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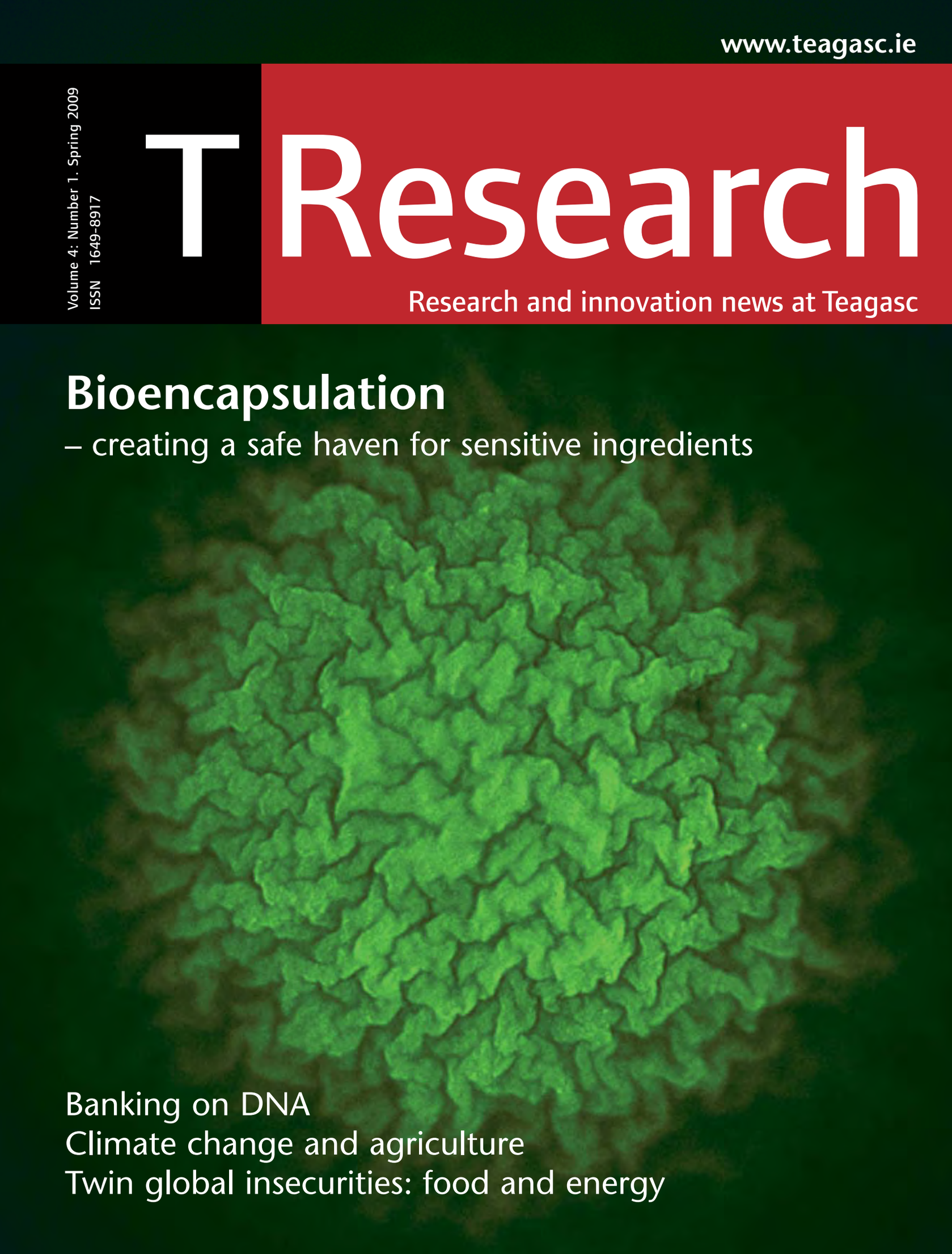
T Research

Research and innovation news at Teagasc

Bioencapsulation

– creating a safe haven for sensitive ingredients



Banking on DNA
Climate change and agriculture
Twin global insecurities: food and energy

Volume 4: Number 1. Spring 2009

T Contents

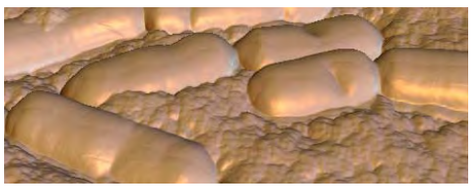
Technology transfer to food SMEs

The development and application of technology – innovation – is a key feature of successful organisations. Innovation has been described as the art, science and discipline of turning ideas into business growth. The average gross profit from new product launches is over eight times as large for innovative companies compared to the industry norms. While these are compelling arguments in favour of the development of an innovation culture, it is also evident that innovation models apply most easily to larger companies in specific sectors who have existing methodology for identifying and managing knowledge, and thereby benefiting from its application in their business. The food industry is generally risk averse and even some of the larger players are often less able to incorporate innovation compared to other sectors. In the case of small to medium enterprises (SMEs) in the food sector, the problem is exacerbated by time and capital constraints, and a lack of awareness of existing technical knowledge. In addition, even if they want to transform their business, SMEs are often unsure where to look for help and support. Research organisations also bear some responsibility, since their priorities tend to be focused on the enhancement of their scientific reputation by dissemination of their work through scientific journals rather than identification of a technology transfer opportunity.

The launch of the Food SME Technology Support Service places Teagasc once again at the centre of innovation and the transfer of technology to the food sector. Up until now the primary commercial beneficiaries of Teagasc's research have been larger companies with structured R&D departments. This new service will engage with smaller companies whose need is for a more bespoke and targeted message. This will enable Teagasc to help smaller companies to benefit, both directly in terms of increased profits, and indirectly, by spreading knowledge and awareness of how to incorporate new technology into their business. Food SMEs comprise a major part of the Irish commercial scene and, therefore, the benefits of this initiative will extend beyond individual companies to the food sector and the economy as a whole.

Bryan Hanley
Assistant Director
Food Research

T Food



T Environment

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T News

EI award for contribution to food industry

Dr Paul Roben, Enterprise Ireland, presenting the Lifescience and Food Research Commercialisation Award to Dr Paul Ross.

Dr Paul Ross, Head of Biotechnology at Teagasc Moorepark Food Research Centre, has won Enterprise Ireland's Lifescience and Food Commercialisation Award 2008.

Presenting the award, Dr Joe Healy, Enterprise Ireland's Food Technology Manager, said: "Dr Ross's success in bringing his research to the marketplace has been phenomenal – in the last four years he has licensed seven new technologies to companies in the food sector, more than any Irish researcher to date".

Dr Ross has also been heavily involved in the recently announced Functional Foods Research Centre, in which Enterprise Ireland is investing €20 million to facilitate the delivery of new high-value innovative food products for health conscious consumers.

Functional foods, convenience foods, food security and traceability are all areas of growth in the food and drinks industry, which had an €18 billion gross output last year and currently employs over 110,000 people in Ireland.

At the event, Enterprise Ireland also launched a Food Research Map, which pinpoints the location of research experts in the food and drinks industry (see www.enterprise-ireland.com). The map lists the names of hundreds of researchers, in 26 research-performing organisations, that are available to do collaborative research with companies in the dairy, meat, beverages, agri-marine and prepared consumer foods sectors.

Over €150 million has been invested in food research in Ireland in the last five years. This funding has greatly expanded the national research infrastructure, which is now primed for increased collaboration with industry to take advantage of the emerging consumer trends for convenience and functional foods.

Dr Ross recently joined The Taoiseach Brian Cowen, TD, and the Minister for Agriculture, Fisheries and Food, Brendan Smith, TD, on a trade mission to Japan, where a special session on 'Functional Foods for Health' took place in Tokyo.

Researcher profile

Dr Fiona Thorne

Dr Fiona Thorne is a Senior Research Officer in the Rural Economy Research Centre, based at Teagasc Kinsealy. Her research focuses on: (i) competitiveness and productivity of agricultural systems; and, (ii) the economics of crop production.

Fiona has published widely on the comparative costs of production and determinants of productivity of different agricultural and horticultural production systems in Ireland and internationally, and has also developed farm-level mathematical programming models to determine the potential impact of policy reform for crop producers using the FAPRI-Ireland model and National Farm Survey data.

Fiona obtained her Batchelor of Agricultural Science from UCD in 1999. She was then awarded a Teagasc Walsh Fellowship and received her PhD on 'Competitiveness of the Irish Hardy Nursery Stock Industry' in 2003.

Fiona is a partner in the International Farm Comparisons Network (IFCN) for dairy production, and is currently collaborating on a number of Research Stimulus Fund projects: two on the economics of GM co-existence, and one on the productivity and competitiveness of Irish agriculture.

She is a member of the Agricultural Economics Society of Ireland, the European Association of Agricultural Economists, the Agricultural Economics Society (UK), and the International Association of Agricultural Economists.

She has published in a wide variety of publications, and has been involved in the production of a number of national reports, including 'FAPRI-Ireland Baseline 2007: Farm Level Analysis', and the IFCN Dairy Report 2007.

She has presented at international academic conferences, and is a keen participant in technology transfer, including media interviews and presentations to stakeholders both in Ireland and abroad.

EU research success stories

Teagasc is featured in a new European Commission book, *Research for Europe: A selection of EU success stories*, which is available free of charge from the EU bookshop – http://bookshop.europa.eu. The projects where Teagasc had involvement are: SEAFOOD (health promoting, safe seafood of high eating quality in a consumer driven fork-to-farm concept); and, WELFARE QUALITY (integration of animal welfare in the food quality chain: from public concern to improved welfare and transparent quality).

T News

ESBN appointment

Dr Rachel Creamer

Congratulations to Dr Rachel Creamer, Teagasc, Environment Research Centre, Johnstown Castle, on her recent appointment to the Steering Committee of the European Soil Bureau Network (ESBN). This network is the European authority on soil research, and focuses on:

- development of harmonised soil maps across Europe, in compliance with the EU INSPIRE Directive;
- identification of areas in Europe that are vulnerable to soil threats such as erosion, loss of organic matter, landslides, desertification and salinisation;
- advising the European Commission on soil-related EU policies; and,
- development of a European model for soil education and awareness.

Last November, Rachel was tasked by the EU Joint Research Centre to develop a mandate on soil education and awareness across Europe. This was in response to a new cross-directorate Teagasc initiative on soil education, proposed by Dr Veronica Nyhan, Kildalton College, and Rachel. This initiative aims to develop 'primary-to-policy' soil education and awareness in Ireland, and will include contributions to the curricula of primary and secondary schools. They will work closely with the team of 10 European member states in an effort to accelerate knowledge transfer on the role of soils in society. This initiative will establish Teagasc as the leading institute for soil research and education in Ireland.

Professor John Connolly retires

The retirement of Professor John Connolly from UCD was marked in November 2008 with a celebration of his career achievements. The event was attended by several current and retired members of Teagasc staff. Professor Connolly worked as a statistician for An Foras Talúntais (AFT) and Teagasc from 1966 to 1989, and was well known to many staff for his contribution to the design and analysis of experiments. His work with Teagasc covered research areas from compositional analyses of carcasses and milk to mixed-grazing experiments and plant competition. After leaving Teagasc, Professor Connolly joined the Statistics Department in University College Dublin. However, he continued to maintain strong collaborations with many Teagasc staff, and has made a valuable contribution to many projects. Professor Connolly's career celebration began with presentations of research highlights by Dr Peter Wayne, Harvard, USA, Dr Andreas Luescher, Agroscope, Switzerland, and Dr John Finn, Teagasc. The presentations highlighted the international calibre of Professor Connolly's publications and collaborations record, and his varied and productive contributions to the design and analysis of mixture experiments, plant competition, and ecosystem processes. Warm tributes were paid to Professor Connolly's personal qualities of mentorship, teamwork and integrity, as well as his pervasive sense of humour.

ProSafeBeef international conference

An international conference on beef safety, 'Advancing Beef Safety through Research and Innovation', is being organised by Dr Geraldine Duffy as part of ProSafeBeef, a European Commission research project, and will be held on March 25 to 26 at Teagasc Ashtown Food Research Conference Centre.

Acknowledged national and international experts will present the latest research findings on known and emergent microbial pathogens and chemical residues in beef. Some of the topics to be addressed will include: the detection and tracking of microbial pathogens and chemical residues in the beef chain; development and application of quantitative risk assessment models to manage microbial and chemical contaminants in the beef chain; development of novel and innovative approaches to control pathogens at key stages along the farm-to-fork beef chain; and, consumer attitudes to and perception of beef safety. The conference will be of interest to researchers, food producers and processors, retailers, public health specialists, environmental health officers, food safety regulators and policy makers. Further information and registration forms can be downloaded from www.prosafebeef.eu, or E-mail: Geraldine.Duffy@teagasc.ie.

New post-doc fellows

Three researchers recently commenced Teagasc's newly established post-doctoral fellowships scheme. William Minchin's project is entitled 'Establishment of a new suckler beef herd at Grange', and he will be working under the supervision of Dr Mark McGee. Dawn Howard's project is entitled 'Development and maintenance of a DNA bank for Irish cattle and sheep and the use of this resource to facilitate the genomic selection programme for dairy cattle and to identify genetic markers associated with traits of economic importance in cattle and sheep', and she will work under the supervision of Dr Frank O'Mara. Noreen Begley's project is entitled 'Genomic selection in dairy and beef cattle in Ireland', and she will work under the supervision of Dr Donagh Berry.

The Teagasc Post-Doctoral Fellowship Scheme aims to provide pre-employment support for scientists of high quality. The Scheme will develop and enhance the science and technology skills and knowledge of high quality scientists, and strengthen Teagasc's scientific base by building a critical mass of research capabilities and knowledge in appropriate and emerging areas of science and technology. It will also help foster the development of Ireland's pool of scientific talent, and thereby complement Government initiatives to develop a knowledge society, which will assist the country to compete successfully as a knowledge economy.

Irish Farming at the Millennium

A new book, *Irish Farming at the Millennium: A Census Atlas*, which explores changes that affected Irish farming during the 1990s, was recently launched by Minister Eamonn O'Cuiv at NUI Maynooth. David Meredith, Teagasc Rural Economy Research Centre, was one of the co-authors, along with first and second authors Dr Caroline Crowley (a former Teagasc Walsh Fellow), a post-doc at UCC, and Professor Jim Walsh, NUI Maynooth.

Teagasc Gold Medal awarded to Liam Donnelly

The first Teagasc Gold Medal in Agriculture and Food Science has been awarded to Professor Liam Donnelly, Director of Food Research, Teagasc. This new award recognises and rewards an individual working in Teagasc who has made an outstanding contribution in their area of activity.

"Over almost 20 years as Head of Centre at Moorepark Food Research Centre and as an Executive Director of Teagasc, Professor Donnelly has directed the development of the centre to become an internationally acclaimed 'best in class' public food research centre," said Dr Noel Cawley, Teagasc Chairman.

Professor Donnelly said that he was honoured to receive this award, and praised the outstanding research undertaken by his colleagues in the food research centres in Moorepark and Ashtown. He said that there are some superb people in Teagasc, as well as excellent facilities, which allow Teagasc to contribute to science and industry at the highest level.

Professor Donnelly presided over the transformation of the Teagasc research programme from a conventional dairy technology programme to one encompassing a wide range of foods and ingredients, with particular emphasis on health and nutrition. While maintaining the centre's core disciplines, he championed the strategic introduction of new molecular sciences and technologies, and invigorated the food research directorate through the introduction of new researchers and by forging linkages with the wider scientific disciplines of the universities. In concert with the expansion and internationalisation of the research programme, Professor Donnelly also oversaw the strategic development of the Moorepark Food Research campus to provide laboratory, pilot plant, central services and conference and training facilities of international quality.

In addition to the pursuit of excellence in science, Professor Donnelly has placed particular emphasis on innovation management and technology transfer to industry. Moorepark Technology Ltd., a pilot plant facility for the food industry, which he conceived, established and directed, is internationally recognised as a uniquely successful model for the transfer of public research to industry. A hallmark of his management approach is that he has always placed emphasis on the scientific quality of the research programme, while retaining very strong industry links. Professor Donnelly has both a national and international profile, being seen as one of the major strategists worldwide in food research. He is commonly included on peer review groups for other food research institutes and food and nutrition departments. His contribution to management of scientific research was recognised by his appointment as adjunct Professor at University College Cork in 2006.

Professor Liam Donnelly (pictured on right), Director of Food Research, Teagasc, is the first recipient of the Teagasc Gold Medal Award. Pictured presenting the award to Professor Donnelly were Dr Noel Cawley, Teagasc Chairman (centre), and Professor Gerry Boyle, Teagasc Director.

PEN project

As part of the Pathogenic *Escherichia coli* Network (PEN) project funded by the EU FP6 Programme and co-ordinated by Dr Declan Bolton, Ashtown Food Research Centre, Teagasc is organising an international conference on 'The Ecology of Pathogenic *Escherichia coli*' to be held in The Norwegian School of Veterinary Science, Oslo, Norway, on March 5 to 6. This is the fourth in a series of five international conferences that have previously included 'Methods of Detection and Molecular Characterisation of Pathogenic *Escherichia coli*' (Chipping Campden, UK, July 2007), '*Escherichia coli*: Pathogenicity, Virulence and Emerging Strains' (Rome, March 2008) and 'Epidemiology and Transmission of VTEC and other Pathogenic *Escherichia coli*' (Stockholm, Sweden, September 2008). The final conference will address control issues relating to pathogenic *Escherichia coli* and will be hosed by AFRC in September this year.

State of the nation

A Science Foundation Ireland sponsored webinar hosted by Science/AAAS on 'Science in Ireland: State of the Nation' is available for download at: http://sciencecareers.sciencemag.org/tools_tips/multimedia/webinars/sfi. The webinar looked at what policy decisions have been taken to deliver on the Irish Government's vision that: "Ireland by 2013 will be internationally renowned for the excellence of its research, be at the forefront in generating and using new knowledge for economic and social progress, within an innovation-driven culture", considered the progress made to date, the funding and research opportunities in industry and academia in Ireland, and the potential growth sectors.

T News

Young Scientists are aspiring ag researchers

Congratulations to John D. O'Callaghan (aged 14) and Liam McCarthy (aged 13), second-year students from Kinsale Community School, Co Cork, who won the BT Young Scientist & Technology Exhibition 2009 with their project, entitled 'The Development of a Convenient Test Method for Somatic Cell Count and its Importance in Milk Production'. The winning pair are pictured here with Chris Clarke, CEO BT (left), and An Taoiseach, Brian Cowen.

Expansion in energy crops needed

Competition from unfairly subsidised imports and uncertainty about future support policies are holding back investment in the further development of the bioenergy industry in Ireland.

Speaking at the National Bioenergy Conference in Horse & Jockey, County Tipperary in February, Teagasc researcher Bernard Rice said that the amount of biomass needed to meet heating/electricity targets far exceeds current availability, so production of energy crops needs to expand rapidly. He also stated that the Biofuels Obligation Scheme and the National Action Plan need to take account of indigenous biofuel producers.

The conference, organised by Teagasc, in association with ACCBank, also heard of the long time lag in building up biofuel capacity, from the establishment of perennial energy crops to the development of processing facilities, and that action on the ground needs to begin without delay.

John Gilliland, Rural Generation Ltd, said that the further development of the bioenergy industry in Ireland would save money and generate wealth in the rural economy. He continued, saying that developing a bioenergy industry would reduce the carbon footprint of the agriculture and food sector, while allowing it to participate in the emerging carbon economy.

Hans Van den Boom, Food and Agri Sector Manager with Rabobank, told the conference that the Rabobank group has set clean tech/renewable energy as a key strategic sector for the entire group. He also said that urgent action is needed if targets are to be met in Ireland.

A simple low-cost ventilation system to store willow chips, developed at Teagasc Crops Research Centre, was outlined by John Finnan, Teagasc researcher. Research trials at Oak Park are looking at ten different varieties of willow while a miscanthus plantation, now in its 14th year, can yield up to 10 tonnes of dry matter per hectare in good years.

Agriculture and rural development conference

The challenges posed for agriculture by growing environmental concerns and the continuing advancement of rural development in Ireland and the UK will be the two main themes for a major international conference on March 30, at the Irish Management Institute, Dundrum. The conference will be hosted by the Agricultural Economics Society of Ireland (AESI). Speakers will be drawn from academia, the food industry and NGOs. In relation to agriculture, Professor Frank Convery, UCD, will outline the environmental challenges facing the sector, while Tom Arnold, Concern, will discuss the implications for the developing world.

The conference programme includes speakers from Great Britain, Northern Ireland and Ireland. Dr Sally Shortall of Queen's University Belfast will outline her experiences of evaluating rural development policy in both Ireland and the UK, while Dr Jim Kinsella of UCD will focus specifically on Irish rural development policy.

The conference provides the opening for almost a week of events organised by the AESI, which will include the Annual Conference of the Agricultural Economics Society (UK), which will be held in Ireland for the first time in its history on March 31 and April 1. For further details on these events, visit www.aesi.ie, or E-mail: secretary@aesi.ie.

The Investigators

Teagasc researchers recently featured in an episode on 'Crops of the Future', with contribution from staff at Ashtown Food Research Centre (Eimear Gallagher and Nigel Brunton), Oak Park Crops Research Centre (Denis Griffin and Dan Milbourne) and Grange Beef Research Centre (Matthew McCabe), in the second series of *The Investigators* on RTÉ television.

Teagasc co-sponsored the series with Forfás, Discover Science and Engineering, the Environmental Protection Agency, the Higher Education Authority, Science Foundation Ireland and Enterprise Ireland.

Pictured at the launch of The Investigators' *second series are: Centre front (from left): Nigel Brunton, Ashtown and Denis Griffin, Oak Park. Centre back (from left): Eimear Gallagher, Ashtown and Dan Milbourne, Oak Park.*

Science Week success

Science Week is Ireland's biggest annual promotion of science to the general public. Teagasc's Science Week programme of events has been going from strength to strength in recent years. CATRIONA BOYLE reports.

Pictured from left are: Professor Gerry Boyle, Teagasc Director; Billy Reynolds, RDS; Galatios Moschonas, winner of the annual Walsh Fellowships seminar; and, his supervisor, Declan Bolton, Ashtown Food Research Centre.

