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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: OZ0148

2. Project title:
   R18 - Evaluating the effect of demonstration farms as a tool for implementation of disease/infection control programs

3. Contractor organisation(s):
   Veterinary Laboratories Agency
   Woodham Lane
   New Haw, Addlestone
   Surrey
   KT15 3NB

4. Total Defra project costs (agreed fixed price): £120,850.00

5. Project: start date..... 01/08/2008
   end date..... 31/03/2011

6. It is Defra's intention to publish this form.
Please confirm your agreement to do so. ..... **YES** ☒ **NO** ☐

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Introduction: This two-phase project presented the farmers' perception of and barriers to implementing intervention on *Salmonella* control on pig farms. Four farms that had implemented interventions and their close contacts took part in a semi-structured interview and were asked to complete two rated questionnaires in the first phase and three in the second phase. The results of these interviews were compared with interviews from control farms selected at random.

Theory: Based on Azjen's pathway to disease control model (Azjen, 1991), three intrinsic factors that influence motivation were evaluated in this study: attitude towards *Salmonella* control, perception of supportiveness of social norms and perception of self-efficacy. Knowledge and skills, one of the extrinsic factors, was also briefly explored during the second phase.

Results and Discussion: Results from the intervention trials had not been made known to most of the farmers at the end of the second phase. Therefore the assumption that the results of a demonstration farm could influence farmer's intent in implementing an intervention could not be confirmed.

Overall, farmers had a positive attitude towards *Salmonella* control and felt that their peers and authorities were supportive when it came to controlling *Salmonella* on farms in both phases. Belief in self-efficacy was more uncertain and became even more uncertain at the second interview. When asked about how the implementation of *Salmonella* control on farms would affect their ZNCP score and human health, very few thought it would have a huge impact on either of them. In fact the majority thought they could improve their ZNCP only very slightly and a large proportion thought it would not have an impact on their score. In the second phase even more farmers thought it wouldn't change anything or failed to answer due to "not known". It became clear during the second phase that while a positive attitude helped, improving belief in self-efficacy would be more efficient to stimulate farmers towards an intent or implementation, whereas the social norms had no or very little effect on the farmers' intent to take actions.

Farmers identified their private veterinarian as the key source of advice to guide them during the process of implementing a change and for providing relevant knowledge. Some were also influenced by an increase in their ZNCP score, especially farmers with a low ZNCP score, but were also aware that it was not an accurate measure of the current *Salmonella* problem on their farm. Some intervention farms and their close contacts would be influenced by their direct customers too, especially those with a very high

ZNCP score.

Farmers strongly believed that they had some sort of responsibility to produce a safe product throughout both phases even though their confidence in how their action can help has dropped. They believed that the whole industry should contribute to the control of *Salmonella* and to the cost of it.

What motivated or influenced farmers' decision to take actions also depended on whether they intended to take action or not. Farmers with intent to take action were motivated by their veterinarian or government, reacted to an increase of their ZNCP score and distributed the responsibility of *Salmonella* control over the whole industry.

Conclusion: This study confirmed that producers recognised the importance of and believed that they have a responsibility in controlling *Salmonella* in pork but also shared that responsibility with the rest of the chain. It showed that farmers were best motivated by their vets, though the ZNCP score also seemed to have some influence on their behaviour. Farmers mentioned the costs of implementing a control measure and the lack of financial benefit for their business as their main barriers to take action on their farm. There is also a need to validate which measures are effective as farmers were not convinced that the current known interventions were effective against *Salmonella* and worth the extra effort and costs. Improving the belief in self-efficacy (an intrinsic factor) would result in an improvement in farmer's intent to take action.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   a. the scientific objectives as set out in the contract;
   b. the extent to which the objectives set out in the contract have been met;
   c. details of methods used and the results obtained, including statistical analysis (if appropriate);
   d. a discussion of the results and their reliability;
   e. the main implications of the findings;
   f. possible future work; and
   g. any action resulting from the research (e.g. IP, Knowledge Transfer).

a) Scientific Objectives

[1] To investigate the effect of using "demonstration farms" to encourage uptake of *Salmonella* control by comparison of the level of intent and uptake in close contact farms compared to non-contact farms.

[2] To capture attributes and motivators for pig farmers to volunteer to participate in British Pig Executive's intervention studies, when compared to those of non-participation farms.

[3] Identify intrinsic and extrinsic barriers that hinder uptake of *Salmonella* control practices and changes in the barriers over time.

[4] To describe pig farmers' attitude to and perception of their role in *Salmonella* control and changes in these perceptions over time.

One additional objective was added for the second phase of this project:

[5] To explore how an extrinsic factor (knowledge, skills and ability) can influence intrinsic factors, by identifying which sources of information are trusted and used, and assess knowledge on current research and available resources on pig diseases and Salmonella – (Added 14/06/10 in amended SID 3)

b) Objectives results

[1] The outcomes of the BPEX interventions trial were mostly unknown and this trial has not succeeded in informing farms of the success or failure of the interventions in the period covered by the two phases of this study. It is therefore difficult to comment on how the uptake of *Salmonella* control was influenced by the BPEX demonstration trial.

[2] This study confirmed that private vets, an increase in the ZNCP score (or a "problem with the pigs") and scientific evidence that a control measure does reduce *Salmonella* and is profitable were amongst the factors that would motivate farmers to take action to control *Salmonella*. Control farms had a lower ZNCP score and were mainly motivated by an increase in their ZNCP score whereas the intervention farms and their close contacts had a higher ZNCP score and were mainly motivated by their private veterinarian.

[3] Following the intervention trials, two of the intrinsic factors—the attitude and the perceived level of support from their peers—remained generally positive throughout phase 1 and phase 2. The third intrinsic factor—belief in self-efficacy—became significantly more negative. In both phases, the social norms, whether they think their peers and industry were supportive or not, had no effect on whether or not to take action. The key intrinsic factor that had an effect on farmers' behaviour was a positive belief in self-efficacy and to some extent a positive attitude. There was no statistical difference between the control farms and the intervention & close contact farms for any of the three intrinsic factors in both phases. Most of the farmers (79%) agreed that costs, or no evident cost-benefit, of implementing an intervention that may or may not work on their premises was their biggest barrier. The impracticality of implementing some interventions, the lack of time or knowledge and the lack of scientific evidence were also mentioned by a few farmers as barriers.

[4] In both phases, a large majority of farmers believed that they had the primary responsibility for controlling *Salmonella* in the pigs produced. They also believed that it should be shared with the rest of the food chain; the abattoir, the consumers and the processor being the main three stakeholders mentioned by the majority of farmers. The key change between phase 1 and 2 was a shift in responsibilities from the government to the retailer. In the second phase, none of the farmers directly mentioned the government as having any responsibilities in controlling *Salmonella* in pigs. Due to recent economic factors, the government's role seemed to have changed and farmers no longer considered the government responsible for control or paying for control, but believed that retailers should have had a larger part of the responsibility in preventing the spread of *Salmonella*.

[5] The questionnaire on knowledge transfer confirmed the importance of the private veterinarian in the farmer's decision process to take action, where vets were the main source of information for farmers. Farmers were therefore directly influenced by their private veterinarian positively or negatively. Farmers preferred face-to-face advice but also appreciated newsletters or reports tailored to their farm and sent directly to them. The internet was a good alternative source of information. They rarely used DVDs to obtain the information they needed, and considered information on *Salmonella* to be less important than pig diseases in general. Pig World reached a high proportion of pig farmers, and may therefore be an effective means to disseminate information and influence farmers. The opinion on "demonstration farms" as a knowledge transfer tool was divided. Just over half the farmers did not like that knowledge transfer tool and just less than half the farmer liked it a little. Some farmers admitted to not looking for information on *Salmonella* and considered information on *Salmonella* less important than on other pig disease control. It was also found that farmers were unaware of most of the sources of information on *Salmonella* that had been suggested by our project team. This may imply that *Salmonella* was not the farmer's priority or main concern or that the information was not disseminated by the most appropriate route.

c) Methods and Results

Study population

The group of farmers recruited was structured around BPEX intervention farms. Each intervention farm recruited generated a cluster with its close contacts. The final study population consisted of four clusters around intervention farms and one control cluster (Chart 1).

Five pig farms enrolled in the BPEX intervention study were recruited in our study. Two of the intervention farms were close contacts of each other, so one was recruited as an intervention farm and one as a close contact. Further close contacts were selected for the intervention farm only. A maximum of nine close contacts were enrolled for each intervention farm. Close contacts were identified and enrolled firstly by the intervention farmer as any other pig farmer, with whom s/he had regular social or professional contact and at least occasionally discussed pig husbandry/farming; secondly by the private veterinarian suggesting farmers, to whom s/he would recommend a successful intervention, because they were considered 'positive' and potential 'early uptakers'; and finally by BPEX as pig farmers that were part of the same regional group and thereby, attended the same meetings and received the same information material as the intervention farm.

A letter was sent to the farmers informing them of the study and the fact that one of their contacts was trialling an intervention to control *Salmonella* on farm. Upon agreement to participate, they were interviewed by a veterinarian or a veterinarian student.

Control farms were randomly selected using BPEX's membership lists in regions, where no intervention farms were operating. The main eligibility criterion was that the farmer did not personally know any of the intervention farmers.

During the first phase, a close contact from the Midlands cluster and a control farm were excluded following the loss of the interview due to a faulty tape. In total, 49 farmers had eligible interviews for analysis.

For the second phase, the same farmers were recruited and interviewed. Three farms were rejected: one control farmer had sold the farm and one close contact farm and one control farm merely refused to be interviewed again. A total of 48 farmers were interviewed.

For comparison purposes between phase one and phase two, only farms that were in both phases were included in the analysis. A total of 46 farms were considered.

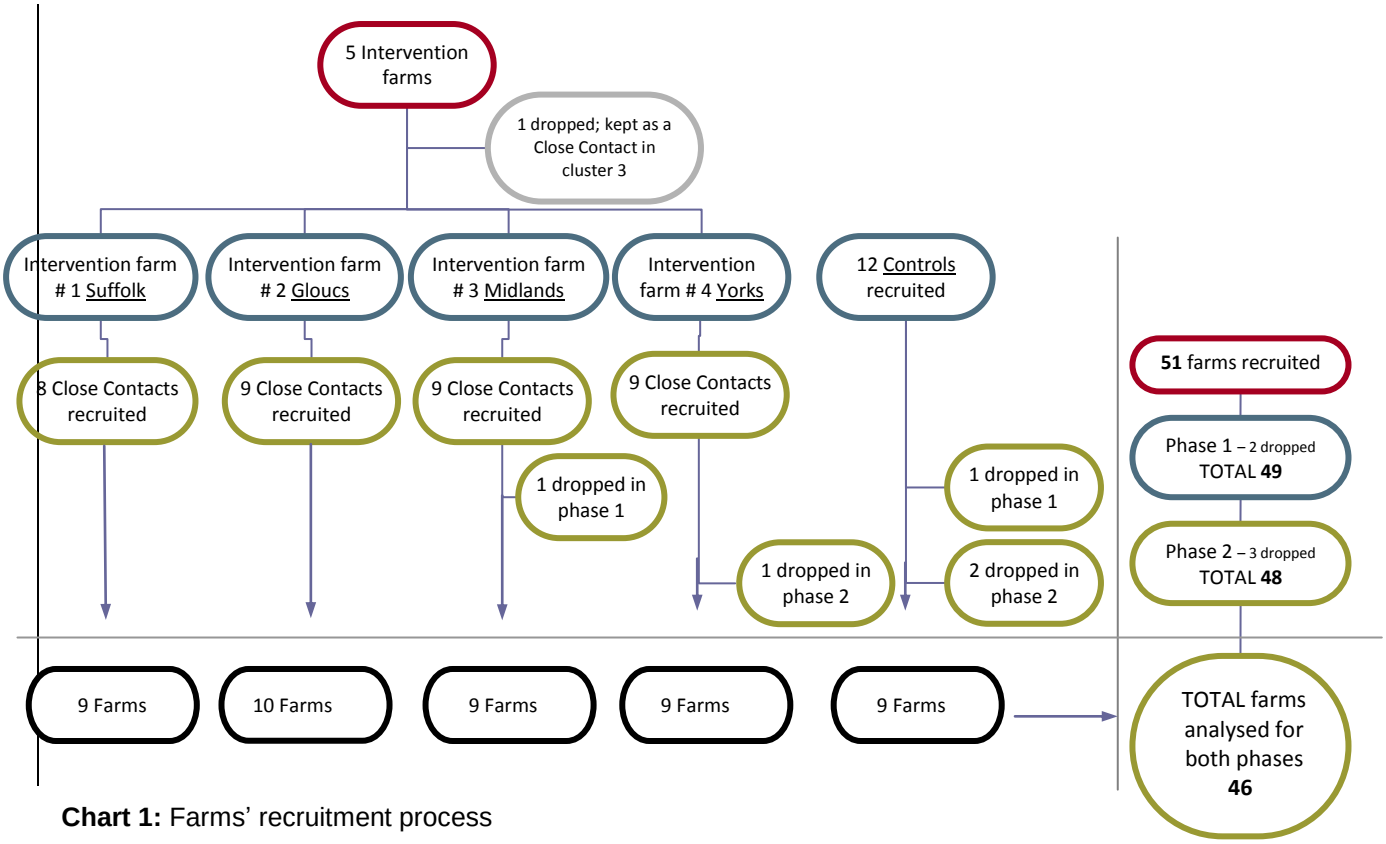


Chart 1: Farms' recruitment process

Data collection

Each farm was visited by an interviewer, who, prior to starting the interviews, had been instructed to follow the same approach for all interviews using a clear set of instructions. At each visit, two questionnaires (Annex 1) were completed and an interview was conducted and recorded on a Dictaphone. A third questionnaire was added during the second phase. The first questionnaire gathered information on the characteristics of the herd and the current *Salmonella* status as well as information on the interviewee (attribute data). The second questionnaire was designed to gather information on intrinsic factors. This included a rated response from the farmers on their attitudes to *Salmonella* control, on their perceived level of support from peers and on their belief in self-efficacy in regards to improving the situation. All three factors were assessed by several questions and rated on a scale from 1 to 5 with 1 being the most positive/supportive/largest and 5 the least. This questionnaire also partly assessed level of intent of implementation. The third questionnaire added for the second phase was designed to briefly explore how an extrinsic factor (knowledge, skills and ability) can influence intrinsic factors, by identifying which sources of information are trusted and used, and assess knowledge on current research and available resources on pig diseases and *Salmonella*.

