the killed S.Typhimurium/Dublin combination vaccine marketed for cattle has been used in pigs and poultry, particularly turkeys and ducks, but the benefit appears to have been relatively limited, based on anecdotal evidence. Similarly the current live S.Typhimurium vaccine which is intended for use in poultry has been used in a small number of trials with finishing pigs with equivocal results. The major use of vaccination for Salmonella in the UK has been for control of S.Enteritidis, and more recently S.Typhimurium, in poultry, particularly chicken, production and so this article and the associated presentation will focus on this.

Background to S.Enteritidis Problems
S.Enteritidis was first identified in 1888 in Germany following infection in a cow and a person who died after eating meat from the cow. In 1937 200 soldiers were ill after eating meat from an infected cow. Between 1958 and 1967 S.Enteritidis totalled 3.3% of Salmonella isolates from humans, 1.6% from poultry and 0.5% from cattle. Between 1968 and 1973 this increased to 9% of poultry Salmonella but by 1974 to 1983 had fallen to 1.2% without being associated with unexpected problems in humans. Between 1981 and 1986 the prevalence increased to 2.2% of poultry Salmonella isolates but within that period in 1984 there were no isolates at all. In 1985/86 there was a rapid increase in S.Enteritidis, particularly phage type (PT ) 4, in humans and by 1988 S.Enteritidis represented 50% of Salmonella isolated from poultry. It became clear that many of the human outbreaks were associated with contaminated eggs and the Chief Medical Officer issued a warning about the use of raw and undercooked eggs. In response the Veterinary Authorities introduced in 1989 the Poultry Laying Flocks and Poultry Breeding Flocks and Hatcheries Orders which specified testing programmes for flocks and a slaughter policy for infected flocks. The monitoring programmes identified infection in both broiler breeders and layer breeders as well as in commercial layers and many flocks were slaughtered. The origin of the particular strains of S.Enteritidis PT4, 6 and 8 which appeared over a relatively short timescale worldwide suggests common sources such as breeding stock, probably after some dissemination in feed. Some evidence does suggest international dissemination of infection via trade in chicken breeding stock. Turkeys were never infected to the same extent as chickens and ducks maintained a mixed selection of S.Enteritidis phage types with PT 9b being predominant.

Some broiler breeder companies experienced severe problems with multiple flocks being infected and recycling of infection between breeding flocks and hatch-
ries. During hatching there was so much contamination that the whole building became contaminated and cleaning and disinfection routines were insufficient to control this. In particular, the type and concentrations of disinfectants used was often unsuitable and in some cases stimulated a proliferation rather than a reduction of Salmonella. This applied particularly to tray wash machines which could spread contamination from trays used for infected eggs to other types of trays used for setting of eggs and collection of eggs on farm. Similarly, trolleys used to collect eggs on farm were often contaminated in the hatchery and carried contamination back to breeding farms. Once the extent of contamination in hatcheries was appreciated most companies improved hatchung procedures, introduced fumigation of eggs and trays entering the hatchery and improved disinfection, including separate tray washers for different types of trays and formaldehyde evaporation during hatch. By that time persistent infection on multiple parent breeding flock sites had become a problem and so hatcheries were still continually seeded with infected eggs which released contamination on premature breaking during setting or transfer, or at hatch. Fortunately no resident hatchery infections were ever established with S. Enteritidis as it appeared to be unable to colonise hatchery equipment on a long-term basis.

Investigations on broiler parent farms showed that, again, cleaning and disinfection standards were sometimes insufficient. In particular programmes involving the use of peroxygen, chlorine based and QAC/glutaraldehyde disinfectants were often unable to cope with surface contamination and films of residual organic matter, and disinfectants were often used at insufficient concentration for bacterial contamination as farmers were more used to disinfecting to remove viruses, which is much easier. There was also a problem on many farms with mice, which accumulated to large populations in minipits which were difficult to bait effectively. Insulation layers and in-house storage areas for litter and slave hopper areas also offered safe refuge for the rodents which were primarily responsible for carrying high levels of Salmonella between flocks during the relatively short turnaround period, since individual mice could remain systemically infected for months or years. The situation in layer breeder flocks and hatcheries was less clear as there was more limited access to these premises but those investigations which were possible identified similar problems to those found in the broiler breeder sector, but it appeared to be more easy to clean up layer parent houses because of the design of the buildings and more limited number of companies involved.

Statutory Action taken in Breeding Flocks prior to Vaccination
In 1989 the Zoonoses Order was introduced which required reporting of Salmonella isolates to the competent authorities. There were already powers to compulsory slaughter flocks, with compensation available under the Animal Health Act 1981. Also in 1989 the Poultry Breeding Flocks and Hatcheries Order was introduced which required registration of breeding flocks and hatcheries, regular sampling and testing for Salmonella and slaughter of flocks found to be infected, after official confirmation, with S. Enteritidis or S. Typhimurium. Similar legislation (Poultry Laying Flocks Order 1989) was introduced for commercial laying flocks as it was recognised that contaminated eggs provided a major risk for consumers. Laying flocks were to be tested for Salmonella regularly during rearing and production and infected flocks slaughtered. In 1993 the Laying Flocks Order was withdrawn and the Poultry Breeding Flocks and Hatcheries Order was amended to remove the statutory requirement for testing in poultry other than chickens, although these could continue on a voluntary basis and receive assistance with the cost of testing. Also around that time the UK received a dispensation from the EU such that instead of slaughter infected broiler breeding flocks (but not layer breeders) could be medicated for Salmonella infection instead of slaughter, since the slaughter of large numbers of infected flocks was causing substantial financial and logistic problems for the industry. Based on work carried out in the Netherlands which demonstrated a significant reduction in infection after use of treatment with fluoroquinolones and competitive exclusion the UK adopted this option for breeding flocks, although in practice this was often not successful and some flocks had to be slaughtered following a second positive test. This practice was last authorised for use in an infected flock in 1997 and in 1999 the option was withdrawn since, after the introduction of vaccination, the number of incidents of infected flocks had fallen to levels which could be dealt with by slaughter.

