EFFECTIVENESS OF SALMONELLA CONTROL STRATEGIES IN FATTENING PIGS

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Abstract The first aim of this study was to examine which control mechanism is the most effective and profitable to control Salmonella in fattening pigs. Three treatments at farm-level were examined: 1) hygiene and management measures; 2) acidified feed; 3) acidified drinking water. The second aim of this study was to examine the correlation between the Salmonella blood titre (immunology S/P value) and the Salmonella excretion in faeces of the slaughtered pig.

Acidified drinking water and acidified feed showed significance reduction of the Salmonella prevalence in fattening pigs. Acidified drinking water showed improvement of the daily gain and feed conversion and is therefore the most profitable control strategy. Farms with high status or mean S/P value had significance more Salmonella excreted pigs than farms with low status or mean S/P value. Focusing on the height of the Salmonella titre on farm level reduces the chance of contamination of the meat processing plant.

Introduction Salmonella spp. has often been mentioned as one of the main bacteria that can cause illness in humans and is therefore a health risk (Berends et al., 1998; Leclerc et al., 2002; Gomez et al., 1997). Contamination of meat and meat products with Salmonella spp. is of growing concern in the modern pig livestock sector. This concern is related to public health, animal health and welfare and to international trade of animals and products of animal origin.

In Denmark, 22.2% of 1,383 investigated pig herds were Salmonella positive by microbiological testing (Baggesen et al., 1999). In Belgium, 92% of the herds were found positive (Nollet et al., 2004), in Canada 67% (Rajic et al., 2005). Berends et al. (1998) estimated that 25-30% of primal cuts and retail-ready pork in butchers’ shops are contaminated with Salmonella while this figure is 50-55% for minced pork and pork sausages. Approximately 22% of the 50,000 Dutch human cases of salmonellosis in 2003 can be attributed to consumption of contaminated pork (Valkenburgh et al., 2004)

These figures show that control strategies to reduce the risk of Salmonella infection in both pigs and humans are needed and several countries have started with its implementation. These control strategies are merely based on neutralization of specific risk factors like (a) prevention of introduction of the pathogen to the farm, (b) prevention of transmission between units within an infected herd, (c) prevention of colonization of the pathogen within the host, (d) prevention of cross-contamination during transport, slaughter and product handling in the meat processing industry (VanderWolf et al., 2001a; VanderGaag and Huirne, 2002; Lo Fong Wong et al, 2004).

Prevention of introduction to a pig herd can (at least partly) be achieved by buying piglets that are not infected with Salmonella (e.g. SPF piglets) and maintaining a strict hygiene protocol for people and goods. Prevention of colonization can be induced by antimicrobial growth promoters (Baggesen et al., 1999), use of acidified drinking water (VanderWolf et al., 2001b) or by feeding fermented feed (VanWinsen et al., 2000, 2001). Acidification might have a direct toxic effect on the pathogens (VanWensn et al., 2000) while its effect on the micro flora in the gut and thus on the colonization and growth of Salmonella still is unclear (VanWinsen et al, 2001).

In the current study we examined the effect of acidified drinking water, acidified feed and an improved hygienic management on the level of antibodies in finishing pigs. Therefore, 36 herds were sampled 8 times within 2 years while the intervention measures were applied after the first year.

Materials and Methods Participating herds In March 2002, 50 farmers running a pig fattening herd were approached to participate in the study. The farmers obtained the feed of a specific feed mill (Hendrix UTD Feed, Lochem) and their pigs were slaughtered in a specific factory (Hendrix Meat Group, Meppel). During the study, 14 herds were withdrawn for various reasons (end of farming, change of feed supplier, decreasing interest and motivation).

