Improve Gut Health to cut *Salmonella* Infection

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The annual cost of *Salmonella* to the UK economy has been estimated at over £46 million and at €2.8 billion across the E.U.

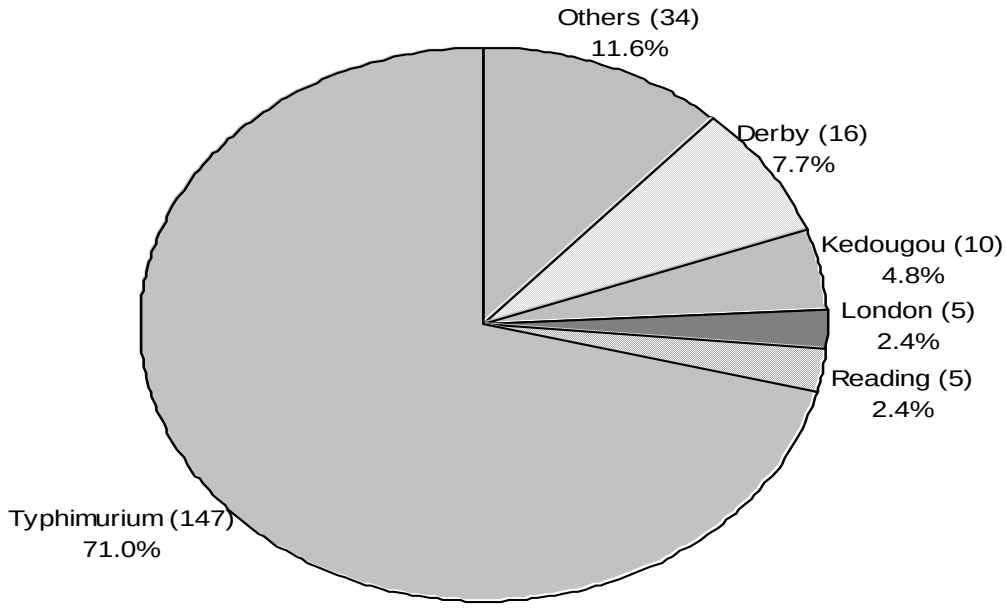
The Food Standards Agency has made it clear that it wants to see a reduction in the proportion of pigs found to be carrying *Salmonella* when they arrive at the abattoir. The most recent results published to date (2000) show that 23% of UK pigs arriving at abattoirs carry *Salmonella* in their gut with 5% of pig carcases and 8% of pork sausages testing positive for *Salmonella*. Cattle and sheep however showed only 0.2% and 0.1% positives respectively.

Salmonella enterica Typhimurium remains the most frequently found *Salmonella* serotype in pigs accounting for 71% of cases (see figure 1). S. Typhimurium poses serious risks to human health. Between 1992 and 1999 a total of 35 out of 83 *Salmonella* outbreaks in humans linked to red meat were associated with pig meat, 13 of these were S. Typhimurium resulting in 2 deaths (Smerdon and other, 2001).

An additional concern is the fact that several *Salmonella* serotypes are highly antibiotic resistant such as S. Typhimurium DT104 carried by 2.8% of pigs.

Figure 1

***Salmonella* serotypes in pigs (number and % of incidents) DEFRA 2002**



Data presented by the MLC in our *Salmonella* Workshop September 2003, suggest the following levels of *Salmonella* infection across the UK.

Table 1

	UK *Salmonella* Survey Results To Date (September 2003)			
	Jul-Sept 02	**Oct-Dec 02**	**Jan-Mar 03**	**Apr – June 03**
Total Samples	19761	23159	22979	21503
Total	26.6%	28.5%	25.9%	21.4%
England	28.5%	30.6%	28.8%	23.9%
Scotland	11.7%	13.9%	13.0%	10.0%
NI			13.2%	15.0%

A recent study (Lynch, 2002) over 59 Irish farms demonstrated that *Salmonella* was present in each of the production stages as shown below. This study also showed that if weaners were infected the samples from finishers were also likely to be positive.

Table 2

***Salmonella* presence by stage (n=59) (Lynch, 2002)**	
	% of farms positive for *Salmonella*
Weaner 1	28
Weaner 2	24
Finisher	27
Gestation Sow	16
Lactation Sow	11
Any Stage	51

This study by Lynch also highlighted the fact that a number of category 1 farms will still have *Salmonella* in some stages, and that some very clean, well managed herds can still produce high levels of *Salmonella* and hence be classed as category 3 farms.

In addition to the considerable importance from a food safety standpoint, *Salmonella* levels in meat from respective countries can be used to create trade barriers between countries. Such differentiation of product may result in an increase in market share. For example, Denmark implemented a *Salmonella* Control scheme in 1993 and is already exploiting the fact that caecal prevalence of *Salmonella* has been reduced from 6.2% to 3.4% over 5 years in Danish herds. *Salmonella* control programmes are also operating in Ireland, Sweden and Germany.

A *Salmonella* testing scheme for weaners sold off farm is also in place in Denmark.

As well as the obvious zoonotic implications, *Salmonella* infection also plays an important role in pig health status. Clinical salmonellosis, particularly in young pigs,

can result in serious diarrhoea and high fever, which in acute cases, may lead to sudden death.

Sub-clinical levels of *Salmonella* infection may not show any direct signs of disease. However, clinical infection may cause diarrhoea and stunting of growing pigs, thereby reducing their performance and may even cause death due to septicemia. Clinical cases of *Salmonella* have been rising over the last 10 years, with most clinical disease seen up to 10 weeks of age. It has been shown that pigs suffering PMWS and PRRS often show higher levels of *Salmonella* infection. It has therefore been suggested that the immuno suppressive nature of PMWS and PRRS diseases may expose pigs to greater *Salmonella* challenge.

There is some evidence to suggest that subclinical *Salmonella* infection may reduce growth performance of pigs (Baum 1997).

Pigs suffering clinical *Salmonella* will excrete large amounts of *Salmonella* in their faeces. Therefore sick pens should be positioned well away from the main herd. In fact our own research work has clearly shown how the close proximity of sick pigs to healthy pigs can increase *Salmonella* levels of the whole herd.

