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Summary of the 2013 *Campylobacter* Strategy Workshop

Tuesday 12th to Thursday 14th March 2013

The Belfry, West Midlands, B76 9PR

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Introduction

Campylobacter causes more foodborne illness than any other foodborne pathogen, in the UK, across Europe and in many other countries beyond. In the UK alone, it is estimated to cause around 460,000 cases in the community of which 22,000 require admission to hospital for treatment and as many as 110 die, with an associated total cost of £900 million.

To tackle this, UK government and Industry are working together to reduce *Campylobacter* in the food chain through a Joint Government/Industry working group with an aim to achieve an agreed target for reduction of *Campylobacter* in UK chicken by 2015.

The complex ecology and biology of this organism mean that the development of effective risk reduction strategies is a major challenge for Governments, livestock producers, processors and retailers. It has been clear for some time that no single intervention is likely to be entirely effective.

In 2010, UK research funders¹ published the UK Research and Innovation Strategy for *Campylobacter* (RISC) - a joint strategy for a multidisciplinary research programme with a clear list of research priorities to support the development of effective interventions at a variety of points in the food chain.

The aims of this 2013 *Campylobacter* Strategy Workshop were:

- to review the progress to date of research undertaken as part of this strategy to address these on-going challenges,
- to evaluate whether the UK RISC is on track and
- to identify further work which may be required.

This workshop provided key invited industry, researcher, funder and policy-maker stakeholders the opportunity to interact directly with researchers and each other, be updated on latest research developments and provide input into the future of the UK RISC to ensure it will achieve its goals.

We are very grateful for the time, energy and expertise that delegates were prepared to contribute to this valuable event.

This report provides a brief overview of the meeting and its outputs as expressed by the views of the participants. The full programme and participant list are available at: www.food.gov.uk/multimedia/pdfs/science-research/campylobacter-strategy-workshop-booklet.pdf

**UK RISC Workshop Organising Committee
July 2013**

¹ BBSRC, FSA, Defra, Department for Agriculture and Rural Development NI and the Scottish Government

Summary of Priorities – UK RISC 2010

Summary of research priorities – RISC 2010

Understanding current practice and potential intervention strategies

- High-quality baseline data and regular monitoring of poultry
 - High-quality baseline data
 - Regular measurements of *Campylobacter* levels in poultry
- Comparison of the different on-farm and in-factory practices that affect *Campylobacter* incidence in poultry
- Understanding the effect of water treatment, feed regimes and supplements for poultry
- Studies around potential interventions in poultry transport/slaughter house/factory practices
- Quantitative modelling of interventions
 - On-farm and processing,
 - Catering, retail and the home
- Human behaviour:
 - On-farm and in production processes
 - Domestic and commercial preparation and cooking practices

The biology of the host and pathogen

- Predictive modelling of the system
- How the bacterium survives in the food supply chain
- Colonisation in the chicken and the chicken immune response
- Increased understanding of the role of microbiota of the chicken gut
- Development of bacteriophage, bacteriocins and other new anti-microbials
- Development of greater resistance to *Campylobacter* colonisation in chickens
- Underpinning the potential for a cost effective chicken vaccine(s)

Development of novel detection and diagnostic tools, and resources for *Campylobacter* research

- The development of a rapid, on-farm test for *Campylobacter*
- A strain bank to assist in understanding the genetic diversity of the bacterium

Key outcomes from the workshop

INTRODUCTION AND SESSIONS 1 - 5

Through a series of presentations, speakers outlined the context of the *Campylobacter* problem and gave details of industry trials, on farm controls, in-plant interventions and improving understanding of interventions. Summaries of these presentation sessions are provided at [Annex 2](#).

These were followed by further sessions to consider delivery, gaps and new areas and to consider delegates' views on progress to date and the future of the RISC.

DELIVERY, GAPS AND NEW AREAS

Through facilitated group discussions, delegates were asked to consider whether the research priorities identified by the RISC in 2010 were being adequately addressed and whether any gaps remained. They were also asked to assess whether the current programme still meets industry, consumer and government needs or needs to be refreshed in light of emerging evidence. The analysis of delegates' responses is presented in [Annex 1](#).

The responses and discussions indicated that the priorities identified in the original 2010 RISC remained relevant and appropriate and there was no need to re-direct the overall focus of the strategy.

Delegates were also asked to identify the top five research priorities that the strategy should focus on in the short to medium term future, and to identify any new areas which should be included.

Of the original evidence needs identified in the RISC 2010, delegates identified the following areas as priorities for consideration for further work:

1. Comparison of the different on-farm and in-factory practices that affect *Campylobacter* incidence in poultry
2. Studies around potential interventions targeted to poultry transport and the slaughterhouse
3. High quality baseline data and regular monitoring of poultry
4. Research on human behaviour throughout the food chain; what prevents and what motivates behavioural change:
 - Educating and motivating farmers
 - Consumer awareness and education
 - Development of improved training methods

5. Understanding how the bacterium survives in the food supply chain

Although delegates considered that the first three of these priority areas were already being adequately addressed through on-going research activities, they considered priorities 4 and 5 shown above had the potential to deliver additional valuable evidence and understanding which could contribute to the wider work to control *Campylobacter*.

Only a quarter of delegates considered that research on human behaviour was being adequately addressed by the strategy. It was clear from discussions that improving knowledge in this area would be critical in identifying ways of ensuring consistent application of hygiene measures, both on-farm, during processing and in domestic and catering kitchens.

