UK Publicly Funded Research Relating to Food-borne Viruses

Report to the Microbiological Safety of Food Funders Group

November 2005

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Research from 1990 to 2005

OVERVIEW

This report is the output of a review by the Microbiological Safety of Food Funders Group (MSFFG) of the research relating to food-borne viruses supported by its members from 1990 to October 2005. This has not been a major research area for the member organisations of the MSFFG, and there has been limited relevant research supported during this period.

Infectious intestinal disease in humans as a result of infection with viruses is common, and two viruses in particular, norovirus and rotavirus, are associated with viral infectious gastroenteritis. The routes of transmission are primarily person-to-person contact and, for transmission of norovirus, the consumption of contaminated food. Within this category, shellfish, in particular bivalve molluscs such as oysters, have been established as an important source of viruses leading to food-borne illness. There is also concern that the increase in consumption of pre-prepared food, fruit and salads may provide a route to exposure to food-borne viruses, if the food is contaminated either during growth or through infected individuals preparing and handling food with inadequate hygiene practice.

Research during the period of the report has focused on reducing the levels of norovirus in relevant foods, primarily shellfish, and in providing appropriate tools to support such research. It is not likely to become a major research area in the future, and will tend to develop in response to microbiological food safety issues in relation to consumer needs and industry practice.

LAY OVERVIEW

Viruses are a very common cause of mild gastric illness, primarily vomiting and diarrhoea, in humans. In general, people become infected through person-to-person contact, rather like catching a cold. However, it is known that eating contaminated food, in particular shellfish or prepared food which has been contaminated during cultivation, preparation or handling can also be a route for transmission of viruses that cause gastric illness.

This report describes work which the UK government and other bodies have funded in the last ten years on food-borne viruses, in relation to the microbiological safety of food. This research has focused primarily on the reduction of levels of viruses in shellfish, and in seeking to understand how the most common viruses could be transmitted to man from different sources. The overall conclusion is that this is not a major research area, and that previous and future research effort will be driven primarily by the needs of the consumer in relation to the microbiological safety of food.

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Research 1990 - 2005

1. INTRODUCTION

1.1 The Microbiological Safety of Food Funders Group (MSFFG) has previously published reports giving an overview of the research funded by member organisations of the MSFFG relating to various food-borne pathogens including Verocytotoxin-producing *Escherichia coli*[1], *Campylobacter*[2], *Salmonella*[3], *Listeria monocytogenes*[4] and *Yersinia enterolitica*[5]. As part of the ongoing process of considering research with all food-borne pathogens supported by MSFFG members, the group has undertaken a review of research on food-borne viruses, as recorded in this report.

1.2 This report gives an overview of the progress of food-borne virus-related research undertaken in the UK and funded by members of the MSFFG. It summarises research in the period from 1990 to the end of October 2005 and seeks to set this in the context of other research and issues within the UK and overseas. In addition, an assessment is made of those areas where further research might be needed.

1.3 Viruses are a frequent cause of infectious intestinal disease and there are several specific viruses associated with this. Viruses causing infectious gastroenteritis are of human origin and, with the possible exception of some rotaviruses, are not zoonotic. This is in contrast with most bacterial food-borne disease, where the bacterium is capable of multiplying in both human and other animal hosts. The most common cause of infectious gastroenteritis in England and Wales are noroviruses [6] (ACMSF (1998), Adak *et al* (2002)). The transmission of noroviruses is generally either by faecal-oral route through person to person contact or through the consumption of contaminated food or water. In general, the symptoms of viral gastroenteritis are mild with diarrhoea, vomiting and possibly mild fever but no further complications.

