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Associations between the proportion of *Salmonella* seropositive slaughter pigs and the presence of herd level risk factors for introduction and transmission of *Salmonella* in 34 Danish organic, outdoor (non-organic) and indoor finishing-pig farms

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Abstract

This paper evaluates the association between herd level risk factors for introduction and transmission of *Salmonella* in farms with three different production systems: organic, outdoor (non-organic) and indoor finishing-pig farms, and the presence of seropositive animals in the herds. Potential risk factors for *Salmonella* in the three pig production systems were identified through a literature review, and management information as well as serological data were collected in 34 pig farms: 11 organic farms, 12 outdoor farms, and 11 indoor farms. There were no general differences in the proportion of *Salmonella* seropositive animals in the organic, outdoor, and indoor pig farms. Correspondence analysis showed that the occurrence of seropositive animals in the herds was mostly associated to the risk of introducing *Salmonella* in the herds by purchasing and transporting growing pigs. No associations between herd risk factors for transmission and survival of Salmonella and seropositive animals in the herds were found.

Key words: Correspondence analysis; organic production; pig production system; risk factors; *Salmonella* seroprevalence

1. Introduction

Pork and pork products are recognized as one of the major sources of human salmonellosis (Wegener and Baggesen, 1996; Lo Fo Wong et al., 2002). Each link in the food chain has its share of responsibility for reducing the risk of food borne diseases (Davies and Funk, 1999). Davies et al. (1999), and Quessy et al. (2005) showed that infection during the finishing phase in the herd is the major source of *Salmonella* found in slaughter pigs. In order to control *Salmonella* in pigs we need to quantify possible risk factors and develop effective management strategies in pig herds.

Organic pig production in the European Union is affected by EU-regulation 1804/1999, which was implemented in 2000 (Anon., 1999). Pigs in organic and outdoor (non-organic) production systems benefit from a low animal density, access to outdoor area, and good conditions for expressing normal behaviour such as locomotion, foraging, exploration and nest building. Further, organic production differs from conventional production in terms of e.g. feeding, weaning age and use of preventive medication (Bonde and Sørensen, 2004). Access to outdoor area might increase the risk of contact with contaminated soil or wildlife and thereby increase the risk of *Salmonella* (Jensen et al., 2004). So it is therefore likely that the risk of *Salmonella* is different in organic, outdoor, and indoor pig productions.

The purpose of this paper is to identify potential risk factors and further to evaluate the association between herd level risk factors for introduction and transmission of *Salmonella* in organic, outdoor and indoor pig production systems, and the occurrence of seropositive animals in the herds.

2. Potential risk factors

The risk of *Salmonella* can be related to introduction of the pathogen in the herd, transmission among the pigs in the herd, and survival of Salmonella in the individual pig, respectively. Several studies, mostly in indoor pig units have identified possible risk factors for *Salmonella* infections, where risk factor is defined as a factor that is associated with either an increase or a decrease (protective factor) in the probability of occurrence of Salmonella infection in the herd (Toma et al., 1999).

2.1. Introduction of Salmonella in the herd

Common routes for introduction of *Salmonella* in a pig herd are through purchased pigs, other animals on the farm, wild fauna, or feed.

2.1.1 Purchased pigs

Fedorka-Cray et al. (1997) showed that *Salmonella* might be introduced through infected pigs added to the herd. Van der Heijden et al. (2005) found that purchase of *Salmonella* positive piglets increased the *Salmonella* prevalence at slaughter. Berends et al. (1996) showed that *Salmonella* imported from the breeding farm probably played a role in about 1-10% of all finishing period infections. Cook and Miller (2005) reported that pigs from breeder-finisher units had a lower risk of testing seropositive for *Salmonella* compared to pigs from specialised finishing herds (OR=0.59) in a study including 1806 farms. Lo Fo Wong et al. (2004) reported that pigs in herds recruiting from more than three supplier herds had three-times higher odds to test seropositive than pigs in herds which bred their own replacement stock or recruited from a maximum of three supplier herds. Likewise, Quessy et al. (2005) found that the odds were lower with one source of finishing pigs than with two or more sources (OR=0.31). There is consensus among authors that the purchase of pigs from infected herds is a risk factor for introduction of *Salmonella*.

2.1.2 Transport

During transportation, pigs are subjected to many stress factors, e.g. noise, smells, mixing with unfamiliar pigs from other rearing pens or farms, high stocking densities, long duration of transport, changes in environmental temperature and a general change of environment (Warriss et al., 1992). Stress can induce carriers to shed *Salmonella* at a higher rate and increase the susceptibility of *Salmonella*-free pigs to infection (Mulder, 1995; van Winsen et al., 2001). Davies et al. (2000) reported that the prevalence of *Salmonella* was higher in faecal samples from gilts after arrival at the breeding farm than before transport; with serotype profiles indicative of both increased *Salmonella* shedding after transport and occurrence of new infections after introduction in the breeding herd.