Control of Salmonella Enteritidis by Vaccination: Parent Breeder Flocks
In the 1980s Government research was commissioned to investigate the development of both killed and live vaccines for S. Enteritidis in poultry. An oil adjuv-
ted bacterin was produced at Weybridge which gave good, but not total, protection against colonisation and dramatically reduced systemic infection after a large intravenous challenge. In parallel with this live defined Aro-single and double deletion mutant vaccines for both S.Enteritidis and S.Typhimurium were produced at Weybridge and these performed well also. Commercial rights to the live and killed vaccines were purchased by a pharmaceutical company which further developed the killed vaccine by propagation at reduced temperature under iron limitation conditions to enhance antigen production and adding an alhydrogel adjuvant for operator safety. This vaccine was field trialed with excellent results and first marketed commercially in 1994 when there was a very good uptake of vaccination by the broiler breeder industry. Vaccination was not widely used in layer breeders because by that time the use of serological monitoring had become well established as a means of sensitively identifying infection which could then be managed by various management procedures and eliminated from the holding at the end of the life of the affected flocks by good disinfection and rodent control during a sufficiently long depopulation period. The killed vaccine produced high antibody levels which interfered with the interpretation of serological monitoring.

After implementation of vaccination it became clear that the effect on the level of Salmonella in broiler breeder flocks which had been vaccinated during rear was dramatic, with very few flocks showing any evidence of carry-over of infection and these were on farms where rodents were a severe problem. Even these few farms became clear of S.Enteritidis after the following flock cycle and the effects of these improvements were seen in a corresponding reduction of Salmonella on commercial broiler farms, though there were some problems of carry-over of infection because of rodents and poor terminal hygiene on a small number of farms.

It is thought that maternal immunity associated with high anti-Salmonella antibody levels in egg yolks and chicks after vaccination with killed vaccine may have assisted with clearance of S.Enteritidis from British broiler flocks. Experimental evidence does suggest some protection but the role of maternal immunity in the field is uncertain. Following the introduction of vaccination there were very few breeding flock breakdowns with S.Enteritidis and these were usually associated with failure to vaccinate fully. A low level of infection in broilers continued but this was often associated with infected imported hatching eggs and subsequent cross-infection in hatcheries. Since this practice has largely stopped S.Enteritidis in broilers is very rare and in some years there are no reported cases at all despite a good industry monitoring programme for broilers which identifies significant numbers of cases associated with 'exotic' serovars. Another factor which is thought to be involved in the dramatic reduction of S.Enteritidis in broilers is the removal of the option for medication of breeding flocks. This practice may have allowed low levels of Salmonella to be seeded into hatcheries from infected flocks.

Although vaccination was never routinely used in layer parent flocks it has been used reactively for birds which are due to be placed on a farm where a breakdown has occurred. This has been a very successful approach and there have been no examples of consecutive flock infections in layer parents.

Vaccination in Commercial Laying Flocks

After the introduction of control programmes for S.Enteritidis and S.Typhimurium in breeding flocks it was initially considered that, as with broilers, the prevalence of infection in commercial laying flocks would naturally fall over time as a result of terminal hygiene and flock replacements. A national survey of eggs carried out in 1995-96 showed 0.85% of six egg pools positive for S.Enteritidis, an increase since the previous survey in 1991. Also, after an initial reduction of human cases between 1993 and 1995, infection began to increase again to a peak in 1997. Since the removal of commercial laying flocks from statutory control in 1993 little bacteriological monitoring was done but major retailers and key suppliers began some serological surveillance which indicated the likelihood of a significant problem. As a result of public health and marketing concerns the British Egg Industry Council (BEIC) introduced the Lion Code which required its members to vaccinate their flocks for S.Enteritidis and carry out some monitoring during rear and at depopulation. Temperature and hygiene controls were also introduced for egg handling and storage and a ‘use-by’ date applied to eggs. By 1997/1998 a substantial proportion of the UK laying flock had been vaccinated for S.Enteritidis and infection rates in humans began to fall dramatically, up to 2001 when phage types other than PT4 began to increase as a result of importation of eggs, especially from Spain. These strains of S.Enteritidis were often resistant to nalidixic acid.
and/or other antimicrobials, which was very rare in domestic isolates.

Although BEIC members were required to vaccinate for Salmonella, and this included most of the major producers, independent farmers – some of whom were represented by the U.K Egg Producers Retail Association (UK EPR A) – followed another route by applying competitive exclusion treatment to birds on transfer from rearing to laying farms. The thinking was that this would help protect against a wider range of Salmonella serotypes but there is little evidence for this in laying flocks. Around 20% of birds were not vaccinated at all and these often supplied local traders and caterers or were involved in direct farm sales.

**Introduction of Live Vaccines**

In 2000/2001 new live metabolic drift mutant vaccines for S. Enteritidis and subsequently S. Typhimurium and a combined killed S. Enteritidis/ S. Typhimurium vaccine were launched and there was much debate in the industry about the relative merits of the various vaccines and combinations. Free-range producers in particular were encouraged to use combination products as they were thought to be at greater risk of S. Typhimurium introduction by wildlife. There was also some speculation, based on serological monitoring, about the possibility of unidentified S. Typhimurium in some cage laying flocks but the consensus was that optimising protection against the major threat - S. Enteritidis is the main priority - with S. Typhimurium vaccine being used where there is a known risk. During 2002/2003 further live vaccines were introduced: a Gallinarum rough mutant vaccine which gives some cross-protection against S. Enteritidis, and an auxotrophic S. Enteritidis PT 4 mutant. These received more limited uptake until recently although the potential advantage of these is that they can be given in two rather than three doses. There is no conclusive evidence from the field about the relative efficacy of the various killed and live vaccine options but the main advantage of the latter is ease of administration, since it is normally given in the water supply during rear although spray application may be used and the second dose of the S. Gallinarum 9R vaccine is normally given by injection when birds are transferred to laying sites. The 9R vaccine has recently been withdrawn from routine use in the U.K because of supply problems. The availability of water administration of live vaccines has led to a greater proportion of farms vaccinating for S. Enteritidis, and more recently S. Typhimurium (ST) since the metabolic drift mutant ST vaccine is being supplied at minimal cost by the manufacturer. Some producers are also using competitive exclusion products for chicks and/or at transfer to laying sites as this has been shown to provide an additive effect when used with vaccines. Evidence from research studies and surveillance suggests that vaccination does have a beneficial effect on infected laying farms, reducing flock and individual prevalence, shedding, environmental contamination and contamination of eggs. In many cases, however, especially in multi-age holdings the challenge associated with ongoing infection in adjacent houses on the site and carriage by rodents and flies overwhelms the protection afforded by vaccine and newly placed flocks become infected despite vaccination. It is therefore vital to combine vaccination with good farm hygiene and pest control and ideally with a whole-farm all in/all out policy.