1.4 The most common cause of infantile gastroenteritis are rotaviruses[7] which infect nearly all children by the age of 3 to 5 years in both industrialised and

[1] http://www.food.gov.uk/science/research/researchinfo/foodborneillness/microfunders/vtec

[2] http://www.food.gov.uk/science/research/researchinfo/food-borneillness/microfunders/campylobacter

[3] http://www.food.gov.uk/science/research/researchinfo/foodborneillness/microfunders/msffg/55669

[4] http://www.food.gov.uk/science/research/researchinfo/foodborneillness/microfunders/listeria

[5] http://www.food.gov.uk/science/research/researchinfo/foodborneillness/microfunders/yersinia

[6] http://www.hpa.org.uk/infections/topics_az/norovirus/menu.htm

[7] http://www.hpa.org.uk/infections/topics_az/rotavirus/menu.htm, http://www.cdc.gov/ncidod/EID/vol4no4/parashar.htm

developing countries[8]. Rotavirus transmission is primarily by the faecal-oral route and there is only limited evidence of food-borne transmission (Fletcher *et al* (2001), Gallimore *et al* (2005)). Although the symptoms of rotaviral-associated gastroenteritis are generally mild, for a small number of rotavirus infections in children there can be a need for hospitalisation to enable fluid and electrolyte replacement. It is estimated that around 18,000 children in England and Wales are hospitalised annually for these reasons[9]. The number of these attributable to food-borne transmission of the virus is unknown but it is thought to be relatively low.

1.5 Less common than infectious intestinal disease caused by noroviruses or rotaviruses is viral gastroenteritis caused by hepatitis A. As with noroviruses, infection with hepatitis A can be through the faecal-oral route or through consumption of contaminated food or water[10] with shellfish being a frequent source of the viruses.

1.6 Adenoviruses are also known to cause viral gastroenteritis in children, as well as more commonly causing respiratory illness. There are no indications of how the transmission of adenoviruses occurs, although Mead *et al* (1999) implied that it is not food-borne.

1.7 The contamination of food with viruses that cause infectious intestinal disease occurs both as a result of contamination during the growth of the foods (as is the case with bivalve shellfish) and through problems resulting from the actions of food handlers (ACMSF (1998)).

1.8 Although it is not straightforward to determine the number of cases of viral gastroenteritis that are due to food-borne viruses, Adak *et al* (2002) estimate that in the UK there were over 84,000 such cases in 2000 (less than 0.1% of all food-borne illnesses), with the majority (over 57,500) being due to Norwalk-like virus infections (norovirus infections, see Section 2 below). No mention is made of hepatitis A. In the same year, *Campylobacter* was estimated as causing almost 400,000 cases of gastroenteritis and *Salmonella* over 40,000 cases. Mead *et al* (1999) estimated that approximately 66% of food-borne illnesses in the US were caused by Norwalk-like virus (see Section 2 below) and 0.3% by rotavirus. Although mentioned, numbers of food-borne infections due hepatitis A were negligible.

2. NOMENCLATURE OF NOROVIRUSES

2.1 There have been a number of changes in norovirus nomenclature during recent years, which are highlighted in this report by the inclusion of research dating from 1995. The research projects refer to Norwalk virus, norovirus, Small Round Structured Viruses (SRSVs) and Norwalk-Like Virus (NLV). All of these are now regarded as being the same genus of viruses and are

[8] http://www.cdc.gov/ncidod/EID/vol4no4/parashar.htm
[9] http://www.hpa.org.uk/infections/topics_az/rotavirus/menu.htm
[10] http://www.cfsan.fda.gov/~mow/chap31.html

currently referred to as norovirus[11]. The genus is a member of family of *Caliciviridae*.

3. METHODS

3.1 This report is based on those research projects that are funded by the member organisations of the MSFFG. At the time of writing this report, these were the Food Standards Agency (FSA), the Department for Environment, Food and Rural Affairs (Defra), the Biotechnology and Biological Sciences Research Council (BBSRC), the Department of Health (DH), the Department of Agriculture and Rural Development, Northern Ireland (DARD), the Food Safety Promotion Board of Ireland (FSPB), FSA Scotland, FSA Wales, FSA Northern Ireland, the Health Protection Agency (HPA), the Meat and Livestock Commission (MLC) the Medical Research Council (MRC), the Scottish Executive Environment and Rural Affairs Department Science and Research Group (SEERAD SRG) and the Scottish Executive Department of Health (SEDH).

