Abstract

This paper describes some of the initiatives that have been implemented by the Danish swine industry with the aim to reduce the prevalence of *Salmonella*. Initially, main focus was on pre-harvest initiatives and correct identification of herds with high levels of *Salmonella*. Then, focus has changed to post-harvest initiatives, such as improved slaughter hygiene. Recently, decontamination applied after slaughter and cost-effectiveness in surveillance have received increasing attention. The Danish system has proven to be successful, because the number of human salmonellosis cases attributable to pork has declined. However, if the aim is to obtain further reductions, then post-harvest initiatives are more cost-effective than pre-harvest initiatives. This knowledge can be used in order to develop and implement appropriate types of surveillance programs in other countries.

Introduction

Infection with *Salmonella* is seldom associated with clinical disease in pigs. However, control is important because the public is concerned about the human health impact. In Denmark, the number of human cases of salmonellosis due to pork increased during the 1990’s reaching a maximum in 1993 where a total of 1,100 cases were reported, corresponding to an incidence of around 20 per 100,000 inhabitants (Anon., 2004). This was politically unacceptable and led to the development and implementation of a surveillance-and-control program for slaughter pig herds in 1995 (Mousing *et al.*, 1997). Since then, several initiatives have been carried out in order to identify risk-mitigating factors all along the food chain; from control of feedstuff over separate transport of finishers from herds with high levels of *Salmonella* to development of slaughter procedures leading to improved hygiene. Recently, focus has changed to application of different decontamination procedures at the slaughterhouse and cost-effectiveness both with respect to surveillance and control costs.

Currently, the veterinary administration and the Danish Bacon & Meat Council are negotiating how a further reduction in the number of human cases related to consumption of Danish pork can be obtained. To identify this, it is of value to go through the development and rational for the Danish surveillance-and-control program for slaughter pig herds.

Materials and Methods

A review of the different initiatives on *Salmonella* surveillance-and-control for slaughter pig herd was made covering the time period from 1995 until today.

Results and Discussion

Pre-harvest initiatives in the early phase

Basically, *Salmonella* can be reduced pre-harvest (in the herd), post-harvest (at the abattoir), or both. In the early years, focus was mainly on the swineherds. From experiments and large-scale epidemiological studies it was found that e.g. feeding acidified feed (Jørgensen *et al.*, 2001) or home-mixed feed (Kranker *et al.*, 2001) resulted in a reduced *Salmonella* burden in pigs. Likewise, rodent control and limited commingling of pigs seemed to be important to avoid transmission of *Salmonella*.

The hypothesis was that if pigs presented at slaughter were harboring little or no *Salmonella*, there would only be a minor problem. Therefore, a classification scheme was developed aiming at dividing the slaughter pig herds according to their level of *Salmonella* burden (Mousing *et al.*, 1997). Concurrent improvements in serological methods made it possible to measure antibodies against *Salmonella* at a large scale by use of meat-juice samples taken at the abattoir in connection with slaughter of the finishers (Nielsen *et al.*, 1995, Nielsen *et al.*, 1998).

The initial classification scheme was based on laboratory results and theoretical knowledge. After 5 years, sufficient data were collected and the classification system was revised. Sample sizes were adjusted with the aim of being able to detect *Salmonella* if present with a minimum prevalence of 5% seen over one year. This could be obtained if 60 samples were taken annually in a herd producing <2000 finishers, 75 in a herd producing 2001-5000 finishers, and 100 samples in...
a herd producing more than 5000 finishers a year (Alban et al., 2002).

Epidemiological analysis showed that there was a clear association between herd serology and the probability of identifying Salmonella bacteria both in the caecal content (Alban et al., 2002) and on the carcass (Sørensen et al., 2004). Studies also indicated that the lower the cut-off of the individual meat-juice result, the higher the correlation between serology and bacteriology. Unfortunately, the lower the cut-off is, the higher is the likelihood of a false-positive result. It was of interest to introduce a Level-0 for sero-negative herds. However, a false-positive result would be detrimental for a Level-0 herd. Therefore, we only lowered the cut-off from 40 OD% to 20 OD% - and not down to 10 OD%.

Moreover, it was noted that the association between serology and microbiology was improved when the Salmonella results of the previous three months were weighted 3:1:1. Hereby, the result of the most recent month should count three times as much as the results of the two preceding months. The weights were identified as the (rounded of) parameters that gave the best fit in a logistic regression model describing the association between proportion of Salmonella positive caecal samples and serology. The weighted average of the seroprevalence was called the serological Salmonella index for slaughter pig herds. Because of the weighting a herd with an increasing seroprevalence will enter a higher level sooner in case a weighting is used compared with no weighting. Likewise, when the seroprevalence is decreasing the herd will sooner leave the high Salmonella level than in a system without weighting of the monthly results. The farmers have appreciated the effect of the weighting, because it acts as an incentive to reduce Salmonella in the herd.

The revised scheme started in 2001 and resulted in a 20% reduction in the number of samples taken without food safety being poorer. By March 2005, 95.7% of the slaughter pig herds were in Level 1, 3.3% in Level 2, and 1.0% in Level 3, the latter subjected to sanitary slaughter.