**Vaccination in other Poultry Species**

Some vaccination for S. Enteritidis, and particularly S. Typhimurium, has been carried out in turkeys and ducks on breeding farms where there has been a problem. Initially use of cattle S. Typhimurium vaccine in ducks appeared to have a limited effect according to anecdotal evidence from industry. The use of combined live and killed S. Typhimurium and S. Enteritidis vaccination in continuously occupied duck rearing premises has been successful in eliminating S. Typhimurium but not S. Enteritidis. More information is required on the use of S. Typhimurium vaccine for breeding and commercial turkeys, particularly the effect of stimulating maternal immunity to increase protection of commercial poults placed on persistently contaminated brooder farms.

**Problems with Administration of Vaccines**

When considering the efficiency of vaccination it is always difficult to assess the role of incorrect or incomplete administration in apparent vaccine failures. In the case of injectable vaccines it is known that even with careful administration there is a small failure rate caused by delivery to the wrong site or problems with multiple injection devices. This increases when there is pressure to rapidly vaccinate large numbers of birds when multiple birds may be held by catchers making accurate injection site location difficult, vaccinators may feel under pressure to get the job done quickly so may be less careful to inject accurately and so miss the correct intramuscular site and may not notice quickly if the vaccination gun is delivering insufficient doses or has run out of vaccine. Theoretically live vaccines...
administered in the water supply should avoid such problems but extreme care is needed to ensure that the correct dose of vaccine is delivered. The water lines must be effectively drained and primed, which is not easy, especially when there are multiple water lines in large cage-rearing houses. The first dose of vaccine is meant to be given at day-old when the vaccine take is greatest but in practice chicks do not drink much at that stage so much of the vaccine is wasted and producers often delay vaccination to a later stage. There may be inhibitory substances or bacterial contamination in the water which reduces the survival of the vaccine and complex calculations are often needed to ensure that the correct concentrations of vaccine are delivered to and taken by all birds in the house before vaccine levels drop, within a matter of 2-3 hours. If this procedure is not carried out correctly then much of the vaccine will be wasted. It is assumed that there will also be some lateral spread of live vaccine from birds which have drunk within the time period to others but this may be variable depending on the dose of vaccine which was finally delivered and the robustness of the vaccine strain in the water supply, in the birds and in the environment. There is a conflict here since licensing authorities require minimal survival of live vaccines but longer survival is likely to provide better exposure of birds to vaccine. Some live vaccines are provided in skimmed milk or coloured protective carriers to reduce the rapid die-off in water supplies and to demonstrate uptake by the presence of dye in the buccal cavity of the birds.

Differentiation of Vaccinated Birds from Infected Birds

Injectable vaccines produce a strong antibody response so may interfere with serological monitoring. The Gallinarum 9R vaccine lacks flagellar antibodies so initial screening can be carried out with a sensitive lipopolysaccharide based ELISA and positives confirmed or discounted using a flagellar ELISA.

Live vaccines may be isolated from vaccinated flocks and may lead to incorrect action if the vaccines are not identified. Some of the live vaccines do not grow well in certain culture media such as M SRV so are unlikely to be isolated when these are used. Some vaccines appear atypical on chromogenic media so this may provide a preliminary indication of a likely vaccine strain but some field strains behave atypically also. The metabolic drift mutant vaccines have antimicrobial resistance markers and can be identified by resistance to rifampicin and borderline sensitivity to erythromycin. The Typhimurium vaccine is also an unusual phase type. The auxotrophic S. Enteritidis vaccine can be identified by growth on minimal media with and without specific amino acids, adenine and histidine, and has an unusual genotype. The Gallinarum 9R vaccine can obviously be readily distinguished from S. Enteritidis by serotyping and biochemical tests but may be more difficult to differentiate from field strains of S. Gallinarum and currently agglutination with acri-flavine appears to be the only reliable test, although it is possible for rough field strains to produce a similar reaction. In the U.K all S. Enteritidis strains and all S. Typhimurium DT9 strains are routinely screened for live vaccine, which adds to the cost of surveillance. Some S. Enteritidis vaccine strains have been found: predominantly from post-mortem tissues of recently vaccinated flocks or following cross-contamination of samples by farm staff who have recently handled live vaccine. In a recent outbreak of S. Gallinarum in a holding where 9R vaccine had been used both field strains and live vaccine strains were found in vaccinated birds at post-mortem but not in environmental samples.

Conclusions

Vaccination for S. Enteritidis has been an important component of the U.K Salmonella control programme and has been extremely successful in the broiler breeding and production sector such that U.K acquired cases in broiler breeders or commercial broilers are now extremely rare. Vaccination in commercial layers has been of benefit in reducing the risk to consumers through contaminated eggs but more work is required to break the cycle of infection on problem multi-age farms where there is persistent environmental contamination. More molecular epidemiological work is also required to assess the current contribution of domestic and imported eggs, poultry meat, travel and secondary spread in human S. Enteritidis cases in the U.K.
Salmonella control in meat producing poultry

History and background
The broiler production started in Sweden in the 1960ies in a small scale and has developed rapidly (fig 1). There was a decrease in production starting in 1986 as consumption decreased 15% due to headlines in the newspapers about the danger of campylobacter in broilers.