Science Week is co-ordinated by the Discover Science & Engineering (DSE) programme. DSE aims to increase interest in science, technology, innovation and engineering among students, teachers and members of the public. DSE's mission is to contribute to Ireland's continued growth and development as a society that has an active and informed interest and involvement in science, engineering and technology. An exciting series of Teagasc Science Week events was held for students at second level (Ashtown, Athenry, Grange and Moorepark), third level (Oak Park) and fourth level (Walsh Fellowships Annual Seminar), and for the general public (RDS speaker series). Professor Gerry Boyle, Director of Teagasc, delivered a talk on 'The Twin Global Insecurities: Food and Energy', at the RDS as part of Science Week, which is featured on p10.

Walsh Fellowships seminar

The annual Walsh Fellowships seminar is organised by Teagasc in association with the RDS, and is a prominent feature of Teagasc's Science Week events.

Galatios Moschonas, Ashtown Food Research Centre, was awarded 'Young Researcher of the Year' at the seminar.

Galatios received the award for the presentation of his research, which led to changes in the way the beef industry packs beef. Blown pack spoilage (BPS) is a major food safety and quality issue facing the Irish beef industry. Prior to this research it was believed that two psychrophilic *Clostridium* species were responsible for BPS and there were no known control measures. This research identified a new, as yet unnamed, BPS *Clostridium* species and led to the development of a new technology to detect the organism, for which a patent has been filed. Also, as a result of this research, new control measures have been introduced into beef factories. Galatios' Teagasc supervisors are Dr Declan Bolton and James Sheridan (now retired) and his university supervisor is David McDowell, Professor of Food Studies at the University of Ulster, Jordanstown.

Paul Geeleher, Athenry Research Centre, won the accolade of best poster presentation for his poster on: 'BioconductorBuntu – a Linux distribution hosting a web-based genomics processing server system'.

Paul's Teagasc supervisor is Dr Dermot Morris and his university supervisor is Dr Aaron Golden, Department of Information Technology, National University of Ireland, Galway.

Both winners' research is presented in more detail in the following pages.

Walsh Fellowship Scheme

The Walsh Fellowship Scheme was named after the first Director of AFT, Dr Tom Walsh, and since the establishment of this system of research grants for postgraduates, over 1,000 students have participated in the Teagasc scheme. The scheme encourages high calibre graduates to stay in Ireland and pursue their research interests. "These graduates go on to make a vital contribution to the agri-food industry in Ireland and further afield," said Teagasc Director Professor Gerry Boyle, who went on to outline planned changes to the scheme. All of these proposals for change were recommended in the review of the scheme undertaken by consultants CIRCA in 2006 and approved by the Teagasc Authority in 2007.

"Teagasc is currently making changes to the Walsh Fellowship Scheme to ensure the long-term development of the scheme and to ensure that it continues to operate as a premium postgraduate training programme. It is proposed that from 2009 a significant number of the fellowships will be awarded as part of 'mini-programmes'

Science week 2008

Clockwise from top left: Dr Paul Simpson is pictured with Midleton College students Grainne Walsh, Kathy O'Callaghan, Ethan Dillon and Emmett Rose in Moorepark during Science Week;
Laura Alvarez, Ashtown Food Research Centre, extracts pigments from spinach with students from Riversdale Community College in Dublin;
Stephen Byrne explains the process of breeding perennial ryegrass using DNA microarrays to students from Carlow Institute of Technology during their visit to Oak Park Crops Research Centre during Science Week; and,
Athenry Vocational College students Marion Ruane and Gary Heagney having a look at a tapeworm at Teagasc Athenry's open day for local schools during Science Week.

aimed at the strategic development of key Teagasc research areas. It is also proposed that Teagasc will now adopt an explicit policy of internationalising the programme with the best universities, research institutes and companies in the world," Professor Boyle explained.

Changes to PhD format

"The PhD, at least traditionally in Ireland," said Professor Boyle, "is a devoutly academic exercise not particularly given to issues of application. But with growth in PhD student numbers and their increasing employment in industry, new modes of doctoral studies have emerged, particularly in Scandinavian countries. Industrial graduate schools have been set up with industrial sectors, and in-industry PhDs have been developed, as well as PhDs based on different research formats. Teagasc will explore with industrial partners and the universities these doctoral training possibilities, which are focused more directly on generating and applying research in industry."

Dr Don Thornhill, Chairman of the National Competitiveness Council, Forfás, and guest speaker at the seminar, echoed the Director's thoughts on this subject.

"There are a number of reasons why we need to pay particular attention to the education and formation of PhDs. The first is that both society and today's students are making a considerable investment in their education. For both moral reasons and in order to ensure the benefits to our society, we need to prepare them for worthwhile and satisfying careers – not just in research but in business and in the public service. This is also necessary in order to continue to attract high calibre PhD candidates." Dr Thornhill described a professional science masters degree (PSM) in the US: "The course work for these degrees includes not just core science education and research but also areas such as industrial and systems engineering, computer science, economics and other social sciences, organisational change and learning, and business and management. Over the last 10 years in the US, salaries of PSM degree holders have grown faster than salaries of those who hold either bachelors or doctoral degrees. Banks and financial operations of industrial firms, the biotechnology industry, and defence firms are among those who have testified to a growing need for workers who fit the PSM profile".

He continued: "I think there are opportunities for us here to take an innovative approach to PhD education. It is time to set up a stream within the PhD programmes where some PhD students do courses that provide them with much of the experience and learning of MBA students. This is not an option that would appeal to all PhD students by any means but it could develop into an extremely prestigious educational option attractive to candidates who want to pursue careers in business and in the public service. Graduates of this stream would be attractive to employers. They would have advanced scientific and engineering knowledge, a familiarity with working at the knowledge frontier but, because of their wider training and learning, they would be equipped to contribute immediately across a range of business functions. This could

Clockwise from top left: Dr Eddie O'Riordan, Head of Teagasc Grange Beef Research Centre, with students from Scoil Mhuire, Trim, at the Centre's open day during Science Week; Judges of the annual Walsh Fellowships seminar (from left): Drs Aidan Moloney, Grange Beef Research Centre; John Finn, Johnstown Castle Environment Research Centre; and, Eimear Gallagher, Ashtown Food Research Centre;

Dr Don Thornhill, Chairman of the National Competitiveness Council, Forfás, was the guest speaker and delivered the keynote address at the annual Walsh Fellowships seminar, which is organised by Teagasc in association with the RDS;
and,
The annual Walsh Fellowships seminar at the RDS.

become an extremely attractive educational career option, which would enhance the attractiveness of taking science in school and in college, and in pursuing careers in science and technology. This new generation of business managers would be leaders in knowledge transfer and the exploitation of knowledge generated in Ireland and across the world for business, economic and social gain. They could be key agents in delivering the objectives of the government's Strategy for Science Technology and Innovation (SSTI)".

Continued investment in research

Dr Thornhill stressed the need for continued investment in research, despite "difficult economic and fiscal circumstances".

"The Government has committed to making substantial investments in making Ireland a knowledge society. The challenge now is to maintain this commitment in difficult times. We have made progress in putting resources into knowledge development but we are not by any means heading the investment tables. Faltering now would be a major policy error."

He continued: "We are late comers to the contest of positioning ourselves as an advanced, high income, knowledge-based economy ... The building up of research capacity is a cumulative process. Knowledge capital accumulates over time, principally in people. Top researchers are mobile. If we neglect investment in research and development we run the risk of losing our leading researchers to our competitors.

And, without the accumulation of knowledge and human capital we will not have the stock of these forms of capital to support a vigorous innovation society.

It is not an 'either or' situation, i.e., investment in knowledge development versus investment in knowledge transfer. A 'both and' strategy is needed. One component of the strategy is incomplete without the other and this is why the SSTI makes considerable provision for supporting knowledge transfer".

RDS funding

At the seminar, the RDS Committee of Agriculture and Rural Affairs announced the provision of €10,000 annually, for three years, to part-fund a Walsh Fellow to study the impact of climate change adaptation and policy instruments on local, regional and national greenhouse gas emissions.

Teagasc's Science Week event programme is driven by an enthusiastic organising committee, which included: Catriona Boyle, Joanne Carroll, Siobhan Culleton, Eric Donald, Hilary King and Lance O'Brien, Teagasc Head Office; Dan Milbourne and Dermot Forristal, Oak Park Crops Research Centre; Maire Caffrey, Ashtown Food Research Centre; Michael Diskin, Athenry; Paul Crosson and Sinead Waters, Grange; and, Stephen Butler, Tim Guinee and Niamh O'Brien, Moorepark.
The Committee acknowledges the contribution of all staff who ensured the success of the Science Week activities.

Twin global insecurities: food and energy

Professor GERRY BOYLE, Director of Teagasc, recently spoke at the RDS, addressing the challenges faced in feeding and providing fuel for the world's population. This is a summarised version of his speech.

The rapidly rising price of food, animal feed and energy pre-2008 took the world by surprise. These price increases cause alarm bells to start ringing for politicians, farmers and consumers in all countries. The forecasts from the World Food Summit were that food, animal feed and energy prices will continue to increase over the next decade as global demand will outstrip our capacity to supply these essentials, although the experience of the past two years shows that there will be considerable price fluctuations.

These conditions have been compounded by the unpredictable effects of climate change and a depressed world economy. The potential social consequences are extremely grave. According to the IMF, the rise in food and oil prices could 'severely weaken' the economies of up to 75 developing countries, so that the prospect of stagflation – slowing growth and rising inflation and unemployment - is real for many.

The World Bank estimates that rising food and fuel costs could reduce the GDP of 40-50 countries by 3-10% pushing at least 100 million people into poverty.

As an agricultural exporter, there are benefits to Ireland on the producer side from food inflation; these are evident in the strong growth in the value of dairy exports prior to 2008, with exports up 6% in 2006 and 13% in 2007 (in value terms).

Current forecasts of population growth suggest that one of the major challenges in coming decades will be to adapt agricultural product supply to the growth in demand for food, while at the same time ensuring more sustainable production. The trends observed in the recent past – the increase in food prices, the emergence of new agricultural production areas, the effects of climate change on agricultural yields, the development of bioenergy, changes to diet – will have consequences for the balance between supply and demand on the global level. Preserving the resources of our planet while alleviating poverty and reducing inequalities is a major challenge for sustainable development, as well as for global political stability.

The link between food and energy insecurity

Strong economic growth in developing countries combined with population growth are the main drivers of a growing demand for food and a shift in demand towards high-value agricultural products and processed foods. Slow-growing supply, low stocks, and supply shocks at a time of increasing demand for food, feed and fuel led to dramatic price increases. Prices of food and energy commodities increased for several years prior to 2008 and the high price trend is likely to resume for several years. High energy prices raise food production costs (e.g., fertiliser and transport costs) and increase incentives for biofuels. Taken altogether, these factors resulted in the sharp price rises in a way that was unprecedented. Although humankind has experienced situations of rapidly-rising food prices before, the recent situation was unprecedented because prices have gone up for nearly all food commodities and because of the simultaneous record prices in energy commodities. In contrast with previous situations of high food prices, this time there was a stronger causal link between food prices and energy prices. Specifically:

- biofuel production has contributed to the changing world food equation and currently adversely affects the poor through price-level and price-volatility effects; and,
- rising global food and energy prices have severe implications for social progress, economic growth and international security.

Food insecurity

The food insecurity issue is simple to state: there is a growing disparity between the world's demand for food and the ability of the global food production system to supply sufficient food to meet that demand while at the same time maintain the quality of the environment in which the food is produced.

Population growth

The most important underlying factor in food insecurity is population growth. According to the UN's 2006 World Population Prospects Revision, the world population will likely increase by 2.5 billion over the next 43 years, passing from the current 6.7 billion to 9.2 billion in 2050. This increase is equivalent to the size that the world population had in 1950 and it will be absorbed mostly by the less developed regions, whose population is projected to rise from 5.4 billion in 2007 to 7.9 billion in 2050. In contrast, the population of the more developed regions is expected to remain largely unchanged at 1.2 billion and would have declined were it not for the projected

net migration from developing to developed countries, which is expected to average 2.3 million persons a year after 2010.

By 2050 it is estimated that almost 70% of the world's population will be in urban areas, with the figure for developing countries being 86%. Growing urbanisation combined with higher incomes and changing preferences are raising domestic consumer demand for high-value products in developing countries. The composition of food budgets is shifting from the consumption of grains and other staple crops to vegetables, fruits, meat, dairy and fish.

Consumption patterns

Today's shifting patterns of consumption are expected to be reinforced in the future. Joachim von Braun, the head of the International Food Policy Research Institute (IFPRI), projects a 4% decline in annual per capita rice consumption in South Asia by 2025, while the consumption of milk and vegetables is projected to increase by 70% and consumption of meat, eggs and fish by 100%.

But cereals remain the key to global food security. They supply most of the calorie needs of humans, and also provide most of the feedstock from which much of the meat and milk in the world is produced.

In order to reduce the number of undernourished in the world and meet growing demands, global food production needs to double by 2050.

Supply side

On the supply side, while total world grain production is still growing, grain production per capita peaked in 1985 and has been slowly declining since. Also, as countries get richer they consume more livestock products and demand for grain tends to grow even faster. Many agriculture-based developing countries have seen their domestic production per capita of food staples stagnate and decline, their self-sufficiency rates decline and import dependence increase since the 1970s. The continued failure to invest in science and technology in order to improve productivity is principally responsible for this situation. During the past three decades, many developing countries have moved from being net food exporters to net food importers. For instance, the African sub-continent used to be a net exporter of basic food staples but in less than 40 years is now relying on imports and food aid. There is clearly a need to put the issue of agricultural production in these countries at the top of the global agenda. Investment in science and technology is critical here. The Irish overseas aid programme could play a role and Teagasc could assist.

Stocks, particularly grain stocks, have been gradually reduced since the mid-1990s and, historically, there has been a strong link between stocks at low levels and sharp increases in world prices. Stocks act as a margin of security. As they decline and the supply-demand situation tightens, global food supplies become more vulnerable to international crises or major natural disasters such as a droughts or floods, inducing greater market volatility.

Grain stocks have been at critically low levels since 2006. By the end of 2008, seasonal cereal stocks (rice, coarse grains and wheat) were at their lowest levels in 25 years. This situation is due to the fact that the total utilisation of cereals has exceeded production every year since 2000, leading to a steady decline in stocks. Major exporting countries have faced production shortfalls as the domestic demand for biofuels has increased.

Global food consumption

Current estimates indicate that global food consumption will double over the next 30 years, driven by population growth and rising prosperity, especially in the emerging economies. The World Bank forecasts that by 2025 China will be the world's largest single economy; the UN predicts that by then China and India alone will account for over three billion people, or 37% of the earth's total population; other Asian nations will add about 20%, giving Asia 60% of the world's total population by 2050. Clearly, Asia looks set to become the dominant purchasing block in the future.

The neglect of agricultural R & D investment, in both developed and developing countries, over the past two decades has led to a situation where our ability to produce sufficient food to feed the world's population is now in growing doubt. In order to reduce the number of undernourished in the world and meet growing demands, global food production needs to double by 2050. By 2020 we will need to produce 36% more food with less water, less fertiliser, less chemicals, not much more land and more extreme weather patterns. We are not on target, and will need to harness every available technology, including GM and other biotechnologies, if we are to even approach such food production targets.

Energy insecurity

One cannot separate food insecurity from the second insecurity – namely energy insecurity. Rising energy costs feed directly into rising food costs (e.g., higher fertiliser prices). In turn, rising energy prices encourage the greater use of food crops for the production of energy. Recent times have witnessed severe rises in energy costs and, although oil prices have moderated in recent months, the long term can only bring higher prices, as we cope with declining fossil fuel reserves, growing energy demand from the developing world, the need to deal with greenhouse gas (GHG) emissions and the costs of introducing alternative energy sources.

Peak oil

According to Dr Colin Campbell, founder of the Association for the Study of Peak Oil and Gas, the peak of oil production has already been passed and the gap between discovery and production has widened since. Despite the uncertainties of detail, it is now evident that the world faces the dawn of the Second Half of the Age of Oil, when this critical commodity, which plays such a fundamental part in the modern economy, heads into decline due to natural depletion. A debate rages over the precise date of peak, but rather misses the point, when what matters — and matters greatly — is the vision of the long remorseless decline that comes into sight on the other side of it. The transition to decline threatens to be a time of great international tension.

The sharp increase in the price of petroleum products, the finite nature of fossil fuels, and growing environmental concerns especially related to GHG emissions and health and safety considerations are forcing the search for new energy sources and alternative ways to power the world's motor vehicles. Biofuels – fuels derived from biomass – are seen as offering a promising alternative.

Biofuel frameworks

Several developed and developing countries are establishing regulatory frameworks for biofuels and providing various subsidies and incentives to support nascent biofuel industries. These developments are expected to spur a sustained worldwide demand and supply of biofuels in the years to come. Production of biofuels tripled during the period 1975-2005 and has increased sharply since 2004. Increased biofuel production since 2004 has coincided with the enforcement of mandates to increase biofuel production and consumption in some developed countries.

T Science week 2008

Cereal and energy prices are linked

World cereal and energy prices are becoming increasingly linked. The prices of commodities used in biofuel production are becoming increasingly linked with energy prices. In Brazil, a pioneer in ethanol production since the 1970s, the price of sugar is particularly closely connected to the price of ethanol. A worrisome implication of the increasing link between energy and food prices is that high energy-price fluctuations are increasingly translated into high food-price fluctuations. In the past five years, price variations in oilseeds and of wheat and corn have been increasing to about twice the levels of previous decades.

The increased use of agricultural commodities for biofuel production is often cited as a key contributory factor in the current crisis, given its potential direct impact on prices and its effect of reducing the availability of access to food. Agricultural commodities, such as wheat, soy, sugar, maize, oilseed and palm oil, are increasingly being used for the industrial production of biofuels. The extent to which biofuels have increased prices is subject to differing opinions. According to International Monetary Fund (IMF) estimates, the additional demand for biofuels accounts for 70% and 40% of the maize and soy price increases between 2002 and February 2008. On the other hand, the US government has claimed that biofuels – mainly ethanol produced from crops such as corn, palm and soy – have been responsible for only a 3% rise in food prices.

Environmental challenge

The challenge we now face is to find a 'third generation agriculture' to address the global food security challenge; to enable us to keep pace with the still growing population worldwide by maintaining and increasing productivity, while also contributing to energy security and multifunctional agriculture. Increasing productivity to meet all these demands, and, at the same time, improving the conditions of the natural environment, is a major challenge.

Land and water resources must be preserved and improved. Farm and other land management businesses must be viable. Forests and aquatic resources must be maintained in a healthy and productive condition. Farmers and other managers of these resources must be able to adapt and respond to existing and new markets. In other words, they must be environmentally as well as socially and economically sustainable. Meeting these challenges will require the very best of science and technology; of research and development; of the diffusion of innovation. We have no choice but to develop ways of satisfying human needs while making least demands on natural resources and with least impact on the natural environment. This is what sustainable development means.

Now add climate change to the challenges

Climate change will create new food and energy insecurities in coming decades. Low-income countries with limited adaptive capacities to climate variability and change are faced with significant threats to food security. In many African countries, for example, agricultural production, as well as access to food, will be negatively affected, thereby increasing food insecurity and malnutrition.

Climate change risks will have adverse impacts on food production, compounding the challenge of meeting global food demand. Consequently, food import dependency is projected to rise in many regions of the developing world (Intergovernmental Panel on Climate Change, 2007). With the increased risk of droughts and floods due to rising temperatures, crop-yield losses are imminent. In a group of more than 40 developing countries, mainly in Sub-Saharan Africa, cereal yields are expected to decline with mean losses of about 15% by 2080 (Fischer *et al.*, 2005). Other estimates suggest that although the aggregate impact on cereal production between 1990 and 2080 might be small – a decrease in production of less than 1% – large reductions of up to 22% are likely in South Asia. In contrast, developed countries and Latin America are expected to experience absolute gains.

Our vision

The Teagasc vision, which has the support of key stakeholders, is for an agri-food sector that is growth-orientated, focused on providing sustainable solutions to the critical challenges of future energy supplies and security of food supply. In this vision, agri-food is a critical component of a broader knowledge-based bio-economy contributing to enhanced economic activity and quality of life through the supply of safe, nutritious food, food attributes and functional foods, energy and fuel, fibres and building materials, and other bio-products that have food, feed, and industrial applications. There are several challenges but also immense opportunities. Challenges include the twin securities of food and energy. Related issues concern climate change and environmental sustainability. To a significant extent these challenges conflict. On the one hand, the sector has the potential to significantly increase output and exports, especially in milk, and thereby contribute to easing global food security. Yet the requirement to ensure environmental sustainability and at the same time alleviate the sector's contribution to the production of GHGs, places clear constraints on the sector's capacity to respond to the challenge of food security. The role of research and knowledge transfer will be central in resolving these conflicting pressures.

Production of biofuels tripled during the period 1975-2005 and has increased sharply since 2004.

Conclusions

Food and energy security are the great challenges facing the world in the future, and with the environmental challenge, they constitute a challenge of sustainability. Farmers and land managers are at the heart of this challenge. They are expected to provide for our food needs, and contribute to our energy requirements, materials needs and water resources management, and more generally to climate change mitigation. At the same time, they are expected to deliver higher levels of ecosystem stewardship and services, and provide the facilities needed to meet the ever increasing demand for recreation. The contribution of Europe's farmers, foresters and other land managers to meeting these challenges is crucial. This must put European agriculture right at the heart of future public debate and policy concerns.

It would be astonishing if European agricultural and environmental science did not play a central role in the required future developments – as it has done in the past. It will be equally astonishing if Europe continued to turn its back on the safe applications of biotechnology in addressing this fundamental challenge.

The author acknowledges the input of Dr Lance O'Brien, Head of Foresight and Strategy Development, Teagasc, to this paper.

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Blown pack spoilage: discovery, innovation and technology transfer

GALATIOS MOSCHONAS received the award of Young Researcher of the Year for his talk on blown pack spoilage at the annual Teagasc Walsh Fellowships seminar.