There are obvious economical consequences of a clinical *Salmonella* outbreak on a unit, which are quantified in table 3.

Table 3

Estimated costs associated with a *Salmonella* outbreak (Neumann and Kniffen, 1999)

Parameter	Effect	Costs in affective groups (£/head)
Average daily gain	Reduced by 45g	0.39
Antibiotic therapy	Mass + individual treatments	0.19
Substandard pigs	Increased by 2%	0.64
Mortality (when applicable)	Increased by 3%	0.80
Quarantine & biosecurity costs	Various	0.16
Total cost per head at affected sites (depending on mortality)		Up to £2.18

ZAP Control Programme

While *Salmonella* cannot be eradicated on pig units, it can be controlled and minimised. With this in mind, the British Pig Executive (BPEX) have developed the "ZAP *Salmonella* Monitoring Programme" as a way of identifying farms with high levels of *Salmonella* and to act as the means of driving down overall levels (MLC, 2002).

In outline terms, the scheme will be an abattoir-based programme and will monitor *Salmonella* levels in pigs by way of a meat juice ELISA test. This test detects antibodies present in the pig's body to most common *Salmonella* types and this testing has already started. From late 2003 onwards, farms will be assigned to one of three ZAP classes, based on the level of *Salmonella* present.

ZAP 1	Low prevalence of *Salmonella* (less than 65% of positive samples)
ZAP 2	Moderate prevalence of *Salmonella* (between 65% and 85% of positive samples
ZAP 3	High prevalence of *Salmonella* (85% or more of positive samples)

As the scheme progresses, the cut off levels between each category will tighten as BPEX will aim to always have around 1% of farms in category 3, with 5% in ZAP 2 and the remaining 94% in ZAP 1. Therefore today's 85% cut off for category 3 could be 75% for example next year.

Three samples will be taken from every batch of pigs covered by a movement order. The samples are frozen at the abattoir and subsequently thawed in a specialist laboratory where the fluid drained from the thawed meat sample is tested for anti-*Salmonella* antibodies.

ZAP status will be updated on a rolling quarterly basis, with a weighting applied to the most recent month's results. The farmer will receive a *Salmonella* status report showing the number of respective positive and negative samples for his unit as shown in figure 2.

Figure 2

Example ZAP *Salmonella* Status Report

Results for the month 10/2002		**%**	**Nat. Average (%)**
No pigs samples		6	
No positive samples	6	100	36.0
No negative samples	0	0	64.0
Results for quarter ending 30/09/2002			
No pigs samples		12	
No positive samples	8	66.7	33.7
No negative samples	4	33.3	66.3
Results for the last 25 samples tested			
Latest date of sampling 06/11/2002			
Earliest date of sampling 17/07/2002			
No positive samples	***18***	***81.8***	
No negative samples	***4***	***18.2***	

Farmers in ZAP 2 & 3 categories will have to draw up and implement action plans to reduce *Salmonella* levels in conjunction with their veterinary surgeon, while ZAP 1 and 2 category farmers will have to be diligent in preventing levels rising again.

Farms consistently in ZAP 3 category will be served a non-compliance notice from March 2004 and if still in ZAP 3 category by November 2004 will be excluded from selling pigs under the British Meat Quality Standard Market.

Holdings that are suspended will have to demonstrate that the farm is a level **1** for 3 consecutive months before being readmitted to the assurance scheme.

The meat juice ELISA test is a non-specific test detecting antibodies to most common *Salmonella* up to around 6 weeks after exposure (ranging from 4-8 weeks according to Danish research). The *Salmonella* ELISA test is applied in the field as a herd test, not an individual animal test. The responses of individual animal samples are evaluated in order to determine the *Salmonella* status of the whole herd.

Antibody levels decline after an initial exposure provided the pig is not challenged by repeated exposure. Thus, if a pig is infected early in life and is not subjected to repeated exposure later, then the levels of circulating antibodies may fall below the ZAP cut off level by the time the pig is slaughtered. Hence the benefit of a well managed AIAO system, which reduces the risk of repeat infection, to good *Salmonella* Control.

However, if a pig is exposed to *Salmonella* at an early stage and then is challenged again, this will re-boost the immune system (like a vaccine) and again increase the antibody level, which is likely to give a positive meat ELISA test at slaughter.

Therefore, when it comes to implementing a *Salmonella* Control Programme, it is important to control *Salmonella* throughout the pig's life in order to avoid re-infection. If piglets are infected they will infect growing/finishing pigs after transfer. Thus *Salmonella* control during the early growing phase is equally as important as during the finisher phase. Therefore directly implementing nutritional strategies to control *Salmonella* in the early part of the life span, may well affect ZAP scores at slaughter.

It has been confirmed (Kranker et al 2001) that there is a strong relationship between *Salmonella* prevalence in different stages of production therefore *Salmonella* control should be practiced throughout the unit, including consideration to sows and the breeding unit.

It should be noted however that implementing feeding and management strategies to control *Salmonella* in young pigs would be of little benefit to reducing ZAP scores at slaughter if *Salmonella* significantly challenges the pigs later in the growing/finishing phases.

Although available for poultry, vaccines against *Salmonella* are not presently available for pigs.

Biosecurity – the key to *Salmonella* Control

To reduce *Salmonella* levels in pigs, it is essential to look first at the place the animals are reared and the practices implemented there. We know a considerable amount about the vectors that carry S*almonella*, and we know how we can control them. Control pays. There is considerable evidence from Denmark and Ireland demonstrating that control programmes can reduce levels on farm and hold those levels lower.

Biosecurity plays a significant role in the control process. Starting with purchased stock, the aim should be to source animals from a supplier of known low or no *Salmonella* status. To prevent cross-infection, producers should operate a rigid all-in all-out system with thorough cleaning and disinfection between batches. Visitors

and vermin must be tightly controlled with effective disinfection routines for everyone and every vehicle coming onto the unit.

Salmonellae may survive up to 3 months in wet faeces and 13 months in dry material.