Initially old farm buildings were converted into broiler houses, however, the standard of the broiler houses, hygiene and management has improved gradually. The health in the broiler production has always been good with few contagious diseases and low mortality. The broilers in Sweden have never been vaccinated. Growth promoters have not been used in Sweden since 1986 and avoparcin was stopped already in 1982. Antibiotics are seldom used for treatment and is never used to treat salmonella.

As broiler meat was recognised as an important source of salmonella infections in humans, a control programme was introduced in 1970. It was a voluntary prophylactic control programme and most farmers joined when they fulfilled the requirements of the programme. The production of turkey, goose and duck meat is small in Sweden and it will not be included in this presentation although they are included in the mandatory control programme.

Monitoring
Initially the surveillance was performed by sending 0.1% of the birds per flock to an authorised laboratory twice during the growth period. A bacteriological examination for salmonella was done from the liver and intestine from each bird (pooled samples). In 1983 an evaluation of this surveillance was done because the costs for the testing had increased. Very few findings of salmonella had been made at the first of these two sampling occasions and a change was suggested in 1984. Now the broilers should be monitored only once 1-2 weeks before slaughter and 0.15% of the birds sampled. Still the owner took the samples and sent them to the laboratory but now he had to pay for the analysis.

The next change came in 1994 when a new regulation with another surveillance model was introduced. Now the farmer should take the samples under supervision of an official veterinarian. From each flock both

Figure 1. Number of broilers slaughtered annually in Sweden between 1970-2005
Caecum samples and faecal samples were collected and sent to the laboratory for bacteriological examination (table 1). Only flocks with negative test results for salmonella was delivered to an abattoir. This is the model still used today.

### Incidence of salmonella

Since 1968, when a proper registration of outbreaks of salmonella started, a large number of broiler flocks have been found infected with salmonella of many different serotypes. The number of outbreaks each year is illustrated in figure 2. Salmonella Enteritidis has never been found in broilers, but S Typhimurium has occurred several times.

The main source of infection appeared to be contaminated feedstuffs. In 1977 with S California and in 1979 with S Liverpool and S Mbandaka. The large numbers of outbreaks during 1981-82 were caused by S Livingstone transmitted with feed delivered from two different feed mills. When the feed mills were cleaned and disinfected the outbreaks stopped.

This was the start of an improved hygiene programme for the feed mills. Since 1990 during the same time as the broiler production increased every year very few farms was found infected with salmonella except 1991 when salmonella was transmitted from a parent flock.

Since 1970 only three broiler parent flocks have been found infected with salmonella. In 1991 a parent flock was infected with S Typhimurium. Infected progeny of this parent flock appear to have been delivered to 12 broiler production farms. The latest salmonella infected broiler parent flock in Sweden belonged to a company that exported all the hatching eggs to Denmark. It resulted in several outbreaks in Danish broilers in 1999.

When joining the EU a monitoring programme was implemented at slaughterhouses as a control of the pre-harvest control. The results show that poultry meat produced in Sweden is virtually free from Salmonella. Since the start of the programme in 1995

---

### Table 1. Sampling for salmonella control in a broiler flock (unit) 1-2 weeks before slaughter.

<table>
<thead>
<tr>
<th>Number of samples per flock</th>
<th>Caecal samples*</th>
<th>Faecal samples**</th>
</tr>
</thead>
<tbody>
<tr>
<td>One epidemiological unit per house</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Several units in a house</td>
<td>10</td>
<td>60</td>
</tr>
</tbody>
</table>

* Pool of 10 samples tested.
** Pool of 30 samples tested.

---

### Figure 2. Number of notified Salmonella infected broiler farms during 1968-2004
between 2778 and 4358 neck skin samples have been analysed yearly. The results for each year are shown in Table 2.

Table 2. Results from neck skin sampling of poultry in the Swedish Salmonella control programme between 1995 and 2004.

<table>
<thead>
<tr>
<th>Year</th>
<th>Analysed samples (no)</th>
<th>No. positive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>2,778</td>
<td>2 (0.07)</td>
</tr>
<tr>
<td>1996</td>
<td>3,922</td>
<td>2 (0.05)</td>
</tr>
<tr>
<td>1997</td>
<td>4,235</td>
<td>0 (0)</td>
</tr>
<tr>
<td>1998</td>
<td>4,010</td>
<td>1 (0.02)</td>
</tr>
<tr>
<td>1999</td>
<td>3,580</td>
<td>2 (0.06)</td>
</tr>
<tr>
<td>2000</td>
<td>3,882</td>
<td>0 (0)</td>
</tr>
<tr>
<td>2001</td>
<td>4,184</td>
<td>0 (0)</td>
</tr>
<tr>
<td>2002</td>
<td>4,358</td>
<td>3 (0.07)</td>
</tr>
<tr>
<td>2003</td>
<td>4,164</td>
<td>0 (0)</td>
</tr>
<tr>
<td>2004</td>
<td>3,649</td>
<td>2 (0.05)</td>
</tr>
<tr>
<td>Total</td>
<td>38,762</td>
<td>12 (0.03)</td>
</tr>
</tbody>
</table>

Improvements of the control programme
In 1984 the state ceased to compensate broilers farmers for the cost of culling and destroying salmonella-infected broiler flocks. This increased the awareness by the industry improved hygiene routine in both feed mills and farms. The same year sampling of broilers became compulsory.

When campylobacter became a problem for the broiler companies in the middle of 1980ies the hygiene programme was revised. A physical hygiene barrier that was at least 30 cm high, preferably possible to sit on when changing footwear was introduced 1987. Since this barrier was introduced the annual number of salmonella outbreaks has been very low (fig. 2). If a farm with several epidemiological unites / flocks in a house became infected with salmonella not all flocks became infected indicating that the hygiene barriers work in practice.

The introduction of nipple drinkers and the routine of flushing the water line regularly improved the water hygiene very much in the houses. Another improvement is that straw, that often attracts rodents during storage, has been replaced by wood shavings as litter in broiler farms.