Pig fattening herds (n = 36) were followed over a full period of 2 years (March 2002–March 2004). Blood samples were taken four times a year at regular intervals at the slaughter line from 15 randomly selected fattening pigs. Samples were collected immediately after bleeding and sent to the Animal Health Service to determine the level of Salmonella antibodies by an indirect ELISA using LPS antigen of S. Typhimurium and S. Livingstone (VanderWolf et al, 2001c) that represent over 90% of all S. enterica serovars found in Dutch finishing pigs (VanderHeijden et al, 1998). S/P
ratios (Sample to Positive control) were calculated for each sample using optical densities (OD %). Based on the average S/P of the 60 samples taken in the first year, the herd was assigned a *Salmonella* status. Herds with status 1 had an average S/P below 0.10 (low infection level), herds with status 3 (high infection level) had an average S/P higher than 0.40, while status 2 herds were in between (moderate infection level).

After the first four samplings, herds were assigned to one of four groups with different control strategies. One group consisted of all 11 herds that had status 1; in this group no control strategy was implemented. The other herds were assigned to three treatment groups.

Treatment consisted of improving hygiene and management, 5 herds, by using a HACCP based *Salmonella* controlling program, acidified feed, 10 herds; 0.85 % Selko®-RAMF; mixture of Formic acid and Ammoniumformate) or acidified drinking water, 10 herds; 0.2 % Selko-pH®; mixture of Formic acid and Ammoniumformate; acetic acid). Assigning herds to treatment groups was not fully random, e.g. herds with stainless steel or PolyVinylChloride waterworks were preferentially assigned to the acidified water group because of insensitivity to acidulous corrosion.

**Herd visits** In March 2003 and March 2004 all participating herds were visited by technical advisors. In March 2003, samples were taken from feed, water and the environment of all status 2 and status 3 herds (treatment groups only). Faecal samples were taken at both visits from 2 pigs out of each age group (less than 1 week old, 1-2 weeks old, 8-10 weeks old and 14-16 weeks old) in all 37 herds. The herds classified with an average *Salmonella* titre above OD% 10 were advised which critical control point have to been taken to control *Salmonella*.

**Bacteriological analysis** Faecal samples consisted of 30 separate droppings that were pooled to one sample and that were cultured and analyzed by VIDAS 30 (NEN-ISO 6579) for presence of *Salmonella*.

**Performance parameters** The following performance parameters were collected and analysed: mortality rate during fattening, final weight, growth per day, feed conversion and energy conversion.

These parameters were collected 3 times: once in the first year (pre-treatment) and 2 times during the treatment period.

**Statistical analysis** Parametric models were evaluated with SAS 8.0 (ref), non-parametric analyses were carried out with STATA 8.0/SE (StataCorp, 2003).

A one-sided non-parametric test (sign test) was used to analyze the effect of treatment on the average S/P ratios before and after initiating the treatment (the average was calculated for the 60 samples before treatment and for the 60 samples after treatment for each herd). The null hypothesis was that the median of the difference is equal to zero, while the alternative hypothesis was that the difference is larger than zero.

A mixed general linear model was used to analyze whether the S/P ratio of each sampling after initiating the treatment was affected by treatment while the average S/P ratio before treatment was forced into the model and while adjusting for a herd effect.

**Results** The average S/P ratio per group is depicted in Figure 1. Status 1 herds showed a low S/P ratio during the first four samplings (by definition) and were able to retain the low level in the second year, though the highest average value is measured at the final bleeding.

Treatment groups showed a decline in average S/P ratio after the treatments were implemented (Figure 1, Table 1) which was significant for the acidified feed group and acidified water groups (Wilcoxon signed-rank test: P < 0.05). A calculation of the *Salmonella* status of the 3 treatment groups by using the Danish status classification during the treatment period showed that all the farms improved their status from status 2 and 3 to status 1.

Herd that tested faecal culture positive had significantly higher average log-transformed S/P ratios (LSMEANS of 2.1 versus 1.6, p < 0.05, residuals normally distributed) at the last sampling when the herd culture status (15 culture positive, 22 negative) was based on all age groups.

Farmers which purchased *Salmonella* positive piglets have had a signifi-
cant higher S/P ratio than herds that purchased negative piglets (45 positive, 87 negative).

