Introduction

Despite Denmark's limited size of just 44,000 sq km, the country produced 22 million pigs, 137 million broilers and 595,000 cattle in 2001. Denmark has approximately 14,000 swine producers, 95% of whom are members of the 150-year-old nationwide producer cooperative, the Danish Bacon and Meat Council. With a human population of 5.3 million inhabitants, domestic consumption accounts for only 15% of the produced pork, whereas the remaining 85% is exported worldwide.

Food safety has been a very high political priority during the last decade in Denmark and has consequently been a precondition for the swine and poultry industries to remain acceptable among the Danes.

The Salmonella, Trichinella and residues programs are the three most important food safety quality assurance programs implemented in the Danish swine sector. The programs are briefly described in the present paper and their food safety values are evaluated.

Salmonella

In 1993, the Ministry of Food, Agriculture and Fisheries of Denmark and the Danish Bacon and Meat Council initiated an ambitious program to eliminate pork as an important source of human salmonellosis. In the beginning of the 1990's, pork had become recognized as an increasingly important source of human salmonellosis in Denmark (Wegener and Baggesen, 1996).

Estimates from the Danish Zoonoses Center show that the total number of cases of salmonella poisoning in Denmark has fallen by more than 50% since 1997. The number of incidents peaked in 1997 when 5,000 people were taken ill compared with around 2,000 cases in the year 2002. The main sources of salmonella poisoning are food related, both domestically produced and imported, as well as travel abroad.

Eggs used for fresh consumption have accounted for the majority of the cases during the past few years.

The cases associated with pork peaked in 1993, after which a series of initiatives to reduce salmonella in the pig industry were implemented. Consequently, pork has steadily declined as a source of human salmonellosis since 1996. Results from year 2001 show an incidence of only 3 cases per 100,000 inhabitants in Denmark equal to a total number of 160 human cases related to pork (Figure 1).
Control from farm to fork

The Danish Salmonella Control Program for pigs operates at all stages of the production chain and has applied nationally since 1995 (Mousing et al. 1997, Nielsen & Wegener 1997, Nielsen et al. 2001). The program is adjusted nearly every year in order to optimize the cost-effectiveness as the swine industry develops fast.

The level of salmonella is controlled at various stages:

- Feedstuffs
- Breeder and multiplier herds
- Weaner producers
- Finisher herds with a production of more than 200 animals per year
- At the slaughterhouse, including special hygienic slaughter of highly infected herds

Feedstuffs

The national program requires mandatory Salmonella testing in all plants producing animal feed. The test involves microbiological analyses of compounded feedstuffs, as well as the collection of samples from critical control points during production. Compounded feedstuffs are heat treated at 81°C to eliminate Salmonella bacteria.

The level of *Salmonella spp.* in final products is low; in year 2001 only 1 of the 1552 examined samples were test positive (0.1%).

Breeder and multiplier herds

Each month, all herds are blood sampled and examined for Salmonella antibodies. Based on the level of antibodies, a salmonella index is calculated. If the index exceeds 5, pen fecal samples must be taken and examined for the presence of *Salmonella spp.*, and the farmer must inform all buyers about the presence of Salmonella on the farm.

Weaner producers

If a sow herd sells weaners to a Salmonella level 2 or 3 finishing herd, pen fecal samples must be taken and examined for the presence of *Salmonella spp.*

Finishing herds

All finishing herds producing >200 finishers per year are tested for Salmonella antibodies. The testing is mandatory and paid by the farmers.

For small herds (annual kill ≤2000 finishers), 60 animals should be sampled per year; for medium sized herds (annual kill 2001-5000), 75 animals per year; for large herds (annual kill >5000), 100 animals per year. This will ensure a detection level <5% in all herds, and in the largest herds down to <3%. Herds producing <200 finishers per
year are not included in the surveillance as they only produce 1% of the finishers in Denmark.