The interview was conducted using a semi-structured interview technique allowing the conversation to develop naturally between the interviewer and the farmer. It also allowed the interview to lead into and to address areas important to the farmer rather than the interviewer. The interview structure has previously been trialled and described (Ellis-Iversen et al., 2010).

Data management and analysis

All completed questionnaires and recorded interviews were sent to CERA, VLA-Weybridge, where questionnaires were entered into a Microsoft Access database. The interviews were transcribed and quotes were sorted using the software **MAX**QDA for Qualitative Data Analysis. All data were cleaned and analysed using Microsoft Excel and STATA (Statacorp, College Station, TX).

Before analysis, four of the interview transcripts from the farms were considered independently by two veterinary epidemiologists. They assessed analyst-agreement and confidence in interpretation of the loose text and conclusions they had drawn on the interview data (annex 3).

The data were described and comparative analyses were conducted using the appropriate statistical models according to type of variable:

- Chi-squared tests were used for comparisons of two binary variables;
- Student t-tests were used to compare the means of continuous normally distributed variables after normalisation of the variables; Data transformation of numeric variables was used before modelling to ensure that data approximate normality for the multinomial analysis.
- Nonparametric K-sample tests were used to compare the equality of medians.
- The Kruskal-Wallis test of equality-of-populations was applied to compare distributions of ranked variables.

To assess farmer's attitude (figure 4), social norms (figure 6) and belief in self-efficacy (figure 8) several rated questions were asked for each factor. The sum of the scores given to each question for a specific factor was calculated. The frequency of the sum of scores from the study population was used to produce the figures. To compare the "control farms" against the "close contacts & intervention farms" (fig. 5, 7, 9), the median of the group of questions was calculated for each farm and then the percentage of farms having the same median was used. The same questions were asked for both phases (table 1).

Attitude. The farmers were asked to rate how important it was to control *Salmonella* in pigs for them, for public health, for the pig industry and whether control of *Salmonella* in pigs was needed. Their answer was rated between strongly agree and strongly disagree.

Social norms. The farmers were asked how they thought their peers would feel if they applied an intervention on their farm. Their answers were rated between very positive (approve) to very negative (disapprove).

Belief in self-efficacy. The farmers were asked to rate how they would affect the burden of *Salmonella* in pigs if they implemented an effective intervention. They were asked to consider whether the intervention would have an effect on their Zoonoses National Control Plan (ZNCP) scores in the short and long term and how it would affect public health in the next few years. Their answer was rated between very positive (large reduction) and very negative (large increase).

Table 1: List of the questions asked to farmers on each of the three intrinsic factors and the score range.

	Attitudes (figure 3)	**Social Norms (figure 6)**	**Belief in Self-Efficacy (fig 10)**
Questions	Control of *Salmonella* is: a. important for me b. important for public health c. important for pig industry d. needed in pigs	How would the following feel about you applying intervention: a. Defra b. Your vet c. Your company d. BPEX e. Consumers f. The EU g. Your assurance scheme (phase 2)	Because of the intervention, the ZNCP score showed: a. in the next few batches b. in the next years c. in the human population
Score	1= Strongly agree 2= Agree 3= Undecided 4= Disagree 5= Strongly disagree	1= They would like that 2= They would most likely to approve 3= They will not care either way 4= They would most likely to approve 5= They will disapprove	1= large reduction 2= small reduction 3= no difference 4= small increase 5= large increase
Sum score (and all scores in between)	4= very positive 8= positive 12= undecided 16= negative 20= very negative	7= very supportive 14= supportive 21= indifferent 28= unsupportive 35= very unsupportive	3= very positive 6= positive 9= no change 12= negative 15= very negative

Associations between different variables such as farm type and ZNCP score and the stage of the pathway to disease control of the farmer were assessed using multinomial logistic regression analysis to test intention or implementation of controls against “no intent to implement any controls” as baseline.

Key groupings of motivation factors, pay factors and responsibility factors were identified using *principal component analysis* (PCA). For example, all of the answers to questions on motivation (answers for each customer, government, science, vet, and ZNCP score) were entered into a PCA and all variables that were mentioned by at least 20% of the study population were included in the factor identification. All factors with an eigenvalue>1, accounting for most of the variability and therefore most relevant, were maintained and the farmers were scored on each of them to generate factor variables. These variables were used as exposures in multivariable regression analysis to assess association with any factors at the different stages of the pathway to disease control. Three models were built and compared against each factor identified: 1) farmers with intent to farmers with no intent; 2) farmers with implemented measures against farmers with intent only and 3) farmers with either intent or implementation against farmers with no intent. A backwards stepwise method was used to deselect the least significant variable (determined by p-value) at each step until only variables that were significantly associated were retained in the model ($p<0.1$). The use of binary data for PCA violates the assumption of the use of linear, normally distributed data, but it is believed that a PCA on binary data yields results comparable to multiple correspondence analysis.

Theoretical background - Level of intrinsic motivation

Intrinsic factors that influence motivation to implement a control programme can be separated into three groups grounded in the individual’s beliefs and values. These factors are non-objective and describe the farmer’s perception of the situation rather than a measurable level. However, on a population level it is possible to assess whether patterns in perceptions are present and thereby, whether intervention is needed to influence beliefs or attitudes.

The three groups are well described and were first presented by Ajzen as the model of reasoned behaviour (Ajzen, 1991). The intrinsic factors have been included in other models, which were developed for specific situations (Panter-Brick et al., 2006). In one of the latest examples, they were used as part of a ‘pathway to disease control’ model, which was developed to describe livestock farmers’ perceptions, motivators and barriers in relation to disease control in their livestock (Ellis-Iversen et al., 2010). This model considers that both intrinsic and extrinsic factors influence such decisions when livestock farmers in Great Britain are often standing in a grey zone between business and life style decision-making (figure 1).

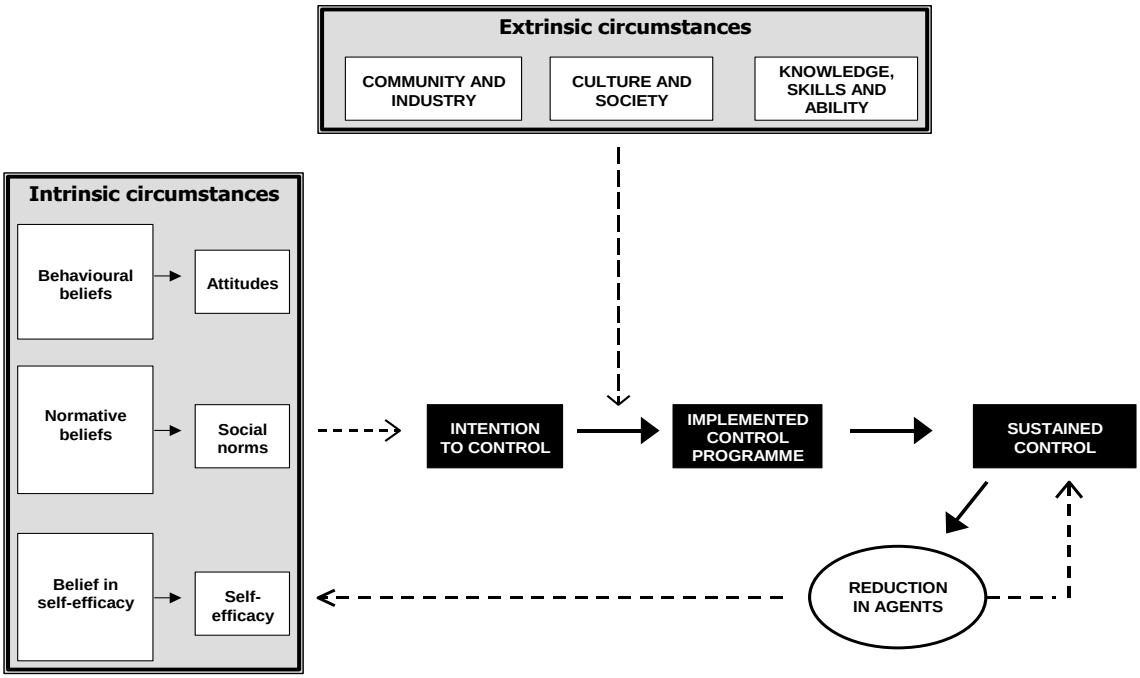


Figure legend: Black boxes = stages in process of behaviour change; circle = desired outcome; grey boxes = circumstances that influence behaviour; non-dashed arrows = movements towards desired outcome; dashed arrows = factors affecting movement between stages of behavioural change.

Figure 1: The ‘pathway to disease control’ model to describe implementation of disease control on farms (Ellis-Iversen et al., 2010).

Interventions trialled

The four BPEX intervention farms tested interventions as agreed and managed by BPEX. One farm added Bio-Mos® to the lactating and dry sow ration to reduce *Salmonella* level in weaners. The second intervention farm switched from pelleted to coarsely ground meal feed in the growers. The third farm used a live-attenuated *Salmonella* Typhimurium vaccine for the sows (Salmoporc STM®) administered by injection at 6 and 3 weeks antepartum and fed weaners & growers with liquid acidified feed. The fourth farm vaccinated weaners at weaning using a live *Salmonella* vaccine (AviPro® vac T) given orally by mixing the vaccine with their gruel.

Results

Intervention results

Farmers were asked whether the intervention trialled worked and helped to reduce the *Salmonella* level in their pigs. None of the farmers reported seeing convincing improvements. Three were unsure of what the results were, including one who believed that it may have helped to reduce *Salmonella* a little. One farmer said that the intervention didn't work at all (table 2).

Table 2: Results of the interventions according to the farmers and their ZNCP score.

N	Intervention	Farmer's observation	Has it worked?	ZNCP score
1	Bio-Mos added to the feed	No changed observed. Farmer didn't hear about any change in ZNCP score.	Unsure	Not monitored
2	Change pellets to meal feed	Pigs didn't grow as well. Farmer didn't see any change in ZNCP score.	It didn't work at all	Small Reduction (58% to 55%)
3	Live-attenuated *S.* Typhimurium vaccine for sows	No change observed and no changes in his ZNCP score.	Unsure	No change (17% to 17%)
4	Live *Salmonella* vaccine for weaners	Farmer believes that the intervention led to a small reduction in *Salmonella*. ZNCP score not monitored.	Unsure	Not monitored (60% to NK)

When "close contact" farmers were asked about the results of the intervention farm in their cluster, 30 out of 33 were unsure of the results or hadn't heard of them. Two thought (from cluster 3 and 4) that the intervention hadn't worked well and one from the cluster 3 heard from the vet that it hadn't worked at all. Therefore, results from the interventions may have been mitigated, but the information was not well disseminated amongst neighbouring farms. Results from farm 4 were published in Pig World 2009: it confirmed the ineffectiveness of the vaccine on the weaners' (and finishers') *Salmonella* antibody level.

Farm detail

At the time of the first interview the study population had a total of 134225 finishing pigs, ranging from 7 to 11500 pigs per holding with an average of 2918 pigs and a median of 3000 pigs per holding.

During the second interview, farm details were collected again to confirm, clarify or to rectify the information previously gathered. There was 3.4% more finishing pigs in the study population with a total of 138804 ranging from 9 to 14500 pigs. This led to a slightly higher average farm size. Half of the farms had a different number of pigs. The change in the study population is explained by an increase in number of pigs for about a third of the farms and a decrease for about a fifth of the farms.

The herd sizes of the clusters were compared to ensure that none of them varied significantly from the control group (table 3).

Table 3: Comparison of the herd size of finishing pigs for each cluster.

a) Phase one

Cluster	Number of farms	Smallest herd size	Median herd size	Average herd size	Largest herd size	p- value for heterogeneity (Regression)
Control	9	7	1400	2111	6000	Baseline
Gloucester	10	23	2800	2701	5500	0.610
Midlands	9	276	2100	3368	11500	0.291
Suffolk	9	459	2800	3051	10000	0.428
Yorkshire	9	2200	3300	3383	4500	0.286
all farms	**46**	**7**	**3000**	**2918**	**11500**	

b) Phase two

Cluster	number of farms	Smallest herd size	Median herd size	Average herd size	Largest herd size	p- value for heterogeneity (Regression)
Control	9	9	1400	2000	5400	Baseline
Gloucester	10	200	2200	2543	6200	0.670
Midlands	9	240	2400	3116	11500	0.395
Suffolk	9	550	3000	3965	14500	0.137
Yorkshire	9	2200	3600	3516	4500	0.249
all farms	**46**	**9**	**3000**	**3017**	**14500**	

The heterogeneity of herd sizes for each of the different enrolment criteria was also considered (table 4). The tables show no major variation between phase one and phase two.