2.1.3 Contacts (Rodents, wild birds, and cats)

Wild fauna as well as other domestic animals living on the farm or in the surrounding environment may introduce and transmit *Salmonella* through direct contact with the pigs, or by faecal contamination of feed or farm equipment.

Rodents are known to be carriers of *Salmonella* (Leirs et al., 2004). Letellier et al. (1999) reported that some rodents in contaminated pig farms were *Salmonella* positive. Meyer et al. (2005) showed that in outdoor farms, increasing intensity of rodents and birds constituted a risk factor for testing *Salmonella* seropositive. Harris et al. (1997) reported that the presence of wild birds was associated with a higher risk of *Salmonella* contaminated feed on the farm. Barber et al. (2002) found that 5% of mice intestine samples and 8% of bird faecal samples were positive for *Salmonella*.

Nollet et al. (2004) found a lower *Salmonella* prevalence (19% versus 80% of lymph node samples) in herds where a cat could enter the pig units. The result is in line with a study by Veling et al. (2002) in dairy herds. Those authors ascribed the lower prevalence to the role of cats as predator of rodents and birds carrying or excreting *Salmonella*. However, Evans and Davies (1996) identified cats as a risk factor in cattle herds because the cats were potential carriers. Rodents and wild birds are potential risk factors for *Salmonella*, while there is no consensus among authors if the presence of cats is a risk factor for *Salmonella*.

2.1.4 Purchased or homemade feed

Cook and Miller (2005) reported that farms feeding home-mixed rations had a lower seroprevalence of *Salmonella* (OR=0.77) in a study including 1806 farms. On the other hand, Harris et al. (1997) found a higher prevalence of *Salmonella* contaminated homemade feed than purchased feed on-farm. The quality and hygiene of the homemade feed might be varying in the studies, and further Harris et al. (1997) investigated only 30 farms. Purchased feed might constitute a risk of introducing *Salmonella* in the herd.

2.2. Transmission of Salmonella within the herd

2.2.1 Floor type

Cook and Miller (2005) found that pigs from farms with solid floor had an increased risk of *Salmonella* infection measured on meat juice ELISA (OR=4.59) in a study including 1806 farms. Davies et al. (1997) and Nollet et al. (2004) suggested that a fully slatted floor was protective because faeces from pigs housed on fully slatted floors immediately flows away in the manure pit. Nollet et al. (2004) reported 100% herd prevalence of *Salmonella* cultured from mesenteric lymph nodes in herds with solid or partially slatted floors compared to 54% herd prevalence in herds with fully slatted floors in a study with 62 herds. Meyer et al. (2005) agreed that partially slatted floors caused a higher risk of *Salmonella* antibodies in fattening pigs than fully slatted floors (OR=1.72). On the other hand, van der Wolf et al. (2001a) found no risk associated to different types of floor. However, most authors agree that solid floor and partially slatted floor cause a higher risk for *Salmonella* than fully slatted floor.

2.2.2 Bedding material

Small et al. (2003) showed that the in-vitro survival rates of *S. kedougou* were higher in deep litter than for hide, concrete, and metal. However, Hamilton et al. (2005) did not find a greater risk of *Salmonella* infection in pigs in deep litter systems compared to traditional concrete floor systems. As an indication that straw may have a protective value against *Salmonella*, Spoolder et al. (2000) reported that straw bedding helped to keep pens and pigs cleaner (59% versus 77% clean floor area for solid floor without straw and solid floor with straw, $P<0.001$). Furthermore, they showed that pigs housed without straw spent more time on potential risk behaviours such as oral manipulation of the pen walls, dung or pen mates, compared to pigs housed in straw-bedded pens. With the present knowledge it is difficult to conclude about the effect of straw on *Salmonella*.

2.2.3 Pen separation

Pigs, which were able to have snout contact with pigs in neighbouring pens (because pen separations were either open or too low) had 1.7-times higher odds to test seropositive for *Salmonella* compared to pigs for which such contact was prevented (Lo Fo Wong et al., 2004). Proux et al. (2001) reported similar results in experimentally inoculated pigs. Dahl et al. (1996a) showed that closed pen separations posed a barrier, which prevented faecal spread between adjacent pens and thereby spread of infection. Contrary to this, Meyer et al. (2005) found that separation between pens did not seem to affect the *Salmonella* seroprevalence in conventional slaughter pigs. However, most authors agree that snout contact between pigs is a risk factor compared to closed partitions between pens.