Outdoor units are particularly vulnerable to *Salmonella* challenge from vermin and particularly birds. However, *Salmonella* bugs are killed by sunlight and if precautions are made to cover feed troughs and weaner kennels are thoroughly cleaned and moved to fresh ground for each batch, *Salmonella* levels can be controlled.

Water, particularly if warm and/or dirty can carry high levels of *Salmonella.* Therefore, another significant area where improvements can be made is water hygiene. Control measures to eliminate biofilm and make the water less welcoming to bacteria including *Salmonella* should be adopted. Buffered formic acid based products added to water have been shown to be highly effective in this respect, for example BASF Lupromix NC the effectiveness of which is shown in table 3 (see Contact number 107).

Table 3

Influence Lupro-Mix® NC on microbial count in drinking water

	Drinking Water untreated	**Acidified with 0.2% Lupro-Mix® NC**
Total microbial count at 22ºC (cfu/ml)	5,100,000	<1
Total microbial count at 37ºC (cfu/ml)	7,400,000	<100

A Dutch trial, over 998 blood samples, carried out by P.J van der Wolf et al (2000) demonstrated that including a buffered formic acid based product at 0.2% from 25kg to slaughter reduced the number of meat juice ELISA positives significantly as shown in table 4

Table 4

Influence of water acidification on *Salmonella* level

	% Positives	
	Control	**0.2% Acid in water**
Meat Juice ELISA cut off >10%	39.9	13.8
Meat Juice ELISA cut off >40%	24.6	4.4

The *Salmonella* status of pigs can be significantly affected by the way the animals are managed throughout life. Stresses caused by feed withdrawal, mixing of animals and water deprivation have all been shown to increase the shedding of *Salmonella* and should therefore be avoided or minimized as much as possible.

The key management practices for the prevention and control of *Salmonella* on pig farms have been summarized by the Veterinary Laboratory Agency as shown in table 5

Table 5

Key Management practices for the prevention and control of *Salmonella* on pig farms

Keep *Salmonella* out of your farm	**Prevent spread of *Salmonella* on your farm**	**Stamp out *Salmonella* by effective cleaning and disinfection**
Purchase pigs from one or as few sources as possible	Use boot dips and change them regularly	Empty each building of all pigs
Keep unnecessary visitors out	Isolate incoming breeding stock	Remove all solid waste
Ask for 24 hours pig freedom for essential visitors	Make ALL IN / ALL OUT the rule on your farm	Empty feed hoppers
Use farm boots and clothing and keep them clean!	Minimise mixing between litters & between sources	Pressure wash using hot water & detergent if possible
Load & unload vehicles on farm boundary	Isolate sick pigs & do not mix them with healthy pigs again	LEAVE FOR AT LEAST 12 HOURS
	Maintain feed security – Closed bins, bird & rodent free stores	Disinfect with an approved product at max. recommended strength
		LEAVE AT LEAST 48 HOURS before restocking
		Control vermin – effective baiting - keep site clean & tidy

Pig feed as a vector of *Salmonella* transmission

Since 1989, DEFRA and the UK feed industry have developed a number of codes of practice for the hygienic production, storage, handling and transportation of animal feedstuffs. The result has been a dramatic reduction in the number of positive samples of *Salmonella* found in animal feed, particularly S. Typhimurium (table 6), and feeding stuff ingredients (table 7)

Table 6

***Salmonella* Typhimurium isolated in UK feedstuffs January to December 2002 (DEFRA 2002)**

Feedingstuff	**Number of positive samples**
Wheat	2
Maize	2
Rape	1
Pig Compound Feed	1

Table 7

***Salmonella* Typhimurium in Feedingstuff Ingredients 2001 – 2002 (DEFRA 2002)**

Ingredient	No of positive samples
Finished Feeds	1
Animal Protein	-
Vegetable Material	5
Minerals	-
Miscellaneous	-
Total	6

A very effective way to reduce *Salmonella* levels in compound feed is to subject the material to heat treatment during the compounding process. However, although effective in reducing the contamination of feed at the point of manufacture (table 8), there is no residual effect to help prevent contamination once the feed leaves the mill.

Table 8

Effectiveness of heat treatment in feed against *Salmonella* Contamination

Temp. (ºC)	Time (secs)	% reduction 5% moisture	% reduction 10% moisture	% reduction 15% moisture
82	20	76.92	98.09	99.8
82	40	89.14	99.02	100
82	80	91.62	99.19	100

Creating an inhospitable environment

Heat treatment itself gives a big clue to the means of preventing subsequent contamination by *Salmonella*. If we can make the environment in feed less conducive to bacterial infection, contamination can be reduced.

To support the growth of *Salmonella* colonies three conditions have to be met. First the temperature must be between 5-47° C, with the optimum range being 35-37ºC (note that is the typical body temperature of pigs). Moisture content needs to be greater than 12%. The other critical factor is pH. *Salmonella* requires a pH of 4.5-9.0. Outside this range results in a slow death for the bug.

Therefore anything that can be done to make the environment in the feed or the gut of the pig more inhospitable will reduce the incidence of contamination. Table 9 shows results from several epidemiological studies indicating the probability of detecting positive animals depending upon management and feeding system imposed.

Table 9

Herd factors associated with seropositivity for *Salmonella* (Lo Fo Wong et al., 1999; Wingstrand et al., 1999)

Variable	Parameter	Odds Ratio
Feed	Non-pelleted and wet	1.0
	Non-pelleted and dry	4.2
	Pelleted and dry	8.2
	Pelleted and wet	10.4
Wet Feeding	Use of whey	1.0
	Non-use	5.6
Production system	Conventional	1.0
	Free range	1.8
	Organic	1.7
Batch	All-in-all-out	1.0
	Continuous	2.0

Salmonella colonization starts as high as the stomach where rapid multiplication and even invasion can take place. Colonization can then spread throughout the small and large intestine, the degree of which will be determined by the initial *Salmonella* challenge and the conditions within the gut itself.

Feed form is an important determinant of the degree of potential *Salmonella* contamination (Contact number 128). Coarse grinding can reduce *Salmonella* compared to the use of finely ground meals or pellets. Danish research indicates that finely ground pellets are associated with four times the level of infection as coarse meals (table 10). This is thought to be due to increased content of solids in the stomach with coarse ground meals, which results in an increased concentration of beneficial lactic acid in the stomach preventing *Salmonella* colonization throughout the GI tract.