Table 4: Comparison of the herd sizes of finishing pigs between the three groups – intervention farm, control farm and close contact farm.

a) Phase one

Enrolment farm type	Number of farms	Smallest herd size	Median herd size	Mean herd size	Largest herd size	p- value for heterogeneity (regression)
Control	9	7	1400	2111	6000	Baseline
Intervention	4	3235	3672	3740	4380	0.273
Contact	33	23	3000	3038	11500	0.318

b) Phase two

Enrolment farm type	number of farms	Smallest herd size	Median herd size	Average herd size	Largest herd size	p- value for heterogeneity (regression)
Control	9	9	1400	2000	5400	Baseline
Intervention	4	3235	3672	3740	4380	0.294
Contact	33	200	3000	3207	14500	0.246

The farmers that were interviewed consisted of both managers and owners, mostly males and above 45 years old (65%). The majority of owners also managed the farm (table 5). Not all information was provided by all farmers during the first interview and subsequently the table had missing values. This information was clarified during the second interview. To ensure they had the power to implement an intervention, they were asked if they were the main person making key decisions about the farm system and changes in the management system. All but one answered yes. The farmer who answered “no” kept finishing pigs for a large integrator and therefore had little control on the management of the farm. The same farmers were met for both interviews except for one farm where the husband was interviewed the first time and the wife the second time; both being managers of the farm.

Table 5: Characteristics of the farmers interviewed

		Phase 1		Phase 2	
Criteria	**Characteristics**	**Number of participating farmers**	**% of study population (n=46)**	**Number of participating farmers**	**% of study population (n=46)**
Age	20-35 years	3	6.5	3	6.5
	36-45 years	13	28.3	12	26.1
	45-60 years	24	52.2	23	50.0
	>60 years	6	13.0	8	17.4
Gender	Female	1	2.2	2	4.3
	Male	45	97.8	44	95.7
Job role	Owner	36	78.3	36	78.3
	Manager	10	21.7	10	21.7
Decision	Yes	---	---	45	97.8

The distributions of farm characteristics of the study population are described in table 6. The results are mutually exclusive except for “other enterprises” where a farm can have more than one type of enterprise. Under “other certification”, schemes were reported to be ABRC, IPPC, ISO9001 and pig health scheme. The farm characteristics remained similar between both phases. Some farmers did not answer some questions during the first interview but did answer at the second interview. This may explain the small changes in characteristics. Some farmers acquired a new certification: six of them received the Freedom Foods certifications, whilst one received the free-range certification. Two farmers started other enterprises: one of them kept sheep, two mentioned they had crops as well and one confirmed that they had a B&B on site.

Table 6: Characteristics of the farms recruited for the study. (Mutually exclusive results except for "Other enterprises").

		Phase 1		Phase 2	
Farm Characteristics	**Details**	**Number of farms**	**% of farms in study population (n=46)**	**Number of farms**	**% of farms in study population (n=46)**
Main production	Specialist finishers[1]	9	19.6	10	21.7
	Farrow to finish	28	60.9	30	65.2
	Farrow to grower	1	2.2	1	2.2
	Farrow to weaner	5	10.9	5	10.9
	No answer	3	6.5	0	0.0
Farms with no breeding sows		9	19.6	10	21.7
Farms with no finishers		5	10.9	5	10.9
Finishers housed outdoors	All/ some	4	8.7	6	13.0
	Never	32	69.6	35	76.1
	No finishers[2]	5	10.9	5	10.9
	No answer	5	10.9	0	0.0
Certification	Quality assured (QA) only	28	60.9	30	65.2
	QA & Org & FR & FF	0	0.0	1	2.2
	QA & Organic & Free range	1	2.2	1	2.2
	QA & Organic	1	2.2	0	0.0
	QA & Freedom foods	2	4.3	8	17.4
	QA & Other certification	4	8.7	4	8.7
	None	2	4.3	2	4.3
	No answers	8	17.4	0	0.0
Other enterprises	None	7	15.2	7	15.2
	Crops	28	60.9	30	65.2
	Cattle	11	23.9	11	23.9
	Sheep	10	21.7	11	23.9
	Poultry	6	13.0	6	13.0
	Horses	2	4.3	2	4.3
	Public access[3]	9	19.6	10	21.7

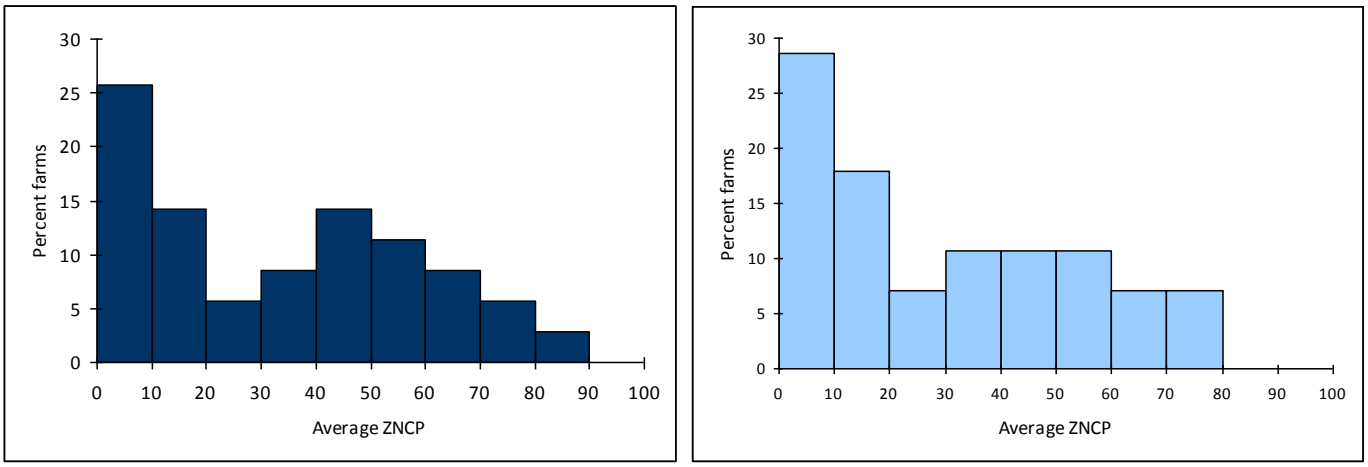
1- "Specialist finishers" includes: farms keeping weaners to finish; weaners to growers; growers to finish
2- "No finishers" includes: farm where pigs were weaned at 4 weeks old (+/- 2 weeks) and sent away to be finished.
3- "Public access" includes farms that offer access to their premise such as school visits, farm shop, B&B. Public foot path were not considered.

Many farms had different practices in place, which they assumed to have some controlling effect on *Salmonella* (table 7). Most farmers had a regular cleaning and disinfection system in place. However, it is not clear how well and consistent this was achieved. At least one farmer mentioned how hard it was to get an accurate dilution rate for the disinfectant and had no idea how much disinfectant the system was using. Vermin control was also a common intervention used to control *Salmonella*. Very few used acid in feed, liquid feeding or vaccination as a mean to control *Salmonella*. When asked what practices they do to specifically control *Salmonella*, a few (13%) farmers answered "nothing specific", because they believed that none of their practices were specific to *Salmonella* but rather were good farming practices. This information was collected during the interviews and was subjected to what the farmer was prepared to say at the time. The variation between the two phases is therefore likely to be due to the farmer not mentioning all actions rather than actions being dropped or added.

Table 7: Different practices used to control *Salmonella* on control farms and close contact farms (multiple answers allowed)

	Phase 1		Phase 2	
Control actions	**Number of control farms (n=9)**	**Number of close contact farm (n=33)**	**Number of control farms (n=9)**	**Number of close contact farm (n=33)**
Regular cleaning and disinfection	7 (78%)	17 (52%)	5 (55%)	20 (61%)
Holistic – a range of actions	5 (56%)	9 (27%)	5 (55%)	9 (27%)
Vermin control	4 (44%)	7 (21%)	2 (22%)	18 (55%)
Acid in feed	0 (0%)	5 (15%)	0 (0%)	2 (6%)
Liquid feed	0 (0%)	5 (15%)	0 (0%)	3 (9%)
Vaccinate	0 (0%)	1 (3%)	0 (0%)	1 (3%)
Acid in water	0 (0%)	1 (3%)	0 (0%)	0 (0%)
All in, All out	---	---	0 (0%)	4 (12%)
Nothing specific to *Salmonella*	---	---	1 (11%)	5 (15%)

To identify any bias in the importance of controlling *Salmonella* to each farmer, the ZNCP score of the farms recruited was considered. The ZNCP scores for the last three months prior to the interviews were collected from the farms that were assured and sent pigs for slaughter (figure 2).



Phase 1: n=34 pig farms.

Phase 2: n=28 pig farms.

Figure 2: Range of average of ZNCP scores from the three months prior to the interview.

Not all ZNCP scores available in 2008 were available in 2010. This may explain the small variation of the average score. Nevertheless, amongst the farms that had a ZNCP score available for both interviews (26), eleven farms saw their ZNCP score increase, twelve had a lower ZNCP score and three were stable. The overall average and average score per group remained stable.

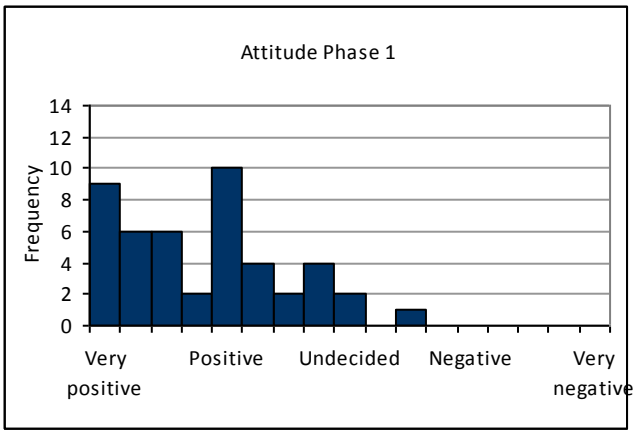
During **phase 1**, ZNCP scores were available for 34 farms: 7 control farms (78% of the control farms), 3 intervention farms (75%) and 24 close contact farms (73%). Eight (24%) were below 10% and the average score was 34% (ranging from 0 – 89%). The control farms had an average score of 8% and close contacts had a statistically significantly higher average score of 40% ($p_{t\text{-}test}$=0.003). Control farms were not significantly more likely to have a ZNCP score <10% than close contacts (p_{chi}^2=0.063). The three intervention farms had an average score of 45%.

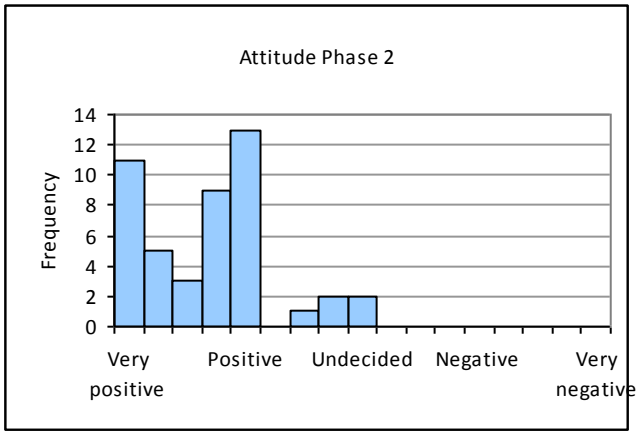
During **phase 2**, ZNCP scores were available for 28 farms: 7 control farms (78%), 2 intervention farms (50%) and 19 close contact farms (58%). Seven (25%) were below 10% and the average score was 31% (ranging from 0 to 72%) The control farms had an average score of 8% and close contacts had a statistically significantly higher average score of 39% ($p_{t\text{-}test}$=0.001). Control farms were significantly more likely to have a ZNCP score <10% than close contacts (p_{chi}^2=0.002). One control farm's and one contact farm's ZNCP score went down below 10% but four of the contact farms' ZNCP score went up above 10%. This explains the variation between phase 1 and phase 2. The two intervention farms had an average score of 36%.

Level of intrinsic motivation of pig farmers to control *Salmonella*

Attitudes towards Salmonella control

In general, the farmers in the study group had a positive attitude and only three farmers did not think that they, or pig farmers in general, had any responsibility or role in *Salmonella* control in pigs, leaving the vast majority (93%) with some positive perceptions of the need to control *Salmonella* on British pig farms (figure 3). During the second phase, the majority of farmers still had a positive attitude towards *Salmonella* control and the need to provide safe food to consumers with 96% having a positive perception to *Salmonella* control (figure 3). Statistically, there was no significant difference between the proportions of farmers with positive attitudes in phase 1 & 2 ($p_{t\text{-}test}$=0.151).

