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Assessing and managing the risk posed by *Salmonella* in farm produced pig feed



Key external stakeholders:

Pig producers, pigmeat processors, feed manufacturers, policymakers, pig veterinarians

Practical implications for stakeholders:

Salmonella carriage in pigs is a significant food safety concern in Ireland and feed may have a role in transmitting *Salmonella* to pigs. The main outcomes/recommendations from this project are:

- Feed plays a role in the transmission of *Salmonella* to pigs, albeit *Salmonella* prevalence in pig feed and feed ingredients was low.
- Continued monitoring of feed ingredients and finished feed for the presence of *Salmonella* is therefore critical.
- Effective control measures are also important and data on heat tolerance of feed- and feed ingredient-derived *Salmonella* isolates obtained as part of the project, as well as information on survival during feed storage, will assist the feed industry and pig producers in implementing these.

Main results:

- *Salmonella* prevalence in pig feed sampled on-farm and feed ingredients and compound feed sampled at feed mills was relatively low, suggesting that feed is a relatively minor source of infection for pigs.
- However, the fact that indistinguishable strains of an emergent *Salmonella* serotype known to cause human illness were recovered from both feedstuffs and pig faeces sampled on the same farm and feed/feed ingredients sampled at feed mills is a cause for concern, particularly, as in one case the feed mill supplied the farm from which the related isolates were recovered.
- Therefore, the presence of *Salmonella* in pig feed must be considered an important risk factor for *Salmonella* in pigs.
- Pelleting reduced *Salmonella* prevalence and indicator bacteria counts in compound pig feed but did not completely eliminate contamination.
- This is in agreement with findings that feed- and feed ingredient-derived *Salmonella* isolates, while not appearing to be much more thermotolerant than *Salmonella* previously investigated, are likely to survive heat processing during feed manufacture.
- However, a sodium butyrate feed additive investigated as a potential control measure for stored pig feed was ineffective in reducing *Salmonella* during feed storage

Opportunity / Benefit:

The outcomes and recommendations from this project will assist pig producers in reducing *Salmonella* prevalence in pigs, thereby helping them to fulfil their obligations under the national pig *Salmonella* control programme. Data generated will also help to formulate policy on pre-harvest *Salmonella* control measures.

Collaborating Institutions:

WIT, DAFM

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External collaborators: Dr. Gillian Gardiner, Waterford Institute of Technology

1. Project background:

Salmonella carriage in pigs is a significant food safety concern in Ireland, with recent studies showing that up to 45% of pigs presented for slaughter carry *Salmonella*, while carcass contamination rates range from 15 to 20%. Feed is a possible risk factor for *Salmonella* transmission to pigs. The objective of this project was to assess the role of feed in transmission of *Salmonella* to pigs and to investigate potential control measures.

2. Questions addressed by the project:

1. Is *Salmonella* found in pig feed on-farm and if so, are the same strains found in pigs?
2. Is *Salmonella* found in pig feed and/or feed ingredients sampled from commercial feed mills and home compounders and if so, are the same strains found in pigs?
3. How heat tolerant are feed- and feed ingredient-derived *Salmonella* isolates and how effective is an organic acid feed additive in terms of reducing *Salmonella* in stored feed?

3. The experimental studies:

1. An in-depth study was conducted on 10 commercial pig farms with a history of high *Salmonella* seroprevalence in order to identify the production stages which were the principal harbours of *Salmonella* infection and to assess the occurrence of *Salmonella* in feed throughout these stages. Each farm was visited twice and a total of 2,975 samples, consisting of 926 faecal samples, 1,011 environmental samples (swabs from feed troughs, water drinkers and feed bins), 453 water samples (from header tanks, nipple drinkers and water troughs) and 585 feed samples (from feed bins, bags and hoppers), were taken across all production stages and analysed for the presence of *Salmonella*.
2. The next phase of the project involved testing feed ingredients and compound pig feed sampled from feed mills (five commercial feed mills and one home compounder), supplying the above farms, for the presence of *Salmonella*.
3. The last part of the project involved examining the survival of feed- and feed ingredient-derived monophasic variants of *Salmonella* Typhimurium in terms of their heat tolerance and ability to persist in stored feed treated with a sodium butyrate feed additive.

4. Main results:

1. *Salmonella* was detected in the pigs on nine of the farms. Overall, it was found in 14.9% of the faecal samples, 9.1% of the environmental swabs and 9.5% of the water samples. This was to be expected, considering that the farms selected for this study had a history of high *Salmonella* seroprevalence. The highest proportion of faecal *Salmonella*-positive animals was detected in 2nd stage weaners (22%), followed by finishers (20%) and gilts (19%). In total, 11 different *Salmonella* serotypes were recovered; 8 each from the pigs, environmental and water samples, and these varied depending on the sample type. Monophasic variants of *S. Typhimurium* (4,[5],12:i:-) predominated in all sample types. These variants are increasingly implicated as a cause of *Salmonella* food poisoning in humans.

