ENTEROPATHOGENIC SALMONELLA CONTROL IN SWINE - EUROPEAN APPROACHES TO PREVENTION THROUGH BIOSECURITY AND WELFARE

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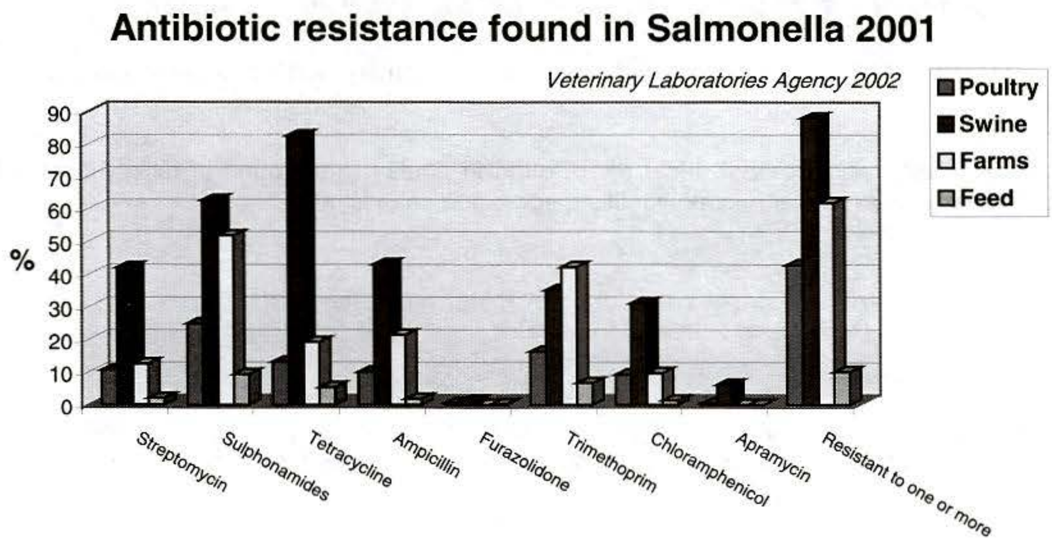
A number of relatively safe drugs have been available to control disease for many years, but excessive reliance on these drugs rather than good animal husbandry has honed drug resistance and many of these have become ineffective on most farms. As a result, the industry now has to rely on a number of stronger drugs, which it now uses to slow the development of resistant strains of bacteria and other problem organisms including coccidia. Most of these drugs are so toxic they could never be used in human medicine, and the effect of their residues in our food is only now being scientifically evaluated. As new data is reported the European Union is restricting the use of all antibiotics and other products such as zinc oxide in pig rations. The result is a major re-think of the procedures used in animal production. These new approaches are based on studies of the incidence of pathogenic species in raw materials, feed, housing and parent stock.

In any attempt to find alternatives to drug therapies it is essential that we understand the sources of the infections in the first place. For several years now, the UK Government has been conducting detailed surveys of Salmonella isolations throughout the Agricultural industry. Part of these investigations has been the testing for antibiotic resistance in any Salmonellae isolated.

These surveys have clearly shown that the main source of Salmonella on pig farms is likely to be by horizontal and vertical transmission between pigs and not, as originally thought, from the feed.



Currently, less than 5% of all animal feed produced in the UK is contaminated with salmonella and the human food poisoning serotypes - *S. enteritidis* and *S. typhimurium* are rarely isolated.

Interestingly this data suggests that, welfare can be at odds with effective salmonella control. Over the last few years the UK government has introduced legislation with the sole intention of improving animal welfare. As a result certain housing systems have been banned and a move to solid floored less intensive systems, with the increased use of bedding material, has been promoted. Deep straw group-housed sow systems are now common. Sow units, where sows were kept in stalls over slats, and fully slatted finishing houses, are now illegal. One of the results of this welfare oriented legislation is that it is now almost impossible to remove faecal material from pig pens and so we have housing systems that encourage, rather than discourage the horizontal transmission of salmonella and other enteric pathogens from pig to pig!

On the plus side, any improvements in welfare, such as more comfortable housing and lower stocking densities will reduce the stress levels of the pigs. Stress, other diseases, poor nutrition or hygiene can all trigger clinical disease (salmonellosis), or shedding of Salmonella in faeces.

