THE WHY'S AND HOW'S OF ELIMINATING CLINICAL SALMONELLA

Paul Schneider, DVM
Elite Swine Inc.
Landmark, Manitoba

ABSTRACT

Salmonella bacteria can be commonly found in the intestinal tracts of many animals including swine. These bacteria in food producing animals are of concern since the organisms may contaminate food products and cause clinical salmonellosis in humans. Salmonella can also cause disease in domestic animals, which is the focus of this paper. Reports of clinical diarrhea and deaths due to Salmonella have increased in recent years. The swine industry must maintain its focus on control and reduction of salmonella to minimize clinical disease and the risk of salmonella in the food chain.

BACKGROUND

Salmonellosis has been a concern in human and animal health for a long time. The main concern is its role in foodborne illness in humans. It can also result in clinical disease in livestock. This paper deals with the clinical disease in pigs as it has been seen recently in some Canadian herds.

Salmonella Facts

Salmonella is the name of the genus of a group of bacteria that can be found everywhere in the world. It can be found in the intestinal tract and other body areas of all vertebrate animals. These bacteria are classified by serotype, some of which are only found in one species of host animal. Salmonella bacteria of these specific serotypes are collectively called host-adapted serotypes. Examples of these are *Salmonella choleraesuis* in pigs and *Salmonella pullorum* in chickens.

More troublesome are some of the members of the more than 2000 non-species adapted salmonella serotypes. These can infect multiple host species, have been implicated in human disease, and are implicated in most food-borne salmonella infections. All serotypes can cause disease, however a small number appear to cause most of the salmonelloses seen in people and pigs. The most common Salmonella serotypes isolated from humans and animals are: *S. typhimurium*, *S. enteriditis*, *S. derby*, *S. infantis*, and *S. heidelberg.*

Salmonella are hardy and ubiquitous in the environment. They can multiply at 7 to 45°C, survive freezing and drying well and thus can survive outside all winter. The bacteria can survive for weeks, months, and even years in suitable organic material. For example, Salmonella has been reported to survive for 8 months in meat-meal fertilizer, and 47 days in manure storage lagoons. Survival is greatly hindered below pH 5.0. The bacterium is inactivated by heat and sunlight, and destroyed by most commonly used disinfectants.

The hardiness of the bacteria is not the only factor to contribute to its widespread presence in the environment. Following infection, animals are not able to rid themselves totally of the organism. A carrier state results that allows the Salmonella to be shed in manure for extended periods of time. For example, one study of *Salmonella typhimurium* infections in pigs showed that the organism could be isolated from the feces daily for the first 10 days post-infection, and then frequently for the next 5 months. Pigs were marketed 4 to 7 months after the initial infection; over 90% were positive for Salmonella in the mesenteric lymph nodes, tonsils, cecum, or feces.

Salmonella typhimurium is primarily an infection of the intestine, producing diarrhea. However, some serotypes are able to enter the bloodstream with ease, especially in stressed or immune-suppressed animals, and create a septicemia where the bacteria moves throughout the body and affects many organs. Affected pigs appear very sick and often die rapidly following the onset of clinical signs.

Salmonella infects animals mainly when the animals have oral exposure to fecal material. Probably most animals ingesting salmonella bacteria do not become visibly sick. Whether a pig becomes ill depends on a number of factors primarily: the amount of bacteria the animal is exposed to, the current state of the gut environment (e.g. pH levels) and stressors that influence the ability of the animal to resist disease.

Treatment Considerations

Treatment for salmonellosis can be problematic for several reasons. Firstly is the high variability in the antibiotic sensitivities among the many serotypes. Usually treatment in pigs involves using antibiotics such as ceftiofur, sulfa-trimethoprim, synthetic broad-spectrum penicillins, gentamycin, neomycin, or apramycin. Isolation of Salmonella early in the course of disease to allow testing for antibiotic sensitivity should be done in all cases. It is common to find resistance to some of the antibiotics that are normally recommended for use.

Another problem encountered in treatment is the apparent range of responses seen, even when testing indicates that the bacteria should be sensitive to the antibiotic used. This may be due to more than one serotype causing the problem. The other types might have a different antibiotic sensitivity pattern than the one isolated and tested. In other cases, the antibiotic appears to be slow in clearing out the problem because treatments may actually increase the level and duration of the carrier state. It has been shown that antibiotic treatment of infected pigs with intestinal salmonellosis did not reduce the duration and magnitude of bacterial shedding in the feces. It is worth noting that uncomplicated intestinal salmonellosis in humans may not be treated with antibiotics. Treatment is directed mainly at supportive therapy to counteract dehydration.