The majority of delegates were unclear whether enough work was being funded to improve current knowledge on the survival of *Campylobacter* outside the host. This work was considered necessary to identify both how the organism can persist in the food chain and how it would respond to different intervention approaches.

In addition, the following areas were highlighted as being important in delivering the strategy:

- Rapid on farm testing: further work in this area would be beneficial to deliver a method that would provide feedback to farmers on the effectiveness of any on-farm controls, and help to motivate them to take action
- Quantitative modelling: to determine the impact of interventions applied (individually and in series) all along the food chain and how this affects human health
- Understanding colonisation in the chicken: including the role of the chicken immune response and the effects of gut micro-flora and probiotics
- Research to underpin the development of a cost effective vaccine: as a long-term solution for *Campylobacter* control in chicken
- How to develop greater resistance to *Campylobacter* colonisation in the chicken host: the impact of genetics and breed specific susceptibility in chickens

Of these areas, delegates highlighted the need for increased emphasis on quantitative modelling, studies aimed at improving understanding of *Campylobacter* colonisation in chickens, and the development of strategies for preventing colonisation, including cost-effective vaccine approaches.

There was strong support for expanding the application of whole genome sequencing techniques to the UK *Campylobacter* research field. The generation of whole genome sequencing data would be necessary to achieve the RISC aim of producing a strain bank to assist in understanding the genetic diversity of the bacterium. Development of a strain bank would greatly enhance our ability to monitor the attribution of human *Campylobacter* infection, and would support vaccine

development. However, it was emphasised that standardisation of sequencing methods, bioinformatics infrastructure and linking outputs to the results of phenotypic analysis would be required to maximise the value of employing whole genome sequencing.

Proposals for new areas of research not identified in the RISC 2010

In addition to the RISC priorities, delegates identified a number of additional evidence gaps which should be addressed through future work. These included:

- Research to elucidate the human immune response to *Campylobacter* infection and investigation of seroprevalence to assess population exposure;
- Ascertainment of *Campylobacter* infection in humans and the importance of different sources and transmission routes (retail, domestic/catering kitchens, environmental)
- The seasonality of *Campylobacter* infection in chickens and humans and how this impacts on the effectiveness of intervention strategies
- The need for more commercial scale intervention studies, particularly in the study of thinning effects and potential adaptations that could be made to processing equipment to minimise cross-contamination in the slaughterhouse.

Finally, delegates noted that support for on-going fundamental research aimed at finding a long-term solution for eradicating *Campylobacter* in chicken should not prevent the implementation of simpler intervention strategies which could help to achieve target reductions as new evidence becomes available. Progress with on-going research will therefore continue to be monitored by the Joint Government/Industry Working Group for *Campylobacter*², and appropriate action taken to promote the use of control measures when evidence for their effectiveness is identified.

In order to ensure this programme of work was adequately supported into the future, those attending the workshop felt that there was scope for other funding organisations to contribute towards the delivery of RISC priority areas, including other Research Councils (ESRC, EPSRC, NERC, MRC) the Technology Strategy Board (TSB), Department of Health and HPA (now Public Health England)³

² <http://food.gov.uk/policy-advice/microbiology/campylobacterevidenceprogramme/>

³ ESRC – Economic and Social Research Council, EPSRC - Engineering and Physical Sciences Research Council, NERC – Natural Environment Research Councils, MRC – Medical Research Council.

Next steps

ADDRESSING THE EVIDENCE GAPS IN THE RISC 2010

The workshop closed with a discussion on whether the research carried out to date had identified effective intervention strategies that could be taken forward in the short-term, and which areas should be targeted for future research.

Delegates recognised the complexity involved in identifying effective controls for *Campylobacter*, and supported the need for a multi-disciplinary approach to solving the problem. However, it was noted that whilst fundamental research aimed at eliminating *Campylobacter* from the chicken production chain should continue to be supported, there was a need to identify more immediate solutions that could have an impact in the short-term.

There was general agreement that the most promising short-term strategy for the UK industry to achieve its *Campylobacter* reduction target would be to focus controls at processing. It was felt that there was currently sufficient evidence to support the development of antimicrobial treatments and rapid surface chilling and that these could have a positive public health impact, particularly if applied in combination with on-going improvements in hygiene standards. The legal, financial and practical issues associated with these interventions are now being actively explored by the Joint Government/Industry Working Group on *Campylobacter*.

Following the workshop these outcomes will be considered further through the Microbiological Safety of Food Funders Group (MSFFG) to determine what new research requirements would be needed to address the priorities identified by the workshop. The MSFFG is a cross-representational body comprising representation from most bodies that fund research on microbiological food safety. The MSFFG secretariat will organise the meeting and liaise with both existing and new funders suggested by the workshop, e.g. the Technology Strategy Board (TSB) and Economic and Social Research Council (ESRC). This meeting is likely to take place in autumn 2013 and new calls for research will follow in due course.