In the late 1960s primal cuts of meat were vacuum packaged (VP) for the first time. In the 1980s this technology was used for retail cuts. Centralised butchering and vacuum packaging of primal joints of beef is widely practised in the meat industry in Ireland. With strict adherence to good manufacturing practices and maintenance of high standards of hygiene and refrigeration, along with the use of packaging materials highly impermeable to oxygen and carbon dioxide, a shelf life of 10 weeks or more can readily be attained. However, in 1989 a type of VP spoilage, later referred to as 'blown pack spoilage' (BPS) emerged in the USA. This was followed by incidences in the UK (1989), New Zealand (1996) and Ireland (2000). Each spoilage event occurred in correctly chilled batches (0-2°C) after two to four weeks and was characterised by the production of large volumes of gas, a putrid smell (H_2S) and a metallic sheen on the meat. Meat spoiled in this way has no commercial value and BPS represents a considerable loss to meat processors in monetary terms. Although the exact costs of BPS-associated losses is commercially sensitive information, and BPS events range from a few spoiled packs to the loss of a whole batch, based on data obtained from several processors, the estimated average cost per BPS event is €375,000. Furthermore, a major incident may result in failure to meet a customer order, thus jeopardising future contracts.

The causative agents of VP BPS are spore-forming psychrotrophic/psychrophilic (cold-loving) Clostridia, specifically *Clostridium estertheticum* and *Clostridium gasigenes*. Prior to our project, the Irish beef industry had no control strategy, relying instead on decontamination of the abattoir environment with peroxyacetic acid and frequent testing of batches. Peroxyacetic acid is highly corrosive and often ineffective due to difficulties in accessing some areas (such as inside chilling units, where spores may collate and be dispersed via the air) and dilution in the film of water that is omnipresent on meat cutting surfaces. Its application by fogging is further complicated by the obstructive nature of equipment, lack of control of airflow and operator inefficiency. In addition, batch testing is prohibitively expensive.

Our research project 'Control of blown pack spoilage in vacuum packaged meat' had five component tasks:

- **development of methodologies to detect and isolate BPS Clostridia;**
- **a survey of Irish beef abattoirs for BPS Clostridia;**
- **an assessment of the ability of isolated Clostridia to cause BPS;**
- **an investigation of the role of heat shrinkage of VP films in BPS Clostridial spore activation; and,**
- **technology transfer.**

The beef abattoir survey found that the spores of *Clostridium estertheticum* and *Clostridium gasigenes* were widespread in the abattoir environment. Furthermore, among the almost 500 psychrotrophic/psychrophilic Clostridia, we discovered several new species using PCR amplification and sequence analysis of the 16S rRNA genes. One of these novel isolates was particularly prevalent in the abattoirs and capable of causing BPS more rapidly than *Clostridium gasigenes*. The organism is currently being characterised, the results of which will be published in the *Journal of Systematic and Evolutionary Microbiology*. We subsequently developed and patented a real-time PCR assay to detect this organism (see p.46).

Our research on the effect of spore concentration, chilled storage temperature and heat shrinkage demonstrated that the latter accelerated BPS. After meat is vacuum packed, the pack is briefly immersed in a water bath at temperatures as high as 90°C to shrink the film. This improves the barrier properties of the film and tightens the pack, reducing drip loss. Corners and edges are also removed avoiding potential snagging in conveyor belts. However, we discovered that this high temperature treatment activates the BPS Clostridia spores and reduces the time to BPS for *Clostridium estertheticum*, *Clostridium gasigenes* and the newly discovered species by 16, 20 and 20 days, respectively. This was highly significant given that the packs are usually stored for 28 to 48 days.

The project outcomes were relayed to the Irish meat industry using a workshop, company visits and electronic dissemination of an advice leaflet based on our findings, as a result of which many processors have removed the VP heat shrinkage stage with positive effect.

This research was funded by the Food Institutional Research Measure (FIRM) of the Department of Agriculture, Fisheries and Food.

Dr Declan Bolton is a Principal Research Officer and **Galatios Moschonas** is a Teagasc Walsh Fellow in the Food Safety Department, Ashtown Food Research Centre. E-mail: declan.bolton@teagasc.ie.

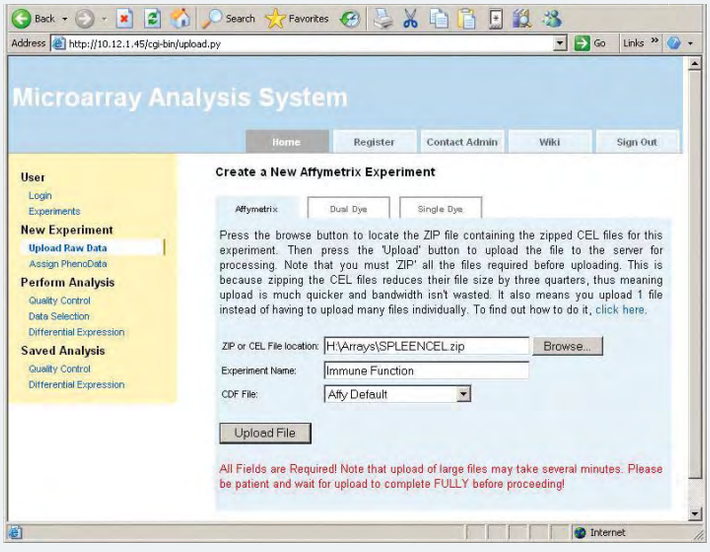
Mining the farm animal genome

PAUL GEELEHER won the award for the best poster presentation at the annual Teagasc Walsh Fellowships seminar. His work in developing a user-friendly interface for microarray analysis is outlined below.

The sequencing of the genomes of many farm animal species, including the cow, chicken, sheep and pig, and the technologies developed in parallel with these endeavours, have now made it possible for animal scientists to examine phenotype-gene associations on large numbers of genes for the first time. One of the tools available to scientists, and the first large-scale genome screening method made available as a result of these developments, is DNA microarrays, which are now widely used for gene expression profiling.

Microarray experimental data, however, needs to be quality assessed and interactively preprocessed before statistical analysis in order to achieve a meaningful result. Therefore, microarray analysis requires a combination of visualisation and statistical tools, which vary depending on what microarray platform or experimental design is used. The most versatile and widely available of these are based on the statistical software R (a free software for statistical computing and graphics) and the Bioconductor Project (an open source and open development software project for the analysis and comprehension of genomic data). However, the analysis pipeline is not always clear, and the desired tools are not always readily available from a particular location without resorting to a command line interface (a mechanism for interacting with a computer operating system or software by typing commands to perform specific tasks), unfamiliar to most animal scientists.

A user-friendly interface was developed to facilitate the preprocessing and analysis of microarray experiments, addressing the most common microarray array formats and following a logical progression through an analysis pipeline that is extensible and capable of addressing current as well as future needs. 'BioconductorBuntu' was developed as a result of this Walsh Fellowship MSc, and is a custom distribution of the Ubuntu Linux computer operating system that automatically installs a server-side microarray processing environment, and provides a user-friendly web-based graphical user interface to many of the tools developed by the Bioconductor Project, whether locally or across a network. Installation is a ready-to-go procedure, simply based on booting off the installation CD or image file. In its current version, several microarray analysis pipelines are supported including oligonucleotide (e.g., Affymetrix GeneChips), dual or single dye (e.g., Exiqon miRNA arrays) experiments, with the existing set of preprocessing methods for normalisation, background correction, and so on, easily expanded. The entire system is designed to be extensible by server side integration of further relevant Bioconductor modules as required, facilitated by its straightforward pipeline construction using the underlying Python (computer programming language) scripting environment. This makes BioconductorBuntu particularly flexible as regards the development of user-friendly processing procedures to facilitate the analysis of next-generation sequencing datasets. The system is best installed on a dedicated network server, allowing any number of registered individuals connected to the same local area network (LAN) to make use of its capabilities. The Microarray Analysis System can be accessed on the Teagasc Intranet or on http://bioinf.nuigalway.ie.



Screen shot showing uploading of data to microarray analysis system.

This work was co-funded by the Teagasc Walsh Fellowship Scheme and by Science Foundation Ireland.

Dr Dermot Morris is a Principal Research Officer at the Animal Production Research Centre, Athenry, and **Paul Geeleher** is a Walsh Fellow based at Athenry. Paul Geeleher's university supervisors are **Prof. J. Hinde** (not pictured), The School of Mathematics, Statistics and Applied Mathematics, and **Dr. A. Golden** (not pictured), National Centre for Biomedical Engineering Science, both at NUI Galway. E-mail: dermot.morris@teagasc.ie.

Anthelmintic resistance in parasitic nematodes

BARBARA GOOD and SEAMUS HANRAHAN report on a survey of the management of gastrointestinal nematode parasites and the evidence for anthelmintic resistance on Irish sheep farms.

The most important nematode diseases of sheep in Ireland are nematodirosis (caused by *Nematodirus battus*) in young lambs and parasitic gastroenteritis (PGE), usually in lambs but occasionally in older sheep. While several nematode species may be present in the gastrointestinal (GI) tract the principal parasites responsible for outbreaks of PGE are *Teladorsagia, Trichostrongylus* and *Cooperia*. Symptoms of PGE include persistent diarrhoea, dehydration, loss of appetite and failure to gain weight.

The development of broad-spectrum drugs has played a crucial role in improving health and productivity by diminishing the effects of parasitism in grazing ruminants. Expenditure on anthelmintics for livestock in Ireland accounts for approximately 25% of the animal health market per annum, clearly indicating their importance to producers. The availability of highly efficacious, and relatively inexpensive drugs (beginning with the benzimidazoles in the 1960s, followed by the imidazothiazoles, tetrahydropyrimidines in the 1970s and the macrocyclic lactones in the 1980s) led to recommendations for parasite control that were focused almost entirely on the frequent use of anthelmintics. However, the benefit of this approach is compromised by the emergence of anthelmintic resistance in the parasite population. Anthelmintic resistance is heritable and nematodes with the genes for resistance survive exposure to the standard therapeutic dose of an anthelmintic and produce offspring with increased resistance. So, over time, anthelmintic administration leads to resistant worms becoming more prevalent in the worm population. The rate at which resistance levels increase depends on a variety of factors, but in particular on the frequency and extent of anthelmintic use.

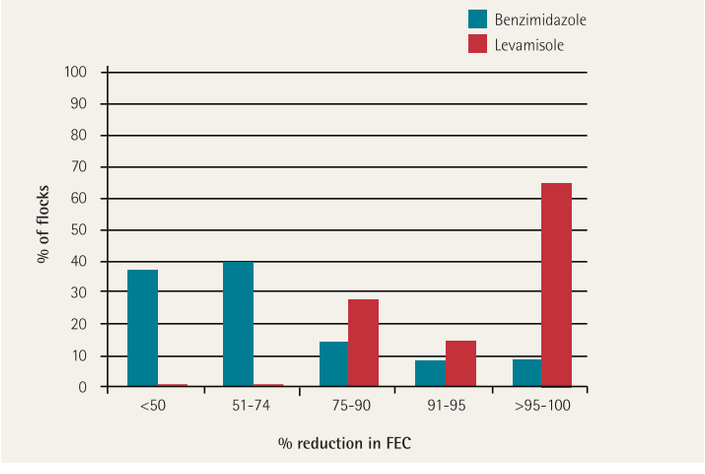


FIGURE 1: Results of faecal egg count reduction test on 16 lowland flocks following benzimidazole/levamisole treatment (source: Good et al.*, 2003, 2007).*

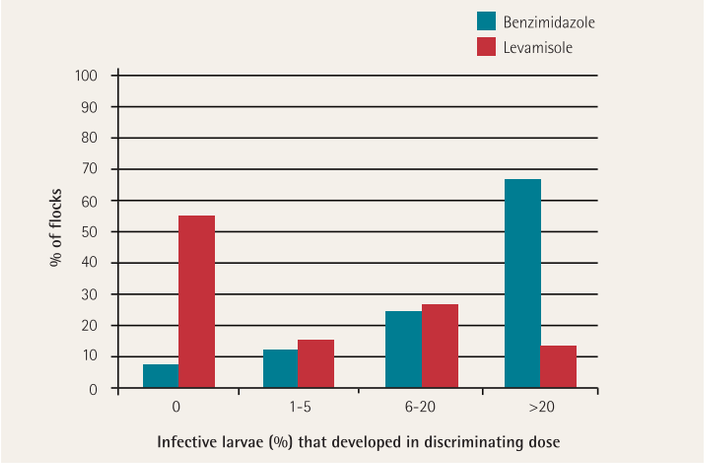


FIGURE 2: Results of larval development test for benzimidazole/levamisole of 64 lowland flocks (source: Patten et al.*, 2007).*

T Livestock

Infective nematode larva recovered from ovine coproculture.

Worldwide, the evidence for nematode resistance to anthelmintics, in particular to the benzimidazoles, is overwhelming. The first evidence for anthelmintic resistance in nematode populations on Irish sheep farms was reported in 1992 (O'Brien, 1992; Parr and Gray, 1992). Arising from a collaborative study on farms (Teagasc, Technology Evaluation Transfer project), which highlighted apparent efficacy problems with anthelmintic treatments, follow-up studies were undertaken on Irish farms to examine the issue of anthelmintic resistance and management of GI parasites. Factors considered important in the development and rate of selection for anthelmintic resistance include suboptimal dosing practices (under-dosing), dosing animals not at risk (unnecessary treatment of adult sheep), frequency of treatment, and biosecurity. The main findings from a postal survey (see below) with respect to these main risk factors for the development of anthelmintic resistance and data from anthelmintic resistance studies are summarised in this report.

Methodology

The most universal methods used to detect anthelmintic resistance are the faecal egg count reduction test (FECRT) and larval development test (LDT), both of which can be used to detect resistance to benzimidazole and levamisole. The FECRT involves calculating the mean reduction in faecal egg count at a defined interval post treatment for a subgroup of the flock. The LDT is based on the development of larvae (from eggs obtained from pooled fresh faecal samples from a subgroup of the flock) in various concentrations of the anthelmintic. In order to ascertain information on grazing and parasite control practices, a nationwide postal survey (n=128) was undertaken. Information on anthelmintic resistance was obtained using the FECRT (16 farms) and LDT (64 farms). For each of the studies, the farms involved had a long established lowland sheep enterprise and a flock size greater than 100 ewes.

Nematode resistance to anthelmintics in Irish flocks

The FECRT was completed on ewe replacements in 16 flocks based principally in counties Monaghan, Wicklow and Kilkenny. Faecal samples were taken from 30 ewe lambs from each flock and then randomly allocated to either a levamisole or benzimidazole treatment. Farms were revisited 10 to 14 days later and the same lambs were resampled. Faecal egg counts were subsequently determined using standard laboratory methods.

Resistance to benzimidazole was evident in 15 flocks (94%) and to levamisole in six flocks (38%) (**Figure 1**). Similar incidences of resistance were observed in the study using the LDT; 95% and 48% of flocks showed some degree of resistance to the benzimidazole and levamisole drugs, respectively (**Figure 2**).

Survey of parasite control measures in Irish flocks

Questionnaires were returned by 72% of recipients, of whom 63% have a dual sheep and cattle enterprise. Unsurprisingly, most of the farmers surveyed (99%) indicated that they used anthelmintics to control GI parasites. Factors relating to treatment strategy and practices are summarised in **Figures 3 and 4**. The bulk of producers (89%) treat on the basis of a set programme. A significant proportion adopts some element of guesswork in calculating the dose to be administered (**Figure 3**), thus increasing the risk of under-dosing and, consequently, the likelihood that worms with genes for resistance survive and the level of resistance increases. Moreover, 61% of farmers surveyed checked the accuracy of the dosing gun. The practice of withholding food prior to dosing, which reduces the rate of digesta passage and increases the exposure of the parasite to the drug, was reported by 22.5% of farmers when dosing lambs. However, in the majority of cases (>90%) the withholding period was less than six hours, which is not effective. The efficacy of oral benzimidazole/macrocyclic lactone is only enhanced where a minimum 12-hour fasting period is imposed prior to treatment. Any dosing programme based on frequent treatment will increase the selection for resistance. While on the majority of farms lambs received three to four anthelmintic treatments, it is noteworthy that the administration of five or more doses was not uncommon (**Figure 4**). Suppressive treatments of young stock will retard the development of immunity. Only a small minority of farmers never treated their ewes (**Figure 4**). As might be expected, the majority of ewes and

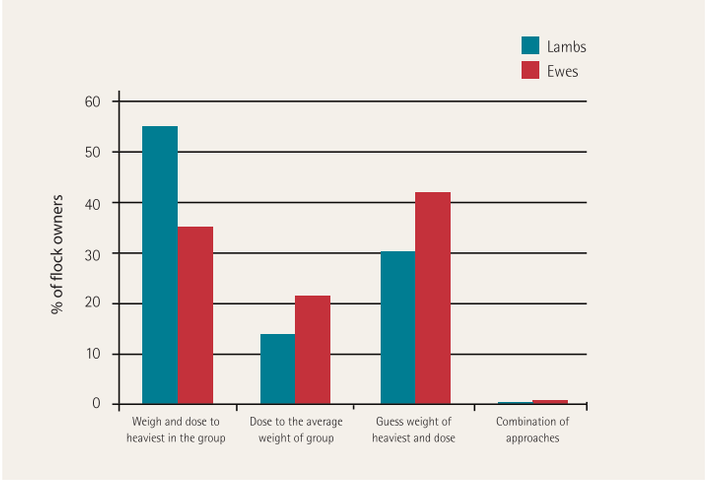


FIGURE 3: Methods applied in calculating dose rates in ewes and lambs (source: Patten et al.*, 2007).*

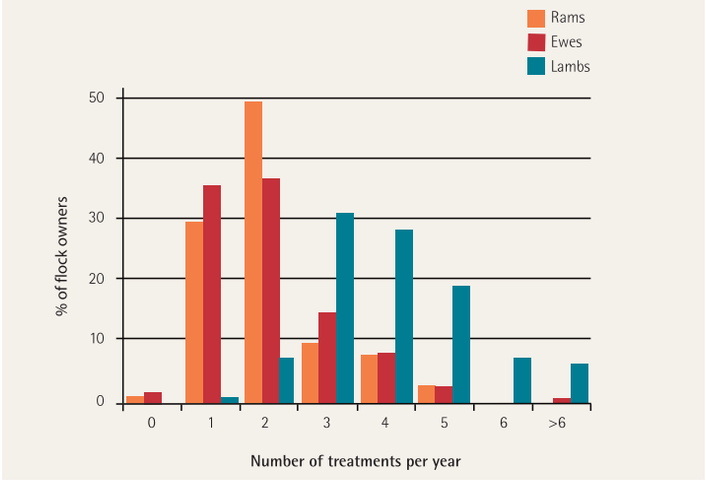


FIGURE 4: Frequency of treatment for gastrointestinal nematodes in rams, ewes and lambs (source: Patten et al.*, 2007).*

rams received fewer treatments (one or two per annum) compared to lambs but a significant number of farmers treat ewes three or more times per annum. Given the fact that ewes are likely to have access to most of the farm at some stage in the year, such frequent dosing of adult stock will expedite the development of anthelmintic resistance. Treatment of ewes in the periparturient period has been shown to delay the rise in faecal egg output associated with the temporary loss of immunity in adult ewes at this time. In the light of anthelmintic resistance, consideration needs to be given to timing of any treatment during this period. To minimise selection for anthelmintic resistance, it is important that ewes have the opportunity to be re-infected before their immunity is fully restored.

Over half of the farmers surveyed indicated that they usually moved lambs to 'clean' grazing immediately after dosing (**Figure 5**), a practice now considered to significantly increase selection for resistance as the vast majority of infective larvae that will become available on such a sward will be the progeny of worms that survived the anthelmintic treatment. Current recommendation is that the movement of treated stock to 'clean' pasture is delayed. In allowing sheep to become lightly re-infected by unselected parasites, this will dilute out contamination from resistant worms that survived treatment when sheep are moved to 'clean' pasture. Another important factor in increasing the risk of anthelmintic resistance on a farm is through purchased sheep that are host to drug-resistant worms. While almost all farmers (93%) reported that purchased animals were treated with anthelmintic prior to mixing with the rest of the flock, 71% indicated that this would be with the same anthelmintic used in the current year. In light of the high prevalence of benzimidazole resistance, it is recommended that purchased sheep are treated sequentially with the macrocyclic lactone and levamisole to minimise the risk involved.

Conclusions

The evidence for nematode resistance on Irish farms to two of the three anthelmintic classes currently available on the market is compelling. It is important that the industry realises that the development of anthelmintic resistance is in progress on many Irish farms. The evidence also suggests that there is a need for a greater appreciation of the principles that inform the sustainable use of anthelmintics. The development of anthelmintic resistance, and its implication for roundworm control, is a serious issue and will impact on animal performance and the sustainability of a sheep enterprise. It is imperative that actions to preserve anthelmintic efficacy (namely, less frequent treatment practices that optimise the efficacy of anthelmintics, practices that avoid importing resistant nematodes) are incorporated in roundworm control programmes on every farm.

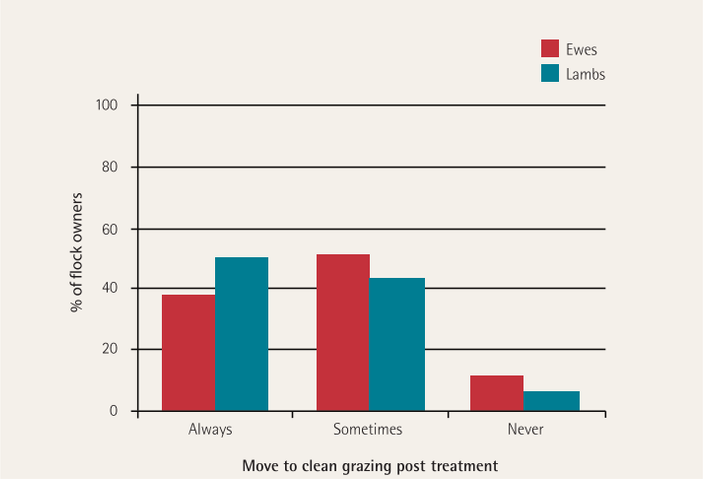


FIGURE 5: Frequency of the practice of moving to clean grazing post treatment in lambs and ewes (source: Patten et al.*, 2007).*

Sustainable control strategies

While research to find new parasiticides is ongoing, it is remarkable that no new anthelmintic class for ruminants has appeared on the market for over 25 years. While there are encouraging developments pertaining to a new class of anthelmintics (amino-acetonitrile derivatives, Novartis Animal Health, Inc.), it must be realised that, like all other anthelmintic compounds, resistance will develop over time and thus the development of new anthelmintics can provide only a temporary solution to roundworm control. Research is needed on the development of more sensitive methods than those currently available for detecting resistance, in order to provide the capacity to develop case-specific action programmes, thus prolonging the lifespan of anthelmintics. Furthermore, there is a need to focus on the development and implementation of sustainable worm control strategies that are less dependent on chemo-prophylactics.