Table 10

Effect of feed processing on performance and gut health (30-100kg)

Group **Grinding on hammer mill:**	**Pellets 2 mm screen**	**Pellets 4 mm screen**	**Meal 4 mm screen**
Production value index	100[a]	83[b]	67[c]
Lactic acid concentration in stomach, mmol/kg digest	15.0	16.0	34.0
Stomach ulceration score	2.9[a]	1.7[b]	0.08[c]
Salmonella positive pigs, %, serum analysis	12.9	5.6	2.8
Coliforms in stomach, log CFU/g	5.2[a]	4.4[bc]	4.2[c]

Source: Jørgensen et al., 1999

[abc] Significant differences

Xylanase enzyme inclusion to grower/finisher rations has also been shown to reduce the incidence *Salmonella* in pigs when included in both meal or pelleted diets (table 11). This again is likely to be due to an increase in the amount of digestible substrate in the stomach resulting in more favourable gut microflora

Table 11

Effect of xylanase in meal or pelleted diets on *Salmonella* on a challenged unit (32-102kg)

	Pellets (2.5mm screen)	Pellets + xylanase	Meal (4mm screen)	Meal + xylanase
Intake (kg/day)	2.34	2.33	2.53	2.48
DLWG (g)	882	901	828	839
FCR	2.66	2.58	3.06	2.96
DKK Prodn val.*	655	695	431	469
% *Salmonella* positive pigs	30.6	24.1	17.6	13.0

* GM/pen place

Partridge et al 1992

Interestingly, several studies have clearly demonstrated that inclusion of Fructo-oligosaccharides in diets of broiler chickens can significantly reduce *Salmonella* (including S. Typhimurium) infection. Unfortunately however such trials do not so far appear to have been carried out in pigs.

Epidemiological research in the Netherlands suggests that *Salmonella* infections are 10 times lower in wet fed pigs than in dry fed herds (Table 9). This is thought to be due to the acidic nature of wet feed. Wet feed incorporating whey instead of water into the mix again significantly reduces the risk of *Salmonella* infection more than threefold.

Incorporating up to 25% barley in rations has also been shown to reduce *Salmonella* colonisation in pigs. This could partly explain why Scottish herds show lower levels of *Salmonella* compared to English herds (Table 1).

Once the feed has been delivered to the farm, there are a number of actions farmers can take to reduce the risk of contamination. The first is to observe high levels of biosecurity. Feed bins and equipment should be kept as clean as possible, not only to eliminate a source of *Salmonella* but also to help in vermin control.

In a recent survey, 100% of mice and 8% of rats were shown to carry *Salmonella*, which have the ability to contaminate significant quantities of feed. For example, over the period of a year 100 mice will produce 100kg of faeces and 75 litres of urine, all of which carry *Salmonella*. Preventing access of mice is particularly difficult given that a mouse can fit through a gap the width of a pencil. Rats contaminate eight times as much feed as they consume. Effective rodent control is therefore a major way of reducing *Salmonella* contamination of feed.

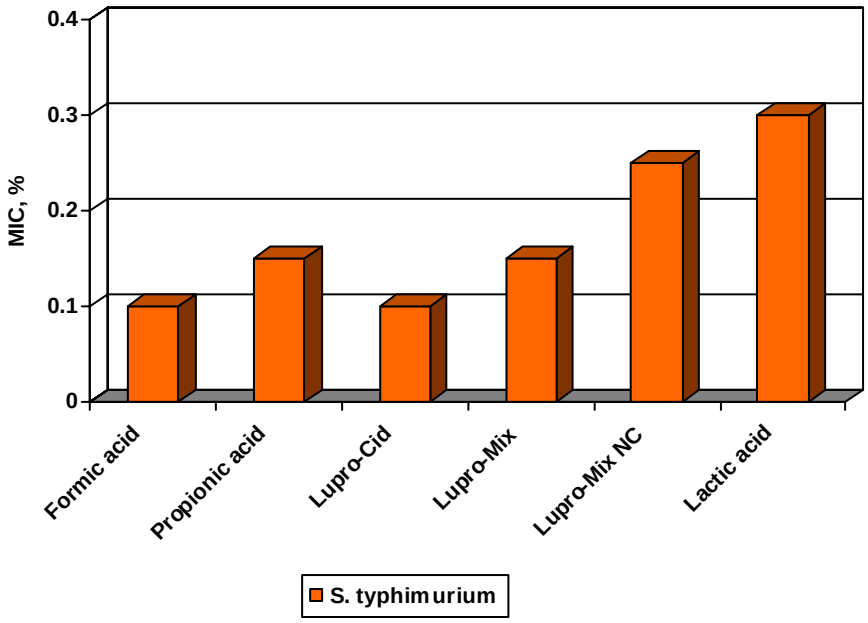
Rodent control should not however rely on cats, which should be prevented access to pig buildings as they are often (1 in 5 cats carry S. Typhimurium) contaminated with *Salmonella* and are a significant vector for *Salmonella* spread.

Flies are also known to spread *Salmonella* and should be controlled.

The other area offering considerable benefits to *Salmonella* control on farm is the acidification of feed ingredients or finished feeds with organic acids, in particular formic acid. The physical treatment of feed with acids reduces the pH to nearer 4.2 (optimal to stop *Salmonella* growth), offering a residual effect against potential recontamination and acting as a barrier to colonisation. The levels required of suitably concentrated products are small (figure 4) to stop *Salmonella* surviving in feed. Furthermore, the act of acidification with formic acid also helps keep feed equipment and bins clean.

Figure 4

Minimum inhibition concentration of organic acids against S.Typhimurium



Modifying the gut environment for *Salmonella* control

Possibly the biggest benefit of feed acidification occurs within the pig itself.