In the late 1870ies and early1980ies salmonella re-occurred in several farm sites despite thorough cleaning and disinfection. As a complement to the sanitation of salmonella infected chicken houses, competitive exclusion was used 1981-1990 in the three consecutive flocks in the same poultry houses. This practice reduced the number of recurrent salmonella infections in broiler flocks (Wierup et al., 1992). However, the method is no longer used, as the commercial products are not available in the Sweden, mainly because these products are not well defined and scientifically validated enough to be licensed as a medicine. Today re-occurrence of salmonella in broiler farms is not a problem.

New potential problems
To improve the profit in broiler production several new routines were introduced that did not comply with the rules in the voluntary control programme.

The farmers wanted to use locally produced whole wheat mixed with pelleted feed from the factory for broilers. As only heat-treated feed were allowed special hygiene rules had to be set up to avoid contamination with salmonella from harvest of the grain to the feeding of the broilers in the house. In 1991 special regulations for handling of whole wheat was issued. The number of salmonella cases since 1991 has been very low and no case has been connected to feeding with whole wheat.

Another change in routine was the introduction of thinning and use of harvesting machinery. Thinning is when a smaller number of the broilers in a flock are sent to slaughter and leaving the rest of the chickens to grow to a higher weight for up to a week. The entrance of containers, harvesters and people in the house is a high-risk operation. The equipment can carry virus or bacteria from another house/flock, as the equipments are difficult to clean and disinfect in between. Therefore the rest of the chickens may become infected before slaughter. We have experienced introduction of viral diseases in broiler after thinning but not salmonella so far. This is probably due to the low prevalence of salmonella in the Swedish broiler population.

References
Salmonella control in broilers - Swedish experiences

Johan Lindblad, DVM, The Swedish Poultry Meat Association - Svensk Fågel
P.O. Box 556 33, S-102 14 Stockholm, Sweden

Abstract:
By Swedish legislation; food from which Salmonella is isolated (regardless of serotype), is considered unfit for human consumption, and by that excluded to be placed on the market. Sweden has achieved an effective control regarding Salmonella in poultry. The key of success has been that all parts of the integrated production chain have taken their responsibilities with a holistic approach to the task. The economic support of the government during the start of the program and a close and fruitful cooperation between national authorities and the industry has also been of greatest importance.

The basic strategy of the program is:
Prevention: by hygienic measurements prevent introduction of Salmonella, regarding the whole production chain.
Monitoring critical control points in the whole integrated chain of production, with the focus to find Salmonella if present.
Action: Firm and immediate actions should be taken to avoid or minimise the effect of positive Salmonella finding.
Keywords: Holistic approach, Prevention, Monitoring, Action

History - Strategy
In the late 60-ies, when broiler production in Sweden still made up a minor part of the total consumption of meat, some severe outbreaks of human salmonellosis could be traced back to Salmonella contaminated broilers. Due to these outbreaks, a "voluntary" Salmonella control program regarding broilers was initiated by the broiler industry - approved and organized by the Swedish Board of Agriculture (SBA). This program with some minor adjustments has been in force in Sweden since 1970.

Structure of the Swedish integrated broiler industry within Svensk Fågel:
Svensk Fågel - The Swedish Poultry Meat Association (SPMA) is the trade association for the Swedish poultry industry, representing approximately 97% of Swedish poultry meat production.

To ensure "salmonella-free" broilers, SPMA require that all members have to be affiliated to the program. A basic requirement and a key of success is that the previous link in the production chain has to be affiliated to the program – holistic approach.

Producers (breeders, hatcheries and growers) who want to participate in the program have to apply to the Swedish Board of Agriculture (SBA). The SBA will then appoint a Salmonella control veterinarian, who will examine the facilities before approval, and thereafter visit the premises in accordance with the program. In addition to preventive requirements concerning day-old chicks, housing, feed/water and hygienic measures, all links in the whole chain of broiler production is monitored within a regulated testing scheme.

Up to 1984 the government provided 90% compensation for all costs due to salmonella infection in poultry flocks that were affiliated in the voluntary program. Since 1984 bacteriological control of all meat fowl flocks, 10-14 days before slaughter is compulsory.

Irrespective of participation in the voluntary program, including all preventive measures, the government does not provide any compensation to the broiler sector for any expenses/absence of income caused by the program. Broiler producers are today covered (participation in the voluntary program provided) to 90% by private insurances, to losses due to Salmonella infections.

Salmonella-free poultry production is based on five basic principles:
1. Salmonella-free day old chickens
2. Should be reared in a salmonella-free environment
3. Provided feed and water free from salmonella
4. Regularly monitoring of the whole production chain
5. Immediate action must be undertaken to fulfil the objective when ever salmonella is detected

Prevention
Day-old chicken: The major part of commercial poultry are imported to Sweden as day-old GrandParents (GP), a minor part as day-old Parents (P). All live poultry (layers, broilers, turkeys, geese and ducks) imported to Sweden are "quarentinized". During this isolation period the flock will be tested with reference to diseases that is not present in our commercial poultry population as well as bacteriological examination regarding Salmonella. In case Salmonella is isolated, regardless of serotype, the flock is immediately destroyed. The results of the control of imported breeders show the impact of this control. In total 12 out of 39 (30.8%) flocks of broiler GP and 3 out of 38 (7.9%) flocks of layer GP were found to be Salmonella contaminated during the years 1982-88. The Salmonella situation has dramatically improved and since 1995. Salmonella has regarding stock of meat type, only been found at one occasion of import: one flock of turkey breeders (P).

**Salmonella control of day-old Grandparent or Parent imported to Sweden**

<table>
<thead>
<tr>
<th>Year</th>
<th>Broiler/layer</th>
<th>Positive/total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982-</td>
<td>Broilers</td>
<td>12/39</td>
<td>30.8</td>
</tr>
<tr>
<td>1988</td>
<td>Layers</td>
<td>3/38</td>
<td>7.9</td>
</tr>
<tr>
<td>1995-2003</td>
<td>Broilers</td>
<td>0/69</td>
<td>0</td>
</tr>
</tbody>
</table>
Since 1970 Salmonella has never been detected in a GP flock after release from “quarantine”, and only in two layer and three broiler parent flocks – all destroyed after confirmation.
Salmonella Enteritidis has up to now not been found in any broiler or layer breeder flock or in any commercial broiler flock.