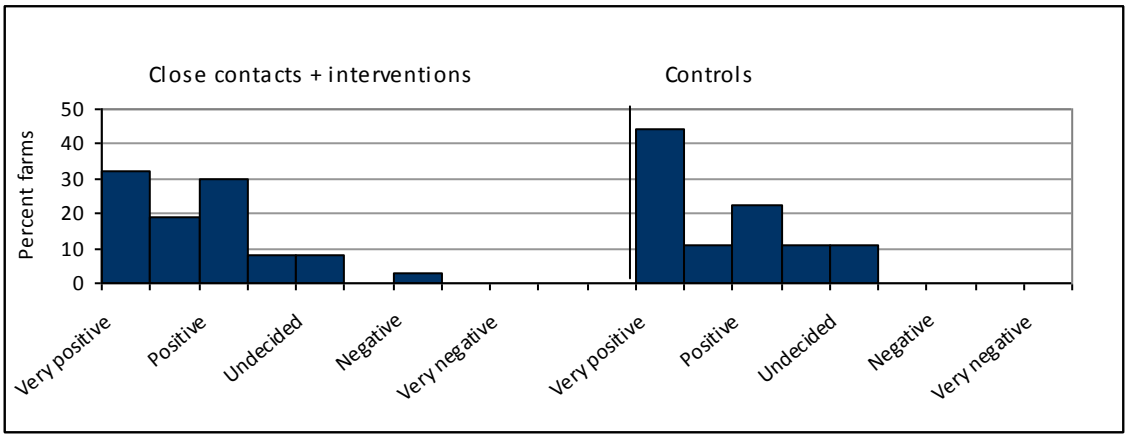




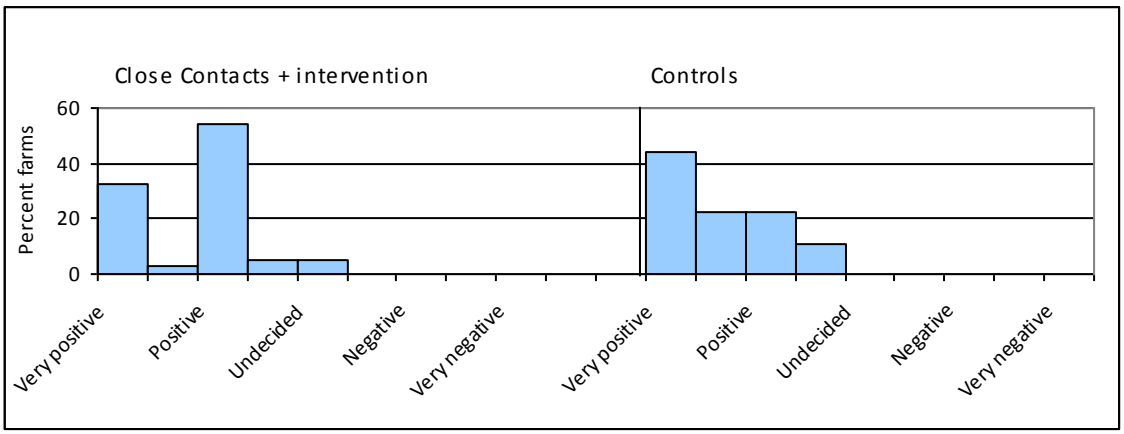
Phase 1 Phase 2

Figure 3: Farmer's attitude towards *Salmonella* control. The frequency of the sum of the scores was used.

The attitude of the control farms was not significantly different to the one of intervention farms and close contacts in both phases. (Phase 1: $p_{kruskall-\ wallis}$=0.740; Phase 2: $p_{kruskall-\ wallis}$=0.299)) (figure 4).



Phase1

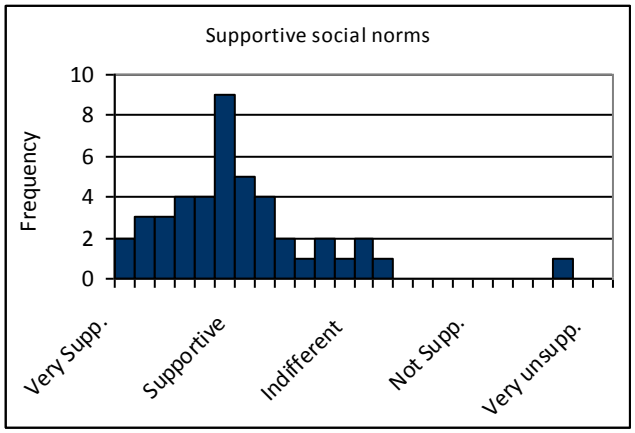


Phase 2

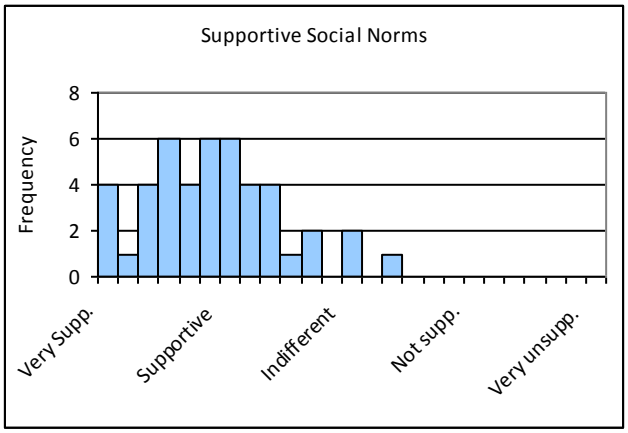
Figure 4: Comparison of the farmer's attitude between close contacts + intervention farms and control farms. The frequency of the grouped medians was used.

Perception of supportiveness of social norms

During phase 1, farmers felt that their peers and authorities were supportive of *Salmonella* control on farms (figure 5). Defra, the company, the private veterinarian and BPEX were perceived as very supportive of *Salmonella* control with a few outliers. However, the farmers were more uncertain about the support from consumers and from the EU. At the second interview, farmers also felt that their peers and authorities were supportive: there was no significant difference between phase 1 & 2 ($p_{t\text{-}test}$=0.9807). However, they perceived BPEX, their vet, their company and their assurance scheme as very supportive whereas Defra, the consumer and EU were perceived as less supportive. As a population, the majority of farmers felt that they had supportive social norms, though a little uncertainty remained.



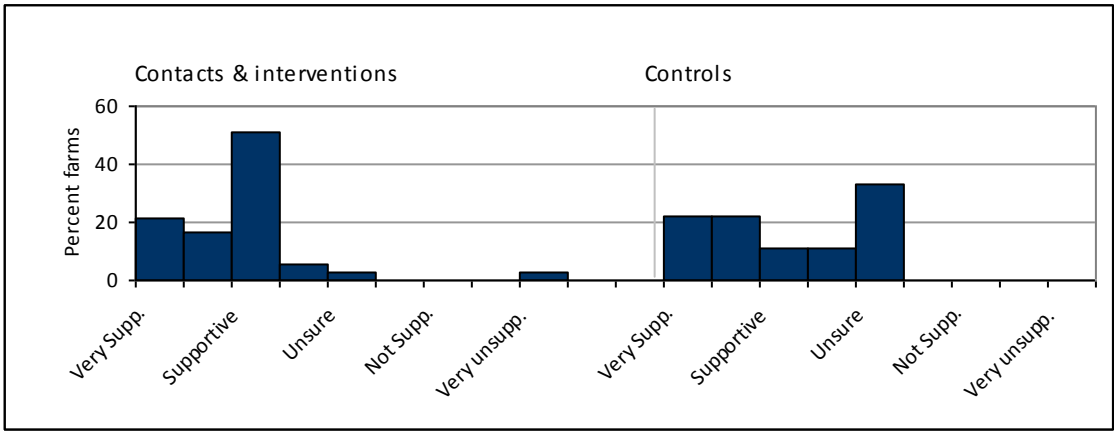
Phase 1 (n=44)



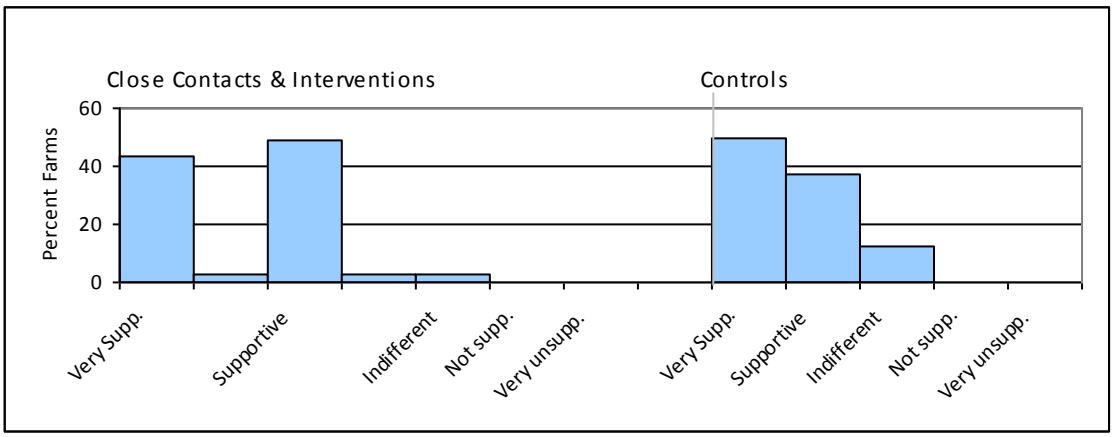
Phase 2 (n=45)

Figure 5: Farmer's perception of the society's supportiveness with regards to *Salmonella* control for phase 1 and 2. The sum of the scores' frequency was used using six variables. Note: some farms were removed due to incomplete set of results for this subject.

The perception of supportiveness of social norms was not significantly different between the control farms and the intervention and close contact farms for both phases, despite an outlier being a close contact farm in phase 1 (figure 6). Phase 1: ($p_{kruskall- wallis}$=0.446); Phase 2: ($p_{kruskall- wallis}$=0.917).



Phase 1 (n=46)



Phase 2 (n=45) – one farmer did not answer these questions

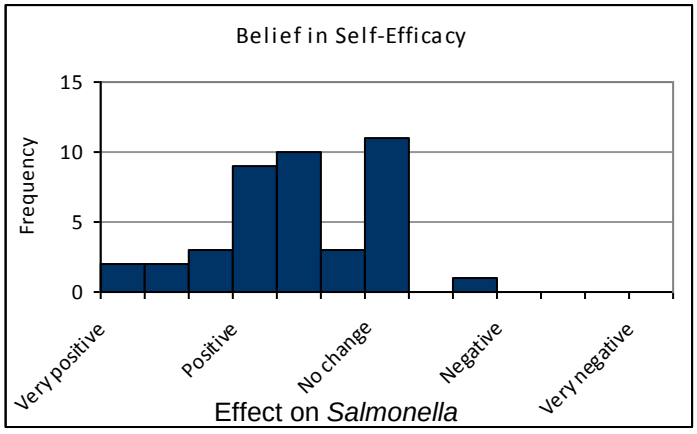
Figure 6: Comparison between close contacts & intervention farms and control farms of the farmer's perception of supportiveness. The frequency of the grouped medians was used.

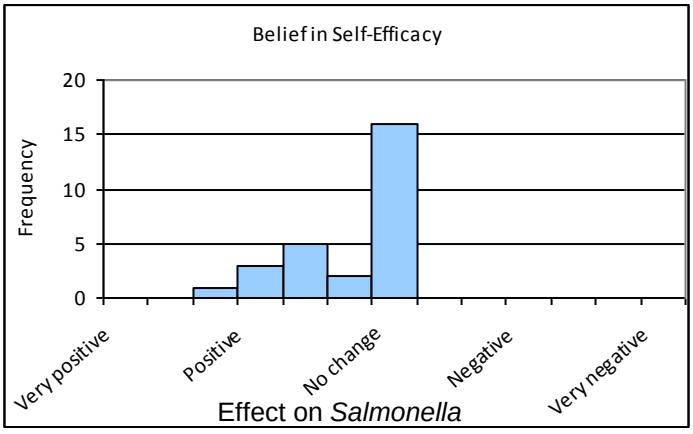
Perception of self-efficacy

Belief in self-efficacy was measured as the perceived effect any intervention carried out by the farmer would have on *Salmonella* and could be positive, negative or uncertain. Belief in self efficacy was less positive than the previous two intrinsic factors.

On average the farmers felt that they could induce a small reduction only or they would have no influence on their ZNCP score or on *Salmonella* in humans. At the first interview, one farmer thought that implementation of an effective intervention would increase their ZNCP scores both in short term and long term perspectives. It may be important to note that this producer kept only 7 pigs. Nobody thought that *Salmonella* control in pigs would increase *Salmonella* in humans and more than half (53%) were not convinced that implementing control measures would have an effect at all on public health. Farmer's opinion was similar two years later. An average of 43% of the farmers thought that implementing *Salmonella* control would not change their ZNCP score (or *Salmonella* level) both in short and long term perspective and 52% thought it would not have an effect on public health. However, 20% thought that *Salmonella* control could reduce their ZNCP score and *Salmonella* in humans a little. These farmers had a lower average ZNCP score than the farmers who did not know or did not believe in any changes. Two farmers thought that implementing control could help reduce their score substantially: one over the next few batches and one over the coming years. About a third of the farmers gave no opinion on how their ZNCP score or *Salmonella* level would vary if they were to implement *Salmonella* control on their farm.

The distribution of belief in self-efficacy in the population was centred somewhere between a vague positive effect and the 'no change' perception (figure 7). Farmers who failed to answer one or more questions were removed from the analysis in figure 7 to avoid skewing the results.