Acknowledgements

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Banking on DNA

A new Teagasc DNA bank offers opportunities for cattle breeding. DAWN HOWARD, SINÉAD WATERS, LINDA GIBLIN, DONAGH BERRY and MICHAEL G. DISKIN have been collaborating on its establishment.

The sequencing of the bovine genome has been completed and presents us with new opportunities to discover the influence of genes on a range of performance traits in cattle. Cattle have up to 40,000 genes, with many affecting the expression of traits such as growth rate or milk yield. We now know that it is theoretically possible for genetic differences to exist among animals at various sites across the genome.

The sites along the DNA sequence that show variation among animals are called polymorphisms. This term is becoming widely used as genomic technologies begin to play an increasingly important role in animal breeding. Differences in even one nucleotide, or single nucleotide polymorphism (SNP – pronounced 'snip'), can result in a change in expression level of the gene or a change in function of the gene product. Such changes can affect the performance of the animal. The challenge, and opportunity, is to identify the genetic basis or SNPs controlling economically important traits such as growth rate, feed efficiency, animal health, fertility and milk production, and to integrate the favourable allele into the commercial population.

A DNA bank resource for Irish dairy and beef cattle is currently being established at Teagasc (Moorepark Research Centre and the Animal Bioscience Centre – Grange and Athenry). To date, protocols for the extraction and storage of DNA from blood, semen and other tissues have been evaluated, optimised and standardised. Fully alarmed freezers and inventory systems have been established for optimum storage of DNA samples. Concurrently, a database is being established to catalogue all sample information, such as concentration of DNA, quality, volumes and storage location. To date, DNA from more than 6,500 cattle has been extracted and stored. These include dairy and beef AI sires as well as the Moorepark dairy research herds. Since 2003, a small sample of blood has been taken for DNA extraction from every dairy cow from every Moorepark research herd, as well as from animals in collaborating commercial herds. Currently, 4,500 dairy cows from several different breeds are represented in this DNA bank. The depository is expanded on a yearly basis to include calves born and replacement heifers.

Genomic selection

Research will generally involve three steps: 1) identification of genetic differences among animals at the DNA level; 2) quantification of the association between the identified genetic variants and traits of importance in cattle, and validation of these results in independent populations; and, 3) exploitation of the results in a breeding programme. For example, if a 'good' genetic variant is identified, then animals possessing this variant can be included by breed organisations or breeders in subsequent breeding programmes. Appreciation of this fact has led to the development of the concept of genomic selection. Genomic selection involves simultaneous estimation of the associations between thousands of SNPs and economically important traits, and the selection of animals that have the best 'DNA signature' across the thousands of SNPs. The research underpinning genomic selection for Irish dairy cattle is currently underway at Teagasc, Moorepark, in conjunction with the national dairy cattle breeding programme, with a view to implementation in Spring 2009. The Teagasc DNA bank is fundamental to the development of the genomic selection breeding programme for Ireland. To date, over 1,000 Holstein-Friesian dairy sires, whose DNA was extracted from semen, have been genotyped. This population will act as the foundation population for estimating the SNP associations. Genomic selection is particularly useful for young animals and for traits that are associated with gender (e.g., milk yield can only be measured in females), traits that take a long time to measure (e.g., measures of daughter survival to fourth lactation are only available when a bull is at least seven years of age), traits where there are considerable management effects or errors in recording (e.g., fertility), and traits that are difficult to measure (e.g., feed efficiency).

The Teagasc DNA bank is fundamental to the development of the genomic selection breeding programme for Ireland.

Young test bulls and cows will benefit most from genomic selection, as with other genomic technologies, through increased accuracy of estimates of genetic merit. Although internationally the research on genomic selection is only in its infancy, early indications are that reliabilities of genetic merit at birth, which are currently around 30%, could increase to around 50%. Research from Ireland suggests that this will increase genetic gain by 50%, or in other words, an increase in annual rate of genetic gain in Economic Breeding Index (EBI) in dairy cows from €23/year to €35/year, which is worth €2.5m annually to the dairy industry and is cumulative and permanent. Genomic selection research for beef cattle will be initiated within the next 12 months.

Dawn Howard extracting DNA from cattle samples at Teagasc Athenry Animal Bioscience Centre.

A DNA bank resource for Irish dairy and beef cattle is currently being established at Teagasc (Moorepark Research Centre and the Animal Bioscience Centre – Grange and Athenry).

DNA bank

Storing a large number of DNA samples from animals of diverse breeds and genetic background in the Teagasc DNA bank will maximise the potential and usefulness of this national resource to identify genetic variation at the DNA level. National identification numbers are stored for each sample allowing the sample, and therefore the DNA, to be linked to live performance (phenotypic data), which may be either detailed performance in Teagasc research herds or estimates of genetic merit of sires. Using this facility, estimates of the associations between individual SNPs or thousands of SNPs, as performed in genomic selection, can be undertaken. This information can then be given to the Irish Cattle Breeding Federation (ICBF), which will integrate the SNP information into their genetic evaluation, thereby increasing the reliability of their published breeding values for individual animals.

Researchers from across the different Teagasc centres and directorates, as well as from University College Dublin, have just embarked on a joint study utilising the DNA from this bank to identify polymorphisms in candidate genes within the Irish Holstein-Friesian AI sire population, with the view to linking these polymorphisms to performance. The end product will be knowledge on which polymorphisms are present in the Irish population and will give an indication of the associations between these polymorphisms and performance. The results, if favourable, can then be used to augment the genomic selection programme to increase the accuracy of identifying genetically superior animals. Similar projects are planned in the near future for beef cattle.

Commercially important traits

Genetic tests consisting of a panel of markers are currently commercially available for traits such as meat tenderness and marbling (GeneStar, Genetic Solutions, Australia), feed efficiency and carcass traits (Ingenity, Merial Limited, USA). However, it has been shown that there is often a lack of association between these commercial genetic tests and the trait being tested. The DNA bank will be an invaluable resource for future development and validation of such genetic tests for economically important traits. By having this DNA bank resource and associated phenotypic and genetic database, Teagasc will be in a unique position to independently and authoritatively evaluate the value of these genomic tests for traits that are commercially important under Irish production systems.

The next phase of the DNA bank development will be to extend the target sampling to include DNA from sheep, so that the sheep production research programme can also benefit from developments in genomic technology. DNA from samples already collected from a range of breeds in Teagasc research flocks will be incorporated, and sampling will be extended to include DNA from flocks participating in the 'Sheep Ireland' programme. Currently, DNA is extracted from whole blood and semen and these protocols will be further developed to include DNA extraction from ear tissue and hair at sufficient quality to be suitable for DNA banking.

Genomic research can also help clarify the underlying biology for important traits related to animal production, health and product quality, thereby allowing animals to be fed and/or managed according to their genetic make-up. These approaches are synonymous with the concept of personalised nutrition in humans.

This project has been funded by Teagasc, the Department of Agriculture, Fisheries and Food's Conservation of Genetic Resources for Food and Agriculture Programme under its Stimulus Research Fund, the Irish Cattle Breeding Federation, and the National Cattle Breeding Centre.

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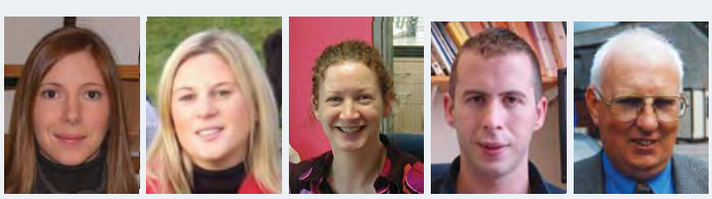

Johne's disease: a risk from herd expansion and cattle importation

DAMIEN BARRETT, SIMON MORE and JOHN MEE summarise the results of a recent joint study on the risk factors associated with Johne's disease in Irish dairy herds, and the implications for future dairy herd expansion nationally.

As the awareness of Johne's disease was lower among farmers that had never experienced a case, it is unlikely that they made any attempt to buy Johne's disease-free cattle.

Johne's disease is a Class B notifiable disease caused by *Mycobacterium avium* subspecies *paratuberculosis* (MAP). The disease is characterised by persistent diarrhoea, weight loss and protein-losing enteropathy. Johne's disease can cause significant economic loss in affected herds, as a result of reduced milk yield, increased incidence of mastitis, altered milk constituents, increased somatic cell counts, poor feed conversion, increased susceptibility to disease in general, reduced reproductive efficiency, premature culling and reduced cull cow values (Barrett *et al.*, 2006; Hoogendam *et al.*, 2009). There are also potential concerns relating to the safety of dairy products derived from the milk of animals infected with Johne's disease. A condition similar to Johne's disease in cattle, Crohn's disease, has been reported in humans, though proof of a causal link is inconclusive. The purchase of animals is a known risk factor in the introduction of Johne's disease to herds.

Young calves have the greatest susceptibility to infection, and infection generally establishes in the first month of life. The management of newborn calves has a major influence on disease incidence. Exposure to adult faeces in the first six weeks of life is considered to be one of the most significant risk factors, and control programmes include measures to prevent contact between adult faecal material and susceptible calves. Colostrum and milk from infected cows can also transfer infection. Transplacental infection is reported to occur in 9% of foetuses from sub-clinically infected cows and in 39% of foetuses from clinically affected cows.

Until 1992, Johne's disease was a sporadic disease in Ireland. However, after the opening of the Single European Market in that year, the abolition of quarantine and pre-movement testing, and the importation of over 70,000 cattle from continental Europe, the incidence of Johne's disease in Ireland increased.

Case-control study

We recently conducted a joint Department of Agriculture, Fisheries and Food/UCD/Teagasc national survey of the risk factors associated with the occurrence of Johne's disease in Irish dairy herds (Barrett *et al.*, 2009). We defined case herds as dairy herds with one or more individual animal having positive faecal cultures for MAP. A total of 67 case herd farmers agreed to participate. Control herds were selected from herds that were seronegative in a national Johne's disease serosurvey. A total of 85 control herd farmers agreed to participate. Control herds were matched to case herds on the basis of the year of detection of MAP in the case herds. We designed a questionnaire to collect data

by structured telephone interview on herd and management factors plausibly linked with the introduction and transmission of Johne's disease. In total, we developed 32 questions in four sections, relating to farm details, clinical history, grassland and animal management. Questions in the latter two sections consisted of two parts. The initial questions related to current practices (or most recent practices, in herds that had ceased dairy production). In the control and case herds, the later questions related to practices carried out prior to the reference year and year of Johne's disease diagnosis, respectively. The herd was our unit of interest and data were analysed using conditional logistic regression models.

The study found that the occurrence of Johne's disease in Irish dairy herds was associated with increased herd size, the introduction of cattle as a result of a depopulation episode and calf management practices (**Table 1**). There was a relatively low level of awareness among control herd farmers about the disease and this is a matter of concern. Similar findings have been reported from the USA, where one study found that almost half of dairy managers had limited knowledge of Johne's disease and this hampered the effectiveness of control programmes.

Risks for expanding herds

There was a significant difference in herd size between the case and control herds in 1997 and in 2007, and herd sizes increased significantly among case and control herds over this decade. These differences were most marked among larger herds. The larger herd size and the greater proportion of herds confined to dairying activities alone suggest that the case herds were generally more intensively managed. Herd size has also been reported as a significant risk factor in the occurrence of Johne's disease in the Netherlands. This has implications for future herd expansions in the Irish dairy industry. Increasing herd size is associated with the occurrence of a variety of diseases. This can in part be attributed to the increased number of animals at risk and to more intensive herd management. As the purchase of animals is such a significant factor in the introduction of Johne's disease to herds, the introduction of Johne's disease can be an unwanted consequence of herd expansion. In 39% of case herds, herd expansion was associated with purchase of imported cattle, while none of the control herds had imported cattle. As the prices of dairy products are increasing worldwide, and with the imminent abolition of milk quotas within the European Union (2015), there is likely to be increased expansion of dairy herds here in Ireland in the short to medium term.

Herd repopulation

The relevance of depopulation as a risk factor is that it resulted in either partial or full restocking, which would have necessitated the purchase and introduction of livestock to the herd. The level of partial or full depopulation due to disease outbreaks among case herds was almost twice that of control herds. A higher prevalence of bovine spongiform encephalopathy (BSE) was also observed in the case herds.

As the purchase of animals is such a significant factor in the introduction of Johne's disease to herds, the introduction of Johne's disease can be an unwanted consequence of herd expansion.

In the present study, Johne's disease was associated with larger herd size. Larger herd size has also been associated with the occurrence of BSE in Ireland, Northern Ireland and the UK. Until 2006, a diagnosis of BSE in Ireland necessitated the depopulation of the entire herd, thereby necessitating the assembly of a new herd, often from multiple sources. As the awareness of Johne's disease was lower among farmers that have never experienced a case, as outlined earlier, it is unlikely that they made any attempt to buy Johne's disease-free cattle.

In addition, 13 of the 67 case herd owners (19%) indicated that they had never had a case of Johne's disease in their herds. It is of concern that farmers with MAP culture-positive cattle in their herd, who continue to deny its presence, may be selling breeding stock on the open market. This could lead to further dissemination of the disease. In the absence of a national accreditation programme, farmers purchasing breeding animals will need to satisfy themselves that the herds of origin are free of Johne's disease to avoid the introduction of disease into their herds.

TABLE 1: Significant risk factors associated with the detection of *Mycobacterium avium* subspecies *paratuberculosis* in individual animal faecal samples from Irish dairy herds (case herds).

Risk factor	Case herds (n = 67)	Control herds (n = 85)	Significance*
Herd size (no.)	106	52	0.02
Depopulation (% herds)	54	29	0.01
Communal calving (% herds)	37	19	0.05
Pooled colostrum feeding (% herds)	35	12	0.01
Waste milk feeding (% herds)	52	25	0.02

**Values of less than or equal to 0.05 indicate statistically significant differences between case and control groups.*

The proportion of case herds feeding waste milk to calves was twice that of the control herds.

Calving and calf management

There was a significant difference in the number of case and control herds feeding pooled colostrum to calves prior to the diagnosis of Johne's disease; 35% of case herds were fed pooled colostrum, compared to 12% of control herds. This finding was not unexpected, as colostrum is known to be a significant source of infection. This would indicate that it is important to establish the herd's infection status if pooled colostrum is fed. It was notable that the level of pooled colostrum feeding fell from 35% pre diagnosis to 15% post diagnosis in the case herds, indicating that this management change was implemented on a widespread basis.

The study found that the occurrence of Johne's disease in Irish dairy herds was associated with increased herd size, the introduction of cattle as a result of a depopulation episode and calf management practices.

There were significant differences in the proportions of case and control herds feeding waste milk (i.e., containing antibiotic residues) to calves before the diagnosis of Johne's disease. The proportion of case herds feeding waste milk to calves was twice that of the control herds. The feeding of waste milk to calves was also found to be associated with the occurrence of Johne's disease in an Australian study. A reduction in the feeding of waste milk was also implemented on a widespread basis in the case herds.

Significantly fewer of the case herds had individual calving pens than the control herds, both before and after Johne's disease was diagnosed. Communal calving areas can facilitate cross-contamination of calves born non-infected from non-infected cows by faeces from infected animals. Mixing of animals of unknown infection status in maternity pens has been associated with the occurrence of Johne's disease in previous studies.

Conclusions

The results of this study clearly indicate the Johne's disease risks associated with future dairy herd expansion nationally. This has implications for national herd health given the apparent low level of awareness currently of many farmers about this disease.

This research was supported by the Department of Agriculture, Fisheries and Food and the Irish Dairy Levy Research Fund.

Associated publications

Barrett, D.J., Good, M., Hayes, M. and More, S.J. (2006). 'The economic impact of Johne's disease in an Irish dairy herd: A case study'. *Irish Veterinary Journal*, 59, 282-288.

Barrett, D.J., Mee, J.F., Mullowney, P., Good, M., McGrath, G., Clegg, T. and More, S.J. (2009). 'A case-control study of risk factors for paratuberculosis (Johne's disease) in Irish dairy herds'. *Preventive Veterinary Medicine* (under review).

Hoogendam, K., Richardson, E. and Mee, J.F. (2009). 'Paratuberculosis sero-status and milk production, SCC and calving interval in Irish dairy herds'. *Irish Veterinary Journal* (in press).

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Health and safety aspects of working with spent mushroom compost

Large heap of SMC stored outdoors, uncovered.

Following a farm fatality, researchers at Teagasc Kinsealy have been investigating the highly toxic compound hydrogen sulphide, which is emitted from spent mushroom compost.

Spent mushroom compost (SMC) is the term given to mushroom compost once all mushrooms have been harvested. It is a by-product of the mushroom industry and is produced in large volumes on a weekly basis. Although it is 'spent' as far as the mushroom crop is concerned, it still contains many nutrients, which can be of benefit to agricultural soils and horticultural potting media. Spent mushroom compost is produced weekly but it is usually only spread on land in spring and autumn; therefore, it has to be stored in large heaps until needed. As a considerable amount of nutrients remains in SMC, it will continue to compost further during storage. Any available oxygen within the heap will be rapidly used up and the interior of the heap will become anaerobic, thereby providing the conditions necessary for gaseous by-products to be formed, such as methane and hydrogen sulphide (H_2S), as a result of anaerobic fermentation within the heap.

Health and safety

A health and safety issue for those working with SMC was identified in 2005. A fatality occurred due to H_2S gas poisoning when SMC was being loaded into a trailer (where the fatality occurred) for removal from the site. This highlighted a previously unknown risk to operators working with SMC.

H_2S gas is a malodorous (the smell associated with rotten eggs) and toxic gas

Small heap of SMC stored undercover in a barn.

that is produced as a result of the anaerobic decomposition of organic matter. It is associated with animal slurry tanks, municipal sewers, and oil and mining industries where there are often procedures in place to protect workers from the hazards associated with it. Brief exposure to high concentrations of >1,000ppm can cause unconsciousness and death due to inhibition of cellular respiration leading to respiratory arrest, while exposure to low H_2S concentrations of <10ppm can inhibit enzymes involved in cellular respiration leading to a shift towards anaerobic respiration (Costigan, 2003). Two occupational exposure standards (OES) exist for H_2S – the short-term exposure limit (STEL) and the time weighted average (TWA). In 2007, the STEL for H_2S was reduced from 15 to 10ppm for a period of 15 minutes and the TWA was reduced from 10 to 5ppm for a period of eight hours, and these values continue to be under review (HSA, 2007).

In the aftermath of the SMC-related fatality, Teagasc is conducting research into the dynamics of H_2S emissions from SMC in order to better understand the risks involved. Preliminary data was collected for two sites where SMC was stored for approximately 20 weeks in the winter/spring of 2006/2007. One heap was generated from weekly deliveries of approximately 10-12 tonnes of SMC and was stored under cover in an open-sided roofed barn with a concrete floor (opposite). The second heap was much larger and was generated from weekly deliveries of about 50 tonnes of SMC. This was stored outdoors, uncovered, on an impermeable membrane in a field (see p23). During the 20-week period, both heaps were gradually built up from back to front, with the younger material at the front.

SMC removal process

During SMC land spreading activity, SMC is removed from the face of the heap using a tractor with a front-end loader: the operator drives the loader into the face of the heap, removes a scoop of SMC then tips it into the trailer of a manure spreader parked nearby. It takes approximately six to eight loads and five to 10 minutes to fill the trailer. The operator then leaves the tractor cab of the loader, gets into the tractor cab of the trailer and drives the trailer away to spread the SMC on nearby land: this takes about 10 to 15 minutes, or more, depending on the proximity of the land to the heap. The operator then returns to the SMC heap and repeats the process.

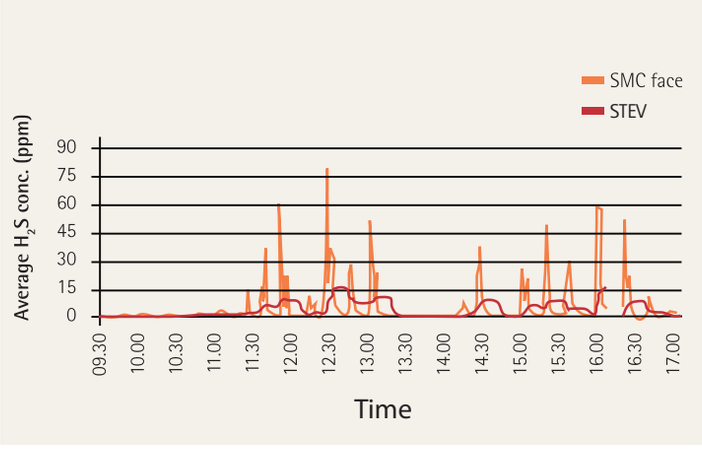

FIGURE 1: H_2S *concentration and STEV recorded during the day at the face of a small indoor heap of SMC during removal and spreading on land.*

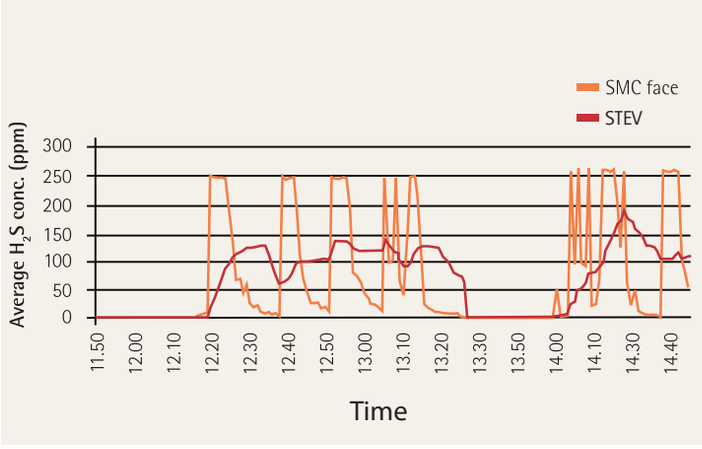

FIGURE 2: H_2S *concentration and STEV recorded during the day at the face of a large outdoor heap of SMC during removal and spreading on land.*

H_2S monitoring during SMC removal and spreading

During the removal and spreading process H_2S gas detectors with automatic data logging capability (QRAE+ and EntryRAE, www.raesystems.eu) were positioned at several locations, including above the receding face of the SMC heaps as they were being excavated and in the tractor cab of the excavating loader. The monitors recorded H_2S gas concentration continually and were set to automatically calculate the average concentration at one-minute intervals for the duration of the exercise. In addition, the short-term exposure value (STEV) and TWA value were automatically calculated by the monitors.