Recently, a study on the effect of introducing risk-based surveillance has demonstrated that it is possible to reduce sampling in herds with no Salmonella without jeopardizing human health (Enøe et al., 2004). According to the present program, 5 samples should be taken monthly in a herd producing 201-3,000 finishers annually (Alban et al., 2002). However, simulation using surveillance data indicated that the number of samples in herds with a zero or low seroprevalence could be reduced to 1 sample per month. Risk-based Salmonella surveillance will be implemented in Denmark mid 2005, and it is expected that it would lower the number of samples taken by 20-25% (Danish Bacon & Meat Council).

A deduction system was also introduced as an incentive for the farmers in Level 2 and Level 3. At current, the deductions are 2% of the carcass value for a Level-2 finisher. For Level-3 finishers, the deduction is related to the number of months the herd has been in Level 3. It begins with 4% and then increases to 6% and eventually reaches 8% (Nielsen et al., 2001). Only few farmers have the economy that enables them to make money while paying these deductions.

Despite the actions taken pre-harvest, it was noticed that the Salmonella prevalence in pork has been constant around 1.4% since 2001 (Anon, 2004).

**Post-harvest initiatives in the second phase**

There were indications that even if swine herds with the highest Salmonella burden were excluded, there would still be enough Salmonella in the remaining herds to fuel the system with Salmonella (Alban & Stärk, 2005). This changed the focus of Salmonella reduction from pre-harvest to post-harvest. It was, moreover, of interest to identify how a further reduction could be obtained in a cost-effective way. A simulation model was built to represent pig production from the piggery to the slaughter plant. The model was based on all available data and expert opinion. Figure 1 describes the Salmonella contamination on the pig/carcass all the way from the loading on the farm until pork after chilling. It is noted that the prevalence of Salmonella increases during transport and lairage, where it reaches its maximum at kill. Hereafter the Salmonella prevalence is reduced due to singeing, however, increases because of polishing, evisceration, and veterinary inspection etc. (Fig. 1). The simulation model was used to study the effect of different intervention measures on the Salmonella prevalence of the final carcass. One example was to half the proportion of herds with a large Salmonella burden – a strategy that turned out to be very expensive and only have limited effect. This is because there is sufficient Salmonella in the remaining system to fuel it with Salmonella. The simulation performed demonstrated that concurrent improvements throughout the production
chain were needed to further reduce the prevalence of \textit{Salmonella} on pig carcasses (Alban & Stärk, 2005). This implies e.g. a high temperature at singeing, enclosing the anus and rectum in a plastic bag, and improved disinfection of tools (Alban & Stärk, 2005).

Recently, a cost benefit analysis has been carried out aiming to identify the economical efficiency of a range of possible national control strategies against \textit{Salmonella}. Only showering pig carcasses with 80°C hot water for 14-16 seconds directly after slaughter turned out to be economically efficient. However, the industry would bear all expenses and society would gain all benefits (Gissel & Alban – elsewhere in this proceeding). A disadvantage associated with this procedure is a large consumption of water, which might be considered environmentally problematic. Furthermore, the equipment requires a lot of space, which makes it difficult to install on several abattoirs.

Other decontamination initiatives are under development. Currently, the Danish Bacon & Meat Council is testing hand-held decontamination by use of steam on high-risk areas on the carcass. Another promising alternative is treatment of carcasses with a combination of steam and ultrasound and this will be pursued further in the future.

Other alternatives for reducing the \textit{Salmonella} prevalence in pigs and pork along the stable to table chain have been evaluated with respect to cost-effectiveness. The aim was to identify how a \textit{Salmonella} prevalence of 1.2% could be obtained in pork at the lowest possible costs. This level was agreed between the Danish Bacon & Meat Council and the veterinary authorities. These studies showed that further pre-harvest initiatives would not be cost-effective compared with post-harvest measures. Besides, none of the pre-harvest scenarios would result in a sufficient reduction in the \textit{Salmonella} prevalence in pork by 2006 to attain the level agreed with the veterinary authorities (Nielsen et al. – elsewhere in this proceeding).

The future of \textit{Salmonella} surveillance in a broader perspective

It becomes evident that veterinary epidemiology, in combination with disciplines like microbiology and food hygiene, has formed a valuable contribution to the development and evaluation of the Danish surveillance-and-control program for slaughter pig herds. The Danish system has resulted in a successful surveillance for \textit{Salmonella} through increasing knowledge about the dynamics pre- and post-harvest. It has proven to be successful, because the number of human salmonellosis cases attributable to pork has declined, e.g. to 202 in 2003 (Anon., 2004).

The new Zoonosis directive recently issued by the EU will be implemented in the years to come (2003/99/EC) and in this context, surveillance program for \textit{Salmonella} and possibly other zoonoses will be developed and implemented in many EU countries. Based on experience from Denmark it is recommended that the development of these programs takes place in a dialogue between the swine industry and the veterinary authorities, as has been the case in Denmark. The Danish experience – good as well as bad – can be used to develop and implement the appropriate type of surveillance program for the individual country. This will depend - among other things - on how widespread \textit{Salmonella} is in the national pig industry and which initiatives have already been put in place.

Conclusion

Surveillance and control for \textit{Salmonella} in pork can be conducted pre-harvest, post-harvest or by a combination of the 2 approaches. Initially, focus in Denmark was on pre-harvest initiatives. The Danish system has proven to be successful, because the number of human salmonellosis cases attributable to pork has declined. However, if the aim is to obtain further reductions, then post-harvest initiatives are more cost-effective than pre-harvest initiatives.

References