In total, 600,000 finishers are sampled on an annual basis. The samples are taken at the slaughter plant after the kill. A small piece of meat is taken from one of three well-defined muscles and put into a container. The container is frozen at minus 20°C overnight and shipped to the laboratory for analyses. On arrival at the laboratory, the meat becomes thawed, and meat juice is passively released into the container. The meat juice contains antibodies and may be used in serological tests as pre-diluted serum (Nielsen et al. 1998).

Each month, the herds are divided into 3 levels with respect to the proportion of seropositive samples during the last 3 months. Level 1 herds are herds with no or few seropositive samples, level 2 herds are herds with a moderate number of seropositive samples, while level 3 herds are herds with a high proportion of seropositive samples. The serological results from the last 3 months are expressed as the Salmonella index. Level 1 herds have an index from 0 - 39.9, level 2 herds from 40.0 - 69.9, and level 3 herds from 70.0 and upwards (Alban et al. 2002). The distribution of finishing herds in levels 1, 2 and 3 in February 2003 is shown in Table 1.

<table>
<thead>
<tr>
<th>Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
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</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>97.4</td>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Table 1 — Distribution of Salmonella level 2 and 3 in finishing herds in Denmark February 2003.

**Level 2 and 3 herds**

The veterinary authorities require that fecal samples are taken in order to identify the salmonella serotype. This is carried out by bacteriological examination of 20 pen fecal samples randomly selected from the different pens in the herd. Additionally, the farmer must inform the authorities from whom he has received the weaners during the last 6 months. These herds also have to take pen fecal samples for Salmonella testing. The swine producer pays for the examination of the fecal samples.

### Special hygienic slaughter of finishers from level 3 herds

Herds assigned to level 3 have to be slaughtered under special hygienic precautions. This is done at specially designated slaughter plants at the end of the day to prevent cross-contamination with other carcasses. Carcasses from level 3 herds also have to be heat-treated or subjected to other special treatment. Slaughter plants may also randomly test carcasses free on the basis of guidelines issued by the Danish Veterinary and Food Administration.

### Financial penalties

The nationwide producer cooperative, The Danish Bacon and Meat Council, has implemented a strict Salmonella penalty system. The purpose is to improve the
salmonella control as much as possible in herds with positive samples. In practice, an intervention plan in order to reduce the prevalence of salmonella carries this out. The producer and his advisers work out the plan in detail.

The level of financial penalty corresponds to the level to which the herd is assigned:

Penalty (% of the slaughter value):
- Level 0%
- Level 2 2% all months while in level 2
- Level 3 4%, 6%, and 8% depending on the number of months in level 3 during the last 12 months

Surveillance for Salmonella in fresh pork

Since 1993, fresh pork has been surveyed for *Salmonella spp.* at the slaughterhouses every month. The prevalence has declined from 3-4% in 1993 to 0.7% in 2000 (Table 2) and has remained at a similar low level since. In general, 10-15 different serotypes are isolated from Danish pork. However, *S. Typhimurium* constitutes approximately 50% of the isolates (Table 3).

**Table 2** — Prevalence of *Salmonella spp.* in Danish pork, 1996-2002. The prevalences of Salmonella in the years 1996-2000 were determined by culture of different pork cuts, whereas the prevalences in 2001 and 2002 were determined by culture of swabs from 300 cm² of a carcass. Numbers marked with * are calculated prevalences for direct comparison.

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<tbody>
<tr>
<td>% Positive samples</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>0.9</td>
<td>0.7</td>
<td>0.65*</td>
<td>0.7*</td>
</tr>
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Multiresistant *S. Typhimurium* DT104 has only been detected very rarely (0.002%) in Danish pork.

From 1993 to 2000 the surveillance was conducted by bacteriological examination of different pork cuts. Approximately 28,000 pork cuts were tested on an annual basis. A new method of Salmonella testing on carcasses was introduced on 1 January 2001.

Five carcasses per slaughter day are swabbed at three defined areas (the sternum, the hind leg near the tail and the jowl) at 100 cm² for each sample. The swabbing areas were originally defined by USDA, USA, and are currently used in the USA as the national Salmonella monitoring method on swine carcasses. This method is twice as sensitive as the one previously used, and consequently the apparent Salmonella prevalence in Danish pork doubled. This should naturally only be regarded as an effect of the improved test sensitivity, and not as increased Salmonella prevalence as such (Sørensen et al. 2001).