Treatment of the septicemic form of salmonellosis is necessary to prevent death, and to allow a faster and complete recovery. Pigs with septicemia need to be given medication as early as possible in the course of the disease since, with this form, pigs can die rapidly after the onset of signs of illness. In outbreaks, the pigs need to be checked frequently. Usually a broad-spectrum antibiotic is offered in the water to help susceptible pigs in the population deal with the organism early and decrease the chances of the infection progressing to the septicemic form. Culture and drug sensitivity tests are essential.

Control and Prevention Considerations

In an outbreak situation, a pig with diarrhea will massively contaminate its pen environment with bacteria in its feces and this is the single most important source of infection for other pigs. With hot strains where death losses add up quickly, I recommend antibiotic injections of all pigs in the pen, not just the sick ones. Preventive medication will protect the animals from disease symptoms (but not from infection).

Control of an outbreak also involves restriction of animal movement to prevent animals from tracking the bacteria around the barn on feet and skin, or the inadvertent movement of carrier pigs. Also control people movement and ensure that contaminated clothing and equipment that have been in contact with diseased pens do not contact healthy groups. Ensure that the water system is providing a good supply of clean water and that the water nipple flow rate is optimal. Scrape pens of sick pigs frequently but be sure that clothing is changed and hands are washed before going to healthy groups. Scrapers and shovels should be dedicated to pens with sick animals only, and washed and disinfected before using elsewhere.

Can a good biosecurity program prevent salmonellosis? Keeping all Salmonella out of a pig barn (or any group of animals) is a challenge and likely not possible. The organism is ubiquitous in the environment and exposure to one serotype or another is inevitable. Understanding the risk factors for Salmonella infection and disease is important.

Most, but not all, of the serotypes that pigs can encounter in the environment will only cause mild scours or even no signs at all. Others such as *Salmonella typhimurium* that can potentially cause more severe problems are more likely to come onto your farm in the intestines of a pig or any other vertebrate animal. Transportation vehicles, equipment or people from other farms, packing plants, collection yards, auction markets, etc are also high-risk sources.

Certainly a good biosecurity program is important. Good sanitation of pig transport vehicles and personnel is essential. Preventing exposure of pigs and pig feed to other animals and their feces is also important. What about replacement breeding stock, weaners or feeders coming onto the farm? Until recently it has been difficult to screen source herds since negative bacterial cultures did not guarantee that the animals were free of infection. A serological test that will detect antibodies to most Salmonella serotypes in an animal’s blood is available. Sampling is still a problem because if a herd is very stable and only a few animals are carriers of the organism, then the chances are lower that they will be sampled and thus detected. Initial surveys should sample at least 30 animals in each stage of production. A higher prevalence of positive animals would be expected in groups that are blood tested in a 2 to 6 week time frame after being moved, mixed, and/or transported.

Thorough sanitation is often given as a key point in prevention and control of Salmonella because it will reduce the level of barn contamination and pig exposure. It is an important factor. But for some of the more virulent serotypes, as discussed above, the level of sanitation needed to reduce the bacteria below the infective level is extraordinary. Salmonella will force us to become very meticulous in the way barns are cleaned.

Another point on control is the ability to help the pig control Salmonella in its own gut. Antibiotics can be effective but are not the solution in the long term. Salmonella bacteria are adept to developing populations with various levels of antimicrobial resistance. And antibiotic use likely promotes the carrier-state in animals.

Much attention is being directed towards the use of other products that make the intestinal tract a less inviting place for Salmonella organisms to grow. In Europe, organic acids, such as propionic or formic acid, are added to the feed or water, or feed is fermented to achieve the same ends. Since Salmonella does not do as well in acidic conditions, especially below pH 5, this reduction in the lower gut pH restricts its growth. Other products attempt to promote the growth of beneficial bacteria that will compete for space and food with the Salmonella, and will also produce organic acids that will reduce gut pH. Probiotics have been tried and have been adopted with some success. Other substances such as bambermycins (Flavomycin®, Intervet Canada Inc.) will alter the normal gut bacteria population and tip the scales against Salmonella. Meal feeds, especially if not too finely ground, also affect gut environment to the detriment of Salmonella.