In summary the research areas identified by the delegates as priority areas for funding and to be considered by MSFFG are:

IDENTIFIED RESEARCH PRIORITIES FOR CONSIDERATION

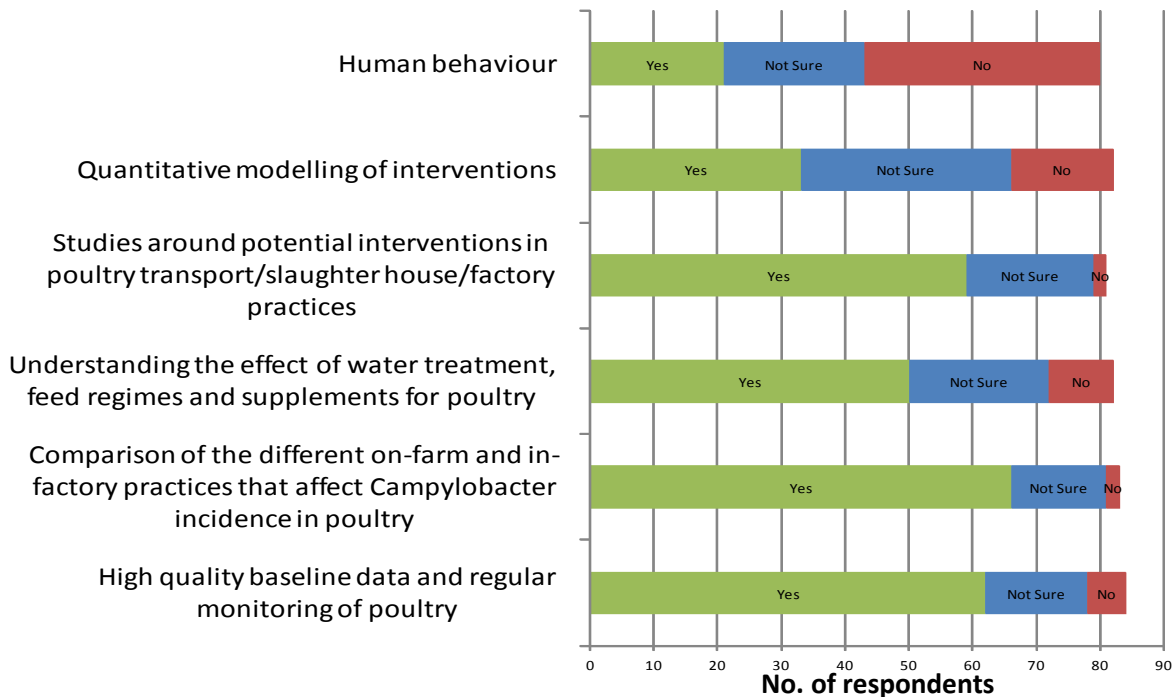
- Research to support the development of a *Campylobacter* vaccine for chickens
- Understanding immunology and resistance in the animal host: investigation of the impact of genetics on *Campylobacter* colonisation and breed specific susceptibility in chickens.
- Elucidating the behaviour of farmers to *Campylobacter* control and motivation for on-farm controls
- Consumer attitudes to *Campylobacter* and motivating behaviour change in domestic and catering kitchens
- The survival of *Campylobacter* in the food chain
- Ascertainment of *Campylobacter* infection in humans and the importance of different sources and transmission routes (retail, domestic/catering kitchens, environmental)
- Elucidating the behaviour of business owners and operational staff to *Campylobacter* control and motivation for improving practices and control in slaughterhouses and processing plants
- The seasonality of *Campylobacter* infection in chickens and humans and how this impacts on the effectiveness of intervention strategies
- The development of quantitative models for determining the impact of interventions applied throughout the food chain (individually and in series)
- Research to elucidate the human immune response to *Campylobacter* infection and investigation of seroprevalence to assess population exposure

Annex 1. Feedback from delegates on progress with the Strategy

Is the research you have heard about on day 1 and 2 delivering against the priorities listed in the Joint Research Strategy?

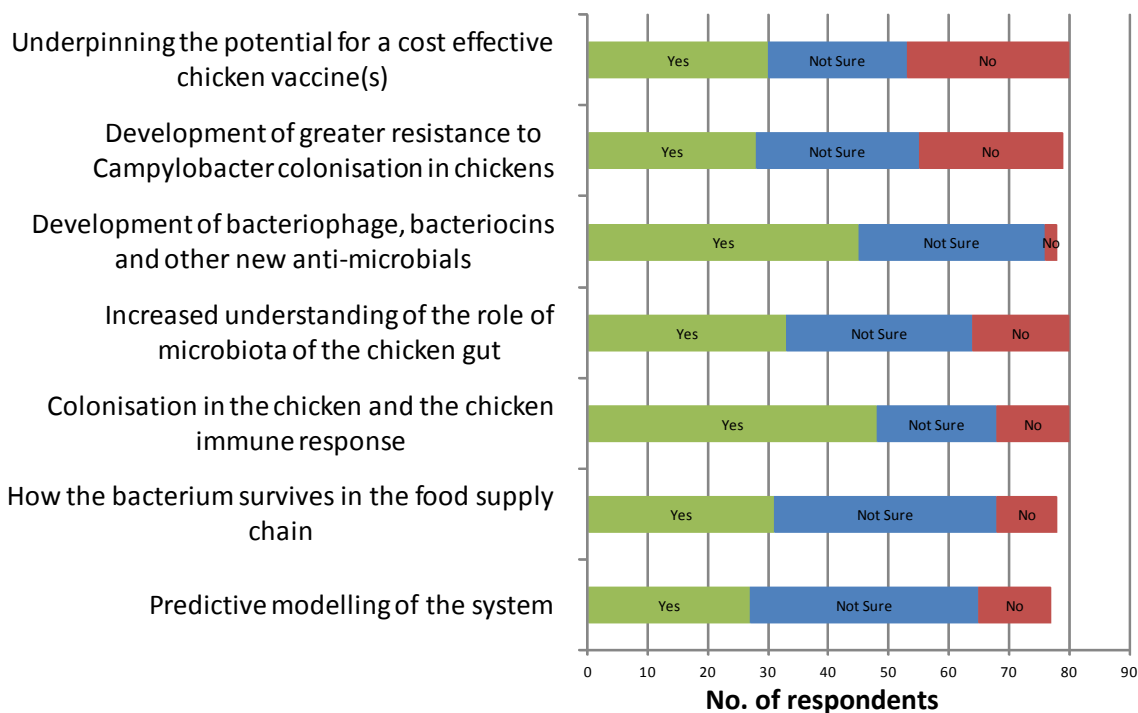
a.