3.2 The MSFFG project database[12] was used to identify projects for inclusion in this report. The food-borne virus-related projects were identified by searching the database for the term 'virus' in every text field in the database. Further checks were run using the terms 'viral', NLV, SRSV, hepatitis, 'adeno' and rotavirus. The projects identified by this approach were checked and a number removed from consideration as they only included the term 'virus' in the scientific subject area (a search term in the database) and no other mention of viruses was made in any other part of the project text. In addition, members of the MSFFG were requested to identify any projects which might have been omitted from the MSFFG project database. This gave a total of 21 projects which are listed in Appendix 2. The earliest of these projects was initiated in 1993.

3.3 Studentships were omitted from consideration.

3.4 Research funded by other agencies, including the Wellcome Trust, Royal Society and NHS Scotland as well as international research is not included within the body of the report. However, a summary of research funded through these bodies is given in section 4 below.

[11] http://www.ncbi.nlm.nih.gov/ICTVdb/Ictv/index.htm

[12] The MSFFG maintains a database (www.msffg.org.uk) containing information about research projects in the area of the microbiological safety of food that are funded by the members of the MSFFG. Members of the Group provide the project information from their respective project record systems. The earliest projects within the database were initiated in 1990. Some historic project data from member organisations joining the MSFFG in 2005 (eg the EA, HPA, MLC, MRC) may be unavailable to the database.

4. RESEARCH SUPPORTED BY OTHER FUNDING BODIES

4.1 Within the UK, the Wellcome Trust supports a variety of research projects on viruses, but with limited relevance to food-borne viruses. Outside of the UK, the US National Institutes for Health database[13] records 36 projects active in 2005 which were focused on rotavirus, and 12 focused on norovirus. Many of the projects consider aspects of the molecular biology, including viral structure and host pathogen interaction. Others, primarily among the rotavirus projects, address vaccine development. In the EU research projects database[14], 18 projects relating to norovirus and rotavirus are recorded, the majority again focussing on rotavirus and including molecular biology, vaccine development and reduction of viral levels in potentially contaminated food.

4.2 The EU has also funded a surveillance project to study the occurrence of food-borne viruses within eleven European countries, *Foodborne Viruses in Europe*[15].

5. RESEARCH SUPPORTED BY THE MSFFG

5.1 Background

5.1.1 In contrast with bacterial food-borne pathogens such as VTEC and *Salmonella*, viruses cannot multiply within or on food, either raw or cooked. The risk of humans acquiring viral gastroenteritis is therefore dependent on the number of infectious viral particles which an individual ingests, and their immune response to these. In general, virus particles are destroyed by cooking, and so the highest risks are associated with the consumption of food that has not been cooked, or only lightly cooked, since becoming contaminated with viruses. Shellfish that are generally eaten raw or lightly cooked (eg oysters) in particular are known to be a source of viruses that can cause gastroenteritis in humans. Other sources of concern are pre-prepared raw food (such as ready-to-eat salads, fruit and vegetables) that has become contaminated in the process either of growth or through infected individuals preparing and handling food with inadequate hygiene practice (**FSA B12001**).

5.1.2 The majority of the research relating to food-borne viruses funded by the MSFFG member organisations has been focussed on the possible contamination with viruses, generally noroviruses, in shellfish for human consumption. In part this reflects a significant concern that shellfish are a known source of viral infections because they are sourced from coastal waters into which sewage is discharged, and then consumed by humans either raw or only lightly cooked. There is also epidemiological evidence to support this route of infection (**FSA B12001**). The issue is already addressed by processes within the food-industry, using depuration and heat treatment. However, there has continued to be a need to develop a variety of tools and techniques in this area both to understand the incidence of contamination and

[13] http://crisp.cit.nih.gov/
[14] http://www.cordis.lu/en/home.html
[15] http://europa.eu.int/comm/research/quality-of-life/ka1/volume1/qlk1-1999-00594.htm

to reduce the risk to human health. In addition, research has been supported to understand and improve the effectiveness of depuration.