Vaccines have been developed against some Salmonella serotypes. These include killed injectable products and injectable or oral modified-live vaccines. In pigs the vaccines have been mainly developed for *Salmonella choleraesuis*. This is the specific pig adapted Salmonella which is of low clinical prevalence in Canada today. The modified-live vaccines are reported to cross- protect against several serotypes of Salmonella, and have been used to prevent outbreaks of clinical salmonellosis as well as reduce the prevalence in groups to control food-borne contamination.

CLINICAL CASE

Background

In July 1996, a new 4-room, 2000-head feeder barn had just been filled with 25 kilogram feeder pigs from 6 sow farms each with on-site nurseries. The feeder barn was a fan-ventilated barn with about 30% of the pen floor space slatted. Water and feed were provided in a wet/dry feeder. Water was obtained from a man-made pond on the farm, and feed was a pelleted barley/soybean formulation purchased from a local feed supplier.

The batch of pigs started without any problems. On the seventh day after the fill, the manager found 4 dead pigs in one room during his morning pen checks. They had a slightly reddish skin coloration especially on the belly area. By that afternoon about 25 pigs in 4 pens were noticed to have a watery amber-coloured diarrhea. Four more pigs in the same room died later that day. The next morning 6 more pigs were dead, 5 from the same room and 1 from another room. A clear yellow-tinged diarrhea was seen in 9 of the 24 pens in the room that first had the problem and in 2 pens in the other room. Problems seemed to "cluster" around certain pens in the barn. Diarrheic pigs were lethargic.

Post mortems were performed and intestine, liver, lymph nodes, lungs, spleen and kidney were submitted to the local diagnostic laboratory for culture and sensitivity. Feed samples were submitted for Salmonella isolation.

The pigs were treated with Neomycin (Neomix Soluble Powder®, Pharmacia and Upjohn Animal Health, 125 gm / 678 litres drinking water) in the water and all sick pigs were injected with sulfa-trimethoprim (Borgal®, Intervet Canada Ltd., Dose – 3 ml per 45 Kg BW intramuscularly). By day 6, mortality rose to 52 pigs in the first room and 25 pigs in the other infected room. Interestingly, the problem stayed out of the other two rooms. Once the "hot wave" of infection subsided after about 10 days, there was no recurrence of problems and the batch went on to finish out normally. Overall, mortality from the outbreak was 3.9%.

The laboratory isolated Salmonella from intestines and, in some pigs, they also found it in other tissues such as lung and kidney. It was later typed as *Salmonella typhimurium* Phage types 104 and 108. No Salmonella was found in the feed samples.

But the story isn't finished. The barn was completely emptied, and it, and all equipment, was cold water washed – no detergent - and disinfected thoroughly. The next group was brought in (same sourcing as the first batch) and the same outbreak of the characteristic clear yellow diarrhea occurred. It affected about 20/96 pens in the barn. The manager started the group on neomycin in the water immediately and mortality was contained to 26 animals or 1.3% of the batch. At the end of that batch, the barns were washed and disinfected more thoroughly, the pits were cleaned and disinfected, and water lines were pulse disinfected with chlorine. Source herds were examined for any evidence of salmonellosis and laboratory cultures of random fecal and pen sampling did not pick up any Salmonella. The feeder pig trailer was swabbed after the routine washing and before transporting the feeder pigs to the barn and no Salmonella was cultured. The barn was filled and within two weeks the same thing happened but again less severe than in the previous batch. This problem continued for two more batches, each time less prevalent and severe than the previous time.

Breaking the Disease Cycle

The barn manager was able to detect the presence of pigs with Salmonella enteritis very quickly and would inject the entire pen with a sulfa-trimethoprim product. This approach would contain the problem to a small number of pens in the barn. An internal biosecurity program was started where boots were changed between rooms and one pair of boots was designated to be worn only in pens with pigs being treated for Salmonella enteritis. Between uses, the boots were stored in a disinfectant bath. The barn was cleaned and disinfected in a normal manner and then various areas were swabbed to detect any Salmonella present. Table 1 indicates where Salmonella was found. A more thorough cleaning was done with hot water and with special attention to feeders and areas of dust accumulation. Routine chlorination of drinking water was started. A more thorough rodent control program was initiated. From that batch to the present no Salmonella problems have been seen clinically.