Only 2.4% of feed samples taken across all production stages were *Salmonella*-positive. These originated on six farms and monophasic variants of *S. Typhimurium* (4,[5],12:i:-) were again the most commonly isolated. Six (43%) of the positive feed samples originated on farms using liquid feed with the remainder (8 samples or 57%) coming from farms where pigs were dry-fed. The *Salmonella*-positive feed samples were generally recovered at only one stage of production on each farm, although on one farm they were found in three stages (dry sows, farrowing and gilts) and on another *Salmonella* was found in both 1st stage weaner and finisher feed. Feed sampled from dry sows had the highest *Salmonella* prevalence. In order to establish if the *Salmonella* carried by the pigs originated in the feed, molecular typing of the *Salmonella* isolates was performed. On certain farms the isolates recovered from the feed were indistinguishable from those shed by pigs across several stages of production (i.e. they had indistinguishable molecular fingerprints). One of the monophasic *S. Typhimurium* variant strains recovered was isolated from 1st stage weaner pelleted feed sampled from a feed storage bin, indicating, at least in this instance, that *Salmonella* originated in the purchased feed. However, as all of the other *Salmonella*-positive feed samples originated in troughs within the animal pens, the possibility of on-farm contamination by the pigs is highly likely.

2. In the feed mill study, *Salmonella* was recovered from only two of the 340 feed ingredients analysed; wheat from one commercial mill and soybean meal from the home compounder, giving an overall

prevalence of 0.6% in the feed ingredients. It was also detected in three of the 313 compound feed samples analysed, giving a compound feed prevalence of 0.95%. The *Salmonella*-positive compound feeds were a dry sow meal and a dry sow pelleted diet, both sampled from the same feed mill and a finisher meal sampled from another mill. The proportion of meal feed samples contaminated with *Salmonella* was 1.6%, whereas only 0.5% of pelleted diets were contaminated. Like those recovered from the farms, all of the *Salmonella* isolates found in the feed ingredient and compound feed samples were monophasic variants of *S. Typhimurium*. Molecular typing showed that *Salmonella* strains recovered from feed ingredients and compound feed were indistinguishable i.e. one type was recovered from wheat as well as sow meal and pellets and another from soybean meal and finisher meal. However, although the ingredients and finished feed from which the same *Salmonella* types were recovered did not originate at the same mill, it is likely that consignments of contaminated feed ingredients had been shared between a number of mills.

Molecular typing was conducted to determine if any of the *Salmonella* strains recovered from the feed mill samples were the same as those found on the pig farms. This showed that two monophasic variant *S. Typhimurium* strains found in the feed ingredients and compound feed were indistinguishable from isolates recovered from both feed and pig faeces sampled on two of the farms. Of these, the *Salmonella* strain recovered from finisher meal sampled at one of the commercial mills had the same fingerprint as that of a strain recovered from finishing pigs (as well as 1st and 2nd stage weaners) and feed (1st and 2nd stage weaner and finisher) on a farm which was supplied with feed for the duration of the study by the same feed mill. As the feed mill isolate was recovered from feed aseptically sampled in the mill, there was no possibility of contamination on-farm or during transport. These data provide evidence that feed has a possible role to play in transmission of *Salmonella* to pigs.

Pelleting reduced *Salmonella* prevalence and indicator bacteria (*Enterobacteriaceae*) counts in compound feed but did not completely eliminate contamination. This, together with the fact that compound feed had higher *Enterobacteriaceae* counts than ingredients, suggests that post-process contamination is likely to have occurred within the feed mills.

3. The last part of the project examined the survival of the five feed- and feed ingredient-derived monophasic variant *S. Typhimurium* isolates recovered during the feed mill study in terms of their heat tolerance and ability to persist on stored feed treated with a sodium butyrate feed additive. There was considerable inter-strain variation in heat resistance, with decimal reduction (D)-values (i.e. the time taken to produce a 10-fold reduction in viable cell numbers) ranging from 397.83 to 689 sec at 55°C, 11.35 to 260.95 sec at 60°C and 1.12 to 6.81 at 65°C. One strain demonstrated a significantly higher thermal tolerance, even though it had been isolated from a meal feed. To our knowledge this is the first study to investigate heat tolerance of monophasic variants of *S. Typhimurium*. Overall, the results indicated that the strains studied, while not appearing to be much more thermotolerant than *Salmonella* previously investigated, are likely to survive heat processing during feed manufacture, as the D-values above were obtained in broth and are likely to be higher in feed. Indeed one strain may have survived heat processing, as it was isolated from a pelleted feed. For this reason, and because feed may become contaminated post-manufacture, the second part of the study investigated the efficacy of sodium butyrate in reducing the monophasic *S. Typhimurium* strains in pig feed during storage. While reductions in counts were obtained, they were minimal, also observed in the control feed (although to a lesser extent) and only observed at certain time points. This lack of efficacy may be due to the fact that the sodium butyrate additive used has a protective coating and its main mode of action is to prevent *Salmonella* invasion of host intestinal cells. Anti-*Salmonella* effects would perhaps therefore only be expected *in vivo* and consequently, the particular feed additive chosen appears unsuitable as an agent for feed treatment.