The general public, that is the person who purchases animal products for consumption in their own family, like to think that the welfare of meat producing animals is being improved. These same consumers are also aware that enteropathogens, such as Salmonella and Campylobacter, in swine production are a problem being faced by the pig producing industry worldwide.

The development of control systems that are not reliant on drug therapies are paramount in the European approach to swine production. However such systems must cover all aspects of production and be based on prevention is better than cure concepts. The schemes proposed do not ban the use of antibiotics totally, but limit them to use in therapeutic situations rather than the prophylactic applications used to try to prevent diseases that were commonplace just a few years ago. However it is not just the use of antibiotics to control enteropathogens that is under scrutiny. Antibiotics used to enhance growth are also being banned as a result of a combination of legislation and antibiotic resistance problems.

In the US, antimicrobial resistance is an increasing concern and in the case of one strain, *Salmonella typhimurium* DT104, resistance to multiple antibiotics has been detected. The occurrence of resistance has been increasing in the USA and Europe, and it has been linked directly to the use of antibiotics in livestock production.

In June 2001 the American Medical Association resolved to oppose the use of non-therapeutic antimicrobials in agriculture. This is a similar action to that taken by the World Health Organisation in 1997.

Sources of infection of food products have also been the subject of recent investigation. According to an article published by the USDA's Economic Research Service (ERS) it has been found most contamination of food products occurs early in the production process, and not just before consumption.

The ERS has compiled a list of foods that harbour the most common food borne pathogens:

- *Campylobacter jejuni* or *coli*. Most often found in poultry, also found in milk, mushrooms, clams, hamburger, water, cheese, pork, shellfish, eggs, and cake icing.

- *Clostridium perfringens*. Most often found in meat, meat stews, meat pies, and beef, turkey, and chicken gravies. Also found in beans and seafood.

- *Escherichia coli* 0157:H7. Most often found in beef, especially ground beef. Also found in poultry, apple cider, raw milk, vegetables, cantaloupe, hot dogs, mayonnaise, and salad bar items.

- *Listeria monocytogenes*. Most often found in soft cheese, pâté, and ground meat. Also found in poultry, dairy items, hot dogs, potato salad, chicken, seafood, and vegetables.

- *Salmonella* (non-typhoid). Most often found in poultry, meat, eggs, milk, and related products. Also found in vegetables, fruits, chocolate, peanuts, and shellfish.

- *Staphylococcus aureus*. Most often found in worker-handled foods such as meat (especially sliced meat), poultry, fish, and canned mushrooms. Also found in dairy products, prepared salad dressings, ham, salami, bakery products, custards, and cheese.

- *Vibrio* sp. Most often found in oysters. Also found in other seafood.

From this data it is obvious that swine producers are not alone in facing problems of contamination. They are not being singled out as an example of poor production processes. All food producers need to improve their systems of production. It can also be seen that Salmonella, although the best-known enteropathogen, is certainly not the only problem and nor is it the most important pathogen found in human food. It is simply that Salmonella is the most studied.

A British survey, conducted between March 1999 and February 2000, reported on the occurrence of salmonellae in pigs at slaughter (Davies, *et al*, 2000). Salmonella were identified in 23% of pig carcasses. *Salmonella typhimurium,* the second most common strain of Salmonella found in humans in the UK, was found in 11.1% of carcasses. Campylobacter species are the biggest cause of food poisoning outbreaks in humans in the UK and Campylobacter was found on 94.5% of all carcasses. Fortunately the most dangerous strains of enteropathogenic *Escherichia coli* were only found in 1.2% of carcasses. Similar results have emerged in the US and other major pig- producing European countries.

Food processors are also facing increased pressure to keep *Salmonella* spp. contamination of food products to a minimum. Denmark's control program targets both the farm and the processor level and has reduced the incidence of *Salmonella spp.* in Danish pork to 1%. Other pork exporting countries are trying to match their success. Prior to export, the USA now requires all Canadian slaughter plants to test carcasses for *Salmonella spp.* contamination. As Canadian processors implement HACCP (Hazard Analysis Critical Control Points) programs (i.e. quality assurance) and control contamination in their plants, the pressure to keep the numbers of *Salmonella* bacteria low has shifted to the farm.