2.2.4 Herd size

Van der Wolf et al. (2001a) showed that small herds (less than 800 finishers/year) were associated with a higher *Salmonella* seroprevalence than larger herds. In contrast to that, Dahl (1997), Carstensen and Christensen (1998) and Kranker et al. (2001) reported that an increased herd size imposed a risk of increased *Salmonella* seroprevalence. Mousing et al. (1997) found that the proportion of serologically positive meat-juice samples ranged from a mean of 2.9% in small herds (101–200 swine slaughtered per year) to 6.1% in large herds (more than 5000 swine slaughtered per year). It is difficult to conclude about the effect of herd size on *Salmonella*. Moreover, herd size may affect other risk factors such as purchase of animals and hygiene practice.

2.2.5 Stocking density

Funk et al. (2001) reported that higher space allowance (more than 0.75 m^2 per pig) was associated with a reduced *Salmonella* prevalence in faecal samples (OR=0.22). Also pen size and group size might affect the risk of *Salmonella* infection due to the effect on possible contacts between pigs. However, we found no reports on this in the literature.

2.2.6 Water supply

Jensen et al. (2004) detected *Salmonella* in water samples from water bowls. Feder et al. (2001) also reported that *Salmonella* were detected in 63% (15 of 24) of the water samples, collected from water bowls or mud holes. Water bowls or drinking troughs might pose a higher risk for being contaminated by faeces compared to water nipples and thereby be a risk factor for *Salmonella*.

2.2.7 Mix fatteners

Mixing of the fattening pigs can result in more shedding of *Salmonella* because of stress (Warriss et al., 1992; Mulder, 1995; van Winsen et al., 2001). Further, mixing increases the possible number of contacts between pigs and thereby the opportunities for transmission of *Salmonella*.

2.2.8 Batch production

Batch production of pigs according to the all-in/all-out principle can help prevent *Salmonella* cross-contamination between batches and allows for cleaning and disinfection between batches. Farzan et al. (2006) found that continuous production compared to all-in/all-out increased the risk of finding *Salmonella* in the individual pig (OR=2.3), and Lo Fo Wong et al. (2004) reported a similar protective effect of batch production as long as hygienic-lock facilities were also present in the herd (OR=0.27).

2.2.9 Cleaning of pens

Utensils contaminated with faeces can serve as a reservoir for *Salmonella* (Letellier et al., 1999; Gray and Fedorka-Cray, 2001; Feder et al., 2001; Small et al., 2003; Rajic et al., 2005; Bahnson et al., 2005). Berends et al. (1996) concluded that farm hygiene was an important risk factor for *Salmonella*. Beloeil et al. (2004) showed that presence of residual *Salmonella* contamination of the pen floor and pen partitions at the time of introduction of growing pigs was a risk factor for *Salmonella* infection. Meyer et al. (2005) found that lack of cleaning of the feeding system can be a risk of increased seroprevalence in conventional slaughter pigs (OR=2.47). Schmidt et al. (2004) reported that cleaning and disinfection effectively reduced the amount of culturable *S. enterica* in lairage pens. There is consensus among authors that lack of cleaning is a risk factor for *Salmonella*.

2.2.10 Disinfection of pens

Pearce (1999) reported that the use of disinfectant when cleaning pens between batches of pigs appeared to be protective against the occurrence of diarrhoea (OR=0.3). Mannion et al. (2005) found lower *Salmonella* prevalence in herds that always washed and disinfected compared to herds that only washed, and Roesler et al. (2005) showed that efficient disinfection procedures were effective in decreasing the contamination with *Salmonella*. Contrary to this, van der Wolf et al. (2001a) showed that the omission of disinfection after pressure washing a compartment as part of an all-in/all-out procedure was associated with a lower *Salmonella* seroprevalence. However, most authors agree that lack of disinfection of the pen prior to the introduction of new pigs is a risk factor for transmission of *Salmonella*.

2.2.11 Boots

Letellier et al. (1999) observed that caretaker boots might be contaminated with *Salmonella* in herds suffering from either clinical or subclinical *Salmonella* infections. Barber et al. (2002) and Rajic et al. (2005) reported that *Salmonella* were detected in 11% and 39% of boot samples respectively. On the other hand, Lo Fo Wong et al. (2004) concluded that changing clothes and/or boots when entering the herd did not reduce the *Salmonella* seroprevalence significantly. However, as part of hygienic-lock facilities combined with batch production (Lo Fo Wong et al, 2004), clean caretaker boots might contribute to reducing the risk of *Salmonella* infection.