If a slaughter plant in four consecutive months has a Salmonella prevalence above 2.3%, an Intensified Control Program must be implemented immediately. In case the prevalence does not decrease as a result of the Intensified Control Program, the
Veterinary authorities may force the slaughter plant to implement additional hygiene measures.

**Table 3 — Distribution of serotypes in Danish pork in 2002.**

<table>
<thead>
<tr>
<th>Serotype</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Typhimurium</td>
<td>49</td>
</tr>
<tr>
<td>S. Derby</td>
<td>18</td>
</tr>
<tr>
<td>S. Infantis</td>
<td>6</td>
</tr>
<tr>
<td>S. Livingstone</td>
<td>3</td>
</tr>
<tr>
<td>Exotic serotypes, n= 12</td>
<td>8</td>
</tr>
<tr>
<td>Rough isolates</td>
<td>15</td>
</tr>
<tr>
<td>Non typable</td>
<td>1</td>
</tr>
</tbody>
</table>

**DT104 Herds**

Herds infected with multiresistant *S. Typhimurium* DT104 have to follow additional restrictions. The herd is given a Zoonotic Restriction Order. This includes a requirement for a herd intervention plan, restrictions on livestock trade, and a requirement for special slurry handling. The herd intervention plan ensures that salmonella-reducing measures are implemented in the herd for at least 12 months, and the restriction on livestock trade is intended to prevent the spread of DT104 infection to other herds.

**Hot Water Decontamination**

Finishing pigs infected with multiresistant *S. Typhimurium* DT104 may either be slaughtered under special hygienic conditions, as with Level 3 herds with subsequent heat-treatment, or may be decontaminated with hot water. Decontamination is applied to carcasses after removal of the organs. The carcass is showered with 80°C hot water for 14-16 seconds, which produces a significant reduction in the bacterial count on the surface. Five carcasses from each batch are tested to ensure that the process is effective. If *Salmonella spp.* is not detected, the whole batch can be used for fresh consumption.

**Laboratory requirements**

The serological testing for Salmonella antibodies is only carried out at one laboratory: The Danish Veterinary Institute, in order to ensure a high cost-effectiveness of the analyses. The more samples tested, the lower the cost per sample.

Bacteriological examinations of pen fecal samples for Salmonella are currently done at two accredited laboratories: The Danish Veterinary Institute or the Veterinary laboratory of the Danish Bacon and Meat Council.

The bacteriological examinations of carcass swabs are mainly done at four different accredited slaughter plant laboratories owned by the Danish Bacon and Meat Council.
Administration, responsibility and finance of the program

According to Danish law, it is mandatory to test for Salmonella. Additionally, the Danish Bacon and Meat Council has set up further requirements that members of the cooperative must meet.

A National Salmonella Steering Committee consisting of the swine industry, the Veterinary authorities, national research institutes, and breeding companies follows and evaluates the program closely. The Danish Bacon and Meat Council chairs the committee, and has the direct responsibility for the daily administration.

The swine industry pays more than 99% of the costs of the entire program. In 2002, the total expenses for the salmonella program has been calculated to be approximately US$ 6.4 million corresponding to US$ 0.3 per finisher produced in Denmark.

Conclusion

Food safety has been given high political priority during the last decade in Denmark, and has consequently been a precondition for the swine and poultry industries to remain acceptable among the Danes. The Danish Salmonella program is the first Salmonella program in a major swine-producing country to focus on both pre-harvest, harvest and post-harvest levels. The program is responsible for a significant reduction in the level of Salmonella in swine herds, in pork and, most importantly, among humans in Denmark. Even though the expenses have been, and still remain high, the Danish swine producers fully support the Salmonella program. The low level of Salmonella in Danish pork makes swine production more acceptable among the Danish politicians, and may also increase Danish pork’s competitiveness in certain parts of the global market.