Quality Assurance Schemes that cover all stages of production from feed through to processed meats are now commonplace in Europe. These schemes require proper monitoring of feed quality, or the purchase of feed, from a mill operating a recognised and approved quality assurance scheme. In Europe the two main schemes are the UFAS scheme, operating in the United Kingdom, and the PDV scheme, operating in the Netherlands.

The most obvious way to control Salmonella and other enteropathogens is simply to try to keep them out of the production unit. This is impossible as they are already there! The goal must be to control enteropathogens to an acceptable level. This means taking care of every aspect of production from replacement stock, feed, bedding, insect pests, rodent pests, vehicles, equipment and people. Strict attention to all these areas will provide the best biosecurity possible and will reduce the risk of these zoonotic organisms occurring on farm.

To start such a programme it is essential to do the following:

- Keep all introduced pigs in isolation for as long as possible; this will restrict disease spread to existing animals from newly introduced and potentially infected stock and give them time to receive veterinary treatments to eliminate infection.
- Introduce strict visitor and vehicle policies.
- Control insect and rodent pests.
- Use safe feed that is protected against recontamination in storage.
- Use clean bedding, slats if possible.
- Do not share equipment from other areas.

Pigs should be monitored for Salmonellae at different stages throughout production. The Danish Authorities and the Scottish Agricultural College in Edinburgh have developed schemes to monitor Salmonella on farm. The use of Salmonella antigen blood testing, makes these schemes more sensitive to fluctuations in Salmonella because the techniques selected tend to eliminate false positives which occur as a result of the persistence of Salmonella antibodies in the host animal.

Antigen test Optical Densities are categorised to give an indication of the severity of the problem.

BREEDING HERDS			
CATEGORY	%OD VALUE	IMPLICATIONS FOR HERD	ACTION
Level 1	<25	Little or no evidence of infection	None required
Level 2	25 -50	Moderate level of infection	Consult Vet
Level 3	>50	High level of Infection	Urgent Action Consult Vet.

Source: SAC Edinburgh.

In finishing herds it is unreasonable to expect the entire herd to fall below certain predetermined Optical Density values so a convenient scale is used to assess the Salmonella status of these herds based on herd size.

	FINISHING HERDS		
FARM SIZE	Percentage of Pigs with an OD%40 or Higher		
No. of Pigs per annum	Level 1	Level 2	Level 3
<100	-	-	-
100 - 1000	<25	25 – 50	>50
1001 – 5 000	<18	18 – 50	>50
5001 – 10 000	<10	10 – 50	>50
>10 000	<10	10 - 33	>33

Source: SAC Edinburgh.

If Salmonella or other enteropathogens are found on farm then procedures already in use have not been sufficient and biosecurity measures need to be improved. Such measures include:

- Rodents and birds can spread disease rapidly between pens through infected feed and bedding. Minimise access of vector species; e.g. birds, rats, mice, cats, dogs, visitors.
- Piglets must only be moved to previously cleaned and disinfected housing.
- Same age operations are essential; never mix older pigs with younger piglets.
- All-in, all-out policies on a room or house basis help break the cycle of reinfection, as there should be a complete break to allow disinfection between groups.

- Staff and pigs should move in one direction – younger pigs to older pigs – and not in the reverse direction. No backward movement of poor performers through the system.
- Lower stocking density helps to lower disease spread. Overcrowding must be prevented.
- Thorough and frequent removal of waste is important. Especially to ensure that there is no movement of muck between batches and pens of pigs.
- Human hygiene of workers must be considered.

To accomplish these improvements staff training is also essential. Failure to involve staff at all levels of biosecurity will result in failure.

- Staff must be involved in developing workable procedures on farm. This way it will be easier to do the job correctly than it is to do it the wrong way.
- Staff should be adequately trained to perform the job correctly.
- Staff should be informed about progress towards a Salmonella-free goal.
- Staff should have all the equipment that they require to do the job correctly.

Disinfection routines are vital in any animal production operation and must be effective. To do this the following guidelines apply:

- Clean all surfaces before disinfection as organic deposits inactivate disinfectants.
- Use disinfectants correctly – dilution, time and temperature are all important.
- Allow surfaces to dry after disinfection as this enhances disinfectant activity.
- Use footbaths at the entrances to buildings. However it must be remembered that organic material on boots inactivates the disinfectant, so once again cleanliness is paramount.
- Feeders and drinkers should be cleaned and disinfected between batches; acidified water will help reduce the spread of infection.