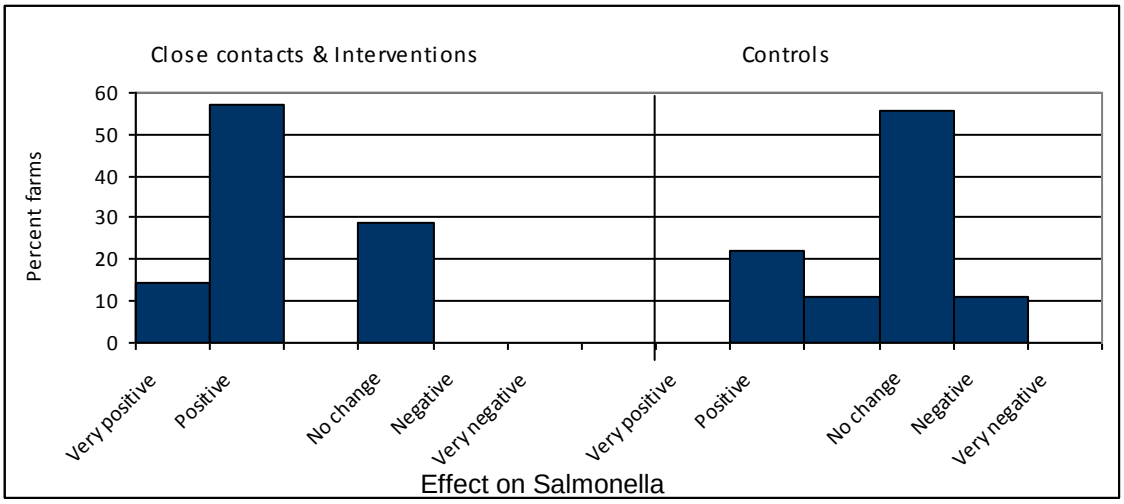


Phase 1: n=41; incomplete set of answers=5 Phase 2: n=27; incomplete set of answers = 7; No answer =12

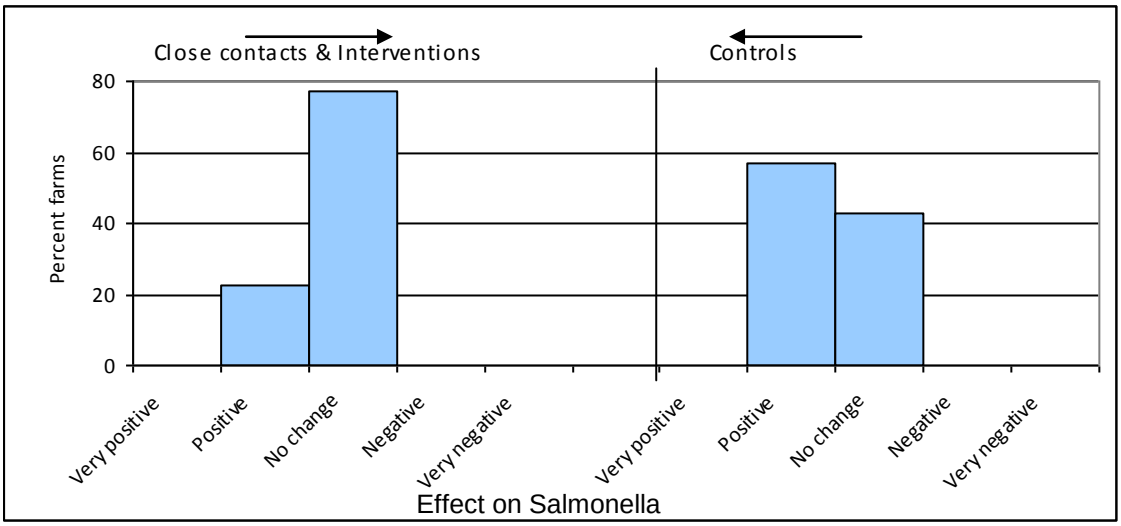
Figure 7: Distribution of how farmers believed their action would affect *Salmonella* in phase 1 and 2. Frequency of the sums of the score was used.

Figure 7 shows that farmers' belief in self-efficacy had moved significantly ($p_{t\text{-}test}$=0.0099) towards a less positive perception between phases, leaving farmers more uncertain of how their action towards *Salmonella* control can affect their *Salmonella* level or, to a further extent, *Salmonella* in humans. The lack of answers from twelve farmers in phase 2 may also highlights this behaviour.

The belief in self-efficacy did not vary significantly between the control farms and the intervention farms including their close contacts (phase 1: $p_{kruskall\text{-}wallis}$=0.489; phase 2: $p_{kruskall\text{-}wallis}$=0.177) (figure 8). In phase 2, control farms seem to have moved towards a more positive belief in self-efficacy whereas the close contacts and intervention farms moved towards a more negative belief in self efficacy. It was not statistically tested due to low number of answers.



Phase 1: n=44



Phase 2: n=29

Figure 8: Comparison between close contacts + intervention farms and control farms of how farmers believed their action will affect Salmonella in phase 1 and 2. The frequency of the grouped median was used.

Stages in the pathway to disease control

The farmers were classified according to their intent to take actions to control *Salmonella*. The distributions of different variables are shown in table 8.

The farms were fairly evenly distributed between the stages. Slightly fewer control farms had implemented *Salmonella* controls than interventions and close contacts during phase 1. However, the two groups are not directly comparable as the intervention farms were selected due to the implementation of control practices.

Table 8: Farms and their characteristics according to their intent or not to take control.

	Phase 1			**Phase 2**		
	No intent	**Intent**	**Implementation**	**No intent**	**Intent**	**Implementation**
Total farms (%) n=46	15 (33)	19 (41)	12 (26)	14 (30)	18 (39)	14 (30)
Interventions + close contacts (%)	13 (35)	12 (32)	12 (32)	10 (27)	14 (38)	13 (35)
Controls (%)	2 (22)	7 (78)	0 (0)	4 (44)	4 (44)	1 (11)
Gloucestershire	2	5	3	3	2	5
Midlands	3	1	5	2	4	3
Suffolk	4	4	1	2	6	1
Yorkshire	4	2	3	3	2	4
ZNCP (average prior 3 months)	32%	22%	51%	28%	30%	33%
Breeding	1	4	3	4	7	5
Production	9	9	7	7	7	7
Both	5	6	2			
Specialist finisher				3	4	2
Herd size (no of pigs)	2881	2667	3361	2234	2917	3313
Attitude (median)	2	1.5	1.5	2	2	2
Social norms (median)	2	2	2	2	2	1
Self efficacy (median)	3	2	2	3	3	3

In phase 1, the Midlands cluster had a higher proportion of farms that had implemented control specifically for *Salmonella*. Since the numbers are small, it may be skewed by the 2nd intervention farm in this cluster. Only one farm in Suffolk had control practices implemented, but with the small sample sizes it is difficult to assess whether this is an important difference compared to the other clusters. Both the Midlands and Yorkshire clusters had less intent than the Suffolk cluster ($p_{multinomialLR}$= 0.094 & 0.099 respectively). No significant differences were found in regards to herd sizes or production types between the stages. Control farms had a slightly (not significant) higher intent, but none had implemented an intervention. Surprisingly, farmers that had implemented an intervention had a higher ZNCP score ($p_{multinomialLR}$=0.09) than farmers that had no intent. It showed an association between the implementation and the score level.

The attitude of farmers towards *Salmonella* control who had intent ($p_{multinomialLR}$=0.042) or had implemented ($p_{multinomialLR}$=0.059) control were more likely to be positive than those of farmers without intent. The belief in self-efficacy of farmers who had implemented control was more positive ($p_{multinomialLR}$=0.066) than farmers without any intent. The difference in belief in self-efficacy between farmers with intent and no intent was not significantly different ($P_{multinomialLR}$=0.470). Perception of supportiveness of social norms was not associated with any stage in the pathway to disease control.

In phase 2, none of the characteristics had an influence on intent to implement control except on the belief in self efficacy. The belief in self-efficacy of farmers who had implemented control was again more positive than farmers without any intent ($P_{multinomialLR}$=0.08). Though not significantly different, farmers with intent to implement an intervention had slightly more belief than those without intent ($P_{multinomialLR}$=0.108).

Motivators and referents

All farmers were asked who they would listen to or who or what would encourage them to implement *Salmonella* control on their farm (table 9). In both phases and for both groups (control versus contact & intervention farms), recommendations from their vets was the best way to incite them to try something on their farm. A change in their ZNCP score would also trigger an action to at least consult someone about the issue. However, during the second phase, an increase in the ZNCP score was not mentioned by as many farmers. Nearly half (41%) of the farmers mentioned “a problem with their pigs due to *Salmonella*” as a motivation to take action. Pigs rarely show any clinical signs of being infected with *Salmonella*. The farmer is therefore often unaware of the problem. The ZNCP score can help monitoring the *Salmonella* level in pigs but actions on the farm are more likely to happen if the veterinarian encourages the farmer to take action (table 9). It was mentioned that the business is about selling the pigs. Farmers would be motivated to take action on their farm if they can’t sell to their direct customer (a finisher, an abattoir). Scientific evidence that an intervention gives significant positive results to reduce *Salmonella* in pigs would attract the attention of at least a third of the farmers. Farmers with a low ZNCP score (ZNCP<10%) identified the ZNCP score as their main motivator and their vet in both phases (data not shown). Farmers with higher ZNCP scores identified mostly their vets and a problem with their pigs as a motivator, but also scientific evidence and the score. Customers were also mentioned as motivators by farmers with the highest ZNCP scores (ZNCP>50%).

Table 9: Motivators that would influence farmers to implement control on their farms. Control farms compared to close contact and intervention farms for phase 1 and 2. (Multiple answers possible)

	Phase 1		**Phase 2**	
	Control farms (n=9)	**Number of close contact + intervention farms (n=37)**	**Control farms (n=9)**	**Number of close contact + intervention farms (n=37)**
Private veterinarian	5 (55%)	20 (54%)	6 (67%)	18 (49%)
Increase in ZNCP score	8 (89%)	15 (41%)	5 (56%)	11 (30%)
Direct customers	2 (22%)	16 (43%)	3 (33%)	11 (30%)
Scientific evidence	2 (22%)	13 (35%)	1 (11%)	13 (35%)
Government	4 (44%)	3 (8%)	0	3 (8%)
Financial penalties or rewards	1 (11%)	7 (19%)	0	9 (24%)
Demand from consumers	0	7 (19%)	1 (11%)	1 (3%)
Their pig company	0	4 (11%)	1 (11%)	1 (3%)
Other farmers	0	4 (11%)	2 (22%)	2 (5%)
Quality assurance scheme	0	4 (11%)	0	1 (3%)
BPEX/levy body	0	4 (11%)	1 (11%)	1 (3%)
Own experience	0	2 (5%)	0	2 (5%)
Problems with pigs			1 (11%)	18 (49%)

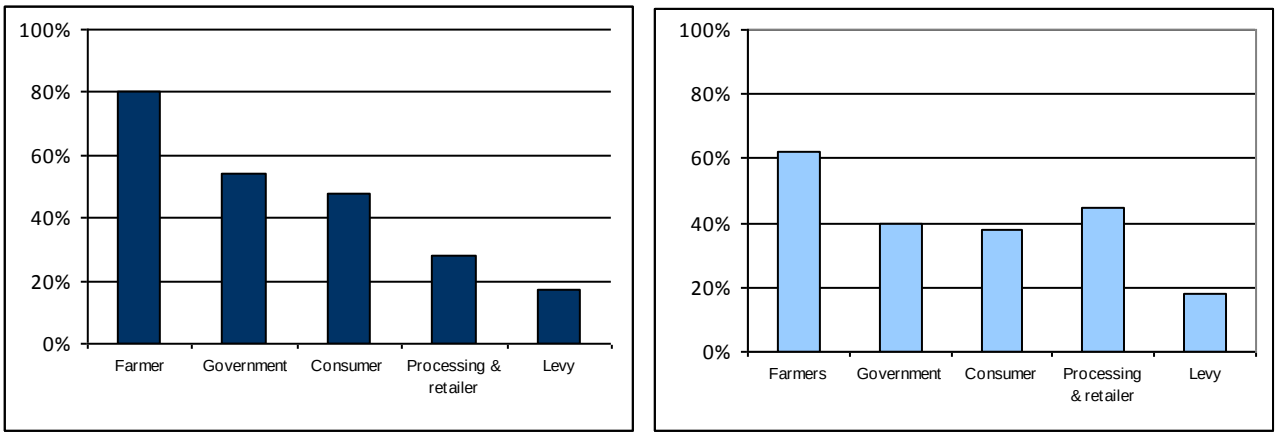
ZNCP score compared with Attitudes, Self-efficacy and Intent

During phase 2, 18 farmers did not have a ZNCP score and were unaware of their *Salmonella* level. The main reasons for not having a score were: “score not monitored”, “no finishers of slaughter weight”, or “abattoir not part of the scheme”. The attitude, the belief in self-efficacy and the intent towards *Salmonella* control was compared between farmers that have no ZNCP score and the ones with a ZNCP score. The average scores for each group is presented in table 10 below where total scores for *Attitude* ranged from 4 to 20, *Belief*, from 3 to 15 and *Intent* from 0 to 2. For *attitude* and *belief*, the lower the score the more positive farmers were. For *intent*, the higher the score, the more intent farmers had.

Having a ZNCP score did not significantly influence any of the criteria. However farmers with a score had a slightly higher intent to control *Salmonella* and a slightly more positive belief in self-efficacy, which may or not be due to chance.

Who should pay for control?

It was discussed, who should pay for any *Salmonella* control on farm. During the first phase, the majority of farmers (37/46) were willing to pay something towards implementing control, but more than a third of these (17/46) mentioned that they would want to reclaim something from the consumers (figure 9). At the second interview, farmers were still willing to pay and still believed that the cost should be shared by the rest of the food chain, including the government, consumers, their customer (processor and retailer) and to a lower extent the levy. Many farmers weren’t sure exactly who should pay but believed that the burden would probably be transferred to the farmers. One said that if it were to become compulsory due to new legislation, the government should pay part of it. However under the current economic climate, many farmers thought the government wouldn’t have the capacity to pay. Therefore, farmers thought the private industry should pay for it.



Phase 1 (n=46) Phase 2 (n=45)

Figure 9: Who farmers think should pay for implementing *Salmonella* control on farms. More than one answer possible. One farmer did not answer that question in phase 2.