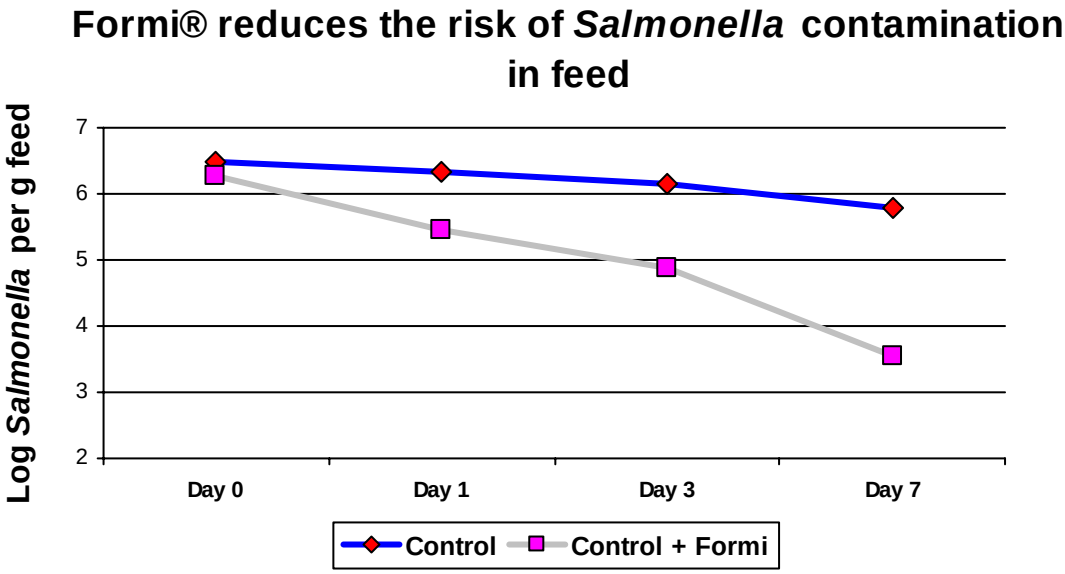
The gut of pigs offers an almost ideal environment for *Salmonella* growth, being within the optimal levels for temperature, moisture and pH. Acidification of the feed will inhibit the growth of *Salmonella* and consequently reduce infection levels and the number of bacteria shed by the animal on a daily basis.

Research trials experience with Formi®, BASF's branded form of potassium di-formate and the first non-antibiotic performance enhancer approved by the EU for use in pigs, shows a significantly reduced incidence of *Salmonella* in both feed (figure 5) and the gut of pigs (figure 6).

A high proportion (88%) of the Formic acid present in Formi passes through the stomach into the small and large intestine (due to the protected nature of the product). Therefore, as well as reducing *Salmonella*, acidification of the feed with

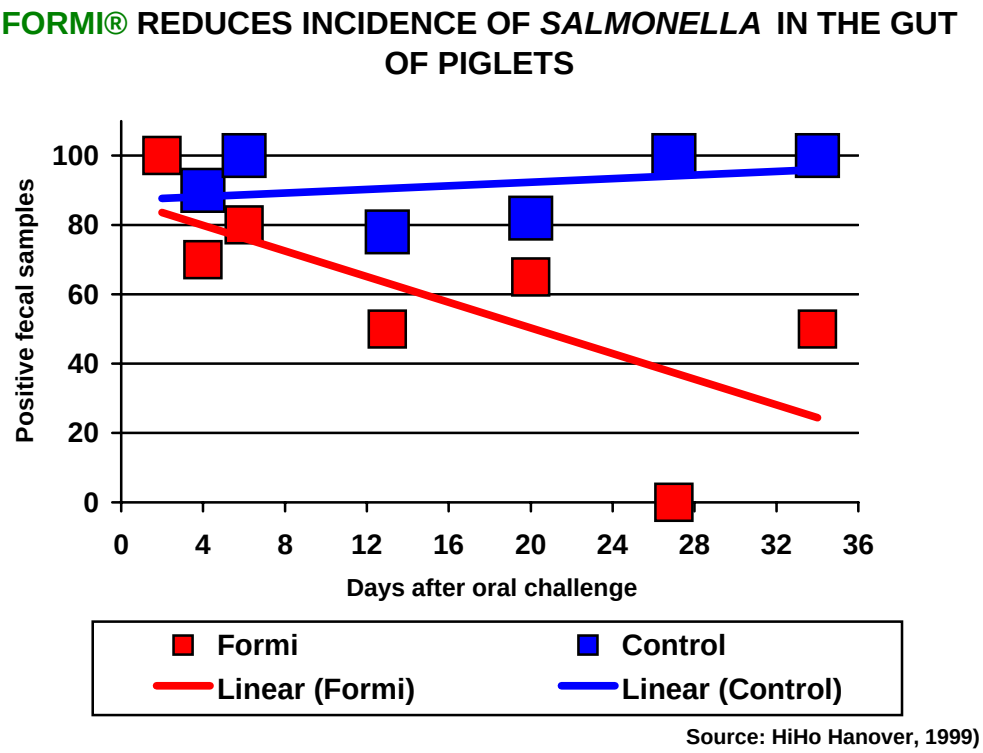
Formi will actually promote the development of an overall more beneficial gut microflora and increase animal performance (Overland, 2003). Practical experience has shown that an inclusion of 6kg/tonne Formi in feed for grower-finisher pigs has good effect on reducing the incidence of *Salmonella* positive pigs in Danish pig herds where a *Salmonella* control programme has been in place since 1993.

Figure 5



Pig feed was artificiallly contaminated with *Salmonella* seftenberg on day 0. Formi markedly reduces the risk of Salmonella in feed.