5.1.3 There is very little current research immediately relevant to the molecular biology of food-borne viruses. Examination of calicivirus genome evolution suggested that these viruses have arisen recently in evolutionary history and this is of potential importance in understanding the evolution of new viruses capable of causing disease in man (**BBSRC 4331219)**.

5.2 Isolation and detection of viruses

5.2.1 A number of projects have focused on research to develop methods for the isolation and detection of viruses in shellfish. In particular, the need has been to develop methods that are reliable, cheap and capable of detecting the low levels of norovirus and hepatitis A virus present in shellfish or in seawater associated with shellfish. Several approaches have been taken to developing such an assay.

5.2.2 It was found that an ELISA-type assay, based on monoclonal antibodies to several noroviruses, was sufficiently sensitive to detect norovirus contamination in shellfish (**FSA B04003**). PCR methods for detection of norovirus and Hepatitis A in molluscs were also developed as was a TaqMan®-based assay, although the latter will not be appropriate for noroviruses until further assay reagents are commercially available (**FSA B04001**). Both assay types were used to determine the presence of viruses in shellfish with success. In research using feline calicivirus as a surrogate for noroviruses, PCR assay was found to detect virus in shellfish samples which did not show the presence of viruses in culture (**FSA FS1028**) which may be due to the greater sensitivity of the molecular method. A rapid nucleic acid-based amplification method was also developed for the detection of RNA viruses and using this both poliovirus and rotavirus could be detected when present at very low levels (100 viruses per test) (**FSA FS1235**).

5.2.3 Both norovirus and hepatitis A cannot be cultured in the laboratory (although see Wobus *et al* (2004)) and an alternative approach to detecting these viruses is to use a surrogate marker for viral contamination from sewage in shellfish and seawater. It was found that an established faecal pollution indicator, FRNA bacteriophage, was potentially an alternative indicator of viral contamination of faecal origin in shellfish and seawater where the levels of contamination were relatively low (**FSA B04009**). In the same research project, it was found that *Escherichia coli* was an appropriate and adequate surrogate marker for viral contamination of shellfish where the levels of sewage pollution were high.

5.2.4 The difficulty of detecting noroviruses due to the inability to grow the virus in the laboratory also applies when seeking to detect and measure the presence of the virus in foods. One project involved research to develop novel isolation, concentration and detection methods for norovirus in food (**Defra FQS38**). Other research developed methods for extracting RNA viruses from soft fruit

and salads, as well as shellfish, using poliovirus as a model (**FSA FS1235**).

5.3 Occurrence and epidemiology

5.3.1 Partly as a result of the difficulty of working with norovirus, there is little information relating to its transmission via food. Recent research found that norovirus was present in 96% of crude sewage samples and 75% of final sewage effluents (such as would be discharged into the sea). It was noted that sewage treatment was less effective at reducing contamination with norovirus than with *E. coli* (**FSA B05001**).

5.3.2 It is important to identify the source of contamination of shellfish and in particular to distinguish between human sewage and agricultural run-off as the source. FRNA bacteriophage and adenovirus detection by PCR was used to demonstrate that these methods could assist in differentiating between these possible sources (**FSA B05005**).

5.3.3 During research to develop and standardise PCR assays for norovirus and hepatitis A, it was noted that the noroviruses identified in shellfish, probably present from sewage, were nearly all strains associated with humans, and no obvious veterinary strains were identified (**FSA B04009**). In a separate project, it was found that the predominant type of norovirus present in clinical samples was the genogroup 2 'Lordsdale virus' (**FSA B04003**).