The majority of farms from all three groups (controls, close contact and interventions) thought farmers should pay something towards *Salmonella* control. No statistical difference was found (chi-squared test) between the three groups in their answers on who should pay for control in both phase 1 and phase 2.

How should it be paid?

During the second phase, when asked how *Salmonella* control should be paid, only half of the farmers had an answer. Various ideas were suggested but the three most frequent answers were to pay a higher price per pig to the farmer (30%); to use the levy money to invest in control measures (26%); to tax pork meat and use the money to invest in implementation of control measures on farm (22%). Three (13%) mentioned that it should come from farmer’s pocket and two (9%) farmers also suggested that products should be differentiated (*Salmonella* free pigs versus unknown status).

Who is responsible to prevent *Salmonella* spread to humans through pig products?

During phase 1, farmers assigned responsibility to various levels of society (table 10). A total of 39 (85%) farmers mentioned that the primary producer (i.e. farmers) had a responsibility to control *Salmonella* in the pigs produced. Steps further up the food chain such as abattoirs (63%) and food processing plants (52%) were also identified as responsible for *Salmonella* control by the farmers. The consumer was assigned responsibility

by 21 (46%) farmers often combined with a suggestion that more education of how to handle raw meat at home is needed.

At the second interview, farmers (89%) confirmed that they thought they had the primary responsibility to control *Salmonella*, but that it should also be shared by the rest of the industry as summarised by this farmer's quote:

> "It should be down to the farmer; it's their responsibility. Once it's left the farm then it becomes the processors responsibility if there is contamination at the slaughterhouse; then it becomes the butchers' responsibility. The same for the retailer and then it becomes the house holder's responsibility to make sure that it is cooked and prepared properly and there is no contamination at that level (farm 6)."

No one directly mentioned the government as having any responsibilities in controlling *Salmonella* in pigs. One farmer mentioned that everybody should take responsibility but whether or not that includes government, it is not clear. At least five farmers, while sharing part of the responsibilities thought that only consumers were mainly responsible to ensure that pork meat is safe to eat.

Table 10: Who farmers thought was responsible to prevent *Salmonella* to spread to humans through pig products. More than one answers possible. n=46

Groups	Phase 1	Phase 2
Farmers	85%	89%
Abattoirs	63%	67%
Consumers	46%	63%
Processors	52%	59%
Customer (retailers)	26%	50%
Pig Company	17%	46%
Industry as a whole	28%	39%
Government	28%	0%

Barriers to implementations

During the second phase, farmers were asked to identify the main barrier to implement an intervention on their farm. Most of the farmers (79%) agreed that costs, or no evident cost-benefit, of implementing an intervention that may or may not work on their premises was their biggest barrier (figure 10). The impracticality of implementing some interventions, the lack of time or knowledge and the lack of scientific evidence were also mentioned by a few farmers as barriers.

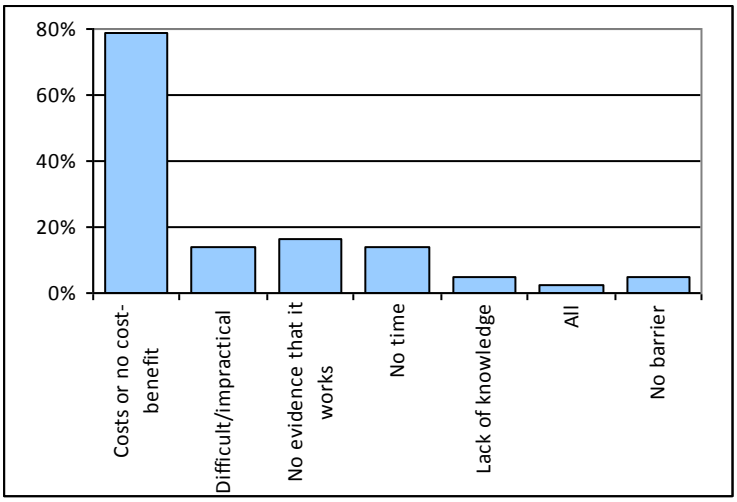


Figure 10: Main barriers (phase 2) identified by farmers to implement new control measures on their farm. (Answers not mutually exclusive n=43)

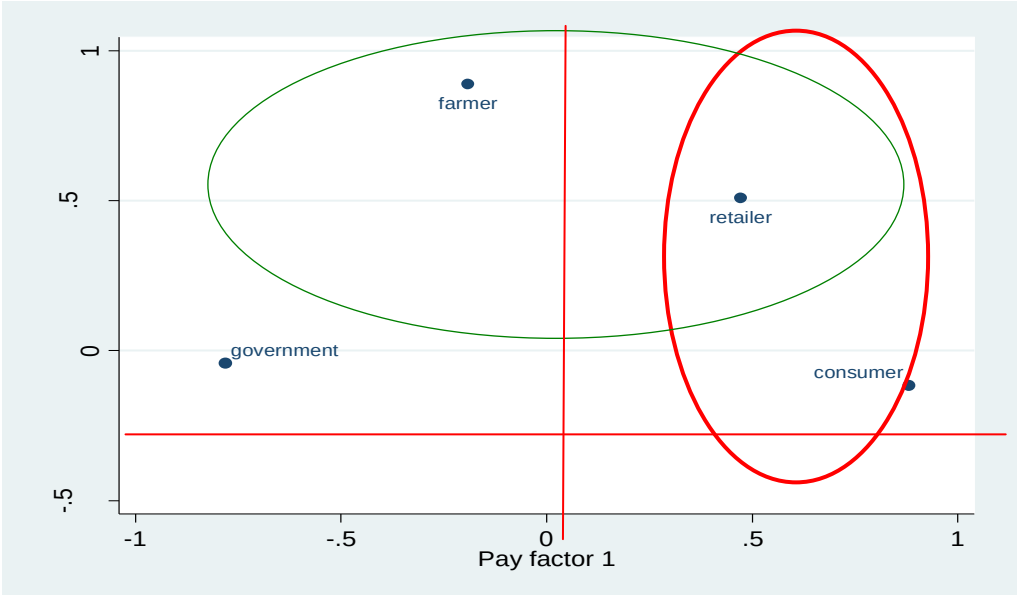
Principal component factors

Following the *principal component analysis* for phase 1, a total of 8 factors were identified: 3 motivational factors, 3 responsibility factor and 2 financing factors.

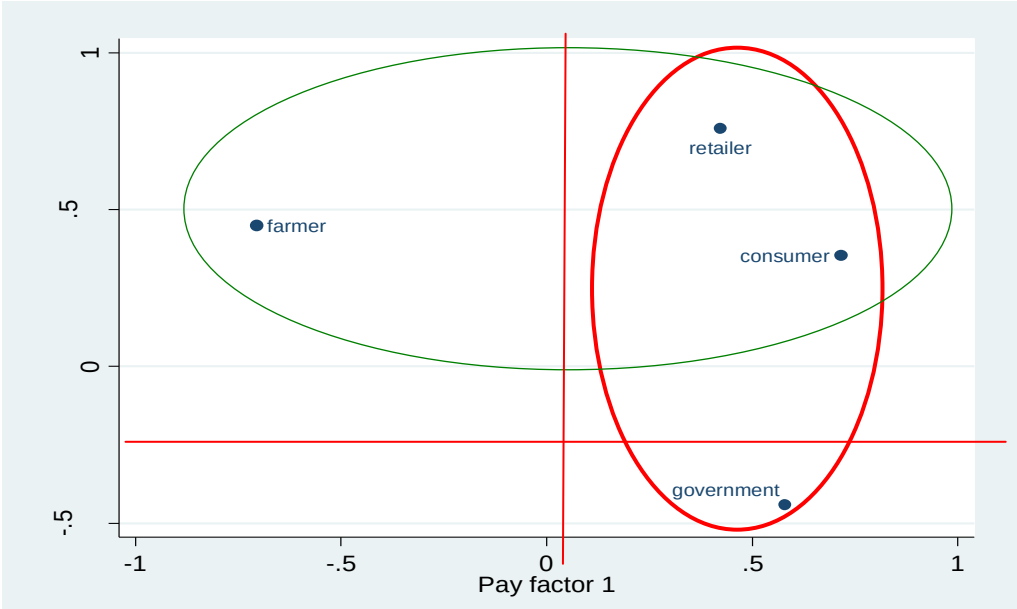
The three motivation factors consisted of various degrees of motivation by customers, ZNCP score increase, veterinary advice, government intervention and evidence-based effect of interventions (table 11). Farmers who scored highly in "motivation factor one" would listen to their veterinarians and government and would react to an increase in their ZNCP scores. Demands from their direct customers were a less important motivator and scientific evidence of effect of any intervention would not motivate them at all. Similarly, "motivation factor two" represented farmers who were mainly influenced by ZNCP score and also influenced by scientific evidence

and the government. In contrast, demand from customers, along with government intervention, were the main motivators for farmers that scored highly in “motivation factor three”. Government intervention, veterinary advice and scientific evidence was less important to them and ZNCP scores would have no influence on their decision on whether or not to control *Salmonella* in their pigs.

When the farmers were asked, who should pay for *Salmonella* control on pig farms, two factors explained the majority of the variance (table 11). Farmers that scored highly in pay factor 1 believed that the consumer and the retailer should pay for interventions solely by increasing prices and feeding the gains back to the producers. Farmers that scored highly in the second factor believed that the chain of pig production from farms and up to retailers should carry the costs. This was often based on the opinion that the consumer has a right to safe food and that the whole pig food chain has to deliver safe food (figure 11).



Phase 1



Phase 2

Figure 11: The relationship between scores in pay factors 1 and 2.

Three different factors were identified in the assignment of responsibility. The farmers who scored highly in responsibility factor 1 assigned responsibility of control of *Salmonella* in pigs to the processors, consumers, direct customers. The farmers that scored highly in responsibility factor 2 believed that the responsibility was amongst producers, government, customer and the pig industry, whereas farmers strongly associated with responsibility factor 3 felt they had little responsibility themselves, but assigned responsibility to consumers, government and pig industry body (table 11).

Some of the factors were associated with what stage the farmers were at in the pathway to disease control framework (table 11). When comparing farmers with intent to control to farmers with no intent to control, the farmers with intent were significantly more likely to score highly on motivation factor 1 (P=0.008), which meant

that they were more likely to look for motivation by their veterinarians and government and would react to an increase in their ZNCP scores than farmers without any intent to control. None of the pay factors were significantly associated with intent to control once the motivational and responsibility factors were accounted for. Farmers with intent were more likely than farmers without intent to score highly in responsibility factor 2 (p=0.078). This meant that they assigned responsibility for *Salmonella* control in pigs more or less equally to everyone including government and consumers.

Table 11: Multivariable comparative analysis of association between factors and whether pig farmers have intent to control *Salmonella* or not.

Phase 1	**Main groups**	**OR (95% CI)** (no intent vs intent)	**p-value***
Motivation factor 1	Veterinarians, Government, ZNCP score	4.5 (1.5-13.8)	0.008
Motivation factor 2	Government, Scientific, ZNCP score	NS	NS
Motivation factor 3	Direct customers, Government	NS	NS
Pay factor 1	Consumer, retailer,	NS	NS
Pay factor 2	Farmers to retailer	NS	NS
Responsibility factor 1	Customer, Processor, Consumer	NS	NS
Responsibility factor 2	Producer, Customer, Government, Industry	2.8 (0.9-8.8)	0.078
Responsibility factor 3	Consumers, Government, Industry	NS	NS

NS= not significant and not in final model; * multivariable logistic regression

Phase 1 (N=34)

Motivation factor 1 was also more likely to be identified by farmers with either intent or implemented control strategies than by farmers without intent (OR 2.9, p=0.010). Motivation factor 2 was associated directly with farmers that had implemented control measures on their farms compared to farmers with intent only (OR 0.45, p = 0. 061).

In phase 2, the principal components analysis identified six factors. Three different factors were identified in the assignment of motivation, two with finance and one with responsibility. However, none of these factors were found to be significantly associated with intent or implementing control, from the multivariable analysis.

Knowledge transfer

An additional questionnaire was completed during the second phase to identify which sources of information were trusted and used, and to assess knowledge on current research and available resources on pig disease and *Salmonella* (full results in Annex 2).

Farmers were asked who they would seek advice from “when a disease problem is suspected”, “when they decide they need control”, “to decide what measure to use”, “to know how to implement the measure” and “to decide on the efficacy of the measure” (figure 12). Nearly all farmers (between 76 and 98%, according to the step) said they would consult their vets to help them make a decision for any of these steps. A good proportion would also consult their stockmen, their nutritionist or other farmers to help them make a decision on which control to implementing and how to evaluate it. Very few would consult Defra (4-12%), their family (6-12%) or an external pig consultant (8-17%) during the process of solving a disease problem.