2.3. Survival of Salmonella in the pigs

The feed influences the *Salmonella* survival in the gut of the pig through affecting the gastrointestinal environment (see e.g. review by Hansen, 2004). Further, the general disease resistance in the pigs may be of importance for the ability of the pigs to clean themselves from infection.

2.3.1 SPF, MS or Conventional herds

A Danish SPF (Specific Pathogen Free) herd is tested free of *Mycoplasma hyopneumoniae*, *Actinobacillus pleuropneumoniae* (most serotypes), *Brachyspira* (*Serpulina*) *hyodysenteriae*, toxin-producing *Pasteurella multocida*, *Haematopinus suis* and *Sarcoptes scabiei* var. *suis*. MS herds are tested free of the same agents as the SPF herds except *M. hyopneumoniae*. Conventional herds had a higher risk of *Salmonella* seropositive animals than SPF herds (Dahl, 1997; Stege et al., 1997). Kranker et al. (2001) found that *Salmonella* in weaned pigs were more likely to be found in pen samples from conventional herds and MS-herds compared to SPF herds. On the other hand Lo Fo Wong et al. (2004) did not observe any associations between health declaration and *Salmonella* seroprevalence in 359 finishing-pig herds.

2.3.2 Porcine Reproductive and Respiratory Syndrome

Wills et al. (2000) observed that weaned pigs inoculated with Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) as well as *S. choleraesuis* showed a higher level and duration of *Salmonella* shedding compared to PRRS negative pigs, especially if the pigs were also subjected to stress. This suggests that herds infected with PRRSV are more susceptible to *Salmonella* infections.

2.3.3 Pelleted or floury feed

Lo Fo Wong et al. (2004) investigated 359 European fattening-pig herds, and showed that pigs fed non-pelleted dry feed had a lower risk (OR=0.57) of *Salmonella* seropositivity, compared to pigs fed pelleted feed. Similar results were obtained in an epidemiological study of 1806 pig herds, where the risk of *Salmonella* was increased amongst herds fed a pelleted ration (OR=1.59) (Cook and Miller, 2005). These results are in line with other studies (Harris et al., 1997; Jørgensen et al., 1999; Meyer et al., 2005; O'Connor et al., 2005). There is consensus among the authors that pelleted feed is a risk factor for *Salmonella*.

2.3.4 Dry or wet feed

The risk of *Salmonella* shedding and seroprevalence in slaughter pigs is increased when dry feed (versus wet feed) has been provided during the fattening period (Farzan et al., 2006; Kranker et al., 2001; van der Wolf et al., 2001b; Beloeil et al., 2004).

2.3.5 Organic acid added to feed or water

Creus et al. (2005) found that a diet including 0.4% lactic and 0.4% formic acids significantly reduced the *Salmonella* seroprevalence compared to a diet without additives. This is in agreement with the results from other studies adding organic acid to feed or drinking water (van der Wolf et al., 2001a,b; van der Heijden et al.,

2005) However, Dahl et al. (1996b) and Hansen et al. (1999) failed to reduce the *Salmonella* seroprevalence in pigs by adding organic acid to feed or water in the finishing period. The reason may be the differences in acid dose or infection level.

2.3.6 Roughage

Hansen (2004) observed that 10% dried sugar beet pulp reduced the incidence of *Salmonella*-positive finishers. Prohaszkal (1991) reported that feeding of silage containing low concentrations of basic matters (ammonia, basic amino acids, biogenous amines) increased the function of defense mechanisms to such an extent that it ensured an adequate protection against *Salmonella* infections. Olsen (2001) showed that pigs with access to roughage (wholecrop silage of barley and peas) spent less time in oral behaviour directed towards pen hardware, dung, and outdoor floor, compared to pigs without access to roughage. Jensen and Jørgensen (1994) and Jensen et al. (1995) found a lower pH in the caecum content in pigs fed a high fibre diet. Roughage is considered to be beneficial to the gastrointestinal function and may reduce *Salmonella* infection.

3. Materials and methods

3.1. Pig herds in the survey

Eleven organic pig farms, 12 outdoor (non-organic) pig farms, and 11 indoor pig farms were recruited for the survey among a random sample of 110 farms with different production systems (21 organic, 38 outdoor and 51 indoor herds) supplying slaughter pigs to two Danish abattoirs. The organic pig production systems were characterised by outdoor housing of sows and suckling piglets on pasture. After weaning at 7-8 weeks of age the pigs were generally moved to indoor pens with access to an outdoor area. However, some of the farms postponed the time of moving the pigs from pasture to the indoor system till later in the fattening period when the pigs weighed 30-80 kg. The outdoor (non-organic) pig production systems also kept sows and suckling piglets on pasture. After weaning at 3-4 weeks of age the pigs were moved to indoor pens with access to an outdoor area. The indoor herds all used indoor systems without access to an outdoor area.