5. Opportunity/Benefit:

The relatively low prevalence of *Salmonella* in on-farm sampled feed and feed ingredients and compound feed sampled at feed mills, suggests that feed is a relatively minor source of infection for pigs. This is a welcome finding for feed manufacturers and pig producers. However, the fact that indistinguishable strains of an emergent *Salmonella* serotype known to cause human illness were recovered from both feedstuffs and pig faeces sampled on the same farm and feed/feed ingredients sampled at feed mills is a cause for concern. In one case the feed mill supplied the farm from which the related isolates were recovered. Furthermore, even minor *Salmonella* contamination in feed has the potential to affect many herds and may subsequently cause human infection. For these reasons the presence of *Salmonella* in pig feed must be considered an important risk factor for *Salmonella* in pigs. Therefore, continued monitoring of feed ingredients and finished feed for the presence of *Salmonella* is critical. Existing control measures should also be adhered to and/or new control measures put in place. In this respect, results from this project provide

an understanding of the behaviour of monophasic variants of *S. Typhimurium* in feed and feed ingredients and provide important baseline data which will assist the feed industry and pig producers in implementing effective intervention strategies for their control.

6. Dissemination:

Project outcomes have been successfully disseminated to stakeholders in the scientific community via three peer-reviewed papers in scientific journals (see below) and one PhD thesis. Oral and poster presentations have also been made at open days and national and international conferences as follows:

- 10th Safepork Conference, September 9th - 12th, 2013, Portland, Maine, USA (oral presentation and paper in proceedings).
- 4th ASM Conference on *Salmonella*: The Bacterium, the Host and the Environment, 5th-9th October, Boston, Massachusetts, USA (poster and abstract in proceedings)
- Agricultural Research Forum, March 12th, 2013, Tullamore, Co. Offaly (oral presentation and paper in proceedings)
- 42nd Annual Food Research Conference, June 27th, 2013, Teagasc Food Research Centre, Ashtown, Dublin 15 (oral presentation and abstract in proceedings)
- Waterford Institute of Technology Research Day, 29th April, 2013, Waterford (poster and abstract in proceedings)
- Safefood Knowledge Networks Conference 1st – 2nd May 2012, Belfast, Northern Ireland (poster and abstract in proceedings).
- Conference on Global Food Safety Solutions for Today and Tomorrow, 23rd – 25th October 2012, Blanchardstown, Dublin 15 (poster and abstract in proceedings)

Findings have also been disseminated to stakeholders such as pig producers, pig processors, feed manufacturers and policy makers at the following events:

- Teagasc Pig Farmers Conference, 21st -22nd October, 2014, Cavan & Tipperary (oral presentation and paper in proceedings)
- Teagasc Pig Research Dissemination Day 2015, 12th & 15th May, 2015, Moorepark and Cavan (oral presentation and paper in proceedings)

Main publications:

Burns, A.M., Lawlor, P.G., Gardiner, G.E., McCabe, E.M., Walsh, D., Mohammed, M., Grant, J. & Duffy, G. (2015). 'Salmonella occurrence and Enterobacteriaceae counts in pig feed ingredients and compound feed from feed mills in Ireland' *Preventative Veterinary Medicine* 121: 231-239.

Burns, A.M., Duffy, G., Walsh, D., Tiwari, B.K., Grant, J., Lawlor, P.G. and Gardiner, G.E. 'Survival characteristics of monophasic *Salmonella* Typhimurium 4,[5],12:i:- strains derived from pig feed ingredients and compound feed' *Food Control* (in press).

Burns, A.M., Duffy, G., Walsh, D., McCabe, E.M., Grant, J., Mohammed, M., Egan, J., Gardiner, G.E., and Lawlor, P.G. 'Assessing the role of feed as a risk factor for the transmission of *Salmonella* in Irish pig production' *Veterinary Microbiology* (submitted).

Popular publications:

Burns, A.M., Duffy, G., Gardiner, G.E., Lawlor, P.G. (2014). 'The Link Between Feed and *Salmonella*' *In Proceedings Teagasc Pig Farmers Conference, 21st -22nd October, 2014, Cavan & Tipperary.*

Lawlor, P., Burns, A.M., Gardiner, G. and Duffy, G. (2015). 'Assessing the role of feed as a risk factor for *Salmonella* in Irish pig production' *In Proceedings Teagasc Pig Research Dissemination Day 2015, 12th & 15th May, 2015, Moorepark and Cavan.*

7. Compiled by: Dr. Peadar Lawlor, Dr Geraldine Duffy and Dr. Gillian Gardiner