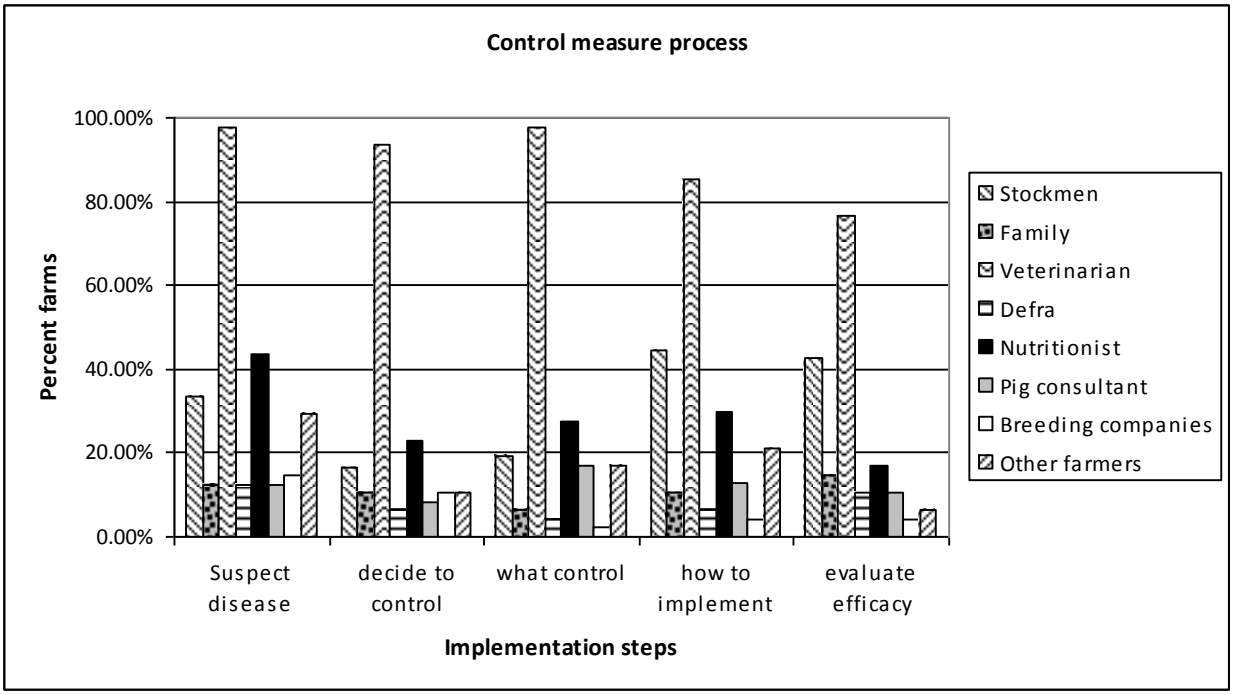


Figure 12: Who farmers would seek advice from in the process of controlling disease on farm

Farmers would mostly prefer direct advice from their vets, other farmers or farmer's meeting to get information on pig diseases (52%) or *Salmonella* in pigs (35%). Over half of the farmers (54%) would also consult pig magazines to find information on pig diseases in general. They would also consult the internet for pig disease (40%) or *Salmonella* (29%) information and other text books. While all farmers do look for information about pig disease, 16.7% of the farmers said they did not look for information specifically about *Salmonella* in pigs. 15% of farmers said they would consult Defra's leaflets or reports to find the information they need on pig disease and *Salmonella*.

Farmers generally agreed that the information they received on pig disease and *Salmonella* in pigs from the different sources mentioned was important to them with 65% stating that it was very important to get information on pig diseases. Farmers did not give as much importance to the information on *Salmonella* in pigs received, with only 37.5% thinking it was very important for the farm. When asked if they found it easy to apply the information found on pig disease or *Salmonella* for their farm, the results were more mitigated. Without knowing exactly what the information was, they found it difficult to answer the question. The majority (66% on pig disease; 57.5% on *Salmonella*) thought it was easy in general to apply the information.

Figure 13 shows the average score given to any suggested media to receive information on *Salmonella* in pigs. The most preferred media for the communication of information on *Salmonella* in pigs was face-to-face advice. Overall, 91% of farmers liked receiving face-to-face advice, with 35% being their most preferred media. The least popular way to obtain information was via DVD (66% didn't like that media for *Salmonella* in pigs). Internet (61%), Newsletter (64%), written report sent to home (74%) and articles in magazine (70%) were also appreciated. Demonstration farms received a range of opinion. Many (53%) did not like that media but 45% liked it a little bit and it was the most preferred media for 2% of the farmers. Their main concern was how they would get the information from this "media" as it is difficult to visit another pig farm due to pig-free-time requirement. Similar results were observed for dissemination of information of diseases in pigs.

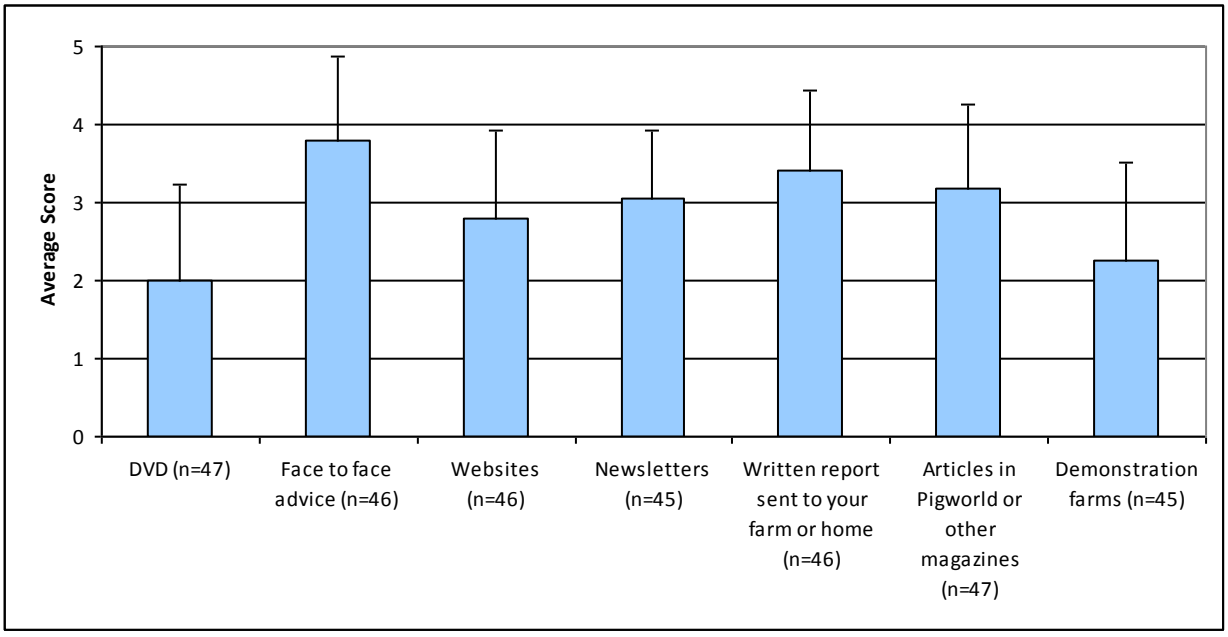


Figure 13. Average score given by farmer to evaluate which media they prefer to receive information on *Salmonella* in pigs. Score varies between 1 (Do not like it at all) and 5 (Most preferred).

Farmers were asked whether they heard or not of various existing resources providing information. The most recognised report was the ZNCP report where 65% of the farmers admitted reading it. Despite the fact that internet was a well received media, a lot of the farmers (48%) admitted not having heard or seen the websites suggested. Many farmers (66.7%) had seen Defra's website and heard of the leaflet "*Salmonella* on pig farms", but may or may not have read it. Overall, most of the farmers hadn't heard of the resources suggested with the exception of the ZNCP report and Defra's website and leaflet on *Salmonella* control. (table 12).

Amongst various publications, Pig World was the most read magazine (71%) followed by Farmers Weekly (35%) and Farmers Guardian (15%).

Table 12: List of various resources on disease and *Salmonella* in pigs and awareness by farmers.

Resources	**Yes (n=48)**
Seen Defra website/ leaflet about *Salmonella*	**66.7%** - but they may or may not have read it.
Read ZNCP annual report	**64.6%**
Seen other websites i.e. Pigworld, for research results	52.1%
Seen Internet journals i.e. thepigsite, pig333, etc.	39.6%
Seen BPEX website (Research and Development section)	37.5%
Seen results-Demonstration farm trial's results (BPEX) n=47	29.2%
Joined Pig Health Scheme (BPEX) n=47	29.1%
Seen DVD "Serious about *Salmonella*" - FSA	18.8%
Seen University of Warwick website on PMWS research	14.5%

d) Discussion

Intervention results

The effect of the BPEX intervention study on uptake and implementation of *Salmonella* control in pig farmers was evaluated. According to farmers, results from the interventions did not seem to have circulated to farms. in the vicinity or that were deemed in communication with the intervention farms. The assumption was that a successful or a failed intervention would motivate or hinder farmers to try the intervention on their own farm. The lack of results from the intervention farms and the lack of communication of the results did not help the farmer community to gain knowledge from these trials. When asked, none of the contact farmers had a clear knowledge of what intervention was used and how successful it was. Even the farmers who implemented the interventions were unsure about the results. It is therefore difficult to comment on how the uptake of *Salmonella* control was influenced by BPEX demonstration trial.

Farm characteristics and practices

Farm characteristics were similar during both phases, indicating that the farms were generally stable. However the practices used to control *Salmonella* varied slightly, although few actually did something to specifically control *Salmonella*. It was not clear during the interview whether the farmer mentioned general practices that they believed helped to control *Salmonella* or practices that were specific to *Salmonella* control. This may explain the variation between the two phases. It is also difficult to confirm the real number of farmers who do regular cleaning and disinfection as this may be seen as not specific to *Salmonella* by some farmers and they may not have mentioned doing it. However, it is interesting to see that most farmers did know that cleaning and disinfecting as well as vermin control are both good practices that are believed to help *Salmonella* control. Whether or not they know how it should be done and whether they follow proper guidelines was not discussed during the interviews. Very few farmers actually did something to specifically control *Salmonella*.

Zoonoses National Control Plan score

The ZNCP score gave a crude measurement at both phases of the level of *Salmonella* of the subset of farms in this study that supplied pigs for slaughter at abattoirs that were members of the ZNCP scheme. It is important to note that the variation observed for each farmer's average ZNCP score between phase 1 and 2 may not be important. The accuracy of the score is dependent on the sensitivity and specificity of the test, the number of batches of pigs tested and the number of samples taken per batch (Snary et al., 2010). Too little information was available to confirm that a lower score in phase 2 indicated an improvement of the *Salmonella* level on the farm studied.

It was interesting to see that control farms were consistently and significantly more likely to have a ZNCP score below 10% than contact farms. The overall average ZNCP score remained the same for control and contact farms even though four of the contact farms that had a score below 10% saw their score at least doubled to rise above 10% in the second period.

The variation in the scores did not affect the overall contact farmer's attitude or belief in self-efficacy compared to control farms, and only a third of the contact and intervention farmers mentioned a rise in their ZNCP score as being an incentive to implement control measures compared with more than half of the control farms. It could be argued whether farmers who might be motivated by "a problem with their pigs" would equate this to observing a rise in the ZNCP score, as a rise may have little or no effect to their pigs. It should also be commented that not all farmers considered the score credible or accurate and the farmers would rather hear about the problem from their vets or, to some extent, from their direct customer: *"if I can't sell my pigs, I have a problem" (farm 12).*

Farmers with a lower ZNCP score seemed to be motivated by a rise in their score as observed in the control farm group. One possible explanation is that these farms might be more aware of their ZNCP score and would tend to keep it low. Therefore they would react and do something as soon as a rise was noticed. Whereas farmers with a higher score may be less worried and are more pessimistic (lower belief in self-efficacy) about their *Salmonella* level and would tend not to act unless it was flagged up to be a problem or perceived to be an enhanced risk, which would be explained by the higher level of implementation for farms with a higher ZNCP score.

It is important to mention that not all farmers had a ZNCP score and many were unaware of their *Salmonella* level. As a whole, farmers with a ZNCP score tended to be more confident (not significant) and had a higher intent to take action than those without score (but not significant). This may indicate that having access to the ZNCP score did provide the farmers with a useful measure that they could use to measure change if required despite the fact that their low level of trust in the score. It might be therefore valuable to find a way to measure the level of *Salmonella* on farms that do not have a score to maintain an awareness of their situation.

Attitude, Perception of Social norms, Belief in Self-Efficacy

In both phases, the attitude remained generally positive as did the perceived level of supports from their peers. The belief in self-efficacy was significantly more negative during phase 2. Farmers confirmed that they were unaware of the intervention trial results, so in theory, the results would not have affected their opinion. However, the lack of communication may have highlighted the fact that interventions may have not been totally effective and this failed to restore their confidence.

The lack of awareness and knowledge about *Salmonella* may have had an effect on farmer's belief in self-efficacy. Some farmers admitted to not looking for information on *Salmonella* and considered information on *Salmonella* less important than on other pig disease control. It was also found that farmers were unaware of

most of the sources of information on *Salmonella* that had been suggested by our project team. This may imply that *Salmonella* was not the farmer's priority or main concern or that the information was not disseminated by the most appropriate route.

Farmers who implemented a control or were contemplating the use of a control measure had more confidence in how the intervention can help and had a more positive attitude than those who had no intention of implementing any measures. On the other hand, farmers that had a high ZNCP score were more likely to implement an action but also had a more negative belief in self-efficacy, indicating an interesting paradox that a farmer with a *Salmonella* problem was more likely to implement a control but would have little faith that the intervention would work.

In both phase, the social norms—whether they think their peers and industry were supportive or not—had no effect on whether or not farmers take action on control. Therefore, it may be important for the farmer to know that their peers are supportive, but the key intrinsic factor that had an effect on farmers' behaviour was a positive belief in self-efficacy and, to some extent, a positive attitude.