Table 1. Salmonella typhimurium isolations.

Area Tested	Number Positive/Number Tested
Dust of feed lines	3/6
Dust in re-circulation box	1/6
Feeder tray	2/8
Solid floor	0/8
Slat top	0/8
Slat side	2/8
Pit slurry	0/6
Concrete back wall	0/6
Mice	2/6

Questions and Discussion

A few questions remain about this disease outbreak.

Where did the Salmonella come from? Did it arrive in the purchased feeder pigs? There were about a dozen other feeder barns that were taking pigs from the same sow sources that did not experience any clinical problems from Salmonella. A random sampling of pigs in the source herd nurseries did not pick up Salmonella.

Did they pick it up from contaminated transportation? The delivery trailers were used only for feeder pig delivery within this network of pig producers. Other barns filled from pigs transported on these trailers did not break with Salmonella.

Did the Salmonella arrive on that farm through other sources? Did people or wild animals track it in? Was it brought to the farm in the intestinal tract of birds, rodents or other animals? During the construction phase there was free access to the building by all.

Was contaminated feed the source? Possibly, but no Salmonella was isolated in this case. No clinical Salmonella was seen in other herds that I service that purchased feed from that mill. North American and Danish surveys indicate that *Salmonella typhimurium* is not commonly found as a contaminant in swine feed.

The problem with verifying a likely source of infection is the ability of all Salmonella to live in low numbers in the intestines of healthy animals. Manure sampling could turn up negative results even on infected carrier animals. This is due to both the sensitivity of the sampling and the testing procedure, which might be too low to detect a low number of organisms present. Moreover, chronic carrier animals will shed Salmonella in their feces only sporadically. When trying to find the bacteria in the environment or feed, low grade levels probably would not be detected because the number of samples needed for detection would be higher than the number that are often taken in barn checks.

Once on the farm, where does Salmonella survive between all-in-all-out batches of pigs? The Salmonella remained on farm in spite of more stringent washing and disinfection. It was not until our investigation showed that this manure-borne organism was found in areas other than floors, slats and pits, that a more thorough reduction of the Salmonella in the barn environment could be accomplished. And what was the role of rodents as a reservoir for the disease organism? My colleagues in the poultry industry have told me that in some barns, rodent control was the turning point in Salmonella reduction programs. A study showed that mice can shed up to 230,000 Salmonella per fecal pellet. It takes as few as 10,000 Salmonella of some serotypes to clinically infect a healthy pig.

What allows the Salmonella to become a clinical problem? Were the animals challenged with a high level of Salmonella? Usually we would associate these problems with unsanitary conditions where the level of Salmonella in the environment is high. This barn was very clean. The pigs dunging pattern was normal and any manure accumulations were scraped away daily. It did not appear likely that a large Salmonella build up caused the problem. One study in chickens indicated that Salmonella could be transmitted through the air. It also indicated that the dose of infective bacteria required to cause disease was less when infection came via the air than via oral exposure. This was dependent on the virulence of the organism. Our barn check showed Salmonella in dust in recirculation ducts and on feed lines (Table 1). This is most likely dust from dried feces and may present another route of Salmonella spread in the barn.

Was it a factor of virulence? Some serotypes of Salmonella require a very small dose of bacteria to create disease in healthy non-stressed pigs (as few as 10,000 organisms compared to a normal infective dose of 100,000,000 bacteria).

Were the pigs in a period where they were more susceptible to infection and the clinical disease? Stressors that suppress the animals' immune system such as transportation, and mixing, are known to allow healthy Salmonella carriers to start shedding the bacteria in large numbers in their manure. The same stressors increase the pig's susceptibility to a disease. Also a change in feed or water, or antimicrobial use can alter the normal balance of bacteria in the gut and perhaps would allow Salmonella to colonize and increase in numbers to a clinical disease threshold level.

CONCLUSIONS

Salmonella infections will continue to be a topic of concern in the swine industry due to its potential to create clinical disease on-farm and because of its role in foodborne infections in humans. Future quality assurance initiatives at the farm level will bring focus to on-farm practices in the control of Salmonella and other potential foodborne pathogens. Total elimination of Salmonella bacteria in a barn is not feasible due to the world-wide prevalence and persistent nature of the bacteria. Reduction and control of the organism is possible through a planned approach involving sanitation and biosecurity plans, and when needed, other tools such as nutritional changes to modify gut environment.

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