Such systems work effectively in practice. However, it is not always practically or financially possible to address every issue that may be identified. Different risks and priorities may exist in different climates and different housing systems.

Simply monitoring performance is not always the best way to identify a problem. A herd tested Salmonella positive at Level 3 in Northern Ireland even though weaners were achieving growth rates of 591g/d with an FCR of 2.08, and finishers were growing at 885g/d with an FCR of 2.51. Blood samples taken in January 1998 revealed that 2 of the 12 samples from finishing pigs contained *S. typhimurium;* the most common serotype isolated from pigs on mainland Europe, Great Britain and the US.

With the aim of reducing the background level of salmonella on the farm, all aspects of animal welfare, husbandry and hygiene mentioned previously were looked at. Wherever there was scope, improvements were implemented and the topics considered were not exclusive to salmonella control. The systems implemented were seen as the basic level of biosecurity and included many things that should always be considered to improve the wellbeing of livestock or when addressing poor or sub-optimal herd performance.

However addressing all these welfare and biosecurity topics are not always enough to reduce the salmonella burden of a pig herd sufficiently. This was the case with the farm in Northern Ireland.

Approximately 12 months after first identifying the problem, making all practical improvements and using periods of medication to control the clinical problems of diarrhoea, further blood sampling revealed that the herd had still only moved into a Level 2 status. This may well have been the result of antibiotic resistance that had developed before the start of the programme.

Consequently the need to find a non-antibiotic remedy to work in the pig intestine and reduce Salmonella to achieve Level 1 status on this unit became a major challenge.

The feed was not implicated in this case, because the mill had, as far as possible, eliminated all possible sources of Salmonella from the feed by careful selection of raw materials and an effective heat treatment programme. Even so, the mill biosecurity programme had identified some Salmonellae in raw materials but these were *S. montevideo* or *S. seftenberg* and not the *S. typhimurium* found in the pigs.

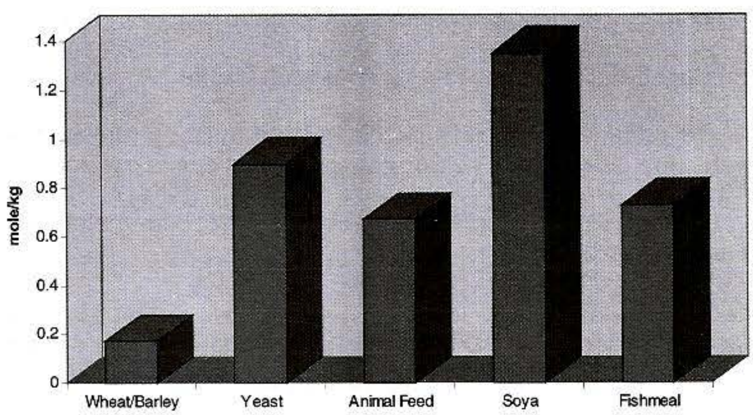
Therefore the farm and/or the breeding sows were assumed to be the major sources of the problem. Salmonellae from the farm or drinking water supply can easily colonise the intestines of the newly weaned pig. The possibility of infection can also be increased if dietary considerations are ignored.

High calcium or soya levels in feed dramatically increase the buffering capacity of the ration. The young piglet is unable to secrete sufficient acid in the stomach to kill potential pathogens or to effectively initiate protein digestion. A high buffering capacity will therefore predispose the animal to infection and poor performance.

A typical animal feed will require about 0.7moles/kg of gastric hydrochloric acid to lower the pH to a level where Salmonella would be killed in the stomach.

This level of acid secretion is never achieved in young pigs and so in this case it was decided to consider

Buffering capacity of feeds



the addition of acid products to the feed.

Unbalanced protein and carbohydrate nutrition in relation to the enzymatic development of the pig gut can also exacerbate the problem for newly weaned pigs as undigested materials may aggravate the gut lining, increasing the risk of pathogen colonisation and diarrhoea. In the younger animals the use of fructo-oligosaccharides and butyric acid are known to overcome some of the problems of an inflamed gut epithelium.

The products eventually selected for use in this unit rely on well-understood principles of microbial development and had been formulated to promote a healthy gut microflora. These principles are that bacteria require four main factors to ensure growth.