3.2. Collection of data regarding system and management in the herds

Research technicians from the Danish Institute of Agricultural Sciences completed a management questionnaire in personal interviews with each herd owner during 2004 and 2005. The questionnaire included 48 questions, 37 of these addressed the risk factors described in Section 2, eight questions regarded herd characteristics (overall production system, system design, herd type, other livestock species on-farm, pig breed, general health, herd size), and three questions concerned details about feeding system, feed ingredients and ration. Most of the questions were closed (e.g. yes/ no), some of them were semi-closed (e.g. number of animals), and a few of them were open-ended.

3.3. Collection and analysis of meat juice samples

Meat samples from on average 45 (range 20-60) randomly chosen slaughter pigs from each herd were collected at the abattoir in 2-6 batches of ten slaughter pigs per herd distributed throughout the period January 2005 – January 2006. The meat sample from each pig was frozen, and meat juice (harvested after thawing) was examined for specific antibodies against S. enterica using an indirect enzyme-linked immunosorbent assay (ELISA). The ELISA combined several S. enterica O-antigens, and allowed detection of antibody response after a variety of different S. enterica serovar infections (Nielsen et al., 1998). Samples with an OD%>10 were identified as seropositive.

3.4. Statistical analysis

Multiple correspondence analyses linked to system factors, and risk factors for introduction of *Salmonella*, transmission of *Salmonella* within the herd, and survival of *Salmonella* in the pigs, respectively were carried out using the PROC CORRESP procedure of SAS (Statistical Analysis System, version 8) (Anon., 1998). The main result of a correspondence analysis is a two-dimensional plot of the associations between qualitative explanatory and outcome variables. The two axes are factorial axes reflecting the most variability in the explanatory variables. The plot identifies clusters of associated variables, with clusters farther from the intersection of the axes having stronger associations. The explanatory variables with quality values less than 0.15 in the analysis were not included in the analysis. The management parameters listed in Table 1 were included as explanatory variables for introduction, transmission and survival of *Salmonella*. The risk of introducing Salmonella associated to the number of supplier herds could not be analysed as only one herd got pigs from more than three suppliers. Further many producers lacked knowledge of the Salmonella status in their supplier herd(s) so this could not be included in the analysis. The analysis using system factors as explanatory variables included overall production system (organic; conventional outdoor; indoor), herd size (small: less than 1100 slaughter pigs per year (25 % quartile); medium sized: 1100-3100 slaughter pigs per year (25-75 % quartiles); or large: more than 3100 slaughter pigs per year) and herd type (integrated sow herd with own fatteners; herd with pigs from weaning to slaughter; or fattening herd with pigs from 30 kg to slaughter). The presence of other livestock species on-farm was not included in the analysis, and neither was the pig breed due to the common use of complicated hybrid breeding systems, and the fact that many producers with specialised finishing herds were not aware of the actual breed of their pigs. The outcome variable was defined as the proportion of seropositive meat juice samples in the herd. Low-Salmonella herds had less than 2.1 % seropositive animals (25 % quartile), medium-Salmonella herds had 2.1-10 % seropositive animals (25-75 % quartiles), and high-Salmonella herds had more than 10 % seropositive animals. Differences between the production systems in the proportions of Low-, medium-, and high-Salmonella herds were tested using a Chi-test.

(INSERT TABLE 1)

4. Results

The herd occurrence of seropositive animals in organic, outdoor, and indoor herds, respectively is shown in Figure 1. The median within-herd seroprevalence was 5.1% seropositive animals (range 0-39 %). There was no significant difference in the distribution patterns for the three production systems (Chi-test, P=0.41).

(INSERT FIGURE 1)

The result from the correspondence analysis of system factors is shown in Figure 2. The first two dimensions accounted for 52.7 % (26.4% and 26.3%, respectively) of the spatial variation in the data. The variables that had the highest partial contributions to the variability were organic herds (0.22), outdoor herds (0.20), herds with pigs from weaning to slaughter (0.19), and large herds producing more than 3100 fattening pigs per year (0.16) for dimension 1; and indoor herds (0.33), and specialised fattening herds (0.29) for dimension 2. A medium or high proportion of seropositive animals seemed to be associated to medium sized herds (1100-3100 fattening pigs per year). A low proportion of seropositive animals seemed to be associated to integrated herds.