Motivators & barriers

Along with direct advice coming from their vets, scientific evidence that an intervention can efficiently control *Salmonella* on farms – more specifically on their farm – was also mentioned by a third of the farmers as a motivator to try an intervention. On the other hand, when asked during the interview what their main barrier to try an intervention would be, very few mentioned the lack of findings as being a key barrier. The first thing farmers identified as a barrier to control *Salmonella* was money. It is important to note that the results may have been slightly more varied if this question was rated using a list of suggested barriers. The difficulty of implementing an intervention (impractical or not adapted to their farm), lack of scientific evidence and lack of time and knowledge were also amongst some farmers' worries.

Farmers were unanimous that when it is time to consider whether or not to take action, it is down to a business decision: it depends on the cost of the intervention and whether or not it provides a net profit. This is reflected by the fact that they have little trust that their actions will have a significant effect on their *Salmonella* level and on *Salmonella* level in humans. There was also little trust that *Salmonella* would not be reintroduced along the food chain, once the pigs left the farm. On this basis, farmers believed that they cannot afford to introduce actions that were not proven to be effective and not commercially profitable. This was also shown in an earlier study about the attitude of pig farmers into adopting biosecurity measures (Fraser et al., 2009). However, another study done in the US found that some farmers may see production of safe food as a special category of expense and may be willing to address these issues with a lower expected financial return than is typically the case (Bahnson et al., 2001).

Farmers believed they had some responsibilities towards *Salmonella* control in pigs and its role in providing safe food to consumers but they also put responsibility on the rest of the chain as also observed in another study (Bahnson et al., 2001). There was a shift in responsibility at phase 2. More farmers believed that consumers, their pig company and the retailers should be responsible for controlling *Salmonella*. However, due to the recent economic factors, the government's role seems to have changed and farmers no longer considered the government responsible for control.

This was also reflected in who should pay for control. They believed the cost of implementing control on farms should be shared by the whole industry. During phase 1, a majority of farmers believed they were responsible for the cost of control along with the government and the consumers and to a lesser extent the retailers. At phase 2, farmers believed that the cost should be more evenly spread along the food chain. There was a shift from the farmer, government and consumer towards the retailer, where they believed the money was. **Farmers did not believe they should be responsible for all of the *Salmonella* control or they believed that their sole action would not solve the whole problem and therefore trusted that the burden should be more evenly spread along the food chain as well as the costs.** Interestingly, the money collected by levy was mentioned by only a few farmers as a potential source of income to fund control measures. The reason for that is unclear, but it may be that farmers believed there was little available money available from the levy or that this money was best used in other areas.

Knowledge transfer

The questionnaire on knowledge transfer confirmed the importance of the vet in the farmer's decision process, where vets were the main source of information for farmers. Farmers were therefore directly influenced by their private veterinarian positively or negatively.

Farmers preferred advice given face-to-face mostly from their private veterinarian, but also from their nutritionist or peers to provide the necessary information to control disease and *Salmonella* on their farm. They also found written reports and newsletters directly sent to them useful. The internet was a good alternative source of information. They rarely used DVD's to get the information they needed, and considered information on *Salmonella* as less important than pig diseases in general. Pig World reached a high proportion of pig farmers, and may therefore be an effective mean to disseminate information and influence them. Articles such as "*Salmonella* prevention measures don't add up – trying to control *Salmonella* on pig farms is a waste of time and money" (pig world, February 2011), may have reached a good proportion of farmers and reinforced their current belief in the poor performance of interventions.

e) Main implications of the findings

These results showed that the use of demonstration farms may not be farmers' preferred knowledge transfer tool by farmers but may still have a certain effect on farmers. Indeed the majority of farmers agreed that hearing of a successful intervention on a farm would be a motivation to at least contemplate the idea of trying the action on their farm.

The study also highlighted that communication was important and played a role in farmers' motivation. Unfortunately, the results of the demonstration farms were not made known and this may have had a negative effect on farmer's intent to take control measures. Also, the lack of demonstrated positive effect of the interventions applied may have reinforced the negative attitude toward *Salmonella* control. It could be assumed that if the interventions had worked and the results made public, farmers would have been motivated to at least discuss with their vet the potential use of these interventions on their farm. Their specific knowledge of *Salmonella* was not assessed in this study but it was found that most of the sources of information on *Salmonella* suggested were not well known by farmers and a proportion (39%) of the farmers who took part of this study had no idea of the *Salmonella* level in their pigs.

Private veterinarians were the key advisers to farmers and therefore influencing veterinarians may help influence farmer's behaviour.

A successful plan to tackle the *Salmonella* level on farms should therefore provide scientific evidence that some interventions succeeded to reduce *Salmonella* levels; provide tangible benefit to farmers; show that the rest of the industry is also taking actions and provide general information on *Salmonella* and its risks. This information should be disseminated via the private vets or via targeted newsletters or reports. Farmers have a positive attitude and appreciate the industry's support but more actions are needed to make them believe that their own actions are worth the trouble and have an effect on human health.

This study suggests that farmers are unlikely to adopt control measures voluntarily, which may render the compliance to any target in reducing *Salmonella* in pigs challenging for the UK. A compulsory approach would equally face challenges in terms of cost sharing and penalty to non-compliant farms but also in defining an acceptable target to fit a wide range of pig farming systems (e.g. outdoor versus indoor; straw based versus slatted floor). Another approach may be to consider control measures that may have other benefits such as controlling diseases with no known zoonotic potential but that have a visible impact on pig performance (and therefore on the farmer's revenue) as well as *Salmonella*. In any case, the aim in controlling *Salmonella* in pigs is to protect public health; it may be worth looking into a whole farm-to-fork approach including a better education for consumers, which may improve pig farmers' motivation to take some actions if they trust they are not the only ones putting efforts into *Salmonella* control.

f) Future work

1- More research on trialling *Salmonella* control measures is highly recommended. Farmers need to know that the action they will implement provides a net benefit, has an effect on producing safe pig meat and would help to improve human health. To meet the future EU target to reduce *Salmonella* level, farmers will require advice and scientific evidence before any concrete actions can be taken.

2- The lack of evidence of efficacy coupled with the recognition that there would be a cost from any intervention suggests that field studies which couple *Salmonella* control with other benefits may be more likely to be adopted. Recently published work *(Smith, R.P.; Sanchez-Vazquez, M.J.; Cook, A.J.C.; & Edwards, S.A. (2011) Abattoir-based study investigating the association between gross pathological lesions and serological tests for Salmonella infection in pigs. Veterinary Record **168** p 240. doi: 10.1136/vr.c6823)* has shown that ZNCP status may be associated with other health issues.

3- Continued knowledge transfer and promotion of the ZNC Plan using private vets to disseminate information but also farmer magazines (i.e. Pig World, newsletters and tailored reports) would create more awareness. There is a need to explore in more detail how information is disseminated amongst

farmers and how key influential people in the industry enhance the effectiveness of knowledge transfer and recommendations on disease control i.e. whether there are key individual trusted sources.

4- Providing a new way to monitor *Salmonella* level on most farms (breeder farms as well as finishers) should enhance awareness and may trigger more intent.

5- Showing that the rest of the industry is also involved and that control measures are in place further down the chain and that the costs are distributed between various stakeholders would help.

6- Since private vets are a key part of the knowledge transfer process, it may be worthwhile conducting a similar study to assess attitudes amongst this community.

Objectives previously mentioned:

1- Assess and describe any association between the economic efficiency of a farm and the intention to control *Salmonella* on farm. Would a highly effective farm be more likely to implement control or believe that no action is necessary when the farm is already doing well? Would an "inefficient" farm be interested in trying to any control measures to help the farm's issues or believe that it would be too hard and expensive to make a change?

2- Compare intent to control *Salmonella* with intent to control endemic disease and evaluate differences between intrinsic and extrinsic factors responsible for the action. Are farmers more likely to take actions to control endemic diseases that may or not have an impact on pigs' productivity? What motivates them? Can knowledge of what motivates farmers to implement control for endemic disease be used to promote uptake of *Salmonella* control?

3- Further research could be done to associate pig's performance to *Salmonella* disease. Does *Salmonella* affect pig's performance (growth rate, feed conversion, number of piglets born, etc.)? An effect on these performance indicators may influence the farmer's decision to take action. A small study is underway; following the results more recommendations will be provided.

g) Action resulting from the research

No action has been initiated to disseminate the results of this study. It is however highly recommended to produce a peer-reviewed paper which will not only publicize the scientific knowledge but also be of huge value as a reference for future projects. A paper on the perceptions, attitudes, motivators and barriers that influenced pig farmers' intent to control *Salmonella* on farm is suggested.

This information would also be valuable to help farmers and their private veterinarian to understand pig farmer's behaviour. A non peer-reviewed article targeting farming magazines or a newsletter along with presentations at suitable veterinary or pig industry meetings are suggested.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Ajzen, I., 1991, The Theory of Planned Behavior. Organizational Behavior and Human Decision Processes 50, 179-211.

Bahnson, P.B., Michalak, M.M., Miller, G.Y., 2001, Pork producers attitudes, knowledge, and production practices that relate to on-farm food safety. Journal of Food Protection 64, 1967-1972.

Berends, B.R., Urlings, H.A., Snijders, J.M., Van Knapen, F., 1996, Identification and quantification of risk factors in animal management and transport regarding *Salmonella* spp. in pigs. Int J Food Microbiol 30, 37-53.

Ellis-Iversen, J., Cook, A.J.C., Watson, E., Nielen, M., Larkin, L., Wooldridge, M., Hogeveen, H., 2010, Perceptions, circumstances and motivators that influence implementation of zoonotic control programs on cattle farms. Preventive Veterinary Medicine 93, 276-285.

Fraser, R.W., Williams, N.T., Powell, L.F., Cook, A.J.C., 2009, Reducing *Campylobacter* and *Salmonella* infection: two studies of the economic cost and attitude to adoption of on-farm biosecurity measures. Zoonoses Public Health 57, e109-e115.

Hill, A.A., England, T.J., Snary, E.L., Kelly, L.A., Cook, A.J.C., Wooldridge, M., 2003, A 'farm-to-consumption' risk assessment for the adverse effects to human health of *Salmonella* Typhimurium in pigs. Proceedings of the 10th International Symposium on Veterinary Epidemiology and Economics.

Jørgensen, L., Kjærsgaard, H.D., Wachmann, H., Jensen, B.B., Knudsen, K.E.B., 2001, Effect of pelleting

and use of lactic acid in feed on *Salmonella* prevalence and productivity in weaners. Proceedings of the 4th International Symposium on the Epidemiology and Control of *Salmonella* and other Food Borne Pathogens in Pork (Salinpork), Leipzig, 109-111.

O'Connor, J.L., Snow, L.C., Cook, A.J., 2005, A trial investigating the effect of organic acids in weaner pigs' diet on *Salmonella* prevalence in finisher pigs. Research in Veterinary Science 78, 25.

Panter-Brick, C., Clarke, S.E., Lomas, H., Pinder, H., Lindsay, S.W., 2006, Culturally compelling strategies for behaviour chnage: a social ecology model and case study in malaria prevention. Soc. Sci. Med. 62, 2810-2825.

Roesler, U., Heller, P., Waldman, K.H., Truyen, U., Hensel, A., 2006, Immunization of sows in an integrated pig-breeding herd using a homologous inactivated *Salmonella* vaccine decreases the prevalence of *Salmonella* Typhimurium infection in the offspring. Journal of Veterinary Medicine - Series B: Infectious Diseases and Veterinary Public Health 53, 224-228.

Roesler, U., Marg, H., Schröder, I., Mauer, S., Arnold, T., Lehmann, J., Truyen, U., Hensel, A., 2004, Oral vaccination of pigs with an invasive gyrA-cpxA-rpoB *Salmonella* Typhimurium mutant. Vaccine 23, 595-603.

Snary, E.L., Munday, D.K., Arnold, M.E., Cook, A.J.C., 2010, Zoonoses Action Plan *Salmonella* Monitoring Programme: An Investigation of the Sampling Protocol. J. Food Prot. 73, 488-494.

Taube, V.A., Neu, M.E., Hassan, Y., Verspohl, J., Beyerbach, M., Kamphues, J., 2009, Effects of dietary additives (potassium diformate/organic acids) as well as influences of grinding intensity (coarse/fine) of diets for weaned piglets experimentally infected with *Salmonella* Derby or Escherichia coli. J Anim Physiol Anim Nutr (Berl) 93, 350-358.

Van Dam, Y.K., Frewer, L.J., Marier, E., Armstrong, D., Cook, A.J.C., 2010, Barriers to adoption of measures to control *Salmonella* in pigs in the UK: A stakeholder analysis. The Pig Journal 63, 50-58.

Van Der Wolf, P.J., Wolbers, W.B., Elbers, A.R.W., Van Der Heijden, H.M.J.F., Koppen, J.M.C.C., Hunneman, W.A., Van Schie, F.W., Tielen, M.J.M., 2001, Herd level husbandry factors associated with the serological *Salmonella* prevalence in finishing pig herds in The Netherlands. Veterinary Microbiology 78, 205-219.

Vanderwal, P., 1979, *Salmonella* Control of Feedstuffs by Pelleting or Acid Treatment. World's Poultry Science Journal 35, 70-78.

Wales, A.D., McLaren, I.M., Bedford, S., Carrique-Mas, J.J., Cook, A.J.C., Davies, R.H., 2009, Longitudinal survey of the occurrence of *Salmonella* in pigs and the environment of nucleus breeder and multiplier pig herds in England. Vet. Rec. 165, 648-657.

Walsh, M.C., Sholly, D.M., Hinson, R.B., Trapp, S.A., Sutton, A.L., Radcliffe, J.S., Smith, J.W., Richert, B.T., 2007, Effects of Acid LAC and Kem-Gest acid blends on growth performance and microbial shedding in weanling pigs. J. Anim Sci. 85, 459-467.