Antibiotic treatment of salmonella infected flocks have since 1970 not been permitted, and never been asked by the industry as an option.
“Competitive Exclusion” flora (Broilact) was used in the beginning of the 80-ies, as a follow up prophylaxis at sites where previous flock had been contaminated with exotic serotypes of salmonella, with good results.

Feed:
All feed has to be sufficiently heat treated (time and temperature), and only lines, silos and trucks designated for heat treated feed is accepted within the program.

The supplementation of whole grain (wheat) to the factory made feed has become more or less general practice. The whole grain concept is cost reducing as well as it is seems to have a positive effect on the bird’s digestive tract. Feeding with whole wheat is restricted with legal regulations regarding fertilizing, harvesting, transportation and storage. To the best of our knowledge there has not been one case of salmonella in broilers that has been traced back to the usage of whole grain.

Environment:
All houses affiliated to the voluntary program are closed with solid hard-made floors, walls and ceiling that should be easily cleanable. The houses should be rodent and wild bird proof.
Due to these requirements organic production cannot be accepted into the voluntary program.
All breeder and broiler houses are furnished with an “ante room” at the entrance. The “ante-room” is divided into a “dirty” and a “clean” area with a “hygiene barrier” in between. The clean area is from a salmonella control point of view where the chickens are kept.
When crossing the “hygiene barrier” footwear and preferably coverall should be changed as well as hands should be washed. In many GP operations the “hygiene barrier” consists of a shower.
Immediately (within 24 hours) after the house has been depopulated all litter should be removed, and dry and wet cleaning will be commenced as soon as possible there after.

Fig. 1.1 No of notified cases (infected herds) of Salmonella in broilers during 1968-2003


Source: SJV
Monitoring
All links of the production chain is on a regular basis sampled at critical control points.
When for solid reasons salmonella is suspected an extended sampling procedure is performed.

Action
In all suspected or verified index cases a veterinarian is appointed by the SBA to carry out an investigation to try to find the source of introduction.
Whenever Salmonella is verified regardless of prevalence or serotype the flock is destructed.
All manure is composted for at least 6 months.
Thoroughly cleaning and disinfection is followed by an inspection including environmental swabs for culturing, before new chickens might be placed on the premises.

Conclusion
Since 1968, there has been a proper registration of isolations of salmonella infections in broilers (Fig1.1). The serotypes isolated has mainly been exotic serotypes - the large numbers of outbreaks during 1979 and 1982-83 were caused by contaminated feed (S.livingstone and S.embandaka). The two involved feed mills were temporarily closed during cleaning and disinfection and some manufactory proceedings were improved. Once (1993) a broilerbreeder flock became Salmonella positive after transfer to the production site. As a result due to egg transmission (Salmonella typhimurium) 12 flocks involving +300 000 broilers became contaminated and were killed/destructed, before that particular breeder flock was traced, killed and destructed. During the last nine years the incidence of flocks contaminated and destroyed due to Salmonella have been less than 0.1%. During the period 1995-2001, out of 26 591 samples taken at slaughter plants, 7 samples have been found positive. (National Food Administration) Neither S.enteritidis nor S typhimurium DT 104 has been isolated anywhere in the integrated broiler chain.
The Swedish salmonella control programme has been running for many years. Its main goal, to provide consumers with salmonella free products has been reached. The costs and benefits of the programme have not been studied in much detail though. The latest study was done in 1992 in conjunction with an international course on salmonella control held in Sweden. Some of the results of that study are presented.

Costs of prophylactic measures of the programme were estimated to 59.5 million (M) SEK (one ECU equalled 8.79 SEK in 1992). Costs were divided into “overcosts” of faecal sampling in humans; 18.9 M SEK, Salmonella control at sanitary slaughter; 4 M SEK, control programme (mainly poultry); 23.1 M SEK and feed control; 13.5 M SEK. Costs due to direct control measures on farm etc. were estimated to 20.4 M SEK and costs due to control of food that is imported to 27.6 M SEK (insurances etc.). The total cost of the Swedish programme was estimated to 59.5+20.4+27.6 = 107.5 M SEK.

The broiler producers’ costs for the control equalled 0.86 SEK per slaughtered broiler. The following costs for the control were estimated:
- Rearing of grand parents 0.02 SEK, production of parent animals 0.13 SEK (hygiene 0.07, testing schemes 0.02, feed 0.04), hatchery costs 0.04 SEK (transportation 0.01, hygiene 0.03), production of broilers 0.52 SEK (hygiene 0.20, testing schemes 0.05, feed 0.27), slaughter 0.08 SEK, buildings 0.07 SEK.

The benefits may be calculated as the difference between the costs for salmonellosis in humans with the present programme and the costs for human illness in the absence of a programme. The annual costs for salmonellosis in humans (reported and unreported cases) were calculated at 10.7 M SEK with the present programme. In the absence of the programme costs were calculated at 117-265 M SEK per year. Costs for pain and loss of leisure were not included in the calculation.

Of course it is difficult to make estimates of a situation where a control programme is abolished so the figures have to be interpreted cautiously. One factor that has not been taken into consideration is the effect on costs of an open market with competition between domestic and international products. Up to 1995 Sweden had a system with strict border controls and price controls of imported foodstuffs, in order to support a sustainable national agriculture production. The costs of this system were ultimately paid by the consumers, by higher prices on some products.

The costs of the salmonella programme in broilers in 1992 are considered fairly accurate. Costs have been reduced considerably in recent years, mainly for reasons of international competition.

Numbers of domestic cases of salmonellosis in humans have not increased after 1995 in spite of the fact that some import regulations as regards Salmonella control of foodstuffs have been slackened. The reasons for this are not clear and there are many factors that need to be investigated such as kind of foodstuffs imported, patterns of consumption etc. As the Salmonella situation in Swedish animal production actually has improved in recent years, number of human cases might even have decreased had not slackened regulations been introduced.