Understanding current practice and potential intervention strategies



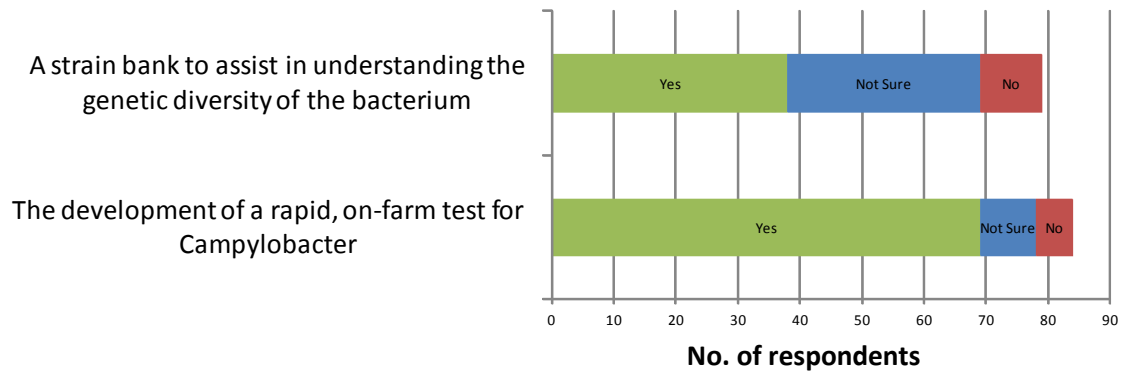
b.

The biology of the host and pathogen

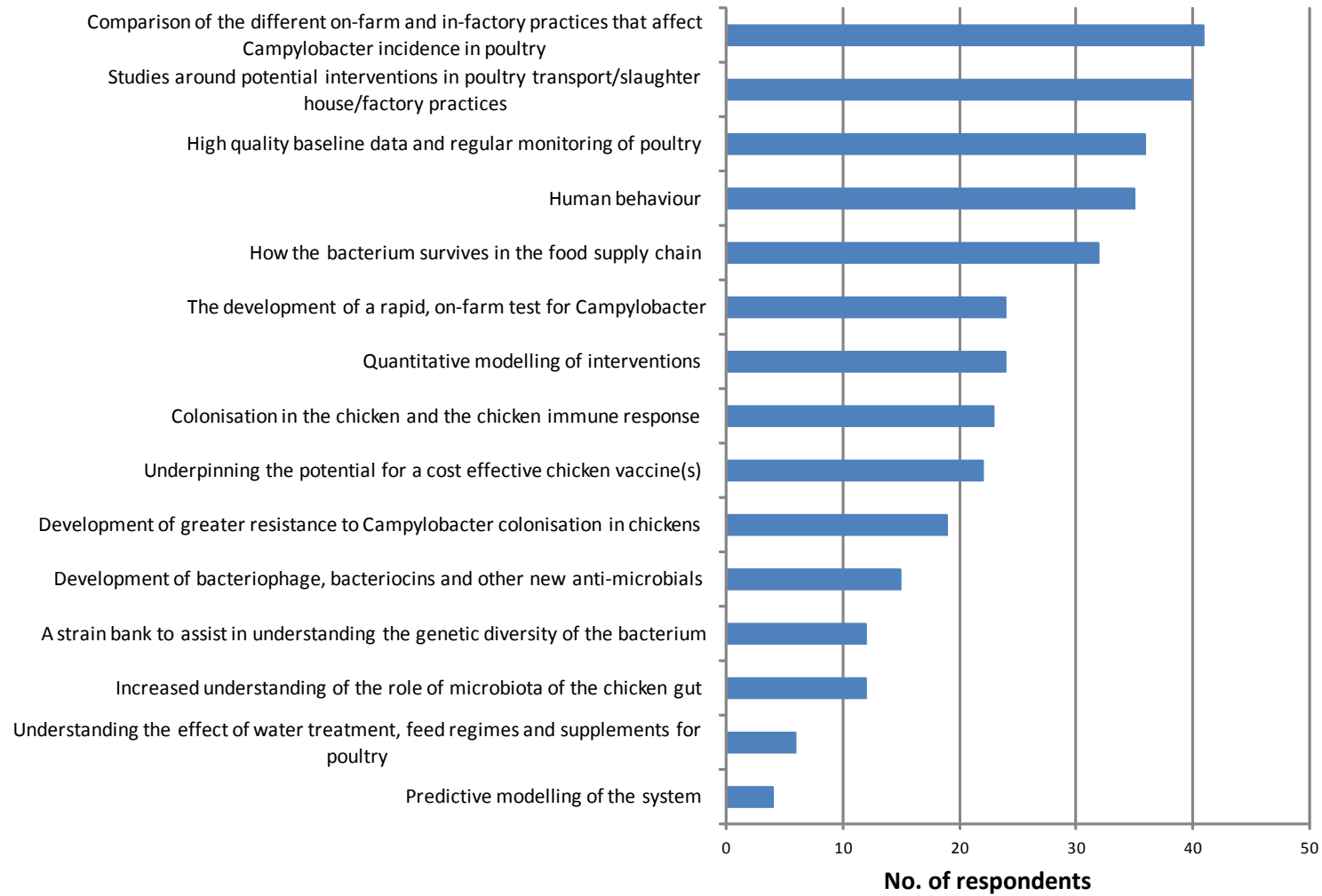


C.