The result from the correspondence analysis including risk factors related to introduction of *Salmonella* in the herd is shown in Figure 3. The first two dimensions accounted for 61.2% (40.6% and 20.7%, respectively) of the spatial variation in the data. The variables that had the highest partial contributions to the variability were no contact to wild birds (0.13), indoor herds (0.11), purchase of sows (0.11), and no contact to rats (0.11) for dimension 1; and outdoor herds (0.31), purchase of ready-mixed feed (0.22), and feeding with home-mixed feed (0.15) for dimension 2. A medium or high proportion of seropositive animals seemed to be associated to purchase of pigs combined with no purchased sows, and transport of pigs, while a low proportion of seropositive animals seemed to be associated to no purchase or transport of pigs. Organic herds were in general less likely to purchase pigs; the indoor herds did not get into contact with wild birds but their pigs were more likely to be transported; and the outdoor herds were more likely to use ready-mixed feed.

(INSERT FIGURE 2 and FIGURE 3)

The correspondence analysis related to transmission of *Salmonella* in the herd included: ‘Snout contact between pens’, ‘stocking density’, ‘floor type’, ‘drinker type’, ‘moving of fatteners’, and ‘cleaning of pens’, as the risk factors ‘continuous production’, ‘mixing of fatteners’, ‘no disinfection’, and ‘no cleaning of boots’ had to be excluded from the correspondence analysis due to low quality values. The result of the analysis showed that the first two dimensions accounted for 43.3% (24.3% and 19.0%, respectively) of the spatial variation in the data. The variables that had the highest partial contributions to the variability were indoor herds (0.18), high stocking density (0.17), and slatted floor (0.12) for dimension 1; and outdoor herds (0.15), medium stocking density (0.16), no cleaning (0.17), and organic herds (0.16) for dimension 2. In the analysis of the risk factors related to the survival of *Salmonella* in the pigs the risk factor ‘health status’ was excluded from the analysis based on a quality value less than 0.15. The analysis showed that the first two dimensions accounted for 52.5% (31.6% and 20.9%, respectively) of the spatial variation in the data. The variables with the highest partial contributions to the inertia were organic herds (0.21), roughage (0.21), and acid added to feed or water (0.14) for dimension 1; and indoor herds (0.26), wet feed (0.21), and pelleted feed (0.13) for dimension 2. The analyses did not show any associations between the risk factors for transmission and survival of *Salmonella* and the proportion of seropositive animals. In general the organic herds were less likely to do a thorough cleaning of pens between groups of pigs, but the pigs favoured from low stocking densities and provision of roughage. The outdoor herds were more likely to wash or do a mechanical cleaning of the pens between groups of pigs, and their pigs were housed with medium stocking density in pens without snout contact to neighbouring pens. Further, the outdoor herds were more likely to use pelleted feed, and to add organic acid to the feed or water. The indoor pigs were less likely to be moved during the fattening period. They were often housed at a high stocking density in pens with slatted floors that were typically cleaned between groups of pigs.

5. Discussion

Our results showed no general differences in the proportion of *Salmonella* seropositive animals in organic, outdoor, and indoor pig farms. The result is consistent with Ledergerber et al. (2003), who reported that there was no statistically significant difference in *Salmonella* infections between conventional and animal-friendly farms in Switzerland. In contrast to this, Jensen et al. (2004) found that seroprevalence data indicated a higher prevalence of *Salmonella* in outdoor than conventional indoor pig production system, and in a survey by Hald et al. (1999) the proportion of pigs from organic production systems testing positive for antibodies against *Salmonella* was not different from pigs reared in indoor production systems, while the proportion of antibody positive pigs tended to be higher in conventional outdoor production systems. Outdoor pigs are exposed to the surrounding environment, and this may cause an increased risk of *Salmonella*. However, our survey suggests that the exposure effect may be counteracted by different hygiene, management, and feeding practices, and indeed Meyer et al. (2005) reported that conventional slaughter pigs (13% of 2270 pigs) were significantly more likely to be seropositive than organic pigs (1.9% of 372 pigs).

We have used multiple correspondence analysis to get a graphic description of the relationship between qualitative herd risk factors for *Salmonella*, and their associations with the proportion of seropositive animals in the herds. The proportion of seropositive animals in the herds seemed mostly associated to the risk of introducing *Salmonella* in the herds by purchase and transport of growing pigs, while integrated herds were less likely to become infected. This has also been reported by e.g. Cook and Miller (2005). Contrary to the expected, the hygiene and feeding measures employed to affect the transmission of *Salmonella* within an infected herd did not seem important to the occurrence of seropositive animals. A relatively small number of herds participated in our survey, and overall the prevalence of seropositive animals in the herds was rather low. This may explain why it was not possible to adequately differentiate between medium and high prevalence of seropositive animals in the herds, as might be the result of different risk levels for transmission of *Salmonella*.