When technical results were compared between treatments (Table 3), a decrease in FCR and an increase of the daily gain due to water acidification was shown (not statistically significant). This was in contrast with the acidified feed group which showed an increase in FCR and a decrease in daily gain (statistically significant). The control group and the hygiene group showed no difference in daily gain and a reasonable higher FCR. The technical results where translated into a net decrease of gross margin per pig compared to the untreated control group previous year (Table 3). For the farms using acidified water, the net gross margin was translated to 2,53/pig after correction for costs for the acid and the dosing equipment.

**Discussion** The current study was designed to quantify the effect of improved hygiene and acidified feed and drinking water on antibody levels against *Salmonella*. Also the effect of treatment on *Salmonella* status and on performance was assessed. Thirdly, a group of herds that showed low S/P values without any treatment was followed over time. It showed that the majority of the herds in this group could maintain this low level for longer periods.

The average S/P of the treatment groups was very similar at the last sampling before treatment started (Figure 1) and thus the pre-treatment infection levels can be considered as comparable.

The average S/P value remained low in Status 1 herds while *Salmonella* frequently was isolated indicates that somehow it can be prevented that the average antibody titre increases.

Due to the acidified feed, water and hygiene measures the *Salmonella* status of the herds decreased according to the Danish classification method (Table 1k). However, the number of herds that were positive after faecal culture was about the same in the treatment and pre-treatment period, indicating that *Salmonella* is continuously present at the farm. Colonization of hosts might then be prevented by lower levels of exposure or to a inhibitory effect of the acidic formulae in the other groups (van Winsen et al, 2000). In their study the use of whey, containing organic acids, also reduced the average S/P value.

Differences between treatment groups regarding the performance parameters were minimal which can be expected as the S/P values of all 3 groups were comparable and most likely no large differences in infection level, potentially leading to differences in performance, were present.

Because of the fact that the amount of acid consumed daily by the feed treatment group was higher than the water treatment group, there was a clear negative effect on daily gain, FCR and feed intake. Probably the high levels of formic acid or formate salts can lead to adverse intake effects and so negatively influence daily gain and FCR.

The water acidified group showed better performance despite the higher summer temperature in the treatment period in contrast to the previous treatment period.

**Conclusion**

- Acidification of water and feed reduce the *Salmonella* titre of fattening pigs significantly.
- Non–significant reduction of *Salmonella* titre can be obtained by strict hygiene measures.
- Application of Selko-pH® via drinking water is the most effective method to decrease *Salmonella* infection, to improve the *Salmonella* status and the technical results at farm-level.
- Use of high levels of formic acid and/or formate salts in the feed probably has a negative effect on the feed intake.
- Purchase of *Salmonella* positive piglets increased the *Salmonella* prevalence at slaughter.
- *Salmonella* status classification based on height of the *Salmonella* titre lowered the amount of excreted pigs at slaughter time so less chance tot contaminate the slaughtering process.
- Acidification of drinking water with Selko-pH® improved daily gain and FCR, such that a net benefit of 2,53 per fattening pig resulted for the farmer.

**References**

<table>
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<tr>
<th>Additional measures on farm-level</th>
<th>Before controlling</th>
<th>After controlling</th>
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<tr>
<td></td>
<td>Farms in Danish status 1</td>
<td>Mean <em>Salmonella</em> titre (O.D.%)</td>
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<tr>
<td>Control Farms (status 1)</td>
<td>100%</td>
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<td>Hygiene</td>
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<td>Acidification Feed</td>
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Table 2: *Salmonella* status based on the Danish classification method and average S/P ratios over all pigs sampled in the year before and after implementation of the treatment.


Table 3: Influence of technical and economical result before and after implementation of the treatment.

<table>
<thead>
<tr>
<th>Technical influence</th>
<th>Treatment group</th>
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<th>After Treatment</th>
<th>Difference</th>
<th>Economic influence / pig</th>
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<td>770</td>
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<td>Correction control farms</td>
<td>Costs of acids + dosing equipment</td>
<td>Total effect of treatment on gross margin / pig</td>
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