**Development of novel detection and diagnostic tools, and resources
for Campylobacter research**



Research priorities



Annex 2: Summary of presentation sessions

SETTING THE SCENE

The workshop was introduced by the Chair of the FSA, Lord Jeff Rooker, who highlighted the significance of *Campylobacter* as a foodborne pathogen in the UK. It has been estimated that *Campylobacter* is responsible for half of the 1 million reported cases and around 80% of all hospitalisations which are attributed to foodborne disease in the UK. Evidence points to chicken as the most important source of *Campylobacter* infection, and surveillance carried out by the FSA has indicated that approximately 65% of fresh chicken on retail sale in the UK is contaminated. In order to address this issue, a whole food chain approach is required and effective partnership working is critical to success.

Javier Dominguez, the head of FSA's Hygiene and Microbiology Strategy unit followed by presenting an overview of the approach being taken in the UK to tackle *Campylobacter* in the food chain. In contrast to Salmonella, for which national control plans and vaccination programmes were clearly leading to on-going reductions in human incidence, *Campylobacter* was proving difficult to control. It was important to note that this is not only a problem in the UK, with the pathogen accounting for around 200,000 confirmed cases annually across the EU. *Campylobacter* continues to be the FSA's key strategic priority and alongside its strategic partners, the FSA is supporting an extensive programme of work to identify effective intervention strategies. This has been informed through learning about progress made at an international level, and the evidence generated by the research strategy will play a vital role in identifying suitable approaches for the UK. A significant step has been the formation of a Joint Government/Industry Working Group on *Campylobacter*, which agreed a target for *Campylobacter* reduction in 2012⁴, providing the UK with a means of monitoring progress. Developments at the EU level which could lead to future improvements were also highlighted, including new proposals for official controls with relevance to *Campylobacter* management in the slaughterhouse, and the recent approval of lactic acid as a treatment for beef carcasses; the first antimicrobial substance to be approved for use in meat production. The key challenge for all concerned was to find a feasible, cost effective solution for tackling *Campylobacter* which was suitable for use at a commercial scale, met with legal requirements and was acceptable to consumers.

Celia Caulcott of BBSRC outlined the background to the RISC which was developed in recognition of the complexity of *Campylobacter*, and the need for the three main research funders in this area to work together to ensure outputs were applied and capable of addressing the key aims, which are to reduce levels of the bacteria in farm animal hosts, and minimise the potential for cross-contamination throughout the food chain.

The key research priorities of RISC 2010 were divided into three broad groups:

- Understanding current/potential interventions
- Biology of the host and *Campylobacter*
- Development of novel detection and diagnostic tools

It was acknowledged that there was a wide spectrum of research activity on farm to fork interventions which was being carried out in the UK and internationally. An important development was the publication, in 2011, of a systematic review of biosecurity interventions⁵. This stressed the importance of incentives to ensure hygiene measures were maintained on-farm, but highlighted that biosecurity was not the only answer and that the

⁴ <http://www.food.gov.uk/multimedia/pdfs/campytarget.pdf>

⁵ Newell et al, 2011, Applied and Environmental Microbiology, **77**, 8605-14.

development of additional on-farm controls such as vaccines or probiotics would be required to eradicate *Campylobacter* from chicken flocks.

The session was concluded by reminding delegates of the importance of industry, researchers, funders and policy makers working together to identify practical solutions for reducing *Campylobacter* infection in the UK and the key aims of the workshop, to:

1. Review all of the progress which has been made since the inception of the strategy
2. Evaluate whether the strategy is on track and
3. Identify further work which may be required

SESSION 1: CHALLENGES FOR INDUSTRY - NOW AND IN THE FUTURE

Chair	Celia Caulcott, BBSRC
Presentations	Dan Pearson, British Poultry Council Alec Kyriakides, British Retail Consortium

The first session of the workshop consisted of presentations outlining industry and retailer perspectives on *Campylobacter* control. These emphasised the commitment of the industry in addressing the issue and acknowledged the progress being made through effective partnership working via the Joint Government/Industry Working Group, which has facilitated a whole food chain approach to identify control measures which are both effective and feasible. It was also noted that chicken was not the only source of infection and it was important that these were taken into account in the development of new intervention strategies.

It was highlighted that all producers and processors in the UK currently have the same *Campylobacter* status, and that it would not be possible to drive competition between companies without effective controls and tools for measuring success. The presenters noted that eradicating *Campylobacter* from chicken would be difficult in the absence of an effective vaccine, and other options would need to be explored to reduce the levels of contamination in the short term. Doubts were raised about the feasibility of implementing fully effective on-farm controls to prevent flock colonisation, and it was felt that there was currently insufficient evidence on the effectiveness of biosecurity to support industry investment in particular measures. Processing interventions were felt to offer greater promise, although their legal basis and acceptability by consumers needed to be addressed before these could be taken forward. In addition to intervention trials, the need to improve understanding of vectors for introducing *Campylobacter* to flocks, and the factors which lead to seasonal variations in infection in poultry and humans were identified as key gaps in scientific knowledge. The role of education was also discussed, and presenters emphasised that, in addition to developing technical solutions, behavioural research would be critical in identifying ways of motivating individuals to play their part in controlling *Campylobacter* through the food chain-from farmers through to consumers.