Peaks and troughs

H_2S gas was detected throughout the day at both sites, with peaks of high concentration being associated with the time when the front-end loader was taking SMC from the face of the heap and loading it into the trailer. Concentrations dropped once the excavating/loading operation stopped and while the filled trailer was being driven away to spread the SMC on land. Peaks of high concentration occurred once SMC excavating/loading began again. The highest H_2S concentrations (one-minute average) were detected in the air immediately above the excavated face of SMC. For the smaller heap of SMC stored undercover in a barn, the H_2S peak concentrations above the heap during loader activity ranged between 4 and 80ppm, while for the larger heap it was considerably higher with peaks consistently registering >250ppm (**Figures 1** and **2**). The STEV above the SMC face at the smaller heap was regularly ≤10 but it occasionally reached 15ppm, while at the larger heap the STEV above the SMC face was continuously >10ppm and stayed between 50 and 187ppm throughout the period of observation (several hours) exceeding the current STEL of 10ppm. These high readings indicate that this location – directly above the SMC face of a large heap as it is being excavated – is hazardous; however, it would be unusual for anyone to be on the top of the heap as it was being excavated. The H_2S concentrations recorded in the tractor cab of the front-end loaders also showed the same pattern of peaks and troughs associated with the SMC face at both sites. The concentration peaked at 2ppm in the tractor cab working at the smaller heap and 28ppm in the cab at the larger site (**Figure 3**). The corresponding STEV were <1ppm during removal operations at the smaller heap, while at the larger heap they were generally 2-3ppm, but rose to 7-10ppm on three occasions. Thus, the tractor driver at the smaller heap was not being exposed to unsafe levels of H_2S, while the tractor driver at the larger heap was exposed to H_2S levels that exceeded the current STEV limit of 10ppm for 15 minutes.

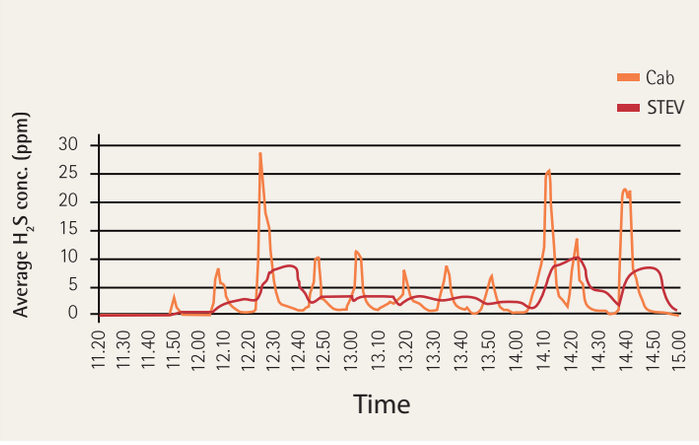

FIGURE 3: H_2S *concentration and STEV recorded in the tractor cab during removal of SMC stored in a large outdoor heap.*

Health and safety advice

These preliminary results indicate that there is a significant health and safety risk associated with working in the vicinity of stored SMC when it is being removed for spreading on land, and that the risk is probably greatest for tractor drivers working with large heaps of SMC over several days. It is therefore strongly recommended that:

- **tractor operators working with heaps of stored SMC should wear a personal H_2S gas monitor and they should ensure that the tractor cab door and windows are shut tight;**
- **if the STEL alarm goes off, the operator should take a suitable break (15 minutes) from the work until the reading returns to zero;**
- **particular attention should be paid to these precautions when an operator is working for several days removing a large heap of stored SMC; and,**
- **on no account should there be any personnel on top of the heap (or in the trailer being loaded with SMC) as concentrations at these locations during SMC removal are hazardous and life threatening.**

Future work

Further data is being generated for other heaps of SMC around the country to determine if there are specific heap characteristics that result in higher H_2S emissions. Controlled experiments are planned to explore the relationship between various SMC parameters such as temperature, bulk density, age and moisture content on the dynamics of H_2S production from SMC. We need to determine if storage undercover is preferable to outdoor storage, as this would prevent the SMC from absorbing rainfall and becoming very anaerobic. Heap size is likely to be a key factor also, as the amount of oxygen penetrating into a large heap will be less compared to a smaller heap.

This research is funded by the Teagasc Core Programme.

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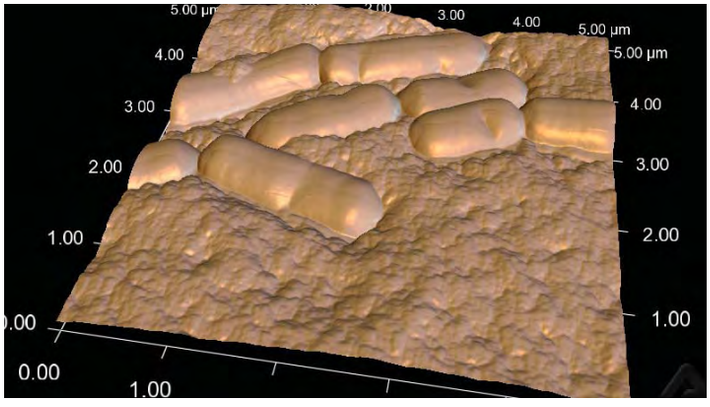
Bioencapsulation – creating a safe haven for sensitive ingredients

Bioencapsulation can be used to maximise the potency of sensitive, health-promoting food ingredients. Researchers at Moorepark Food Research Centre have been making strides in this emerging field.



Atomic force microscopy image of probiotic bacteria embedded in a protein/polysaccharide gel matrix.

As consumers become more health conscious, food manufacturers are pursuing innovative ways to produce food that can deliver specific health benefits without compromising the taste or quality of their products. Incorporation of bioactive compounds, or 'nutraceuticals', into food systems can provide a simple way to develop novel 'functional foods' with health-promoting and/or disease-preventing properties. Well-accepted examples of functional foods are probiotic drinks or cholesterol-lowering spreads.

Bioencapsulation is going to play an important role in the development of food that contains added health-promoting ingredients.

Bioencapsulation

Bioencapsulation, or entrapment, is the process by which the active ingredient is densely packed into minute particles of liquid or solid material (encapsulant) or coated by a shielding material. The size of these micro-particles may vary from nanometres to millimetres, though they are mostly between 5 and 300 micrometres in diameter; therefore, the process is commonly referred to as microencapsulation. Bioencapsulation refers to the use of biomaterials as encapsulants.

Why encapsulate?

Many bioactive ingredients are reactive and can interact with other food ingredients. The results are often undesired secondary products, or even degradation of the bioactive material and, ultimately, a loss in the commercial value of the food product. Encapsulation can prevent this by shielding the bioactives from detrimental environmental conditions met during processing, shelf-life and gastro-intestinal (GI) digestion, such as heat, low pH, oxygen, digestive enzymes and bile salts. Overall, encapsulation can reduce production losses, improve plant capacity and lower transport costs, while ensuring delivery of the active ingredient to the target site within the GI tract and, ultimately, offering a health benefit to the consumer. However, encapsulation is generally only applied when absolutely necessary, as it may also increase the cost of production, or complicate formulation, although in many cases it pays off. According to Frost & Sullivan research service (2005), there are key growth opportunities for microencapsulation in the food ingredients market, which are mainly stimulated by the need to fortify traditional products with healthy ingredients. However, consumer demand for novel products is the key motivator. Others see the main drivers behind the growth in microencapsulation as the need for 'clean labels' (no E-numbers), shelf-life extension, lower cost in use, and also to mask undesirable flavours.

A growing field

New microencapsulation technologies are relentlessly devised and invented by academics and industrial researchers: approximately 2,000 scientific papers and reviews have been published annually over the last decade. The enormous industrial potential of microencapsulation is also demonstrated by the increased number of filed patents. Encapsulation is one of the few scientific fields where patents nearly outnumber published papers.

The field of applications for encapsulation can be subdivided into roughly four groups: biomedical and pharmaceutical, industrial biotechnology, cosmetics and food. While the main encapsulation technology for food is spray drying, other more sophisticated methods developed for the pharmaceutical industry are increasingly applied to food ingredients. Examples include extrusion, prilling, emulsion, fluid bed technologies and molecular inclusion. However, encapsulants that may be acceptable for pharmaceutical purposes are generally not suitable for the food industry as they may conflict with the healthy, natural image of the final food product. Therefore, the main challenge for food application lies in the adaptation of technologies that utilise only natural ingredients, preferably indigenous to the food product. There is no magic bullet for encapsulation – methods and technologies are usually only applicable for a very narrow group of ingredients, or only suitable for certain types of food product. Nature has provided us with some terrific models for custom-made encapsulation vehicles that ensure protection of vital nutrients from degradation and targeted release of the active components. The casein micelle, a natural nano-particle made from the dairy

protein casein, is packed with essential nutrients such as calcium and phosphorous. A complicated and still not fully understood sub-structure provides remarkable stability, even at ultra-high temperatures, and ensures delivery of the necessary nutrients to the target sites in the gut. Other natural examples include lycopene, the red pigment and phytochemical from tomatoes and other red fruit. When added to food, the delivery and bioavailability is very poor, but it can be improved by smart encapsulation, although the best delivery is ensured by consuming the 'naturally encapsulated' lycopene in tomatoes or red fruit.

The field of applications for encapsulation can be subdivided into roughly four groups: biomedical and pharmaceutical, industrial biotechnology, cosmetics and food.

Microencapsulation in dairy products

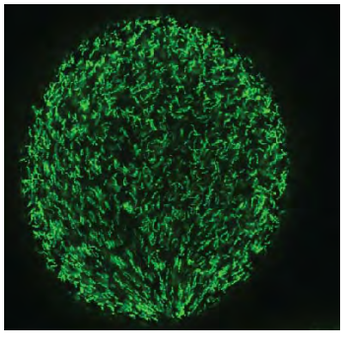
Microencapsulation has many implications for the food industry and will play a vital role in the development of novel functional foods, and dairy foods in particular. The good and wholesome image of milk and dairy products makes them attractive as delivery vehicles for a range of nutraceuticals. Nutritionists, material scientists, food technologists and food processors are all closely involved in the development of new encapsulation technologies and applications. Apart from academic and semi-state research, it is mainly large multinational food companies that develop encapsulation technologies, often in collaboration with smaller, highly innovative companies. The incorporation of probiotics into dairy and non-dairy foods has been recognised as a particularly challenging task and has been subject to numerous studies over the last five years.

Probiotic food products

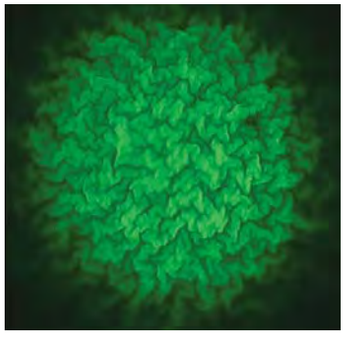
Probiotics are defined as live bacteria, which beneficially affect the host by improving its intestinal microbial balance, in other words the balance between good and bad bacteria. Probiotics have been reported to play a therapeutic role by modulating immunity, lowering cholesterol, improving lactose tolerance and even preventing some cancers. Microorganisms such as *Lactobacilli* and *Bifidobacteria* are being used in commercial food products. However, viability of probiotic bacteria in a product at the point of consumption is seen as essential for their claimed health benefit. Bacteria must survive during processing, shelf life and transit through the harsh conditions of the upper GI tract. Analysis of probiotic products in different countries has confirmed that only a few probiotic strains exhibit acceptable survival in traditional fermented dairy products, and even fewer survive gastric transit. Simple encapsulation is seldom the right solution. It is about targeted delivery, getting it to the right place, which for probiotics is the lower GI tract.

At Moorepark, we are interested in developing novel technologies to ensure high probiotic survival during processing, storage and gastric transit. Probiotics entrapped in gel particles made from dairy protein/polysaccharide formulations showed good viability in various liquid and gel food products. Three distinctly different methodologies were developed that can result in a variety of gel networks: (i) highly monodisperse, (ii) polydisperse, spherical gel particles of 5 to 350µm diameter, and (iii) loose gel agglomerates. The developed methods can be scaled up. Probiotic survival during extended storage was improved significantly, especially at elevated temperatures. It was shown that bacteria were highly enriched in the gelled material or on the interface to the bulk phase. However, closer examination by atomic force microscopy (AFM) and optical biosensor analysis revealed a micro-phase separation between bacteria and gelling matrix, depending on the gelling conditions. We can therefore assume entrapment of bacteria within the gel matrix rather than a coating of bacteria with the encapsulants. Further microscopic analysis in the National Imaging Centre in Moorepark revealed interesting surface morphologies of some of the micro-particles. Surprisingly, the gel particles appear very porous. This may imply that entrapment of probiotics within gel networks follows a different protective mechanism than the previously known encapsulation by shielding or coating. Furthermore, researchers at Moorepark succeeded in designing gel particles that are stable enough to protect bacteria during storage and transit under simulated stomach conditions. However, changes in the environment trigger a complete decomposition of the gel particle, right at the target site, namely the lower GI tract.

Work on bioencapsulation will continue in Moorepark and will mainly concentrate on three areas: (i) transferring existing technology to the food industry, (ii) adapting technologies for more diverse food applications, and (iii) developing methodologies to follow detailed interaction between encapsulants and bioactive ingredients.



Confocal microscopy images of probiotic bacteria entrapped in a gel particle. Live bacteria appear green.



Confocal microscopy image reveals the highly structured, porous surface morphology of gel particles.

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Molecular sub-typing of *Campylobacter* in intensive Irish poultry flocks

Molecular sub-typing analysis can enhance our understanding of the epidemiology of the economically significant pathogen, *Campylobacter*, in intensive poultry flocks. ALESSANDRO PATRIARCHI, ÁINE FOX and DECLAN BOLTON describe work they are carrying out in this area on tracing on-farm transmission routes using DNA sequencing-based approaches.

Ireland is the highest consumer of poultry meat per capita in the EU and sales of poultry in Ireland have increased by 5% for the year to July 2008, reaching a value of €227m (Bord Bia, 2008). A high level of colonisation of *Campylobacter* among intensively farmed poultry is a major problem for the poultry industry and has an appreciable economic impact.

Campylobacteriosis is a human gastroenteric disease of global significance, and the incidence of the infection correlates with the prevalence of thermophilic *Campylobacter* species. Campylobacteriosis manifests as an acute gastrointestinal illness, which is usually self-limiting; however, intervention with antimicrobials may be necessary in certain individuals. The illness can also be associated with an increased risk of contracting more severe immune-mediated neurological sequelae such as Guillain-Barré syndrome (GBS).

Outbreaks of the disease are most commonly sporadic; however, there is a seasonal influence, with infection rates increasing in the summer months. In 2007, a total of 200,507 confirmed cases of campylobacteriosis were reported among 27 European Union member states (EFSA, 2009) and *Campylobacter* is the most common cause of bacterial gastroenteritis in Ireland. Gastroenteritis represents a huge economic burden in this country and *safe*food has estimated that the cost of gastroenteritis to the economy of the island of Ireland is approximately €135m per annum (*safe*food, 2008). Therefore, it is clear that an appreciable impact on public health could be achieved on a Europe-wide basis by seeking to reduce the rates of this illness.

Epidemiology and risk factors

The principal reservoir of *Campylobacter* is the alimentary tract of mammals, both domesticated and wild, and birds, where the bacterium is a commensal organism. Other sources implicated are foodstuffs, including poultry, pork, beef, other meat products, raw milk, mussels and fresh vegetables. *Campylobacter* has a low infectious dose (ID) of 500 to 800 organisms and may be transferred to humans via one of two routes: either through direct contact with contaminated animals; or, indirectly via ingestion of contaminated food or water. The risk of contracting campylobacteriosis by the consumer has been attributed to several sources. The major risk source has been identified as poultry meat products, with cross-contamination from poultry products to ready-to-eat foods also being an important factor. The route of infection with the pathogen is generally via direct hand-to-mouth transfer during food preparation.

Investigation of the population biology of *Campylobacter* species in their natural reservoirs is necessary to understand the dynamics and sources of human infection. However, elucidation of the epidemiology of this zoonosis is complicated by the pathogen's wide distribution, relatively high levels of antigenic and genetic diversity, and the sporadic nature of campylobacteriosis. New molecular approaches to studying *Campylobacter* are beginning to shed light on the complex epidemiology of this economically significant pathogen in Ireland and further afield.

The main aims of work ongoing at Ashtown Food Research Centre investigating the epidemiology of *Campylobacter* in Irish poultry flocks are: (i) to assess the distribution of *Campylobacter* species present in a subset of commercial poultry farms throughout a rearing period; (ii) to evaluate to what degree the spatio-temporal dynamics of *Campylobacter* can be related to farm-specific management strategies (including poultry house and transport equipment cleaning and disinfection); and, (iii) to transform these findings into farm management and biosecurity recommendations for the Irish poultry industry that would facilitate the delivery of *Campylobacter*-free poultry to processors, thus leading to significant upstream improvements in public health in Ireland.

Ireland is the highest consumer of poultry meat in the EU. (Image courtesy of Bord Bia.)

Epidemiology of *Campylobacter* in poultry flocks

The epidemiology of *Campylobacter* infection in poultry flocks is complex. Once poultry becomes exposed to *Campylobacter* species, the alimentary tract is rapidly colonised and there is a subsequent rapid spread of *Campylobacter* throughout the entire flock (i.e., within days). Infected birds are then capable of secreting large numbers of viable organisms into the poultry house environment. Studies have found that there is a linear relationship between the prevalence of *Campylobacter* in a flock and the probability of illness in a given population. It is evident, therefore, that, for example, a two-fold reduction in the prevalence of the pathogen at flock level would result in a two-fold decrease in the probability of contracting campylobacteriosis.

The pathways involved in *Campylobacter* contamination of poultry flocks remain unclear and suspected sources or vectors of contamination include transmission from parent to progeny, exposure to contaminated water, a previously contaminated rearing environment and personnel.

Enhanced biosecurity is the primary intervention strategy adopted with the aim of controlling *Campylobacter* in poultry. This primarily involves measures to prevent entry of the organism into the poultry house from the external environment. One major risk factor for the contamination of flocks is the process of partially depopulating the flock by removing a proportion of the birds during the rearing process (i.e., thinning). During this process, there is repeated incursion into the poultry house by individuals and equipment. At AFRC, we have been investigating a subset of *Campylobacter* isolates collected over the lifespan of selected poultry flocks from within poultry houses and from diverse sources in the adjacent farm environment (concrete apron, soil, cattle faeces, wild bird faeces, transport equipment and puddles) with the aim of defining transmission routes, using molecular approaches.

flaA-SVR sub-typing of *Campylobacter*

Campylobacter species are genetically and phenotypically very diverse. They have a high genomic diversity, which may reflect quite rapid adaptive changes during colonisation or infection cycles. In *Campylobacter*, there are several mechanisms that can drive the generation of novel variants, and among these are natural transformation, genomic rearrangements, intra- and inter-genomic recombination and chromosomal point mutations.

The overall cost of gastroenteritis to the economy for the island of Ireland is conservatively estimated at approximately €135m per annum (safefood, 2008).

As a result of this 'genome plasticity', *Campylobacter* species can be said to display a 'weakly clonal' population structure, i.e., having significant linkage of alleles at different loci in a population while not demonstrating tree-like phylogenetic relationships, making it difficult to define relationships between strains. However, in certain circumstances, this genetic diversity can be exploited to discriminate between isolates. Motility (provided by the flagellum) is required for efficient colonisation of intestinal cells, and thus represents a major pathogenic mechanism. The flagellin gene locus contains two flagellin genes (*flaA* and *flaB*); these are arranged in tandem and are separated by about 170 nucleotides. The *flaA* gene is known to be highly variable and has been used in several genotyping schemes. Analysis of the *flaA* sequence (1,764 nucleotides) reveals two highly variable regions: a larger region comprising

With more detailed knowledge concerning Campylobacter *transmission routes, current best practice measures can be subject to a continuous quality improvement element as new information becomes available.*

bases 700-1,450; and, a short variable region (SVR) comprising bases 450-600. Additionally, this region is flanked by conserved sequence regions on either side. For *flaA*-SVR sub-typing, genomic DNA is isolated from the strain of interest and the SVR is amplified by polymerase chain reaction (PCR). The amplified region (amplicon) is purified and DNA sequence analysis is performed. Forward and reverse chromatograms are verified and confirmed sequences are trimmed to 321bp and used to interrogate a publicly accessible international FlaA database using a BLAST analysis function integrated into the database (http://pubmlst.org/campylobacter/flaA/). Novel *flaA* sequences are deposited in the database and are subsequently available to the global scientific community. On our study farms, 15 FlaA peptides and 24 *flaA*-SVR alleles were detected among *C. jejuni* and *C. coli* isolates collected. These results demonstrate the high level of diversity of *Campylobacter* strains that are present on Irish poultry farms.

Delivering* Campylobacter*-free poultry to processors should be a key priority for the Irish poultry industry leading to significant upstream improvements in public health.