There is a need for a new cost benefit analysis of the Swedish programme, using modern analytical techniques and taking into account changes taking place after Sweden entered the European Union in 1995.
Economical aspects of the Salmonella control program in layers

Henrik Larsén, Swedish Egg and Poultry Association

Abstract
Swedish Egg and Poultry Association is an interest organisation for the egg industry and the board of producers. We act through working groups, information, PR, statistics and forecasts. One of our main ways of communicating is through our periodical “Fjäderfä”.

Background
Eggs free of salmonella are one of our best arguments in order to achieve customer satisfaction on the Swedish market.

In 1953 there was an outbreak of salmonella in Alvesta in the south of Sweden where 90 people died and 9 000 fell ill. Since then, Sweden has been determined to control and fight salmonella in all lines of the egg production and to avoid that it comes in contact with the consumer.

This has been a successful model. Of all salmonella cases in Sweden (4 000 to 5 000), only 15% has a domestic origin. This is one of the reasons why the salmonella conference of WHO in 1993 took place in Sweden.

Consumer surveys in 2000 and 2002-2003 show that salmonella security is one of the most prioritized issues of Swedish animal production.

Only 12% of the Swedish consumers feel worried about salmonella in food produced in Sweden. This shows the high confidence in Swedish food safety among our consumers.

The board of directors of the farmers union, LRF, has set valuations and guidelines for a secure and sustainable food industry. According to this, Swedish farmers shall offer secure food and consumers shall rely on us and feel safe. We shall protect our animals from infections in all lines of production, including import of animals, feed manufacturing, breeding and slaughter.

Action
How do we live up to these high expectations?

- Strict control in breeding
- Feeding stuff free of salmonella
- Control by regular tests during production period
- Voluntary and preventing control program
- Destruction of infected flocks
- Cleaning and disinfection of empty houses
- Insurance

Conclusion
As shown below our strict work has been successful. Of course we also expect consumer eggs which are imported, to have the 853/2004 EG and 1688/2005 EG of the EU commission. This decision says that flocks shall undergo microbiological sample examination in the remitting country. The negative result shall be attached to the delivery. An alternative is that the country of origin has a control program set by the EU Standing veterinarian committee. Today only Sweden and Finland have such rules.
Salmonella in a country with a low incidence, human aspects

Salmonella introduction

Salmonellosis is a common zoonotic disease found all over the world. The animal host seldom becomes diseased but can transmit the disease directly or indirectly to humans through contaminated food. Common symptoms among humans are diarrhoea, abdominal pain, fever, nausea and sometimes vomiting, severe cases with septicemia might occur. The incubation period is normally 1-3 days, but can differ from 6 hours to more than 10 days.

The situation in Sweden

Sweden has since 1874 had laws and regulations for counteracting the spread of infectious diseases considered to pose a serious threat to human health. In 1953, a large outbreak of salmonellosis occurred in Sweden. The source of the outbreak was meat and meat products originating from a slaughterhouse, with about 9 000 cases and 90 deaths (Figure 1).

When the consequences of this large outbreak became known the Swedish authorities decided to act powerfully. After this the Swedish surveillance programme among domestic animals was launched. Successful interventions in episodes of Salmonella, especially in broiler flocks and cattle, decreased the amount of Salmonella in animal production and food. It was also decided that all human salmonellosis outbreaks should be investigated to stop further large outbreaks and increase the knowledge of the source of infection. These precautions have led to Sweden having a low number of domestic salmonellosis cases among humans. The total number of human Salmonella cases reported yearly is about 4000, with about 85% of the cases reported to have contracted the disease abroad. However 400-950 indigenous cases are reported annually, resulting in an incidence of <10 per 100,000 (Figure 2).

Food borne outbreaks

All Salmonella outbreaks are investigated even if involving only a few cases. In Sweden it is mandatory to report all Salmonella cases, both by the attending physician and the diagnostic laboratory. Food borne outbreaks are either detected through the surveillance system or locally by the environmental protection

Figure 1. Total number of reported cases of salmonellosis in Sweden 1940-2005. The increase from about 1970 is mostly due to more frequent travelling abroad.
Between 2000-2005, 52 food borne Salmonella outbreaks involving a total of 1,315 cases have been reported, of these 6 outbreaks were S. Enteritidis and 21 S. Typhimurium and the remaining outbreaks of other serotypes (one outbreak involved a double infection with S. Enteritidis and S. Hadar). The most common sources of infection from these outbreaks were: red meat (13), white meat (3), egg (1), cheese (1), chocolate (1), fish dish (1), vegetables and seed products (10) and the rest mixed food or unknown. A change in the trend of outbreak associated food type has been recognised in recent years in Sweden. Meat and meat products were earlier seen as the greatest risk for contracting salmonellosis and outbreaks from kebab and salami are rather commonly reported. Food items such as: bean sprouts, rocket salad, iceberg lettuce, fresh spices and products like tahini and helva (both sesame seed products) have been involved or suspected to be involved in foodborne outbreaks or found in the product.

The huge problem with S. Enteritidis (specially PT 4) from eggs and chicken that has occurred in most European countries has not occurred in Sweden. Food borne outbreaks from eggs rarely occur in Sweden, as Swedish hens and eggs are normally free from Salmonella. During 1991 infected laying hens on one farm in the very south of Sweden caused at least 10 outbreaks of S. Enteritidis over a few months and an increase of sporadic S. Enteritidis cases. This tells something of the potential egg-associated Salmonella can have as a cause of many and large food borne outbreaks.

Salmonellosis among humans in EU and Norway

The EU Zoonoses report estimates nearly 200,000 cases of salmonellosis among humans during 2004 with an incidence of 42.2 per 100,000 people, with a large variation between different countries (1). The incidence increased with 22% compared with 2003 probably due to a high incidence in the new member states.