The Danish Salmonella program is a model for similar Salmonella control programs currently being implemented in Germany, The Netherlands, Belgium, Ireland and United Kingdom.

Trichinella

Trichinellosis in humans is still an important parasitic zoonoses in many swine-producing regions. In Eastern Europe, the Baltic, Russia, China and South America, Trichinella is still a common infection in domestic swine and frequently causes human outbreaks with many fatalities.

For decades, Trichinella has almost been absent from domestic swine in Western Europe (Anon, 2001), and frequently local veterinarians consider Trichinella as a historical parasitic problem. Countries within the EU inspect all pigs intended for interstate trade, and some of the countries also require inspections of pigs intended for domestic consumption. The cost of this testing is enormous, approximately US$ 570 million per year (Pozio, 1998). As a result of the intensive surveillance, the prevalence of Trichinella in domestic swine has been found to be close to zero. Only two member states, Finland and Spain, have Trichinella infections regularly in domestic swine. Usually, the infection does not stay at
an individual farm from year to year, but emerges once or twice and then disappears. When Trichinella is found in a herd, normally few pigs are positive in regions where the infection pressure is low.

Within Europe, wild boars may be Trichinella positive constituting an uncontrolled reservoir as well as a specific food safety problem, as these are not always examined for the presence of the parasite before consumption. Additional wild life reservoirs for Trichinella are primarily foxes, raccoons, dogs, rats and cats. Four species of Trichinella have been isolated in Europe: *T. spiralis*, *T. britovi*, *T. nativa* and *T. pseudospiralis*. In Europe, *T. spiralis* and *T. britovi* are common species isolated from livestock and wildlife, respectively.

It may be speculated that trichinellosis is an emergent zoonoses in Europe as a number of risk factors have developed over the last decade, e.g. the number of wild boars, free range out door domestic swine is increasing rapidly in many European countries, as is the number of raccoons (Dupouy-camet, 1999).

In Denmark, all swine slaughtered at export authorized slaughterhouses plants have been examined for Trichinella for more than 100 years. The last Trichinella positive swine was detected in 1929. Consequently, the Danish swine population is considered to be free for Trichinella.

However, due to the European meat inspection legislation, more than 21 million swine are tested every year in Denmark, as 85% of the Danish pork is exported worldwide.

Within the EU, seven Trichinella detection methods are currently approved for examination of swine carcasses. The method used in Denmark is briefly described as follows: A sample of meat (2 grams) from the pillar part of the diaphragm is taken from every carcass. In the laboratory, 100 samples are pooled and pepsin-digested. The solution is filtrated, and the liquid is inspected visually for Trichinella larvae by specially trained laboratory staff. The Trichinella examinations are typically carried out at the slaughterhouses own laboratory. The annual expenses for the Danish Trichinella testing program are US$ 3.1 million (Table 5).

The European Commission is currently working on a new Trichinella strategy, making it possible for certain well-defined regions within the EU to become recognized as Trichinella non-endemic regions. Denmark strongly wishes to become recognized as an official Trichinella non-endemic region, as this allows Denmark to discontinue the Trichinella examinations of the 21 million conventionally produced finishers. In the proposal from the EU, only swine produced under free-range production systems have to be examined. From a Danish point of view, this would be a significant improvement of the EU legislation.

### Surveillance for residues

Member states of the European Union must ensure that a certain proportion of swine carcasses are examined for residues from antimicrobials, hormones, pesticides and heavy metals.

The official surveillance takes places at two levels: random sampling of ordinary carcasses, and sampling of carcasses which are under suspicion for residues. Swine with signs of injections or swine known to be slaughtered too early after medical therapy must be examined. The examined carcasses must not leave the slaughterhouse
before the results are known. Positive carcasses must be destroyed, and the Danish Veterinary and Food Administration will conduct an investigation of the farmer and the relevant veterinarian.