5.3.4 Enteric viruses, as represented by poliovirus, were found to persist on fresh fruit and vegetables for several days under storage conditions commonly used in the domestic setting (**FSA FS1263**), supporting the view that these foods could be a route of transmission of viruses to humans.

5.3.5 In order to better understand the routes of transmission of norovirus, a study linking the epidemiological and molecular data for norovirus outbreaks in Ireland has been initiated (**FSPB 03-RESR-002**). The data will be used to assist in identifying foods implicated in norovirus outbreaks.

5.3.6 The Infectious Intestinal Disease study (**FSA B08004**) included noroviruses and the linked faecal specimens archive includes 60 samples from norovirus infections and 87 samples from rotavirus infections, viral DNA being successfully extracted from 72 and 15 of these, respectively (**FSA B14004**).

5.3.7 Rotaviruses are common animal pathogens and there is the potential for transmission between animals and humans. It is known that there are several rotavirus types that occur in humans and animals (**Defra OZ0406**) and it has been demonstrated that rotaviruses isolated from one species of animal can infect another species. Genetic re-assortment occurs frequently within rotaviruses, normally between common strains for a single host (eg humans) but can also occur between human and animal strains. It has also been found that within the human population are several uncommon rotavirus genotypes, some of which can be found in domestic animals. It is not known whether these have arisen in the human population by zoonotic transmission or other mechanisms, such as gene transfer and re-assortment. The incidence of

such strains in the UK human population is low, suggesting that whatever the mechanism it occurs infrequently.

5.4 Reduction and elimination

5.4.1 Awareness of factors affecting occurrence of norovirus in sewage will enable shellfisheries to manage the impact of sewage discharges. It was found, using *E. coli* as the marker for faecal contamination, that season, tidal cycle and rainfall were the primary environmental factors influencing *E. coli* levels in shellfish (**FSA B05002**). Initial models were developed to assist in interpretation of results and in developing advice for relevant organisations. It was noted that *E. coli* levels were reduced by almost 3 logs during sewage treatment, whereas norovirus levels were only reduced by approximately 1 log (**FSA B05001**). Laboratory investigations showed that treatment with sunlight or varied water temperature also differed in effectiveness against norovirus compared with *E. coli*. Norovirus survival was reduced by sunlight, although less than bacterial survival, whereas variation in water temperature had only a marginal effect on viral survival. This suggests that bacterial indicators may underestimate the potential for viral contamination, particularly during the winter when the levels of sunlight are lower (**FSA B05001**).

5.4.2 FRNA bacteriophage was found to be a suitable marker for the elimination of norovirus from oysters during depuration (**FSA B04002**). Using FRNA bacteriophage as a surrogate measure for norovirus, it was found that raising the temperature during depuration (to 17°C or more) for prolonged periods (up to 5 days) gave significantly greater reduction in FRNA bacteriophage levels in native and Pacific oysters as compared with depuration at ambient temperature. Depuration at increased temperatures should therefore lead to increased removal of virus. There was, however, a slight reduction in the shelf life of native (as opposed to Pacific) oysters as a result of the treatment.

5.4.3 Other methods for the reduction of virus levels in shellfish have been investigated. It was found that treatment of mussels with high pressure could give a significant inactivation of a model viral contaminant, bovine enterovirus (**FSPB 01-RESR-105**). Heat treatment of some shellfish is also used to inactivate pathogens, and it was found that current standard treatments (85-90°C for one minute) was sufficient to inactivate feline calicivirus, used as a model for norovirus. It was also found that the feline calicivirus was more heat labile than hepatitis A virus (**FSA FS1028**).

5.4.4 Although shellfish are associated with the occurrence of viral gastroenteritis, there is also concern about the possible transmission of viruses on fresh produce supplied in a ‘ready-to-eat’ form. It was found that model viruses and bacteriophage could survive on fresh fruit and vegetables for prolonged periods, in many cases beyond the shelf-life of the product (**FSA B02014**). In the laboratory, washing of products with water removed a proportion of the viruses present. Chlorinated water was more effective still, but even using chlorine levels commonly used by the food industry for washing fruit and vegetables did not remove all the contaminating virus. As with shellfish and seawater studies, bacteriophage appeared to be potential surrogate markers

for human enteric virus contamination of fresh foods (**FSA B02014**).