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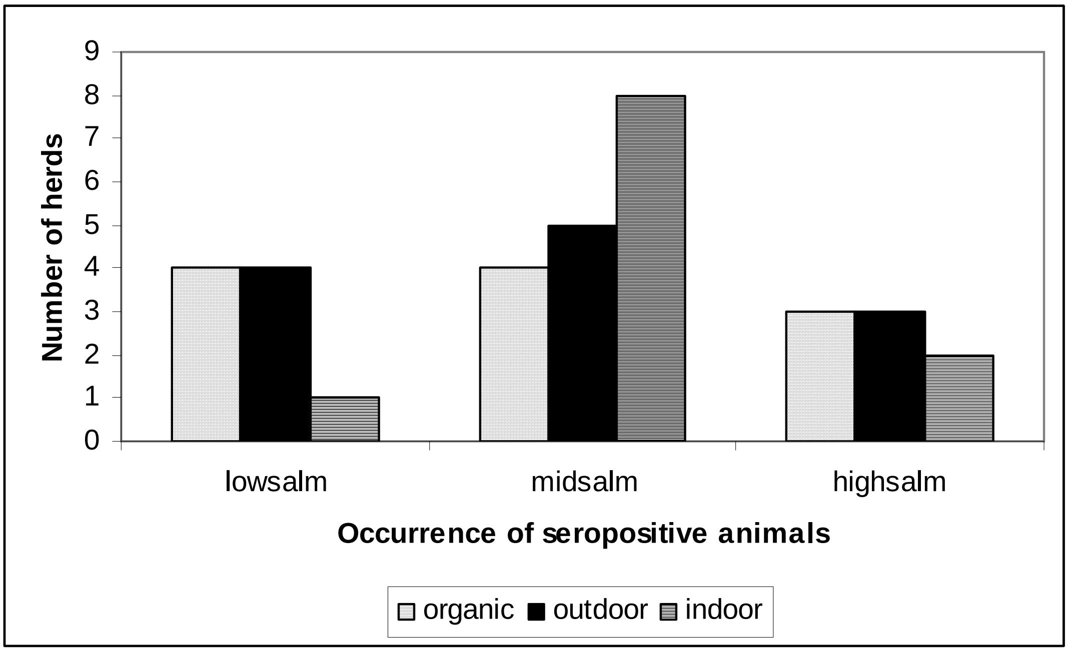

Figure 1. The distribution of organic, outdoor, and indoor herds according to the herd occurrence of slaughter pigs testing seropositive against *Salmonella* (Lowsalm: < 2.1 % seropositive animals; Midsalm: 2.1-10% seropositive animals; Highsalm: > 10 % seropositive animals).