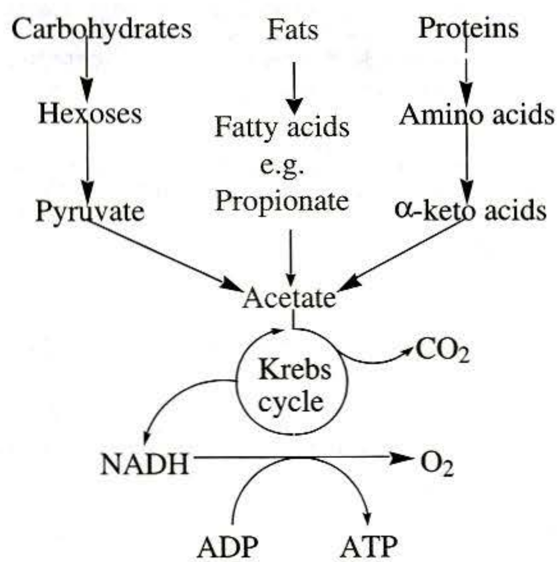
1. Temperature - the body temperature of a pig is ideal for both enteropathogens and probiotic organisms such as the lactic acid producing bacteria.
2. Nutrients - the nutrients required for piglet growth are also used by bacteria.

3 Water - this is essential to both piglet growth and bacterial multiplication.
4 pH - the pH of the small intestine is perfect for *E. coli* and the pH of the large intestine and caecum is ideal for Salmonella.

Out of all these variables it is only considered possible to alter the pH. There are, however, some nutrient sources known to be specific for lactic acid producing bacteria, that are not metabolised by the animal, but could be used to support lactic acid production in the hind gut.

Approximate pH Ranges for Optimum Microbial Growth	
Organism	Optimum pH for growth
Escherichia coli	6.0 – 8.0
Lactobacillus spp.	5.4 – 6.4
Salmonella spp.	6.8 – 7.2
Bifidobacterium spp.	6.5 – 7.0

The simple addition of organic acids to the gut through the drinking water or the feed is known to be ineffective as formic acid is excreted through the kidneys almost immediately whilst acetic, propionic and other acids are generally metabolised as energy sources.



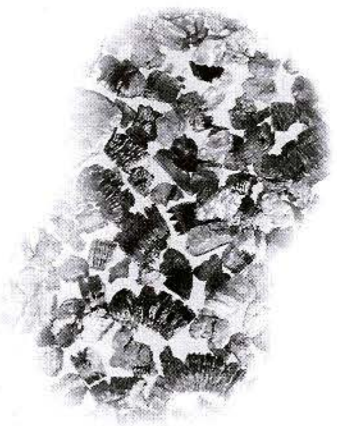
However at very high concentrations, certain organic acids when incorporated into pig diets have been reported to reduce the incidence in diarrhoea by 40% (Van den Broek, 2000). These rates are generally uneconomic. In Denmark the use of fermented liquid pig feeds provide high levels of free fatty acids such as lactic, acetic, propionic and butyric directly to the animal. This concept, although expensive, is becoming widely accepted in some large European pig units. It is an expensive option because dual fermentation vessels are required to allow sufficient time for the fermentation to complete. Cleanliness is also essential as the fermentations can also go wrong and cause more problems that they are designed to solve.

The simple addition of sufficient acid to animal feed to have a direct impact on pH is impossible due to the buffering capacity of the feed mentioned earlier. In Northern Ireland a mineral carrier protected the acids used and they behaved more as a prebiotic by supporting the growth of lactic acid bacteria, rather than having a direct impact on the Salmonella.

By providing an acidic environment within a bacterial supportive carrier within the intestine it is possible to promote the development of certain bacteria and inhibit others.

The concept of acidification of the gut, by indigenous bacterial populations, is seen as a highly beneficial and "natural" means of preventing the growth of pathogens that tend to favour more neutral to slightly alkaline pH values for optimal growth.

The carrier system in the products tested protects the organic acids from immediate digestion and allows them to pass through the stomach to the small and large intestines. This protection is achieved by absorption of the acids onto an indigestible mineral carrier matrix that does not affect the acids, but absorbs them and transports them as an acid nucleus to the intestines with controlled release into the gut lumen.