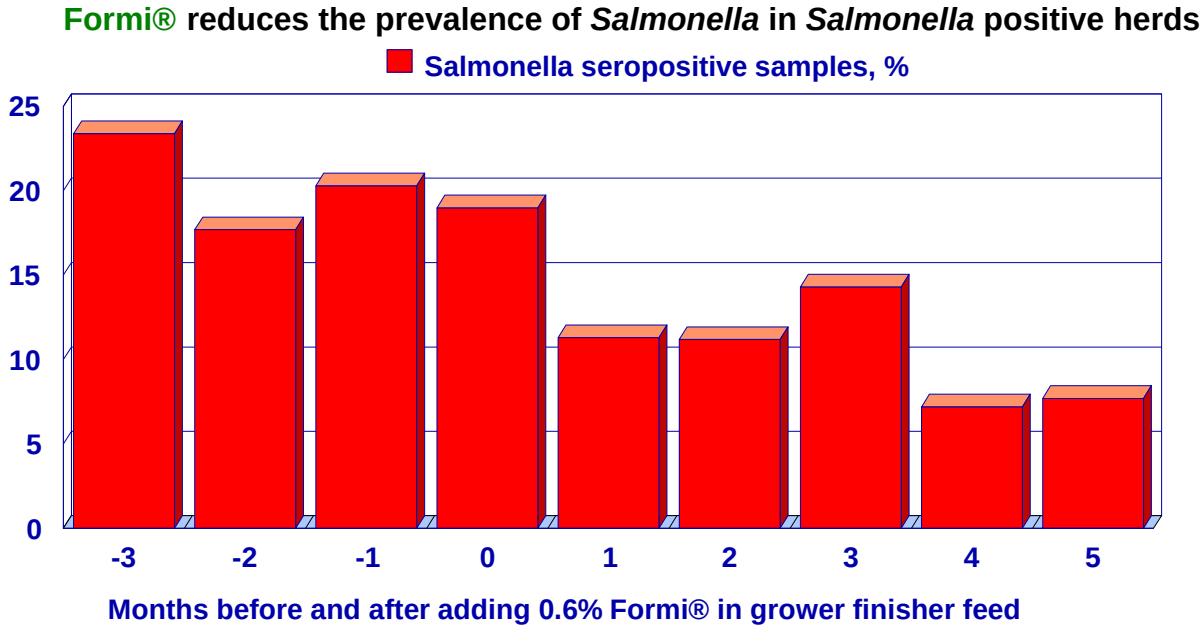
Figure 6



Source: HiHo Hanover, 1999)

By collecting data from the Danish *Salmonella* Control Programme, the feed company KFK looked into the effect of adding 6kg/t Formi to grower-finisher feed. The data was collected from 15 grower-finisher herds, which for at least 5 months had used compound feed from KFK including 6kg/tonne Formi. The percentage of pigs testing positive for *Salmonella* are shown in figure 7.

Figure 7



Source: TiHo Hanover, 1999

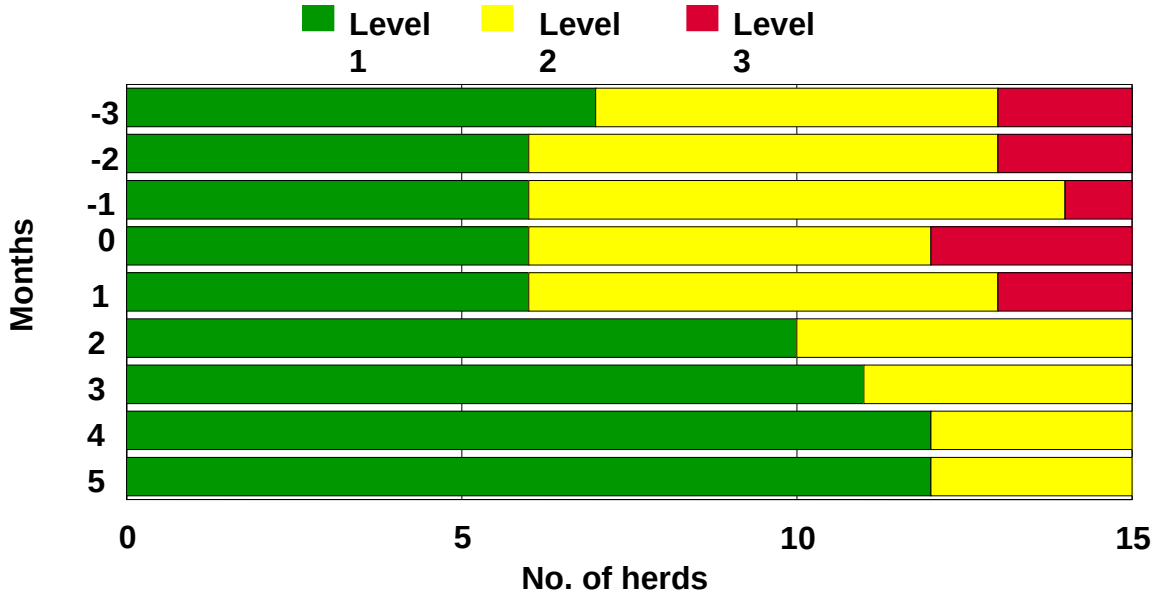
The Danish *Salmonella* Control Programme divides the finisher herds in to three levels of *Salmonella* with respect to the proportion of *Salmonella* seropositive samples.

- Level 1 = None or very few positive antibodies
- Level 2 = Medium number of positive antibodies (2% reduction in carcass price)
- Level 3 = High number of positive antibodies (4% reduction in carcass price)

The 15 herds shown in figure 7 were divided in to the above-mentioned three levels of *Salmonella* as shown in figure 8. The figure shows that from two months after the start of including 6kg/tonne Formi to the feed there is a significant reduction in the number of herds in level 3 and level 2. From experience to-date we know that it takes about 6 weeks after the start of including Formi to the feed before a reduction in the prevalence of *Salmonella* in seropositive herds is seen.

Figure 8

Effect of adding Formi in grower finisher feed on the prevalence of *salmonella*. (Level 3 = high level of *Salmonella*. Month 0 = 0.6% Formi added to the feed from this month)



These results led KFK to recommend the inclusion of Formi, in conjunction with good management practices and changes to feed structure as shown in table 12, into grower-finisher diets on farms with a high incidence of *Salmonella*.