Multi-locus sequence typing

A fundamental requirement for epidemiological surveillance in any setting is the ability to accurately distinguish between strains within a species. A number of genotyping techniques have been developed that exploit the differences in DNA sequences between strains, including real-time PCR (RT-PCR), amplified fragment length polymorphism (AFLP), restriction fragment length polymorphism (RFLP) and pulsed field gel electrophoresis (PFGE). Depending on the particular epidemiological question posed and the sensitivity of the criteria required, a specific technique or combination of techniques may be chosen. Each of these techniques present advantages and disadvantages; however, one of the biggest disadvantages is that of inter-laboratory reproducibility and this has provided the impetus for the development of molecular techniques that are reproducible globally in any laboratory. MLST is a DNA sequence-based sub-typing method that allows the unambiguous identification (via the Internet) of strains of bacterial pathogens. International MLST databases are available for many pathogenic species and allow researchers in different countries to unambiguously compare their strains. MLST indexes variation directly by nucleotide sequencing of gene fragments and MLST data can be represented in two different forms: firstly, the sequence type (ST), which is a unique combination of seven alleles; and, secondly, MLST data can be represented as a clonal complex (CC). A CC represents a group of related STs, e.g., differing at <2 of the seven alleles, which are hypothesised to possess a more recent common ancestor than those strains that do not possess the same CC designation. Therefore, a CC can be thought of as a group of related sequence types related by a progenitor ST.

Fundamental to the design of MLST is the emphasis on neutrally evolving core genes. These genes encode enzymes that are involved in central metabolism (also designated housekeeping loci) and are thus not subject to diversifying selection. Core housekeeping genes are generally ubiquitous within a population. Dingle and colleagues developed an MLST scheme for *Campylobacter* species (Dingle *et al.*, 2001) that is based on sequencing seven loci with lengths of 402-507bp. The following alleles form the basis of the scheme for this species; *aspA*, *glnA*, *gltA*, *glyA*, *pgm*, *uncA* and *tkt*. Each of these loci is widely separated on the *Campylobacter* genome (16.4Mb). The MLST procedure requires that each of the loci is amplified using specific primer pairs and subjected to DNA sequence analysis. Sequences obtained are used to interrogate the *Campylobacter* MLST database (http://pubmlst.org/campylobacter/) and an ST and CC designation are returned. Additionally, putative phylogenetic relationships among the MLST types can be visualised via a minimum spanning tree constructed using the appropriate bioinformatic software (e.g., Bionumerics, Applied Maths).

Findings on Irish farms

On our study farms, 13 STs were identified that can be assigned to seven CCs. ST45 was the most common ST identified and accounted for 20% of isolates analysed. The most frequently represented CC in the study was the ST-45 complex, and this complex has been reported previously in both broilers and humans. More recently, ST-45 complex has been identified as a strain that shows increased fitness under environmental conditions and is, therefore, hypothesised to represent a strain that may bridge the various recognised environmental, livestock and human transmission settings for disease. Several novel STs were identified during the course of the study and are being submitted to the international MLST database – thus representing the first Irish isolates in the database. MLST studies are providing conceptual advances in understanding the epidemiology and population biology of *Campylobacter* species and are helping to define host and source associations for particular MLST types. With the continuing fall in the cost of high-throughput sequencing, it is envisaged that the use of MLST in routine surveillance studies will become more widespread. MLST, in conjunction with *flaA*-SVR sub-typing, has allowed us to confirm the clonal nature of *Campylobacter* strains isolated from cattle and transport equipment and strains subsequently found within our study flocks, thus establishing two important transmission routes on selected Irish poultry farms.

Increasing our understanding of the molecular basis of* Campylobacter *epidemiology should drive measures in biosecurity improvement in the poultry industry.

Prioritisation of environmental sources of *Campylobacter* on poultry farms

Effective intervention and control measures for *Campylobacter* infection on poultry farms can only be designed or implemented when the principal sources of the pathogen are identified. Cattle have been found to be common carriers of *Campylobacter* in previous studies. Research shows that some *Campylobacter* MLST types are more strongly associated with certain types of livestock and, indeed, that certain MLST types are more frequently associated with particular poultry processing companies. Emerging information from epidemiological studies should shed light on the correlation of virulence with certain MLST types and this information could be integrated into current food chain quality management risk assessment models.

Our study has provided new information regarding biosecurity risks on Irish poultry farms. It appears that biosecurity installations in place (dedicated anteroom, boot dipping, change of clothes) may not be fully utilised by farming personnel during the rearing period and this may explain why environmental strains are being introduced into flocks. Significantly, identification of the involvement of transport equipment (crate modules) and livestock (cattle) in the dissemination of this pathogen at farm level has implications for current biosecurity practices in place on Irish intensive poultry farms.

Conclusions

The epidemiology of *Campylobacter* is complex and defined routes of transmission within the farm/poultry rearing environment have not been fully elucidated, although a growing body of evidence is beginning to point toward the significant role that the environment is playing as a source of this pathogen. As full environmental eradication is not a feasible approach, it is therefore vital to identify the flow patterns of transmission and examine the spatio-temporal distribution of the pathogen in these settings.

The dissemination of this pathogen at farm level has implications for current biosecurity practices in place on Irish intensive poultry farms.

We have been able to exploit the combined discriminatory power of *flaA*-SVR sub-typing and MLST to establish transmission routes of *Campylobacter* in selected intensive Irish poultry flocks. Thus, molecular sub-typing techniques provide a promising approach for the identification of routes of transmission of the pathogen on Irish poultry farms. With more detailed knowledge concerning such routes, current best practice biosecurity measures in place can be subject to a continuous quality improvement element, as new information becomes available from national and international studies. Identification of critical sources of *Campylobacter* contamination in poultry will allow for the further development of intervention strategies that will aggressively target specific locations, facilitating the production of pathogen-free poultry entering the next stage of the food chain.

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Strong relationships take centre stage at Teagasc

DEBBIE KELLY, MAEVE HENCHION and PAUL O'REILLY discuss the importance of strong relationships between researchers and industry as a basic criterion for improving technology transfer within the food sector.

Setting the scene

Technology transfer has been a popular topic within academic literature and political discussions in recent years. Placed within the context of today's globalising economy, where knowledge is seen as a foremost strategic resource and where obtaining value for taxpayers' money is an important research objective, achieving successful technology transfer is a fundamental goal for publicly-funded research organisations. The current competitive environment demands that industry draws upon external sources, including public sector organisations, to improve innovation and competitiveness. This is particularly important in the Irish food industry where the level of company expenditure on R&D is low (Forfás, 2006).

The survey found that food companies tend not to use Irish or foreign public science providers (PSPs, e.g., universities and research institutions) to achieve their R&D objectives.

Furthermore, public research bodies are under increasing pressure to maximise the economic benefits of their work through effective technology transfer, and validate their position within the overall knowledge economy. This pressure was reinforced by the Department of Agriculture, Fisheries and Food's Value for Money Report (2007) on the Food Institute Research Measure (FIRM), which asserts that there is scope for further returns from publicly-funded research. Current programmes, such as FIRM, Science Foundation Ireland (SFI) and EU Framework Programmes, all encourage researcher collaboration and interaction with industry, as a means to address technology transfer performance. Hence, when seeking to improve technology transfer, enhancing researcher–industry relationships acts as the fundamental backbone.

Behind the scenes

The Food Market Research Unit based at the Ashtown Food Research Centre (AFRC), in collaboration with DIT, is close to completing a three-year FIRM-funded project, which aims to produce a technology commercialisation toolbox for publicly-funded food research. The objective is to provide current and contextually relevant information on the food innovation system in Ireland by exploring the levels of interaction and nature of relationships between public and private organisations, as well as examining researcher and industry perspectives on the barriers, motivations and attitudes that affect technology transfer. Through quantitative and qualitative research, the nature and quality of relationships emerged as major themes in terms of barriers that affect interaction and the ability to influence the realisation of technology transfer.

The current script

To ascertain the level and nature of interaction between food companies and public research institutions, parallel surveys were conducted with food companies and researchers. Given the current emphasis on technology transfer, it is clear that most researchers are avidly aware of the necessity to engage with and contribute to industry on some level. However, the researcher survey suggests that more effort is required to improve researchers' levels of interaction in several areas. While most researchers interact with a range of external organisations, nationally and internationally, the main reason they do so is to conduct collaborative research

Table 1: Researcher interaction with selected partner organisations (% of researchers who said yes).

Purpose / Partner organisation	Technology transfer %	Collaborative research %	Access facilities %	Contract R&D %	Commercial services %	At least 1 %
Irish HEI	11	64	16	12	7	74
Irish PRC	5	47	13	11	7	60
International HEI	3	39	9	4	3	42
International PRC	6	22	7	5	5	32
Food company	19	24	18	20	22	53
Food industry supplier	7	7	5	5	6	20

PRC = Public Research Centre; HEI = Higher Education Institute

with other public sector organisations. Only about half of the researchers surveyed reported that they interacted with food companies, and interacting, for purposes that relate to technology transfer such as utilising facilities, providing commercial services or conducting contract R&D remains low in overall terms (**Table 1**).

A similar picture is evident on the industry side. When asked to rate the importance of various innovation sources to their organisation, public science institutions, including Teagasc, universities and institutes of technology, were all rated much lower than sources such as internal R&D, customers, suppliers and competitors. Furthermore, the survey found that food companies tend not to use Irish or foreign public science providers (PSPs, e.g., universities and research institutions) to achieve their R&D objectives. At best, 18% of food companies reported using PSPs to achieve quality improvements or develop new products (**Table 2**).

The results on the levels of interaction from both sides show that current levels of interaction between the two is lower than desirable to improve knowledge and technology transfer within the sector. In essence, neither actor views the other as a partner in the context of carrying out their respective roles.

Table 2: Industry interaction with public science providers (PSPs) for defined purposes (% of companies that said yes).

R&D aims and objectives	Irish PSP %	Foreign PSP %
Quality improvements	18	12
Cost reductions	3	3
Development of new products	18	13
Safety	6	3
Ensure compliance to regulations	9	8
Customer request	2	3
Environmental impact improvement	6	2

TABLE 3: Frequency and effectiveness of knowledge transfer activities.

	Frequency 1 where 1 = not at all and 5 = very often		Effectiveness where 1 = not at all and 5 = very effective	
Knowledge transfer activities	PSP mean	Industry mean	PSP mean	Industry mean
Resource sharing (use of PSP facilities by industry	2.3	1.7	2.9	2.4
Personnel transfer (researchers to industry or vice versa)	2.3	1.9	3.3	2.2
Patents/licences	1.6	1.9	2.5	2.2
Scientific publications	3.7	2.3	3	2.3
Trade publications	1.9	2.6	2.8	2.7
RELAY submissions /bulletins	2.9	2.3	3	2.2
Scientific conferences	3.7	2.3	3	2.5
Training courses	2.5	2.9	3.3	3.2
Informal contacts	3.2	3	3.4	3
Best practice guides	1.9	2.7	2.7	2.7
Technical brochures and reports	2.5	2.9	3	2.6
Internet	2.6	2.9	3	2.7

PSP = Public Science Providers

Reading from different scripts

An important element in building and maintaining relationships between the various actors within the food sector is to ensure that routes of communication are visible, transparent and comprehensible. The way in which partners currently interact indicates that both are utilising different channels as a means to receive and obtain information. In terms of knowledge transfer mechanisms, **Table 3** shows that researchers use scientific publications and RELAY bulletins as their most frequently used communication devices, while industry rates informal contacts as their most used knowledge transfer activity, although evidently, overall usage rates of these activities are low in terms of industry responses. Interestingly, despite disparities in terms of how communication is currently carried out, there seems to be convergence of opinions in relation to the activities that are viewed as effective. Researchers and industry are in agreement about the effectiveness of informal contacts and training courses. The recognition of the effectiveness of these activities suggests a requirement for direct and active engagement between the two actors and indicates awareness from both sides of the potential importance of greater interaction.

Building solid and mutually beneficial relationships between researchers and industry represents one of the biggest challenges and solutions in addressing the longstanding issue of enhanced technology transfer.

Taking the lead

In addition to the surveys, case studies were conducted, which focused on the behaviours and attitudes of researchers to industry interaction. The case studies revealed that the presence or absence of strong relationships between researchers and industry had an undeniable impact on the success of the research project in terms of technology transfer. In cases where technology transfer was not attained, relationships tended to be more formal, less interactive, and lacking in personal contact compared to cases where technology transfer was attained. Additionally, industry had less overall involvement in and impact on research projects, from research proposal development stage through to completion. Comparatively, in cases where technology transfer occurred, relationships were described as casual and personal, and were characterised by regular interaction and industry involvement in the research project through all stages. While relationships were characterised as informal, they had purposeful objectives such as the provision of general information and feedback, gaining access to raw materials and the facilitation of scale-up. Committing to building relationships with industry partners was, therefore, not seen as an act of altruism on the part of the researcher but rather they recognised its ability to assist them in achieving and maximising personal and organisational objectives while simultaneously realising benefits for industry.

Thus, the nature of the relationship between the researcher and industry contacts was seen as a core criterion for successful interaction in facilitating technology transfer. Additionally, the presence of a good relationship impacted favourably upon other reasons for successful technology transfer such as obtaining genuine industry interest at an early stage, compiling well planned proposals and utilising knowledge of the industry to determine specific research tasks and directions.

Rewriting the script

Building solid and mutually beneficial relationships between researchers and industry represents one of the biggest challenges and solutions in addressing the longstanding issue of enhanced technology transfer. Achieving this, however, requires changes on many levels. Current cognitive mindsets relating to research objectives and researchers' core responsibilities, which are influenced by internal reward and measurement systems, need to be amended to a level where engaging with industry takes precedence alongside peer-reviewed publications and access to funding streams. This, in turn, requires greater support and advisory systems as well as the establishment of appropriate measurement criteria. Additionally, industry needs to adjust its stance on longer-term research projects and trust in its own ability to have an input into research conducted by public science organisations. As a starting point, sincere and consistent dialogue, framed by realistic expectations and commitment to long-term vision, must occur in order to re-write the current script and enable both sides to work towards achieving a common narrative.

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The Water Framework Directive – troubled waters or water under the bridge?

Following an international conference on the Water Framework Directive in Teagasc, Johnstown Castle, ROGIER SCHULTE, KARL RICHARDS, OWEN FENTON, GER SHORTLE, MARK GIBSON, NOEL CULLETON and HUBERT TUNNEY outline the implications for agriculture in Ireland.

Two years after the implementation of the Nitrates Directive, the Water Framework Directive (WFD) is now being implemented and requires all waters to reach "good" status by 2015. Will this pivotal piece of EU legislation impose further restrictions on farm practices in Ireland? In November last year, Teagasc, Johnstown Castle organised an international conference on 'Grassland and the Water Framework Directive' to provide clarity on these questions, and to agree on an approach to the WFD that recognises the concerns of all stakeholders. This conference brought together scientists from Ireland, the UK, Europe, the USA and New Zealand, advisors, policy makers and farmer representatives. In this article, the organisers of the conference summarise the consensus that arose from the presentations and the discussions.

What is the Water Framework Directive?

The WFD is an important piece of EU legislation that was adopted by the European Commission in 2000; it aims to bring together and integrate the many existing directives related to protecting water quality, such as the Groundwater Directive (1980), Nitrates Directive (1991), Drinking Water Directive (1998) and Bathing Water Directive (2006). It commits all member states to ensure that all water bodies (i.e., groundwater, surface water, coastal waters) and groundwater-dependent terrestrial ecosystems are of at least "good status" by 2015. There are numerous potential causes of deterioration in water quality; therefore, a concerted effort by all sectors of society is required, and such a cross-sectoral approach is at the heart of the WFD. So-called Programmes of Measures (POMs) must be implemented as early as 2012.

What is the difference between the Nitrates Directive and the WFD?

There are many differences between the Nitrates Directive and the WFD; the most important ones are:

1. The Nitrates Directive is explicitly aimed at reducing nutrient losses to waterbodies from agricultural sources only. The Nitrates Directive is one of the directives that will now be brought under the umbrella of the WFD, together with other directives that refer to other sectors (e.g., the Urban Wastewater Treatment Directive, 1991; and, the Dangerous Substances Directive, 2006) and, as such, is a POM in itself.

We can see the WFD as an umbrella directive, co-ordinating the efforts of the different sectors in society to protect and improve water quality.

2. The Nitrates Directive was based on chemical water quality standards, i.e., nitrate and phosphorus concentrations in groundwater and surface waters; these single standards are now being implemented across Ireland and, indeed, Europe. The WFD integrates chemical standards with ecological standards. As different aquatic species and ecosystems respond differently to nutrient enrichment, this may result in varying nutrient targets across regions and member states. Under the WFD, the ecological status will be a critical acid test.

3. This means that, whereas the Nitrates Action Plan largely entailed a single plan of measures for the entire country, the WFD will be based on a regional approach, delineated by River Basin Districts, which are effectively the catchments of our larger rivers. The Republic of Ireland has seven of these River Basin Districts, five of which fall entirely inside the Republic, with two cross-border districts that are shared with Northern Ireland. Individual River Basin Management Plans have been developed for each of these districts, the first drafts of which were published in December 2008.
4. The Nitrates Directive was aimed at water quality in surface waters and groundwater; based on these criteria, over 70% of our surface waters were classified as "unpolluted", which puts Ireland in a relatively favourable position compared to many of our EU partners on the continent. The WFD now includes coastal waters. In recent years, less than half of our estuarine waters have been identified as "unpolluted". Currently, little is known about the causal links between land use practices upstream in the catchment, and ecological responses in estuaries.

There was consensus at the conference that it is essential that local farmers are involved in the development of these measures.

Is the WFD the big brother of the Nitrates Directive?

Not really. Rather, we can see the WFD as an umbrella directive, co-ordinating the efforts of the different sectors in society to protect and improve water quality. It is widely recognised that, in Ireland, the Nitrates Directive will be the main 'basic' measure for agriculture under the WFD, i.e., the Nitrates Directive will be the main agricultural tool in the WFD toolbox. However, it cannot be ruled out that, on a regional basis, additional measures may be required. Areas where these are most likely include: 1) catchments with waters that are highly sensitive to eutrophication; and, 2) areas that are highly vulnerable to nutrient loss:

1. Areas with highly sensitive ecosystems are those that currently have "high ecological status", the highest of the five ecological categories. Most of these concern near-original ecosystems that often include rare aquatic species, such as arctic char or the freshwater pearl mussel. The conference heard that in many cases these areas are already subject to ecological protection, and have been designated as Special Areas of Conservation (SACs) under the Habitat Directive; in this scenario, the WFD may not require measures over and above the measures that already apply to SACs. However, in some cases freshwater pearl mussels have been identified in catchments that are characterised by productive agriculture; the protection of their ecosystems may in some cases require water quality standards that are more stringent than those used in the Nitrates Action Plan. In order to reach such stringent standards, measures additional to those that form part of the Nitrates Action Plan would be required, which is cause for great concern for agriculture.
2. Areas that are highly vulnerable to nutrient loss are those areas where there is very high connectivity between the land and a waterbody; this connectivity can either comprise shallow excessively drained soils underlain by carboniferous limestone, or excessive overland flow on poorly-drained soils with a dense surface drainage network. In these areas, there is a strong causal link between land use and water quality. In areas where the implementation of the Nitrates Action Plan fails to translate into "good status" in the waterbodies in the future, additional measures may be required. These could be aimed at either breaking the "link" between land and water, or at reducing nutrient pressures by further improvements in nutrient efficiency.

What type of measures can we expect?

Most importantly, if and where additional measures are required, these will be regionalised and targeted towards specific ecosystems and practices, and not necessarily applied nationwide. There was consensus at the conference that it is essential that local farmers are involved in the development of these measures: this not only ensures that the measures are practical and acceptable, but also increases the likelihood that the measures will be effective. The conference heard examples from the UK and from Ireland, in which this participatory approach has been highly successful. For example, in the cross-border Lough Melvin catchment, farmers, policy makers and researchers agreed that a support package for nutrient management planning and soil sampling, as well as installation of sediment traps in existing streamlets, and the planting of hedgerows and riparian margins under the REPS scheme, were measures that are both effective and acceptable to farmers (Doody *et al.*, 2007).

In addition, cost-effectiveness is central to the WFD; assessment of the cost-effectiveness of any measures is an essential element of the River Basin Management Plans. The WFD stipulates that member states are not expected to implement measures where these are associated with "excessive costs", nor should a single sector of society bear a disproportional share of the total costs. The WFD facilitates mechanisms for "cost-sharing" between sectors; details of such mechanisms are currently under development.

Is it realistic to expect "good status" in all waterbodies by 2015?

No, there is now general agreement that it will be almost impossible to return all waters to good ecological status by 2015, for a variety of reasons. Most importantly, even if the current measures of the Nitrates Action Plan are fully effective, in some catchments it may take many years for the impact of these measures to translate into improvements in water quality. This is simply caused by the fact that the travel time of surplus nutrients to a waterbody may range from days to centuries, depending on soil, subsoil and geology. In addition, historical surpluses of phosphorus have been stored in lake and river sediment through chemical adsorption processes; these sediments may now continue to slowly re-release this phosphorus for decades. For example, as far back as 1985, Denmark was one of the first countries to adopt measures to reduce nitrate and phosphorus loss to water; however, improvements in water quality, particularly nitrate levels, have only become evident in recent years, 20 years after implementation, with no improvement yet in phosphorus levels from diffuse sources.

Also, the restoration of ecosystems to "good status" is an asymmetric process; this means that once an ecosystem has deteriorated, it may not always be possible to return it to its original state. The conference heard examples from Chesapeake Bay (USA) and Lake Sempach (Switzerland) where, although it was found that nutrient reduction programmes were successful in reducing nutrient concentrations, and moderately successful in increasing species diversity, they had not resulted in restoration of the "original" ecosystems; in addition, genetic diversity remained low. Therefore, a consensus emerged from the conference that prioritising protection of ecosystems of "high status" over restoration of ecosystems that have already deteriorated, would represent the most effective approach.

The restoration of ecosystems to "good status" is an asymmetric process; this means that once an ecosystem has deteriorated, it may not always be possible to return it to its original state.

Should we do anything in addition to the Nitrates Directive?

Yes we should. Most importantly, if Ireland fails to meet "good status" in all waters by 2015, simply because it takes time for the effectiveness of the current Nitrates measures to show up in improvements in water quality, then it is imperative that we have scientific evidence that these measures will have a positive effect in the long term, and will translate into improved water quality in future; this evidence should go a long way towards negating additional, stricter measures post 2015. To provide this evidence, Teagasc, with financial support from the Department of Agriculture, Fisheries and Food, has embarked on a large-scale, integrated advisory/research study, the Agricultural Catchment Programme, which will work closely with farmers, advising on and studying the Nitrates measures in small catchments across the country, and identifying indicators of change resulting from the farmers' efforts. The scientific evidence provided by this Agricultural Catchment Programme will not only be invaluable in the context of the WFD, but could also be critical in securing future derogations for the Nitrates Directive.