Discussions following this session covered:

1. UK progress in reducing *Campylobacter* in chicken. It was noted that progress in achieving target levels would be measured after a full year of monitoring data had been collected at the end of March 2013, although preliminary findings suggested that there had been little improvement since 2010.
2. How to achieve behaviour change. Delegates highlighted the need to improve the motivation of farmers to maintain and monitor effective biosecurity. It was noted that in Iceland, where there has been some success in tackling *Campylobacter*, it had taken a

number of years to incentivise farmers to consistently adopt good practice, even when penalties were in place. The need to link hygiene measures with positive outcomes was emphasised, including the added benefit of biosecurity in controlling other pathogens. Strategies for changing behaviours in relation to the safe handling and cooking of chicken were also discussed, including the role of retailers in communicating hygiene messages to consumers, and the introduction of packaging which would minimise the risks of cross-contamination.

SESSION 2: INDUSTRY TRIALS - PROGRESS REPORT BY THE JOINT GOVERNMENT/INDUSTRY WORKING GROUP ON *CAMPYLOBACTER*

Chair	Robert Martin, FSA
Presentations	Jane Downes, Consultant for Tesco
	Mary Howell, FSA
	Jeremy Hall, Bernard Matthews

The second session aimed to provide delegates with an overview of the trials which are being taken forward by the industry and which are being reported through the Joint Government/Industry Working Group on *Campylobacter*. This included presentations on progress with on-farm controls and processing interventions, including a summary of progress with rapid surface chilling; a post slaughter carcass treatment which has been investigated by a major UK turkey producer.

With regard to on-farm controls, the introduction of Red Tractor Farm Assurance Standards in 2011 was recognised as a major step forward with regard to improving biosecurity on poultry farms. An on-going project was described which is examining the impact of biosecurity measures on 14 farms of variable type (old, new and mixed), all of which are being tested for *Campylobacter* status at the thinning and de-population stages. This work is providing further evidence that difficulties in maintaining biosecurity, particularly during thinning, present a major challenge in keeping *Campylobacter* out of flocks. In addition, data has suggested that the implementation of standards has had little effect on the summer peak in infection levels. It was noted that whilst farmers and catchers were capable of implementing biosecurity, the paucity of evidence for effective control measures, coupled with a lack of methods for enabling them to measure success, was resulting in demotivation. Disease reduction could be achieved through sustained controls, but this will require significant effort to change behaviours, attitudes and beliefs across the industry.

Presentations on slaughterhouse interventions included preliminary results from industry partnership projects which could lead to the development of improved methods for the decontamination of transport crates and modules. Data was also presented on trials to assess the potential of a range of processing aids including electrolysed water, chlorine dioxide, lactic acid, 'Sonosteam' (combination of steam and ultrasound) and post-slaughter rapid surface chilling. To date, the results have been variable in terms of the efficacy, practicality and impact on meat quality associated with the application of these methods. However, it was clear from the data presented that the intervention which showed most promise was rapid surface chilling, which consistently provided a 1-log reduction in counts. This method involves taking only the surface of the carcass down to below 2 °C without freezing the meat itself, and is capable of achieving reductions in *Campylobacter* levels within 20-25 seconds. The carcass temperature is stabilised within 2 minutes post treatment, and the process has minimal impact on the quality of the meat or shelf-life. It is also considered to be both cost-effective, practical for the industry to implement, and is deliverable at batch scale.

Discussions following this session covered:

1. How to effect further improvements to biosecurity. Delegates acknowledged that the thinning process presented a particular challenge to the industry. It was also noted that changes could be made to make it easier for farm workers to implement effective biosecurity such as the use of benches for boot changing. The role of fly screening was also discussed, and it was suggested by one delegate with experience in this area that both fly screens and hygiene measures were needed in order for biosecurity to have an impact during the summer months. The need for auditing of farm practices was also highlighted, and it was noted that annual audits of trial farms had revealed a non-compliance rate of 28%, suggesting further work was required.
2. Processing interventions. The effect of biofilms on crates and equipment was raised, and it was noted that research had demonstrated that these could be generated rapidly in processing environments, highlighting the challenges involved in undertaking effective cleaning regimes. The testing methods used to assess the efficacy of processing aids were also discussed. The speakers confirmed that ISO accredited methods had been used, involving the plating of samples. Clarification was also sought on costs of the rapid surface chilling method, which was estimated to be around £100 K for each plant.

SESSION 3: ON FARM CONTROLS

Chair	Michael Bailey, NFU
Presentations	Nick Sparks, Scottish Agricultural College Lisa Williams, University of Bristol Malcolm Taylor, Agri-Food and Biosciences Institute Tom Humphrey, University of Liverpool

Session 3 focussed on the current findings of research relating to the efficacy of on-farm controls for *Campylobacter*. The chair introduced the session by describing the pressures on the industry resulting from increasing demand for chicken and the drive for consumer choice. It was noted that modern broiler farms are increasing in scale and it therefore critical that building and farm design can adapt to ensure *Campylobacter* is effectively controlled. The need to continue to support research in identifying the most effective on-farm hygiene controls was highlighted. In terms of ensuring the implementation of controls, the chair highlighted the Red Tractor assurance scheme as being the most effective tool for driving the uptake of these measures across the industry.