Only a few countries differ domestic and imported cases in their reporting system. Only Finland, Norway and Sweden reported fewer cases of S. Enteritidis than S. Typhimurium and also a higher percentage of other serovars than S. Enteritidis (1). In most EU countries the increase of Salmonella cases occurs during the summertime. The same situation is seen in Sweden for total number of cases, but the summer peak is not that marked among domestic cases.
Cooperation among different authorities in Sweden
The laws regulating animal husbandry, food handling and infectious diseases affecting humans are powerful weapons against the spread of domestic diseases. At the national level, any increase in one specific serotype of Salmonella in humans will initiate an epidemiological investigation, including age, sex, geographical distribution and other relevant epidemiological information, in order to investigate a suspected source. Any connections with food handling, or animal sources are examined in the endeavour to reveal the sources of infection. Close co-operation between the veterinary-, food- and health authorities is necessary in order to achieve this goal. This co-operation has led several times to the success in combating both international and domestic outbreaks, as when the first human case of domestic S. Enteritidis PT 4 suddenly occurred in 1991. That investigation quickly led to a Salmonella infected poultry farm being identified as the source of the outbreak. All the above mentioned measures are undertaken to protect Sweden from domestic cases of salmonellosis.

Reference
Live animals
The Swedish poultry production is strictly regulated and the population has a hierarchical structure. Egg and broiler meat production are the most important branches, the production of turkey is comparably small. The production of ducks and geese is minor. The number of holdings and flocks are listed in Tables 1 and 2 - data are from 2005.

\textbf{Gallus gallus} - layers
The import of breeding flocks is restricted. Grandparents and Parents are imported from Germany, Netherlands, Denmark, UK, Canada and USA. The commercial layer population consists of several lineages (Lohmann, Hy-Line and Bovans). There are four hatcheries for layers. The layer population is situated throughout Sweden.

\textbf{Gallus gallus} - broilers
The import of breeding flocks is restricted. Only Grandparents are imported as day-old chicks from UK. The commercial broiler population consists of two lineages (Cobb and Ross). There are two hatcheries for production of Parent stock, and three for commercial broilers. The broiler production is mainly located in the southern and middle part of Sweden.

\textbf{Turkey}
The import of breeding flocks is restricted. Only parents are imported, and only from the United Kingdom. The commercial turkey population consists of one lineage, white turkeys from British United Turkey. There is only one hatchery for turkeys. The turkey population is located in the southern part of Sweden.

\textbf{Ducks}
The import of breeding flocks is restricted. Only parents are imported, and only from the United Kingdom. The commercial duck population consists of one lineage, white Peking ducks from Cherry Valley. There is one hatchery for ducks. The duck population is located in the southern part of Sweden.

\textbf{Geese}
There were no import of geese breeding material during 2005. There are four low capacity hatcheries for geese with approx. 40 000 hatched eggs per year.

Table 1. Number of breeding poultry holdings and flocks produced in Sweden 2005

<table>
<thead>
<tr>
<th>Production category</th>
<th>Number of flocks</th>
<th>Total Nr holdings</th>
<th>1000-2999</th>
<th>3000-10000</th>
<th>&gt;10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layers – grandparents</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layers – parents rearing</td>
<td>12</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Layers – parents production</td>
<td>25</td>
<td>16</td>
<td>3</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Broilers - grandparents</td>
<td>16</td>
<td>15</td>
<td>10</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Broilers – parents rearing</td>
<td>46</td>
<td>17</td>
<td>19</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Broiler – parents production</td>
<td>59</td>
<td>30</td>
<td>24</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Turkeys – parent rearing</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkeys – parent production</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ratites
The approximated number of ratite farms is 100. Most farms include the whole breeding chain with both breeding birds and birds for slaughter. In 2004, about 900 ostriches were slaughtered at slaughterhouses in Sweden.

Slaughterhouses and cutting plants
In November 2005 there were 14 Swedish poultry slaughterhouses approved according to Directive 92/116/EEC, article 6 and 12 approved according to article 7 (low capacity). During 2004 - 69, 6 million chickens were slaughtered (91,2 thousand tonnes). The number of cutting plants was 14 (whereof 10 integrated with slaughterhouses) approved according to article 6 and 9 (whereof 7 integrated with slaughterhouses) approved according to article 7. All poultry slaughter houses slaughtering more than 10 000 birds per year are approved by the NFA and under veterinary control according to SLVFS 1994:11 3§ and following Council Directive 71/118/EEC.

Egg packing centres
There are 143 approved egg packaging establishments in Sweden of which 6 are major. The production of table eggs in 2004 was 75,5 thousand tonnes.

---

Table 2 Number of production poultry holdings and flocks in Sweden 2005

<table>
<thead>
<tr>
<th>Production category</th>
<th>Number of flocks</th>
<th>Number of holdings/size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>1000-2999</td>
</tr>
<tr>
<td>Layers</td>
<td>931</td>
<td>351</td>
</tr>
<tr>
<td>Broilers</td>
<td>3000</td>
<td>130</td>
</tr>
<tr>
<td>Turkeys</td>
<td>35-40</td>
<td></td>
</tr>
<tr>
<td>Ducks**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geese**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratites</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

** For these production categories, information on the number of holdings and size is not available.
Structure of the feed industry

The total volume of commercial feed for food producing animals was 2.2 million metric tonnes in 2004 of which 510 000 tonnes was consumed by poultry. Fattening chickens consumed 190 000 tonnes and 227 000 tonnes of feed was consumed by layers and 41 000 ton was consumed by chicken breeders. The rest was consumed by other categories of poultry. Currently, fifteen major feed mills produce approximately 95% of all feed consumed from the feed industry production of feed. Some egg producers do produce their own complete feed made of separate ingredients, but there is no integrated feed and fattening chicken producers known. Another category of poultry producers buy complementary feed and add whole cereals (mainly wheat) in order to create a whole ration. About 70% of the mills are farmers’ cooperatives. In feed mills where poultry feed is produced, pig feed and sometimes also cattle feed is manufactured, however different production lines are used in the mills. In addition mills with a more limited feed production are subjected to Salmonella control on a regular basis. Only pelleted feed is used for the feeding of poultry, however the feeding of whole-wheat grain to poultry is done by some premises at a regular basis. Most of the grain is handled at the farm level only and special regulations apply to the storage and handling of the grain to prevent any Salmonella contamination.