In addition, in the "highly sensitive" and "highly vulnerable" areas discussed previously, immediate action will allow time to develop targeted, cost-effective, practical and acceptable measures in consultation with all stakeholders, i.e., measures with minimum impact on the economic sustainability of farms. Indeed, Teagasc's current research programme on improving nutrient efficiency is identifying farm practices that return a "double dividend" in the form of reduced fertiliser costs and reduced risk of nutrient loss to water; these include improvements in manure management (Lalor and Schulte, 2008), dirty water treatment and nitrate remediation (Fenton et al., 2007), grazing strategies (Hoekstra and Schulte, 2008), and the use of clover (Black and O'Kiely, 2008).

At the close of the conference, the Director, Professor Gerry Boyle, affirmed that Teagasc is committed to providing solutions for a productive agricultural industry to co-exist in an environment of "good status".

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Climate change and agriculture

FRANK O'MARA discusses the challenges facing Irish agriculture and the progress made to date in reducing greenhouse gas emissions from agriculture.

Introduction

Climate change has been identified as the most significant and threatening global environmental problem facing humanity today. There is an almost universal global consensus that significant cuts in global greenhouse gas (GHG) emissions are needed over the next century in order to stabilise concentrations of GHG in the atmosphere at twice the pre-industrial level. The Kyoto Protocol was the first major international agreement to reduce emissions. Under it, the EU agreed to an 8% reduction by 2012 and, as part of the EU target, Ireland has agreed to limit the growth in GHG emissions to 13% above 1990 levels by 2012. More recently, the 2008 December Council meeting of EU leaders agreed to a further reduction in GHG of 20% by 2020 compared to 1990, or 30% if a new global agreement is reached.

The main GHG in Ireland is carbon dioxide (CO_2), mainly arising from the burning of fossil fuel in transport, heating and electricity generation. Irish emissions of other GHGs, including methane (CH_4) and nitrous oxide (N_2O), are proportionately higher than most other developed countries. Agriculture is the main source of these, and the goal of reducing their emissions presents a major challenge for the agriculture sector. However, there are also opportunities, and growing biomass crops as a source of energy is an example.

Agriculture accounted for 26.8% of total Irish GHG emissions in 2007, down from 35% in 1990. In an international context, Ireland's profile of emissions is unusual in the developed world (**Figure 1**). New Zealand is the only developed country with a higher proportion of emissions from agriculture than Ireland, and the EU average is substantially below our level. This is due to the importance of agriculture in our economy. Over 50% of agricultural emissions are CH_4 from enteric fermentation, and most of the remainder is N_2O released from soils.

Agricultural emissions have decreased by 1.36m tonnes CO_2 since 1990, or 6.8%. The 2007 provisional data represents a 3.8% reduction on 2006 for the agriculture sector (**Figure 2**). This is accounted for by a drop in cattle numbers of 3.1%, a drop in sheep numbers of 7.6%, and a drop in N fertiliser use of 4.1%.

Recent projections from Teagasc's economic forecasting unit, FAPRI Ireland, suggest that agricultural emissions will decrease by 8.5% from 2005 to 2020. This is mainly due to a forecast drop in suckler cow numbers, as FAPRI analysis indicates that dairy cow numbers will increase to 1.2m by 2020.

Challenges for reducing emissions:

- food security will require an increase in food production;
- reducing emissions in Ireland by reducing food production will cause 'leakage' of emissions to whatever country increases production;
- gaining credits for afforestation and biomass production for bioenergy is problematic;
- there are economic, social and moral implications of reducing the livestock herd; and,
- new technical solutions require a sustained research effort.

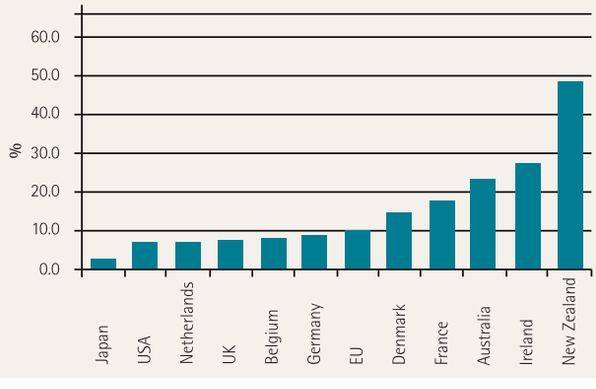

FIGURE 1: Emissions from agriculture as a percentage of total national emissions in various countries worldwide (source: UNFCCC).

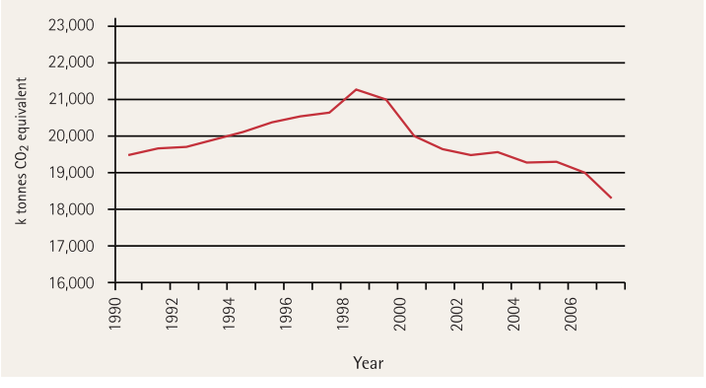

FIGURE 2: Trend in tonnes CO_2 equivalent from agriculture (1990 - 2007) (source: EPA, 2008).

Progress to date

Significant progress has been made over the past number of years in reducing GHG emissions from agriculture. For example, improved nutrient management has led to a 35% reduction in N fertiliser use in the last 10 years, equivalent to a reduction of over 0.5m tonnes per annum of CO_2 equivalent. We will continue to seek maximum efficiency of nutrient use in research and advisory programmes, ensuring that this trend continues.

Table 1: Potential greenhouse gas mitigation from crops.

Biofuels	270,000t CO_2
Electricity	830,000t CO_2
Heat	1,700,000t CO_2
C sequestration	50,000t CO_2
Total	**2.85MT CO_2**

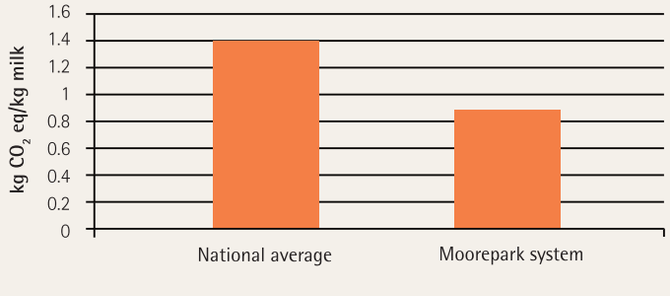

FIGURE 3: GHG emissions per kg of milk using average production data from the National Farm Survey or production data from Moorepark (Lovett *et al.*, 2008).

Decoupling milk production from greenhouse gas emissions

With the relaxation of milk quotas prior to their elimination in 2015, Ireland will have the opportunity to expand milk production significantly. If this is to happen without a serious impact on GHG emissions, then milk production needs to be decoupled from GHG emissions. Evidence to date suggests that this is possible. Technological advances in dairy production have led to a drop of 12.4% in the amount of methane produced per kg of milk between 1990 and 2006, thereby demonstrating the relationship between greater efficiency and reduced emissions. A recent study (Lovett *et al.*, 2008) indicated that while average emissions on Irish dairy farms were 1.385kg CO_2 equivalent per kg of milk produced, this figure could be reduced to less than 0.9kg by using best technology in a grass-based system (**Figure 3**). There is an urgent need to bring the national average towards this figure, and Teagasc will prioritise this in its dairy research and advisory programme. Efficient rearing of cattle leads to earlier slaughter and lower lifetime GHG emissions. Over the period since 1990, the age of slaughter of beef cattle has been significantly reduced. In 1990, 44% of male cattle were over 30 months of age at time of slaughter; this was reduced to 15% in 2006 resulting in significant reductions in GHG emissions. Teagasc now has a significant research programme aimed at reducing GHG emissions from agriculture and assessing the opportunities for carbon sequestration. The strategies being investigated for CH_4 mitigation include dietary modifications, additives or probiotics to reduce CH_4 production, breed selection, increasing the length of the grazing season, and improved pasture quality. The breeding of more efficient animals producing more product from a given amount of feed, and thus having less emissions per kg of milk or meat produced, is very important. This requires a lot of basic science to understand the physiological and genetic factors controlling digestion and microbial processes, and emissions of CH_4 from the rumen.

N_2O is produced from soils as part of the N cycle, and is a significant source of GHG. Technologies being researched by Teagasc to minimise its release from soils include optimising the application of organic and inorganic sources of fertiliser to further reduce N fertiliser usage and emissions, the application of nitrification inhibitors (e.g., DCD) and other fertiliser technologies, the more efficient use of clover as a source of N, and reducing the load of N excreted onto pasture.

Other abatement strategies

Crops production for energy can make a significant impact on mitigating GHG emissions (**Table 1, previous page**). Biofuel production is possible up to a maximum of perhaps 270,000 tonnes CO_2 equivalent, which would equate with our national 2% biofuel target. The development of one or two first generation ethanol plants would also pave the way for the second generation, by establishing a logistics infrastructure, process expertise and markets for the produce. Growing energy crops to meet the government co-firing target would mitigate approximately 830,000 tonnes of CO_2 if the target is to be supplied by energy crops exclusively. Energy crops, particularly willow, can also contribute to government heat targets (12% renewable heat by 2020). The GHG mitigation potential of using energy crops for heat depends on the acreage used for this purpose in addition to the types of fuels replaced, but could amount to up to 1.7MT CO_2 equivalent. The anaerobic digestion of agricultural waste mixed with energy crops or other organic waste also has potential. However, obstacles include the high capital cost of the equipment together with the high cost of grid connection.

Conclusions

Teagasc has an extensive research programme dealing with minimising emissions from agriculture and also with the policy issues and financial consequences of climate change and GHG mitigation. The goal of reducing GHG emissions presents a major challenge for the agricultural sector. If milk production is to expand without impacting on emissions, then it must be decoupled from emissions, which will require a big effort to improve efficiency. However, reducing emissions also presents opportunities, and growing biomass crops as a source of energy is an example. There is no doubt that research can play a significant role by developing innovative solutions. Teagasc will continue to develop the most appropriate and cost effective solutions for dealing with this issue.

Teagasc greenhouse gas research is mainly finded by the Department of Agriculture, Fisheries and Food Research Stimulus Fund.

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Reducing ammonia emissions

Researchers at Teagasc Johnstown Castle and UCD are developing cost-efficient abatement strategies to reduce ammonia emissions from agriculture.

The National Emissions Ceilings Directive (2001) aims to reduce emissions of pollutants that cause acidification, eutrophication and ground-level ozone in order to protect the environment and human health. Its long-term objective is to ensure that pollutant levels remain below their critical loads (i.e., the amounts of pollutants below which significant adverse effects do not occur). Under this legislation national ammonia emissions are limited to 116,000 tonnes by 2010, with further, more stringent targets currently under discussion. In light of the fact that the vast majority of these emissions are livestock-sourced, future targets may prove challenging in the context of a sustained increase in global food demand. In response, researchers at Teagasc Johnstown Castle and UCD are developing cost-efficient abatement strategies to address this issue.

Atmospheric ammonia is both a local and transboundary pollutant, emitted primarily by agricultural sources. Agriculture comprises 98% of national ammonia emissions, with cattle accounting for 80% of sectoral emissions. In terms of agricultural practices, the land spreading of slurry and animal housing comprise 47% and 34% of total emissions, respectively, while the remainder is split between manure storage and animal deposition (Hyde *et al.*, 2003; **Figure 1**). Considering the principal ammonia sources, any change in the size of the national herd, in response to either quota abolition or market forces, will have significant implications for national transboundary targets. Thus, the challenge for Teagasc research is to draw up cost-effective abatement strategies in order to provide sustainable solutions to farmers in the context of maintaining production potential.

Pollution impacts of ammonia emissions

Ammonia (NH_3) volatilisation has been identified as a major factor in the transport of atmospheric nitrogen (N) and is responsible for significant reductions in the nutrient value of manure. While not a direct greenhouse gas (GHG), deposition of nitrogen oxides (NHx) may also indirectly lead to increased GHG emissions (principally nitrous oxide [N_2O]) or reduced consumption of methane (Melillo *et al.*, 1989).

Local impacts: At a local level, emissions occur at ground level, with ammonia rapidly deposited by: a) dry deposition as gaseous ammonia or particulate ammonia (NH_4^+); or, b) wet-deposition as dissolved NH_4^+. This deposition is extremely heterogeneous and is tightly correlated to the distance from the point source, with 90% occurring within 50 to 100m. Within a 5km radius, total ammonia deposition can be up to 20kg N/ha/annum and this can lead to the eutrophication of nearby water courses and a decrease in species richness in fragile ombrotrophic ecosystems such as bogs and heathlands (Assam *et al.*, 2004).

Transboundary impacts: Ammonia also reacts with acid pollutants such as the products of SO_2 and NO_x emissions to produce fine ammonium (NH_4^+)-containing aerosols. These aerosols may subsequently be transferred over several hundred kilometres (Fowler *et al.*, 1998). Hence, ammonia emissions contribute to transboundary air pollution and, as such, are subject to the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Pollution (CLRTAP).

Climate change impacts: As ammonia N can be re-introduced into terrestrial systems via the above processes, a proportion of this N is available for de-nitrification to nitrous oxide (N_2O), resulting in so-called 'fugitive' emissions. Indeed, this loss pathway accounts for almost 10,000t CO_2-equivalents/annum of national GHG emissions. In contrast, the ammonium aerosols, such as ammonium sulphate, can decrease global warming via enhanced albedo effects (i.e., increases light scattering and cloud formation; Adams *et al.*, 1999).

Considering the principal ammonia sources, any change in the size of the national herd, in response to either quota abolition or market forces, will have significant implications for national transboundary targets.

Emissions legislation

The UNECE Gothenburg Protocol (1999) and, subsequently, the EU National Ceilings Emissions Directive (2001/81/EC) were established in order to reduce levels of transboundary pollutants. Under this legislation, Ireland is limited to producing 116,000t of ammonia per year up to 2010. Currently, national emissions are 10% below this limit but a new national ceiling emission level will come into place post 2010 and is likely to be more stringent (**Figure 2**). This target, in tandem with both Nitrates and GHG targets, will constitute a major challenge to agriculture.

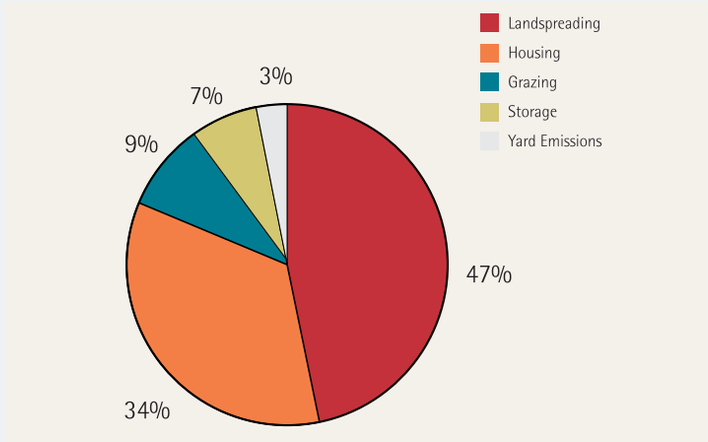

FIGURE 1: Sources of ammonia emissions within the agricultural sector.

Factors influencing ammonia volatilisation

The volatilisation of ammonia takes place when soils are moist and warm, the soil is alkaline and the ammonium source is on the soil surface. Hydrolysis of ammonium to ammonia occurs and, as the soil dries, the ammonia is volatilised to the atmosphere. Thus, the main drivers of volatilisation are temperature, energy input and wind speed. Solar radiation (energy input) is the principal driver (**Figure 3**). Other factors that can affect ammonia emissions include the dry matter (DM), and total ammonium-nitrogen content (TAN) of the slurry itself. Slurry with a high proportion of TAN has the capacity to emit more ammonia, while changes in the slurry DM content will increase the rate of infiltration into the soil, and thus reduce emissions.

Ammonia abatement strategies

The principle focus for abatement of ammonia is targeted at:

a) reducing N in animal diet;
b) altered land spreading technique;
c) optimisation of timing of application; and,
d) alternative housing.

Although the proposed targets are onerous, emissions mitigation and the application of best management practices can provide opportunities to optimise production efficiency. Indeed, ammonia emissions represent a decrease in N available for plant uptake. By reducing emissions, we can maximise the N fertiliser replacement value of slurry, thus reducing farm expenditure on inorganic fertilisers. Teagasc research, therefore, aims to identify those abatement measures that protect the environment in the most cost-effective way. Considering the main sources of ammonia (**Figure 1**), the focus of research at Johnstown Castle has been aimed at investigating alternative land spreading and housing strategies and, more recently, the manipulation of animal diets.

Diet manipulation

Altering animal diets to low crude protein, high net energy feed, such as maize or supplementation with amino acids, has been shown to reduce the amount of N excreted without impacting on performance (Oenema *et al.*, 2005). New research being carried out by UCD in association with Teagasc, Johnstown Castle, aims to assess the effects of reduced crude protein on production efficiency, the proportion of excreted urine N, ammonia and GHG emissions.

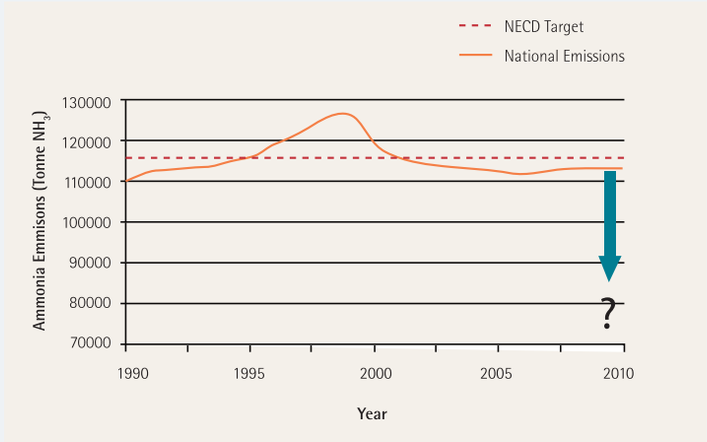

FIGURE 2: The national ammonia emissions profile along with current and proposed ceilings.

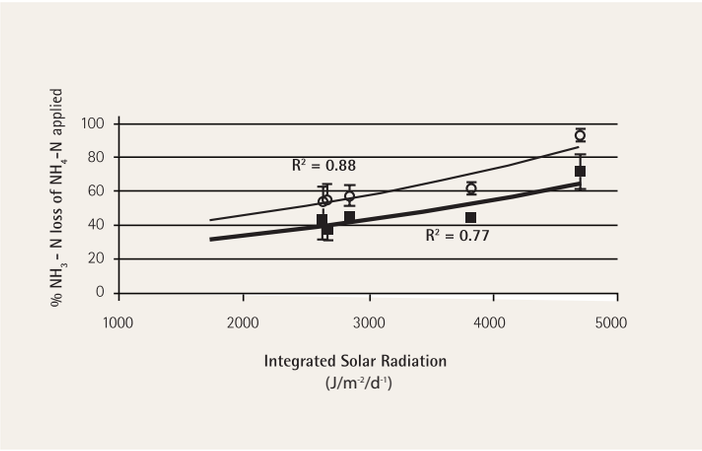

FIGURE 3: The relationship between daily integrated solar radiation and ammonia emissions from splash plate (circles) and trailing shoe applications (squares).

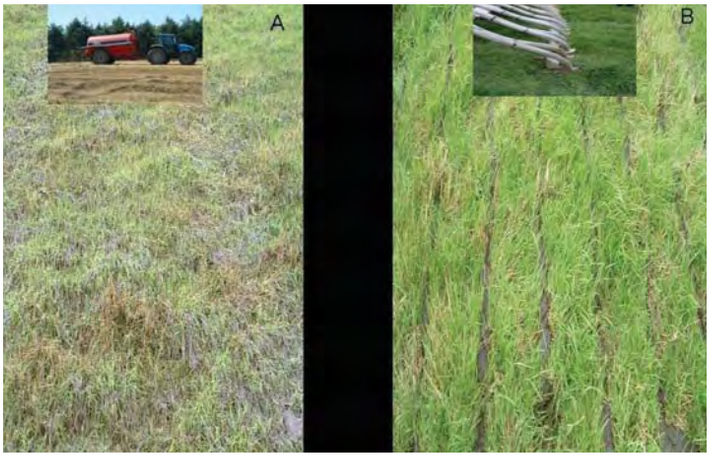

FIGURE 4: Slurry applications: a) splash plate; and, b) trailing shoe.

Land spreading strategies

The vast majority of Irish cattle slurry is spread using a splash plate application, where the slurry is pressurised against a plate and spread in a thin uniform layer on the ground, which can volatilise quickly. The land spreading of cattle slurry in any one year can typically account for 40% of total national NH_3 emissions. Therefore, a method of slurry application that reduces NH_3 emissions will impact substantially on Ireland's emission levels. The reduction of NH_3 also offers the opportunity for greater recovery of the N in manure. Therefore, abatement strategies will assist in increasing N efficiency on farms, which is a requirement of the Nitrates Directive Action Plan and the National Climate Change Strategy. The trailing shoe is used to apply slurry in narrow bands on the soil surface and beneath the crop canopy (**Figure 4**). The bands are approximately 5cm wide and this leads to a 79% reduction in the area exposed following application with the low emission techniques, which restricts the potential for ammonia exchange from the slurry surface to the atmosphere.