Table 12

Danish recommendations in how to reduce the prevalence of *Salmonella* in *Salmonella* positive herds

- **Strict all in – all out production**
- **Thorough cleaning and disinfection**
  - The pens should be soaked before cleaning to soften the organic matter
  - Wash out around and underneath feed hoppers
  - The pens must dry out before disinfection
- **Avoid crowding**
- **Avoid birds in buildings**
- **Good water hygiene**
  - "Consider using Formic acid based additives"
- **Efficient rodent control**
- **Buy *Salmonella* negative piglets/breeding stock**
- **Include 0.6% Formi in the feed**
- **Use 25 – 30% coarsely ground barley/wheat in combination with 0.6% Formi**
  - "The reduction in the prevalence of *Salmonella* can normally be seen after 6 weeks of feeding Formi"

Danish work has shown that the meat juice ELISA test will measure antibodies to *Salmonella* from an average of up to 6 weeks after the exposure. This means that if a pig was exposed to *Salmonella* at an earlier point, followed by a period of over 6 weeks without re-contamination, the ELISA test at slaughter would be negative. This explains why intervention with Formi in the grower and finisher stage is so successful.

UK *Salmonella* Trial

Given these Danish results showing effectiveness of Formi against *Salmonella*, a trial was initiated in the UK to test this finding on a typical UK grower/finisher unit.

A well managed commercial 2000 place East Anglian unit was chosen with a history of high levels of *Salmonella* infection, including symptoms of clinical *Salmonellosis*.

Pigs entered the unit at 38kg, from a single outdoor unit. At this stage the pigs tested negative for *Salmonella*. However 7 weeks after arrival they sero-converted to *Salmonella* positive, suggesting a *Salmonella* challenge in the grower/finisher unit.

A VLA *Salmonella* inspection of the unit immediately prior to the feeding of Formi showed widespread *Salmonella* infection at **82% positive** by blood test.

Formi was included at 6.25kg/tonne in all grower and finisher rations for a period of two months i.e. for one complete batch. During this 2 months period no other major changes in nutrition or herd management were made.

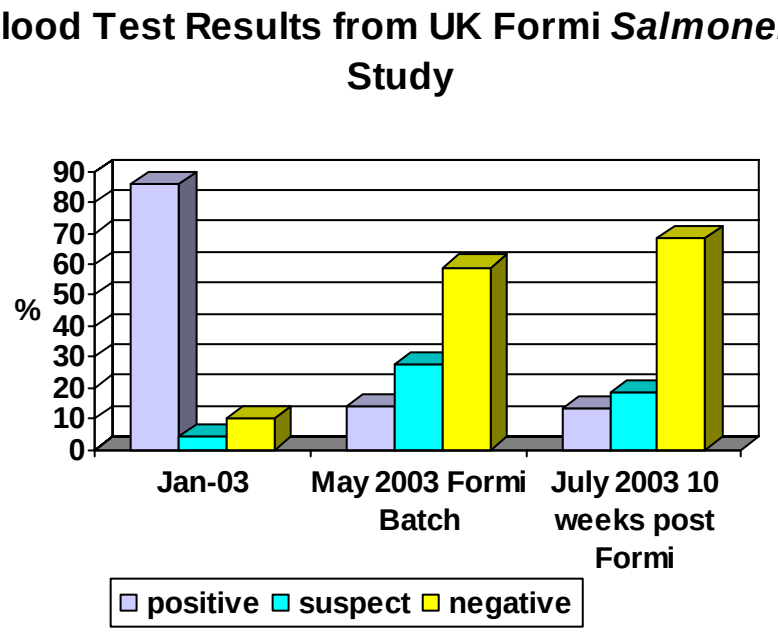
Below are shown the Meat Juice ELISA scores before and during this trial:

- Annually to December 2002 56.4% positive
- Quarterly to December 2002 59% positive
- Formi batch of pigs 27.3% positive

Figure 9 shows the blood test results taken before, at the end of the Formi trial and 10 weeks post Formi respectively. These results clearly show a significant reduction in *Salmonella* blood test levels following Formi feeding, which appears to be sustained following Formi removal.

Both UK trials and practical experience from Denmark has shown that *Salmonella* levels are likely to remain at a reduced level following Formi removal for up to 3 or 4 months. Given that the major route of transmission of *Salmonella* through a unit is from pig to pig, this finding is perhaps not surprising. However, it should be noted that unless the original vectors of *Salmonella* on the unit are removed, then *Salmonella* levels will inevitably gradually increase again once Formi is removed from diets.

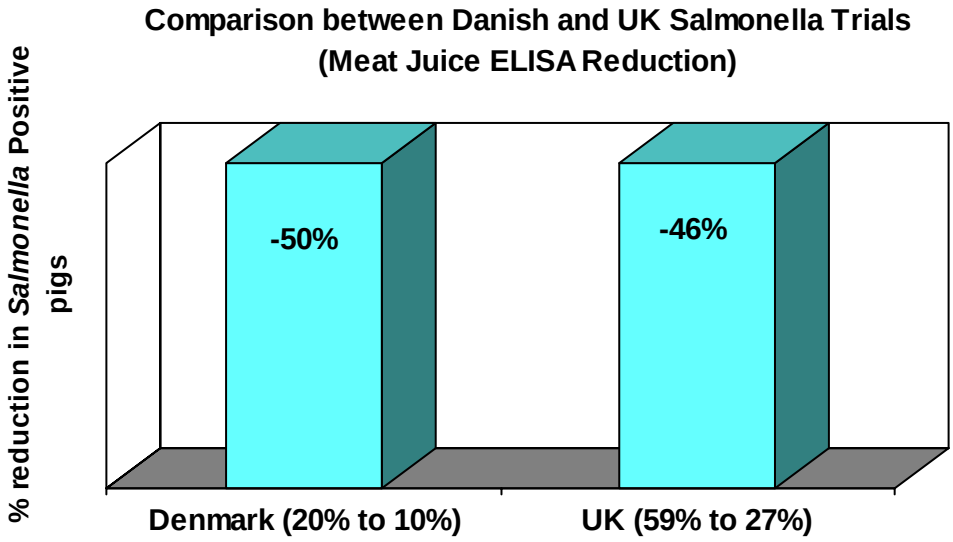
Figure 9



A VLA *Salmonella* inspection report at the end of the trial showed "a much lower level of infection" (**13% positive** samples).

This trial clearly confirmed the findings of the KFK work demonstrating that Formi can reduce these number of *Salmonella* positive pigs in a herd by around 50%, illustrated in Figure 10.