The presentations in this session discussed the findings of research on a range of biosecurity measures including hygiene barriers, the use of fly screens and acidification of water sources. The findings of this work have been largely inconclusive, although it has re-enforced the role of farm personnel in the spread of *Campylobacter* in housed chicken flocks, particularly catchers. It was noted that there was a need for more routine and accurate testing on-farm to identify the key points at which biosecurity breaks down. Such testing was key to provide feedback to farmers and catchers and motivate them to take appropriate action. The session also covered progress in relation to the development of a rapid on-farm test which would allow flock colonisation status to be determined. This has demonstrated that boot swab sampling followed by analysis by reverse transcription PCR (RT-PCR) has the potential for feeding back the *Campylobacter* status of a broiler house within 30 hours of sample collection. Further trials are being planned to assess the effectiveness of this method across the industry.

A further presentation in this session looked at the potential of increasing polyunsaturated fatty acid (PUFA) levels in feed for reducing the colonisation of broiler chickens with *Campylobacter*. PUFAs are known to reduce inflammation, which is believed to play a role in the mechanism by which birds are colonised. This research demonstrated a reduction in *Campylobacter* levels in the livers and intestines of birds which have been administered with increased levels of PUFAs through the addition of fish and linseed oils. The findings to date suggest that PUFA supplemented feed could have a role to play in the control of *Campylobacter* in chicken flocks as part of an integrated intervention programme.

The final presentation in this session examined research on the relationships between production systems, bird welfare and endemic disease on *Campylobacter* susceptibility in chickens. It was noted that the key outputs of this work have been delivered through collaboration between researchers, the major producers and retailers, and on-going exchange of ideas and experience between these parties will be key in identifying a solution. Research on factors which affect *Campylobacter* colonisation in the absence of thinning has been undertaken using boot sock sampling which has proven useful in identifying the point at which a flock becomes positive. This work has demonstrated that seasonality is a factor, with higher infection rates recorded in the summer months, and that poor welfare conditions can be an indicator of colonisation. Further research is underway on adaptive and innate immune responses in chickens, the impact of breed on *Campylobacter* colonisation, and the link between colonisation and mucosal damage to the intestine caused by mixed infections.

Discussions following this session covered:

1. The assessment of biosecurity practices. There were discussions on how differences in the use of hygiene barriers on control and test farms were being assessed and whether the impact of fly screens had been measured under conditions which would enable their impact to be properly assessed (e.g. warm weather). It was noted that regardless of the intervention, the focus should be on changing human behaviour, as this would have the most critical impact in ensuring that controls were being implemented effectively. One participant highlighted the challenges in identifying individual biosecurity measures which will be likely to have the biggest impact, given the diversity in house design and farm practices. There was also a need to include a social science element to intervention studies, in order to tease out the motivational factors which would encourage farmers to take action.
2. Issues associated with the modification of chicken feed. A number of questions were raised about the implications of using PUFA based feed supplements. It was accepted that the sustainability of fish oils may present a future issue and could impact on costs. Consumer acceptability was also highlighted, and parallels with the sale of omega-3 eggs were noted.
3. Relevance of *Campylobacter* strain types employed in research. Several participants highlighted the need to ensure that intervention studies and trials of on-farm tests were based on *Campylobacter* strains which were found in real farms and known to be infectious to humans. It was agreed that the research should focus on the most relevant strains, although the difficulties in working with such a dynamic organism were noted.

SESSION 4: INTERVENTIONS

Chair Ursula Lavery, Moy Park
Presentations Dean Burfoot, Campden BRI
Mike Hutchison, Hutchison Scientific Ltd
Viv Allen, University of Bristol
Mike Jones, University of Nottingham

The presentations in Session 4 focussed on research examining other potential interventions for controlling *Campylobacter*, as well as the work that has been undertaken to monitor the prevalence and changes of *Campylobacter* numbers on poultry in slaughterhouses.

The findings from trials conducted to examine the efficacy, practicality and cost of potential interventions to reduce *Campylobacter* contamination in slaughterhouses were presented. These projects included both methods that were currently allowed in the EU for reducing the numbers of campylobacters on chicken carcasses and also those methods that would require further approval for their use.

Spraying of electrolysed water and chlorinated water, at EU acceptable concentrations, did not produce significant reductions (<0.5 log) in the counts of *Campylobacter*. Treatment with ozonated water was not found to have a significant effect however further trials will be required due to the low counts present on the untreated carcasses during the trials. Dipping in, or spraying with, hot-water caused an adverse effect on the appearance of carcasses with the flesh being torn and swollen. Lactic acid treatment, with acid concentrations up to 8%, produced reductions in *Campylobacter* up to 1.9 log. However, treatment with 8% lactic acid resulted in an unacceptable appearance of the carcasses. It was found that a buffered solution with 4% lactic acid was the highest concentration that produced a visibly acceptable product although this only gave a *Campylobacter* reduction of 0.4 log on the breast skin. Consumer sensory trials on the acceptability of the product need to be undertaken. Rapid chilling of the surfaces of carcasses was shown to reduce *Campylobacter* by up to 1.2 logs, further larger scale industry trials are now proposed to determine the practicality of the process in the slaughterhouse.