5.4.5 Awareness of the limitations of chlorine washing and other sanitation procedures is behind research to develop new processes for the inactivation of viruses and other pathogens found on the surface of ready-to-eat foods (**BBSRC 4348473**).

5.4.6 A UK study found that the most common routes of transmission of norovirus were person-to-person, food-borne transmission via bivalve shellfish and via raw and ready-to-eat foods. This information was used to develop models of norovirus transmission which will enable better estimation of the impact of a reduction in food-borne transmissions on the occurrence of disease (**FSA B12001**).

5.4.7 It was noted that very few of the laboratories providing commercial tests for food-borne pathogens are undertaking any tests for food-borne viruses (**FSA B09005**).

6. GAPS IN CURRENTLY FUNDED RESEARCH

6.1 The focus of research effort in relation to food-borne viruses is primarily on issues that are known to influence the risk of occurrence of human illness from consumption of virally contaminated food. Any requirement there may be for further research is focussed on the need to understand better the epidemiology of food-borne norovirus and rotavirus, in particular the zoonotic potential of the latter, the routes of transmission of the former and the reservoirs of both within the food-chain. This work would benefit from improved laboratory methods for subculturing the viruses, and alternative model viruses (such as FRNA bacteriophage) which could be used as surrogates in laboratory and epidemiological studies. In addition, there may be benefit in developing new differentiation methods (see Vinjé *et al* (2003)), but it is likely that DNA sequencing will provide a sufficiently cheap option that alternative methods will not be needed.

6.2 In terms of the decontamination of food for human consumption, there may be a need to undertake further studies with ready-to-eat fresh fruit, vegetables and salad, as well as a continued focus on depuration. These studies could include both industrial and consumer practice as well as surveillance and epidemiology.

7. CONCLUSIONS

7.1 Research supported by the member organisations of the MSFFG addresses many different areas of relevance to the microbiological safety of food. The subject area of food-borne viruses is relatively small, partly reflecting the difficulty in working with the viruses, but also because of the comparatively mild nature of the disease caused by them and the fact that such illness generally requires no medical intervention. These factors are unlikely to change in the near future, and research in this area will primarily be driven by the perceived needs of specific industries or aspects of the food-supply chain.

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APPENDIX 1: GLOSSARY

Bacteriophage
Virus that infects a bacterium.

Caliciviridae
A family of RNA viruses which includes the genera *Norovirus* and *Sapovirus*.

Depuration
The process by which shellfish harvested from moderately contaminated sea water (>230 - <4600 *E. coli* per 100mg of flesh) are placed in clean sea water in order that they clear themselves of microbial contamination. The shellfish are held in shallow tanks of re-circulating sea water for a minimum period of 42 hours. Re-circulated sea water is continually disinfected by ultraviolet light. During this period the molluscs function naturally and discharge their microbiological contaminants. Shellfish faecal detritus settles on the base of the tank and is not recirculated.

FRNA bacteriophage
F-specific RNA bacteriophage. Specific bacteriophage which infects *E. coli* (the standard bacterial marker for faecal contamination) and a candidate for a surrogate marker for viral faecal contamination.

PCR
The Polymerase Chain Reaction. A technique used extensively to generate multiple copies of a target DNA sequence by amplification

Rotavirus
RNA viruses, a genus in the family *Reoviridae*. Group A rotaviruses are major pathogens in humans and animals.

TaqMan® Assay
Commercially available assay reagents for undertaking PCR measurements of RNA or DNA levels.

VTEC
Verocytotoxin-Producing *Escherichia coli* that characteristically produce powerful toxins that kill a variety of cell types, including Vero cells on which their effects were first demonstrated

Zoonosis/Zoonotic
Diseases and infections which are transmitted naturally between vertebrate animals and man.