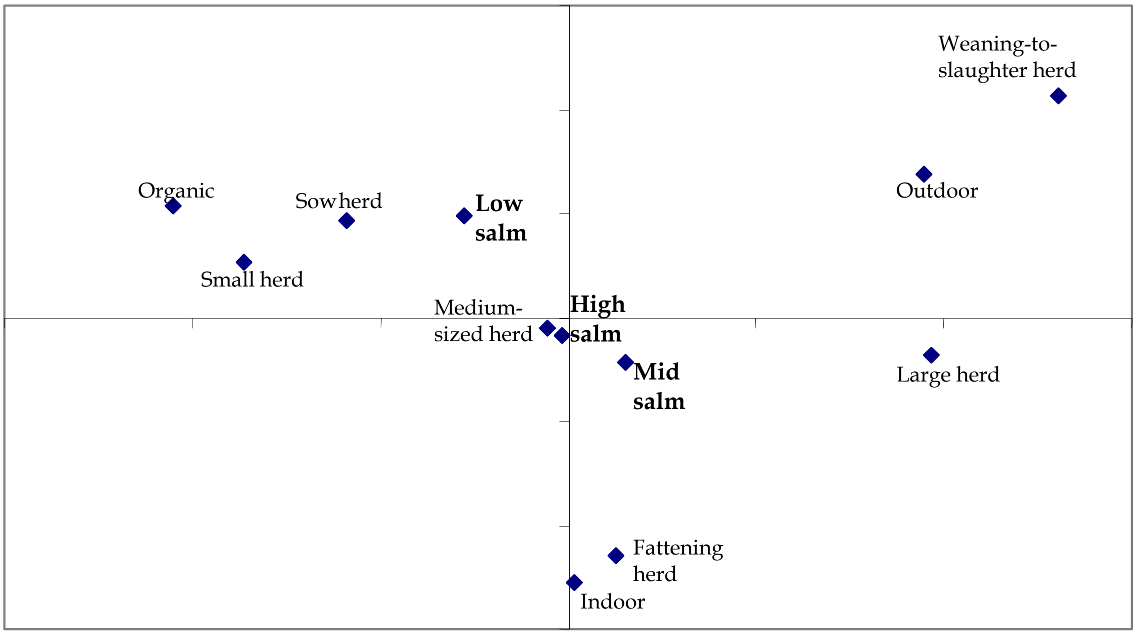

Figure 2. Plot of correspondence analysis results of the associations between herd occurrence of slaughter pigs testing seropositive against *Salmonella* (Lowsalm < 2.1 %; Midsalm 2.1-10%; Highsalm > 10 %) and farm characteristics in 34 Danish pig herds. Dimension 1 in the analysis is illustrated as the horizontal axis, and dimension 2 is illustrated as the vertical axis.

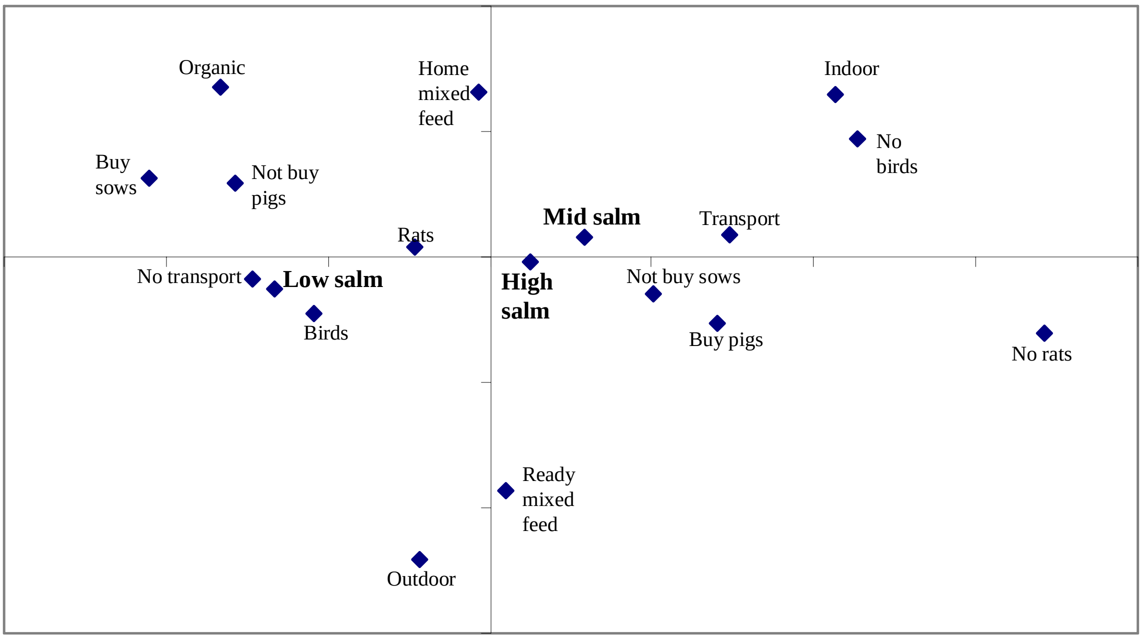

Figure 3. Plot of correspondence analysis results of the associations between herd occurrence of slaughter pigs testing seropositive against *Salmonella* (Lowsalm < 2.1 %; Midsalm 2.1-10%; Highsalm > 10 %) and risk factors for introduction of *Salmonella* in the herd in 34 Danish pig herds. Dimension 1 in the analysis is illustrated as the horizontal axis, and dimension 2 is illustrated as the vertical axis.

Table 1. *Salmonella* risk factors concerning introduction of *Salmonella* in the herd, subsequent transmission of *Salmonella* and survival and spreading of *Salmonella* from the pigs

	Risk factors
Introduction of *Salmonella* in the herd	Ready mixed feed (versus home mixed feed)
	Buying sows or pigs
	Transport of fatteners to other estate
	Contact to rats and wild birds
Transmission of *Salmonella* within the herd	Snout contact between pens (versus closed partitions between pens)
	High stocking density (<0.75 m^2 per pig) (versus medium or low stocking density)
	Solid or partially slatted floor or deep litter (versus fully slatted floor)
	Water bowl (versus drinking nipple)
	Continuous production system (versus all-in/all-out)
	Moving and mixing of fatteners
	No cleaning between batches (versus scrape, wash, high pressure wash)
	No disinfection (versus lime wash or disinfection)
	No washing of boots
Survival of *Salmonella* in the pigs	Conventional health status (versus SPF/MS)
	PRRS positive
	Pelleted feed (versus floury feed)
	Dry feed (versus wet feed)
	No organic acid added
	No supply of roughage