The next presentation presented the findings to date of a project which was aiming to determine if industry-donated, quantitative *Campylobacter* test results can be utilised to monitor the levels of *Campylobacter* on chicken carcasses in the UK. In addition to the test results, questionnaires to capture the farm and processing plant infrastructures were completed to identify farming or processing practices which are associated with lowered numbers of campylobacters on the carcasses. Initial analysis of the current dataset suggests there may be an association between some practices or infrastructure in the processing plant with *Campylobacter* numbers, such as the stun method employed.

Work has been undertaken to investigate the changes in *Campylobacter* numbers on chicken carcasses during and following processing to identify which processing stages and variations in plants have an impact. Sampling undertaken at 19 major plants, producing $>85\%$ of UK chicken throughput, showed that at the majority of plants, scalding resulted in a significant reduction in *Campylobacter* numbers whilst defeathering caused a significant increase, due to the pluckers squeezing out faecal material. A reduction in campylobacters on neck skins during processing, except for scalding, appears to be after inside/outside wash and during chilling. Many plants have a good reduction at either one of these sites but not normally at both. Further work is planned to examine processing lines where modifications based on the process recommendations have been implemented and also to determine the significance for cross-contamination from colonised to un-colonised flocks.

The session concluded with a presentation on *Campylobacter* phase variation and its impact on immunity to aid vaccine development. Findings suggest that the spread of infection in flocks could lead to different phase variants contaminating different birds which would have implications for vaccine development.

Discussions following this session covered:

1. Sampling methodologies. A number of questions were raised on the methodology employed during the monitoring of *Campylobacter* on chicken. It was confirmed that all samples taken were from post-chill neck skins, and as the neck is at the bottom, you need to ensure the bird is not too wet when it goes into the chill. The questionnaire developed to capture the farm and processing plant infrastructures solely focussed on areas that were measureable and did not incorporate any social science aspects.
2. Modification of current processing practices. The variations in *Campylobacter* numbers observed at the different stages along the processing line, posed many questions on where the main focus should be for tackling the problem. The differences in bird size/shape was highlighted as the main issue at the defeathering stage and that it was difficult to change the plucking settings, however even if this stage was solved the later evisceration stage was still a problem, therefore it was proposed the inside/outside wash was a better place to focus efforts. Anonymised data has been shared amongst the processing plants so that they can compare their data with others and learn from effective practice.

SESSION 5: IMPROVING UNDERSTANDING FOR INTERVENTIONS

Chair	Jeremy Hall, Bernard Matthews
Presentations	Ian Connerton, University of Nottingham
	Ken Forbes, University of Aberdeen
	Sarah O'Brien, University of Liverpool

The final session of presentations covered a range of projects which are aimed at further improving our understanding of the biology of *Campylobacter* to enable effective interventions to be implemented.

Evidence has shown that chickens can be colonized by a number of different species and strains of *Campylobacter* that go through sequential population succession during the course of rearing. These strains are carried into the poultry processing plant where there is evidence that differences in processing can affect the prevalence and diversity of *Campylobacter* populations recovered from carcasses. The initial findings were presented from a project which aims to gain a better understanding of the with-in flock *Campylobacter* population epidemiology. *Fla*-short variable region (SVR) sequence typing of a limited number of isolates revealed that a single *fla* type was observed when multiple houses on a farm were positive on the same date. This indicates that either a predominant type existed in the house environment or personnel were responsible for taking the organism between houses. This *fla* type was unique to each farm. New strains coming into the flock can be very effective very quickly, whilst other strains are not so successful and can be phased out depending on the competition with other resident strains. Organic, free range flocks strains have more diversity and phage compared to housed flocks which may be an indication that biosecurity is keeping them out.

Predictive modelling has been undertaken to optimise phage intervention against *Campylobacter* in poultry. Historical data has shown that broiler flocks with more phage have

less *Campylobacter*. The project looked at both *in vivo* phage therapy and the use of phage as a biosanitiser post-slaughter. The phage needs to be administered at a certain concentration (at least 10^7) before having a significant impact and be a cocktail of different phage to deal with different *Campylobacter* strains.

The final two presentations focussed on increasing the understanding of human epidemiology and sources of *Campylobacter*. Multi-locus sequence typing (MLST) has shown a change in the abundance of the most common sequence types from clinical cases between 2005 and 2011. However the attribution to source remained unchanged with retail chicken being the most important source of human infection. A large consortium project of 5 inter-linked studies is underway to identify the key reservoirs, environmental and social drivers of *Campylobacter* that affect human disease. It is envisaged that looking at the same disease from different angles will lead to a step-change in understanding this major public health problem.

Discussions following this session covered:

1. Application of phage intervention. Questions were raised on how you apply the phage intervention without knowing the strains of *Campylobacter* in the flock. It was confirmed that a cocktail of phage would need to be produced that would be effective against a high percentage of strains. Resistance to phages does not appear to be an issue as the resistant strains appear to be outcompeted by non-resistant strains. Work in the US has shown that biosanitisation at the pre-chill stage is best.
2. Source attribution. There were discussions on how the model used (asymmetric island vs. structure) during source attribution can have an impact on the actual percentage attribution, however the relative rankings to each source remain the same. It was also acknowledged that sufficient isolates of each source are needed to prevent any bias during the attribution modelling.
3. Relying on public participation and recall. It was highlighted that recall of food histories for under 5's was particularly challenging, however through the use of questionnaires for parents, the use of social media (e.g. Facebook profiles) and food diaries from nurseries this should be overcome. The use of supermarket loyalty cards should be employed to get purchasing histories for households.