Based on an EU risk assessment, 3,500 carcasses of the 22 million produced finishers must be examined for antimicrobials on an annual basis. The Danish Bacon and Meat Council has decided to sample an additional 18,500 carcasses as part of an own check program. In total, 22,000 carcasses corresponding to 0.1% of the produced swine are examined annually. During the last decade, only 1 to 6 carcasses have been found positive for antimicrobial residues per year. Residues of hormones, pesticides and heavy metals have never been detected (Table 6).

The examination for residues is done at the slaughterhouse laboratories and by the Danish Veterinary and Food Administration. The annual expenses for the residue surveillance are US$, 3.1 million (Table 5).

**Table 4** — Expenses of the Danish Salmonella surveillance and control program 2002. All costs are in thousands US$.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Paid by farmer</th>
<th>Paid by slaughter plant</th>
<th>Paid by DBMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding herds</td>
<td>157</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow herds</td>
<td>460</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finishing herds</td>
<td>714</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat juice analyses</td>
<td></td>
<td>570</td>
<td>857</td>
</tr>
<tr>
<td>Carcass swabs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special slaughter level 3 herds</td>
<td></td>
<td></td>
<td>2,857</td>
</tr>
<tr>
<td>Zoonoses dept. DBMC</td>
<td></td>
<td></td>
<td>642</td>
</tr>
<tr>
<td>Sub total</td>
<td>1,331</td>
<td>3,569</td>
<td>1,499</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>6,399</td>
</tr>
</tbody>
</table>

**Table 5** — Total food safety expenses year 2002 in the Danish swine industry. All expenses are given in US$

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total annual expenses (million)</th>
<th>Expenses per swine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella</td>
<td>14.3</td>
<td>0.65</td>
</tr>
<tr>
<td>Salmonella DT104</td>
<td>5.1</td>
<td>0.22</td>
</tr>
<tr>
<td>R&amp;D food safety DBMC</td>
<td>3.6</td>
<td>0.16</td>
</tr>
<tr>
<td>Trichinella</td>
<td>3.1</td>
<td>0.14</td>
</tr>
<tr>
<td>Residues</td>
<td>3.1</td>
<td>0.14</td>
</tr>
<tr>
<td>Meat inspection</td>
<td>30</td>
<td>1.36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59.2</strong></td>
<td><strong>2.7</strong></td>
</tr>
</tbody>
</table>
Table 6 — Surveillance for antimicrobials, hormones, pesticides and heavy metal in Danish pork 2001.

<table>
<thead>
<tr>
<th>Residue</th>
<th>No. of tested pigs</th>
<th>% of swine killed</th>
<th>No. Positive</th>
<th>% positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimicrobials</td>
<td>21,914</td>
<td>0.1</td>
<td>1</td>
<td>0.005</td>
</tr>
<tr>
<td>Hormones</td>
<td>7,792</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pesticides</td>
<td>327</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>5</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Conclusion

The three described food safety quality assurance programs guarantee the safety of Danish pork. The Salmonella program is of major interest in Denmark, as many consumers are aware of the risk for zoonotic bacterial infections. The swine producers, veterinary authorities and the government recognize the cost-benefit of the program.

In contrast, the Trichinella and residues programs are almost unknown for the ordinary consumers. As a global exporter, Denmark is forced to continue the Trichinella program even though no Trichinella has been detected in Danish swine since 1929. Danish pork is known to be free from Trichinella. Consequently, the US$ 3.1 million spent on Trichinella testing every year does not benefit the Danish or global consumers. New EU legislation defining Trichinella free regions is therefore highly relevant from a cost-benefit point of view.

The testing for residues has also demonstrated that the risk of finding chemical residues in Danish pork is negligible. However, recent problems with residues within the EU have demonstrated the value of continued testing for chemical residues in order to maintain the consumers’ confidence.

References


SØRENSEN, L. L., H. WACHMANN, J. DAHL, B. NIELSEN. 2001. The new Danish Salmonella surveillance on fresh pig carcasses based on pooled swab samples including compatibility with levels of the former system; Salinpork 2001. 2.-5. Sept., Leipzig, Germany.