Figure 10

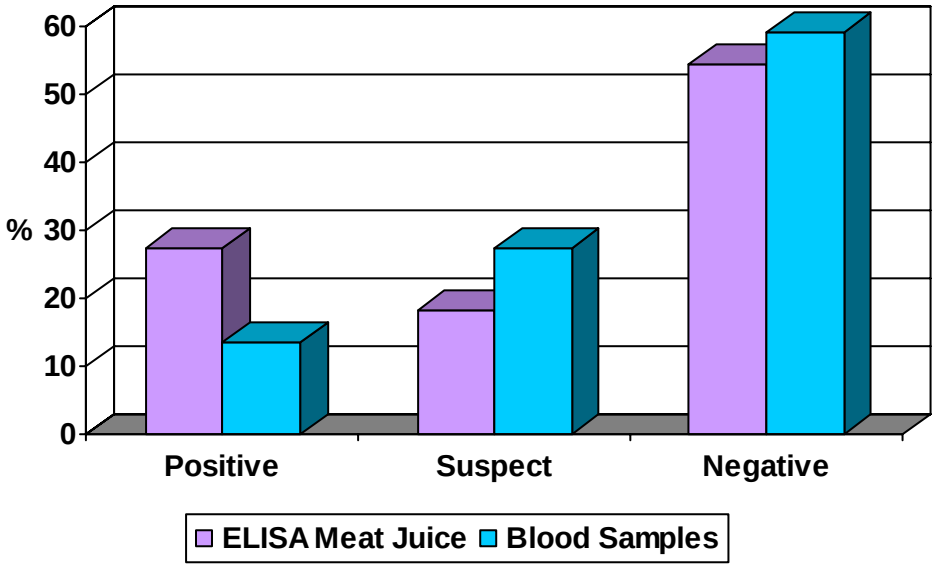


Comparison of blood test and ELISA results

The meat juice ELISA test is reported to be less sensitive than serology. The accuracy of both ELISA tests and serology results from our recent UK trial was

compared, as can be seen in figure 11. This exercise in fact showed a reasonable correlation between the methods of analysis, particularly for detecting negative pigs.

Figure 11 **Relationship between blood sample results and meat juice ELISA test taken at point of slaughter in recent BASF trials**



It should be noted, that *Salmonella* infection may not necessarily result in *Salmonella* invasion and therefore immunostimulation resulting in high antibody levels detected in either meat juice or blood. The degree to which *Salmonella* infection will result in invasion will depend upon the following factors:

- Species of *Salmonella* (S. Typhimurium is one of the most invasive, hence immunostimulating *Salmonella*)
- Overall *Salmonella* challenge
- General health status of the pig
- Stresses imposed on the pig (i.e. feed withdrawal)

When farmers are attempting to evaluate the effectiveness of different management and nutritional practices on *Salmonella* level it is preferable to obtain blood test results from a representative number of pigs rather than rely upon the meat juice ELISA samples taken at slaughter.

Results from such blood tests taken by a vet will be available to the farmer far quicker than ELISA results and will also show the level of suspect cases as well as positive and negative results.

Is there a payback?

Inevitably the accusation will be made that *Salmonella* controls are yet another burden being placed on the pig farmer, leading to increased costs and no return. However as an industry we must react to developments and do all we can to

promote the integrity and quality of domestic meat supplies. For those farmers who fail to meet the standards there will be the risk of financial penalties or the loss of a market for the pigs.

The good news however is that Danish research (Salinpork 2000), based on an evaluation of 48 commercial farms, has demonstrated that there can be a financial payback as a result of the improved management practices required to control *Salmonella* and these are summarised in Table 13.

Table 13

The financial payback of implementing *Salmonella* controls in the average herd (Salinpork 2000)

	£
Performance benefits	
Improvement of 2.82% in DLWG with 2.65 reduction in days to slaughter	4,900
Improvement of 2.61% in FCR	10,250
Total benefit	**15,250**
Control programme costs	
Formic acid treatment of feed and water	7,100
Comprehensive disinfection and cleaning programme including use of cleaning agency	2,300
Total control costs	**9,400**
NET BENEFIT	**5850**

Reducing *Salmonella* infections and improving feed conversion and growth rates could have an immediate payback to producers in advance of the implementation of the ZAP scheme. Due to it's registered and proven performance-enhancing effect, Formi when used within a *Salmonella* control programme is also likely to be very cost effective. Assuming a typical improvement in FCR from including 6kg/tonne Formi to grower/finisher diets of 3.0% and an improvement of DLWG of 5%, these improvements alone will cover the cost of Formi inclusion, as shown in table 14. These advantages exclude reduced veterinary bills and culling rates that can accompany *Salmonella* outbreaks and benefits arising from reduced variability in performance.

Table 14

Covering the cost of FORMI in grower/finisher rations
(MLC 2002 average feeding herd results)

Before Formi (30 – 95kg)

- 65kg gain x 2.72 FCR = 176.8kg Feed @ £135/t = Feed cost £23.87/pig
  Daily liveweight gain = 635g/day = 102.4 days

After Formi (6kg inclusion of Formi at £1.20/kg)

- Assuming 3% improvement FCR – 65kg gain x 2.64 = 171.6kg Feed @ £142.20 (including Formi) = Feed cost £24.35/pig
  Daily liveweight gain assuming improvement of 5% = 667g/day = 97.45 days
  = Reduction in days to slaughter of 5 days

  MLC calculate a cost of 16p/pig cost saving for each reduced day to slaughter, **therefore 5 days reduction = £0.80/pig**

Net Benefit

- FCR and DLWG benefit of Formi will save 32p/pig. On an average 500 sow herd this saving would equate to over £3,600 plus benefits of reduced *Salmonella* positive ELISA tests (no ZAP penalties) reduced variability in performance and reduced veterinary bills.

Conclusion

Salmonella control on farms has to be implemented through an overall strategy of which feed is just one element. The crucial thing is that pig farmers must start acting now if they are to achieve ZAP 1 status and secure the market for their pigs when the scheme is launched.

Farmers should therefore be encouraged to develop ASAP with their veterinary surgeon an appropriate *Salmonella* control programme for their specific unit.