On average, there was a 28% reduction in NH_3 volatilised for slurry spread by trailing shoe application compared with the splash plate (**Figure 5**). Up to 80-90% of emissions occurred in the first 48 hours after splash plate application. However, the reductions in total NH_3 emissions from the trailing shoe compared with those from splash plate application were observed to depend on the timing of application. For instance, there was no significant effect of application method on emissions in April, while emissions were reduced by 40% in May. Thus, targeting spreading to low volatilisation conditions can reduce ammonia emissions by a similar proportion as changing spreading technique without additional cost in terms of new machinery. While this would generally imply shifting spreading towards spring, summer applications could still be carried out providing they occur on dull calm days or in the late afternoon.

In terms of choosing an application technique, the trailing shoe offers more consistent emission reduction as well as facilitating longer grassland spreading windows, as the slurry is applied below the canopy, thereby eliminating potential problems with slurry contamination of the crop. In addition, odours may be reduced using this technique.

Housing: the role of out-wintering pads

The majority of cattle are housed over the winter period in slatted sheds. The main source of ammonia emissions arises from concrete surfaces, where a urease enzyme present in the faeces hydrolyses the urea present in the urine into ammonium; this ammonium can later volatilise into ammonia. Therefore, abatement strategies were aimed at the separation of urine and faecal matter. The out-wintering pad (OWP) is a lower cost method of over wintering cattle compared to the conventional slatted shed. The animals are kept on a bed of wood chip approximately 40cm deep. Under the woodchip there is a drainage layer of stone; the effluent is collected by a drainage system and is generally stored in a nearby lagoon. Pads allow lower stocking density compared with slatted sheds and have been shown to improve animal health, particularly in terms of limb health (O'Driscoll *et al.*, 2008). In addition, GHG emissions and nitrate leaching may be reduced by 10% and 40%, respectively. In terms of ammonia abatement, OWPs reduce urea hydrolysis due to the fact that the urine and faeces are separated relatively quickly. In addition, precipitation will dilute the N concentration of the urine and the air temperature is generally lower than inside a shed.

In terms of choosing an application technique, the trailing shoe offers more consistent emission reduction as well as facilitating longer grassland spreading windows.

A comparative assessment of emissions from both slatted sheds and OWPs is currently being undertaken using a combination of direct measurements and Gaussian dispersion modelling, with uncertainty analysis used to assess measurement error.

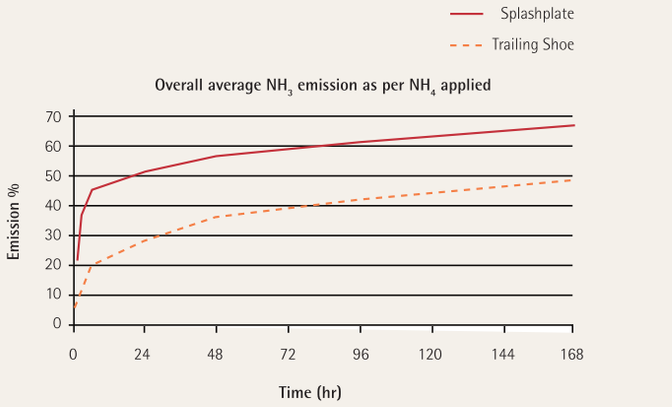

FIGURE 5: Temporal profile of ammonia emissions from splash plate and trailing shoe expressed as a percentage of total ammonical nitrogen lost.

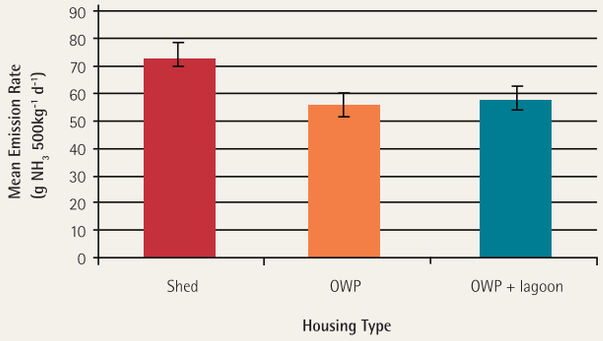

FIGURE 6: Ammonia emissions per 500kg per day compared to over-wintering type.

Over a seven-week measurement period at the start of 2007, ammonia emissions were found to be 23% lower per 500kg live weight on the OWP compared with those from the slatted shed. Average daily total emissions from the shed and OWP were 5 and 6kg, respectively.

As there were higher stock numbers on the OWP, ammonia emissions per 500kg per day were 77.3g for the shed and 57.1g for the OWP. The inclusion of the ammonia emissions from the lagoon added only 1.45g $500kg^{-1}d^{-1}$ to the OWP value (**Figure 6**).

The out-wintering pad (OWP) is a lower cost method of over wintering cattle compared to the conventional slatted shed. The animals are kept on a bed of wood chip approximately 40cm deep.

Conclusion

In light of the more stringent emissions ceilings approaching, cost-effective abatement strategies are needed. Adoption of the trailing shoe offers consistent reductions in emissions with the added benefits of more flexible spreading windows, but with added costs.

More targeted spreading, on the other hand, will reduce emissions substantially without extra cost. However, this strategy is dependent on accurate climate forecasting, particularly during any summer application. In addition, the use of OWPs for housing offers a low cost alternative to sheds with reduced ammonia and GHG/N losses. Adoption of these measures will contribute substantially to the agri-sector meeting future transboundary pollution targets.

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An economic analysis of the returns from biomass crops in Ireland

DARAGH CLANCY, JAMES BREEN, FIONA THORNE and MICHAEL WALLACE analyse the returns from willow and miscanthus production in Ireland.

There has been a recent surge of interest in the potential of biomass as an alternative to fossil fuels within both Ireland and the EU. Rising oil and gas prices, concerns about the security of imported energy supplies and Kyoto targets to reduce greenhouse gas emissions have been the principal drivers of government policy to increase the use of biomass in energy and heat production. As in other countries, the Irish Government has enacted measures to incentivise the production of biomass crops (Department of Communications, Marine and Natural Resources, 2007). Farmers who diversify into biomass crops can receive establishment grants to offset part of the initial set-up costs. In addition, the decoupling of direct payments from production now affords farmers greater freedom to switch to alternative enterprises, such as biomass crop production, without reducing the value of their existing Single Farm Payment entitlements. Consequently, farmers may have an important diversification opportunity that merits careful financial analysis.

A difficult decision

From the viewpoint of an individual farmer such analysis is not straightforward. There are important risks associated with adopting an enterprise that does not yet have a proven track record. The risks associated with biomass crops are accentuated by their lengthy production horizon compared with traditional enterprises. Consequently, it is not surprising that farmers are sceptical about the prospect of biomass crops as a viable alternative agricultural enterprise. A recent survey of Irish farmers (Connolly *et al.*, 2006) found that only 8% of respondents were willing to consider/investigate the production of biomass crops. The research reported in this article seeks to address some of the information deficit about the economics of biomass crops in Ireland.

The research

This research employed the well-established discounted cash flow (DCF) method to evaluate willow and miscanthus as investment projects. The results of the DCF are presented in terms of both the net present value (NPV) and the internal rate of return (IRR) of each investment. The NPV values an investment as the sum of the project's net cash flows discounted at the business' opportunity cost of capital. The investment project is deemed to be 'worthwhile' if it generates a positive NPV. The IRR is the discount rate that results in a project generating an NPV of zero over its economic life. This is a useful measure of the percentage return from an investment and is generally regarded as providing a better measure for ranking investments than the NPVs.

An important feature of this study was the explicit inclusion of the opportunity cost of land, through the inclusion of foregone potential returns from the market rental value of the land used to produce the biomass crop. Thus, the results presented include the estimated investment returns from a decision to switch a hectare of land from a land rental situation to a biomass crop such as willow or miscanthus.

The assumptions made relating to yields, costs and revenues from willow and miscanthus were based on a review of the relevant literature and in consultation with the Teagasc Energy Systems Specialist (**Table 1**). **Table 2** presents some of the key findings related to the economic feasibility of biomass production in Ireland, based on the NPV, the IRR and the pay back period. Table 2 shows that the IRR for miscanthus (10.15%) is significantly higher than that of willow (1.62%). Miscanthus generates a positive NPV (€929), suggesting that it would be a financially worthwhile alternative enterprise for a profit maximising farmer who currently rents out his land. Under the same rationale, the negative NPV for willow (-€489) suggests that this investment should not be made. The payback period is the point at which an investment has recouped its set-up costs and is calculated as the year in which the sum of undiscounted cash flows becomes positive. The payback period for willow is 16 years while for miscanthus it takes nine years to recoup the set-up costs. In other words, for a landowner currently renting out his/her land, it would take 16 years to make a positive return from growing willow and nine years to make a positive return from growing miscanthus, if the switch was made to biomass production. The lengthy payback period for both projects suggests that they are risky compared to conventional agricultural enterprises. A sensitivity analysis was also conducted to examine the effects of variation in key parameters on the IRRs generated from investments in willow and miscanthus. This analysis showed that the superseded enterprise, establishment grant level, yield level, price level and length of production lifespan significantly influence the returns generated by investments in willow and miscanthus.

Conclusion

It can be said that, given realistic assumptions and costings, both willow (1.62%) and miscanthus (10.15%) generate positive IRRs and can, therefore, be financially worthwhile for a profit maximising farmer. However, at least in the case of willow, the additional return is probably too low for most farmers to invest in this enterprise while foregoing average returns from a conventional enterprise. Miscanthus consistently outperformed willow in terms of investment performance. Consequently, based on these results, miscanthus is most likely to be the biomass crop of choice, given its superior yield potential, annual production cycle and cash flow profile subject to the suitability of the land for biomass production. The agronomic and economic characteristics of willow and miscanthus make them risky alternatives





TABLE 1: Model cost and revenue assumptions for willow and miscanthus.

	Willow	Miscanthus
Maximum production period	16 years	16 years
Number of harvest cycles	7 harvest cycles	15 harvest cycles
Yield level[i]	7t/DM/ha first harvest 10t/DM/ha every harvest thereafter	6t/DM/ha first harvest 10t/DM/ha every harvest thereafter
Establishment grant	€1,450 (75% payable in year 1, 25% in year 2)	€1,450 (75% payable in year 1, 25% in year 2)
Harvest strategy	Stick harvested, naturally dried, stored outdoors then chipped	Baled harvest, naturally dried, stored outdoors
Moisture content	25%	20%
Price per tonne[ii]	€55	€60
Land Rental Value	€236	€236[iii]

i All willow yield levels are expressed in annual terms unless otherwise stated.

ii Assumed price levels for willow and miscanthus based on August 2008 market prices.

iii The grazing land rental value was calculated as the average received per hectare by farmers engaged in this activity in the National Farm Survey from 2005-2007.

TABLE 2: Baseline investment performance in per hectare terms.

	Net present value*	Internal rate of return	Payback period (years)
Willow	-€489	1.62%	16
Miscanthus	€929	10.15%	9

** Discount rate is 5%.*

compared to many conventional farm enterprises. For example, the lack of information regarding the crops' suitability to Irish soil and climate means that yield levels are difficult to predict. The price level is also highly uncertain as the market for energy crops in Ireland is still in its infancy. Moreover, the lengthy production lifespan of energy crops serves to heighten the level of risk associated with key parameters. Uncertainty about critical variables such as the annual yield level and the energy price make it difficult to accurately calculate the returns of such investments. However, ongoing research projects in Oak Park Crops Research Centre are addressing these knowledge deficits. Accordingly, it can be expected that more risk-averse farmers are unlikely to find biomass production an attractive investment prospect during the pioneer stage of the bioenergy market in Ireland. More widespread adoption is only likely when the economic merits of these crops have been proven over an extended period.

This research was funded by the Department of Agriculture, Fisheries and Food Research Stimulus Fund.

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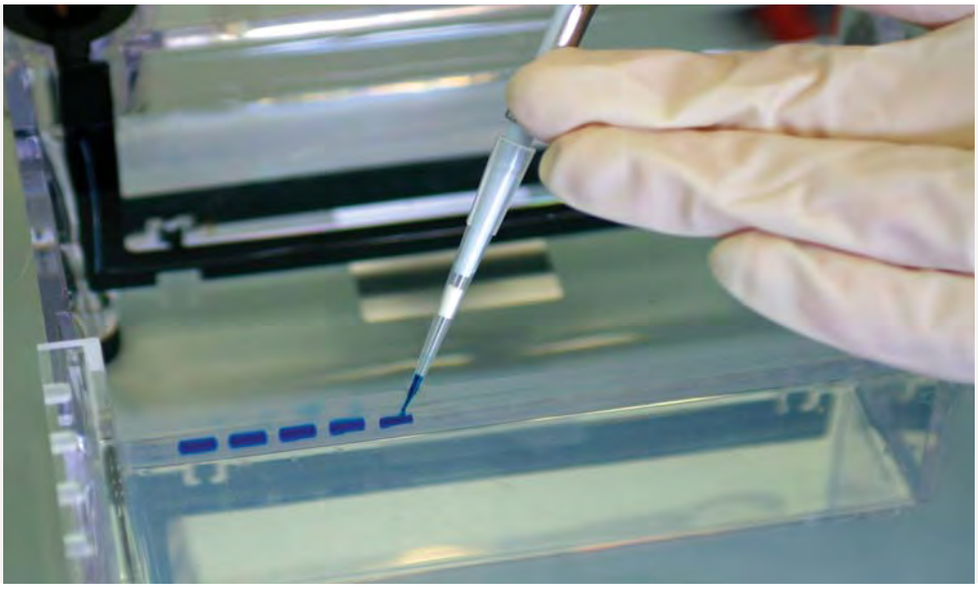
Technology opportunities at Teagasc



Rapid assessment of bacterial load in perishable foods, a PCR-based approach

(Ref CO 002)

The microbial quality and safety of a food is dependent on the microbial load, diversity and composition of the microflora. A rapid means of evaluating microbial load of perishable food products has been developed at Ashtown Food Research Centre, based on a specific nucleic-acid based assay, which measures both gram-positive and gram-negative bacteria, as reported in the previous issue of *TResearch*. This assay has been validated against the gold standard Total Viable Count (TVC) method for meat and shown to offer time and precision advantages for microbiological assessment and shelf-life prediction. Subject to further funding, the group aims to continue work in this area on validation for other perishable food products, including fish, ready-to-eat foods and raw milk. This would greatly broaden the potential applicability of the assay.

Teagasc would like to hear from companies that currently carry out such total viable count assays on a large scale and who would be interested in this rapid assay, with the aim of evaluating and validating this assay for a range of food products, commencing with meat. Following such evaluation, there may be the opportunity for such companies to license this technology from Teagasc to use in specific fields of use.

Method of detecting a recently discovered source of blown pack spoilage in meat using real-time PCR

(Ref CO 003)

Although blown pack spoilage (BPS) of vacuum packaged meat by psychrophilic Clostridial species is a food quality rather than safety issue, meat spoiled in this way has no commercial value and thus represents a considerable loss to meat processors in monetary terms.

A PCR-based means of detecting a newly discovered source of BPS in meat products was reported by a group at Ashtown Food Research Centre in the previous issue of *TResearch*. Indeed, a patent application has been filed in this area. The new species causes BPS at an intermediate rate between those of *C. gasigenes* and *C. estertheticum* and contaminated vacuum-packaged meat would spoil within four to six weeks. This novel technology is essential in assessing the risk of spoilage, to validate decontamination procedures, etc.

Teagasc is currently devising a commercialisation plan for this technology with a view to being able to provide such a service either directly to interested end users or through licensing this technology to interested parties following validation and cost benefit analysis.

Further details of these offers were reported in TResearch 2008; 3 (4): 50.

For further information on development and licensing opportunities contact: Miriam Walsh, PhD, Intellectual Property Officer, Teagasc.
E-mail: miriam.walsh@teagasc.ie; Tel: 059 918 3477; Mob: 087 911 3960.

T Events

Science Events

March

Botanic Gardens, Clonakilty, Ballyhaise, Gurteen, Pallaskenry, Kildalton, Mountbellew

Teagasc colleges open days

See web for details of dates for open days at each college. *www.teagasc.ie*

March 3 — *Ashtown Food Research Centre*

Food Law Update 2009

Presented by Leatherhead Food International, the 2009 Food Law Update will highlight new and developing legislation of interest to the food and related industries. This training course will be of benefit to those wishing to keep up-to-date with a broad range of food law issues, those interested in increasing their awareness, or those with only limited responsibility in this area.
help@leatherheadfood.com *www.leatherheadfood.com*

March 5-6 — *Norwegian School of Veterinary Science, Oslo, Norway*

The Ecology of Pathogenic *E. coli* – international conference

As part of the Pathogenic *Escherichia coli* Network (PEN) project funded by the European Commission's Sixth Framework Programme and co-ordinated by Dr Declan Bolton, Ashtown Food Research Centre, Teagasc is organising an international conference on 'The Ecology of Pathogenic *Escherichia coli*', to be held in The Norwegian School of Veterinary Science. This is the fourth in a series of five international conferences that have previously included 'Methods of Detection and Molecular Characterisation of Pathogenic *Escherichia coli*' (Chipping Campden, UK, July 2007), '*Escherichia coli*: Pathogenicity, Virulence and Emerging Strains' (Rome, March 2008) and 'Epidemiology and Transmission of VTEC and other Pathogenic *Escherichia coli*' (Stockholm, Sweden, September 2008).
declan.bolton@teagasc.ie *www.pen-europe.eu*

March 12-13 — *Tullamore Court Hotel*

Agricultural Research Forum Meeting

The Agricultural Research Forum (ARF) is a resource that provides Irish agricultural researchers with a means to inform colleagues about their work. Areas covered include animal and crop science, environmental and soil science, food science, agri-economics, forestry and related topics.
The annual meeting of the ARF provides an opportunity for the presentation, discussion and publication of research results.
michael.diskin@teagasc.ie *www.agresearchforum.com*

March 20 — *Ashtown Food Research Centre*

The Epidemiology of *Campylobacter* on Irish Poultry Farms – seminar

This project was funded by the Food Safety Promotion Board (safefood). The project investigated the sources and dissemination patterns of *Campylobacter* on six Irish poultry farms and examined antibiotic resistance profiles. The results will be presented and discussed with a view to establishing clear recommendations for poultry farmers on how to reduce the risk of poultry infection with *Campylobacter*.
declan.bolton@teagasc.ie *www.teagasc.ie*

March 25-26 — *Ashtown Food Research Centre*

ProSafeBeef – international conference

ProSafeBeef is a European Commission Sixth Framework Programme-funded project, co-ordinated by Teagasc, Ashtown, aimed at 'Advancing Beef Safety and Quality through Research and Innovation'. The key findings presented at this international conference will be in the area of strategic and targeted controls for microbial pathogens and chemical residues in beef.
The ProSafeBeef project is an EU 'food-chain' RTD initiative. The ProSafeBeef consortium is multidisciplinary and is comprised of 41 participants from research institutes, universities, private companies and industry organisations from 13 European countries, as well as Brazil, the United States, Canada, Australia and New Zealand.
geraldine.duffy@teagasc.ie *www.prosafebeef.eu*

March 30-April 1 — *Irish Management Institute, Dundrum, Dublin 16*

Agricultural Economics Society Conference – international conference

The challenges posed for agriculture by growing environmental concerns and the continuing advancement of rural development in Ireland and the UK will be discussed.
In relation to agriculture, Professor Frank Convery (UCD) will outline the environmental challenges facing the sector, while Tom Arnold (Concern) will discuss the implications for the developing world.
secretary@aesi.ie *www.aesi.ie*

April

April 2 — *Hudson Bay Hotel, Athlone*

Organic Conference

www.teagasc.ie

May

May 7-9 — *Prague, Czech Republic*

Research Connection 2009

A networking event for scientists, industrialists and researchers, this event will present the opportunities available from three major ongoing research initiatives: The Seventh Framework Programme, The Structural Funds and The Competitiveness and Innovation Programme.
rtd-2009@ec.europa.eu www.ec.europa/research/rtd-2009

June

June 9 — *Moorepark Food Research Centre*

Moorepark Food Research Centre open day

www.teagasc.ie

September

September 9-11 — *Teagasc Johnstown Castle, Wexford*

Soil quality: does it equal environmental quality?

A joint meeting of the British Soil Science Society and the Soil Science Society of Ireland. This conference will address the following issues: What is the significance of soil quality; and, specifically: What can soils do for the wider environment? What are the benefits to the biosphere, agriculture and humanity? What are the threats to soil quality and what is the extent of these threats in Britain and Ireland?
rachel.creamer@teagasc.ie *www.soils.org.uk*

September 21-22 — *Moorepark Food Research Centre*

***Listeria monocytogenes* conference**

With increasing cases of listeriosis in recent years, it is important that the results of a large number of research projects on this subject are disseminated. This conference will be of interest to industry personnel that need to be aware of *L. monocytogenes* and to those working with the organism in a clinical or surveillance setting.
kieran.jordan@teagasc.ie *www.teagasc.ie*

October

October 14 — *Hudson Bay Hotel, Athlone*

Artisan Food/Rural Tourism Conference

www.teagasc.ie

November

November 12 — *Hudson Bay Hotel, Athlone*

Equine Conference

www.teagasc.ie

Leading the knowledge-based development of Ireland's Farming and Food Industry

Teagasc, the Agriculture and Food Development Authority, generates and applies new knowledge for the sustainable development of agriculture and the food processing industry to enable it to respond profitably to consumer demands and requirements and contribute to a vibrant rural economy and society.

Through the continuing development of Centres of Excellence in biotechnology, Teagasc will implement new research strategies based on scientific excellence, to underpin the long term knowledge needs of the agri-food industry.

Teagasc research science focuses on:

- Enhancing competitiveness through innovation in sustainable agricultural production and the food-processing sector
- Strengthening our capacity in molecular biology and gaining an increased understanding of living organisms with a view to increasing their application in the agri-food industry
- Providing sound scientific basis for decision-makers in protecting the integrity of the food chain, protecting the rural environment and addressing the concerns of the consumer
- Analysing and projecting the impact of policies for the agri-food sector
- Nourishing links with academic institutions through the Walsh Fellowship Postgraduate Programme

To deliver our ambitious scientific programme,
Teagasc needs to continuously attract and recruit the best and brightest people.

Details of opportunities are available on
www.teagasc/careers.ie

NDP
National Development Plan 2007 - 2013
Transforming Ireland

teagasc
Agriculture and Food Development Authority