APPENDIX 2: MSFFG PROJECTS USED IN THIS REPORT

Return to Methods

Project Code	Title	Funder	Contractors	Start Date	End Date
4331219	Molecular Biology of Food Borne Viruses	BBSRC	Institute of Food Research	Apr-2000	Mar-2003
4348473	Inactivation of fungi, bacteria and viruses in foods using minimal processes	BBSRC	Institute of Food Research	Jan-1999	Dec-2000
OZ0406	A report on the zoonotic potential of rotaviruses	Defra	Central Science Laboratory	Jul-2002	Mar-2003
FQS38	Improved Detection of Foodborne Viruses	Defra LINK	Leatherhead Food Research Association	Sep-2002	Aug-2004
B02014	Survival and decontamination of viruses on fresh produce	FSA	Campden and Chorleywood Food Research Association	Feb-2000	Apr-2002
B04001	The development of improved, simplified and standardised PCR based techniques for the detection of Small Round Structured (Norwalk-like) Viruses and Hepatitis A Virus in Molluscan Shellfish	FSA	Centre for Environment, Fisheries and Aquaculture Sciences	May-2000	Apr-2003
B04002	Development of procedures for improved viral reduction in oysters during commercial depuration	FSA	Centre for Environment, Fisheries and Aquaculture Sciences	May-2000	Apr-2003
B04003	Developing methods for the isolation and detection of viruses in shellfish, particularly SRSVs	FSA	University of Southampton	Apr-2000	Jun-2003
B04009	Evaluation and validation of alternative indicators of viral contamination in bivalve molluscan shellfish	FSA	Centre for Environment, Fisheries and Aquaculture	Dec-2000	Nov-2002

			Sciences		
B05001	Survival of small round structures viruses and potential viral indicators in sewage treatment processes & in marine environments	FSA	Centre for Environment, Fisheries and Aquaculture Sciences	Sep-1999	Oct--2002
B05002	Evaluation of methods for the assessment of sewage discharge consent applications with respect to shell fisheries	FSA	Centre for Environment, Fisheries and Aquaculture Sciences	Oct-1999	Jul-2001
B05005	Development of procedures to distinguish between human and animal faecal contamination in shellfisheries	FSA	Centre for Environment, Fisheries and Aquaculture Sciences	Aug-1999	Dec-2002
B08004	A study of the long-term clinical complications of infectious intestinal disease and the associated cost	FSA	London School of Hygiene and Tropical Medicine	Oct-1995	Jul-1998
B09005	Review of microbiological methods in the food industry	FSA	Campden and Chorleywood Food Research Association	Jun-1998	Mar-2001
B14004	Generation of an archive of extracted nucleic acid for the IID archived faecal specimens	FSA	Health Protection Agency	Jan-2003	Dec-2007
B12001	Microbiological Risk Assessment for NLV infection - Contribution to the overall burden afforded by food-borne infections	FSA	Centre for Applied Microbiology Research (now Health Protection Agency)	Aug-2002	Jan-2004
FS1028	Heat inactivation of viruses in shellfish	FSA	Public Health Laboratory Services	Dec-1993	Nov-1994
FS1235	Development of methods for the detection of viruses in foods	FSA	Central Science Laboratory	Apr-1995	Jun-1998

FS1263	A short study on survival of viruses in soft fruit and salad vegetables	FSA	Central Science Laboratory	Jul-1998	Mar-1999
01-RESR-105	Use of high pressure to improve quality and safety of shellfish	FSPB - Food Safety Promotion Board (NI)	Queens University Belfast, University College Cork	Aug-2001	Jul-2004
03-RESR-002	Epidemiology and Molecular Analysis of Norovirus Outbreaks in Ireland	FSPB - Food Safety Promotion Board (NI)	Mater Hospital, Dublin	Jul-2004	Dec-2005