This method of acid delivery is so effective that these products use buffered acids to prevent restrictions to digestive enzyme activity as a result of a shift in pH. The buffering also has the secondary benefit of reducing acid volatility. The UK Meat and Livestock Commission confirmed that there was no loss of palatability with these carrier-based acids at all stages of feeding. The MLC also demonstrated that performance, in terms of weight gain and feed conversion, matched that of positive control group with the antibiotic growth promoter avilamycin (Hyden and Powell 2001).

The mode of action is relatively straightforward to understand. The mineral carrier is slightly more acidic than the surrounding digesta in the gut lumen and becomes colonised by more acid tolerant, acid-producing, organisms that ferment feed carbohydrates to lactic, propionic and acetic acids. These acids lower gut pH and create an environment that is antagonistic to the growth of enteropathogens such as Salmonella. In combination with probiotics such protected acids have, in some cases, shown enhanced activity compared with a positive control group.

Two products were used to try to eliminate the Salmonella problem on the Irish farm. The first product is a protected formic/propionic blended biosecurity product to control pathogens such as Salmonella.

The second product is a more complex acid blend incorporating butyric acid and a fructo-oligosaccharide.

Butyric acid is known for its anticlostridial activity and its role in gut epithelium regrowth after pathogen attack.

Fructo-oligosaccharides are particularly valuable in creep and starter feeds because at the time of weaning the main fermentable carbohydrate source (lactose) is removed from the diet. This loss of fermentable lactose causes the beneficial Bifidobacteria species to rapidly die-out, as they are unable to ferment the complex carbohydrates found in the cereals of creep and starter diets. Bifidobacteria in the digestive tract of young pigs will convey a greatly improved immune response to the piglet through the production of pathogen specific bactericins. The Bifidobacteria are vital in the development of a healthy gut microflora. Fructo-oligosaccharides also support other fermentative bacteria that produce lactic acid (LAB's). These bacteria produce secondary metabolites such as nisin and hydrogen peroxide in the intestine, which are strongly antimicrobial. Hydrogen peroxide is also known to be a potent virucide.

Dietary acid inclusions commenced in March 2000 using 3kg/Te of protected acid with fructo-oligosaccharide in the first stage diet (up to 12kg). The biosecurity product was used at 3kg/Te in the finisher and lactating sow diets. Dry sow diets on the farm contained 2kg/Te of the biosecurity product to try to reduce background levels of pathogens on farm. In the first month the farmer noticed several improvements. The salmonella-type scour seen periodically was beginning to subside; the use of antibiotic injections to control this scour was stopped.

Veterinary treatments were reduced and the use of prescription medicines was greatly reduced over the next two months. The use of antibiotics in the grower diets ceased altogether except for a potentiated sulphonamide to control a single outbreak of pneumonia in the finishers.

To maintain feed costs the specification of the diets was lowered whilst using the protected acids. There was no loss in performance with the lower diet specifications.

Standard diet formula		Revised diet formula	
Protein	19.00%	Protein	18.00%
Oil	4.50%	Oil	5.00%
Fibre	4.50%	Fibre	4.50%
Lysine	1.05%	Lysine	1.00%
DE	14.00 MJ/kg	DE	13.75 MJ/kg

Three months after the start of the study twenty finishing pigs were blood sampled. The average optical density of 8.75%, illustrated a great improvement in the salmonella status of the herd. Only two pigs produced optical density values greater than 40% indicating, that the herd status had now reached Level 1

In conclusion this trial identified that:

Protected acids are able to offer excellent control of Salmonella even in already infected herds. Such protected organic acids are approved as feed additives and do not contain antibiotics.

Protected acids help to control of potentially pathogenic intestinal microflora in pigs.

Cost savings can be achieved by using a lower specification diet without compromising performance.

Protected acids can be less expensive that Antibiotic Growth Promoters such as avilamycin and offer positive control of enteropathogens such as Salmonella.

The elimination of Salmonella from a well-run pig herd in Northern Ireland was the result of a multi-factorial approach. The problem was reduced but not eliminated using a full veterinary approach to the problem. However with a thorough programme of animal welfare, feed quality, biosecurity, veterinary care and the correct choice of feed additives a highly cost effective solution was found. The result is that the herd is now Salmonella free with an excellent performance record requiring minimal veterinary intervention.

The acid biosecurity agent Agil Ltd, UK, provided BACT-A-CID.
The acid / fructo-oligosaccharide PREFECT, also provided by Agil Ltd, UK

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