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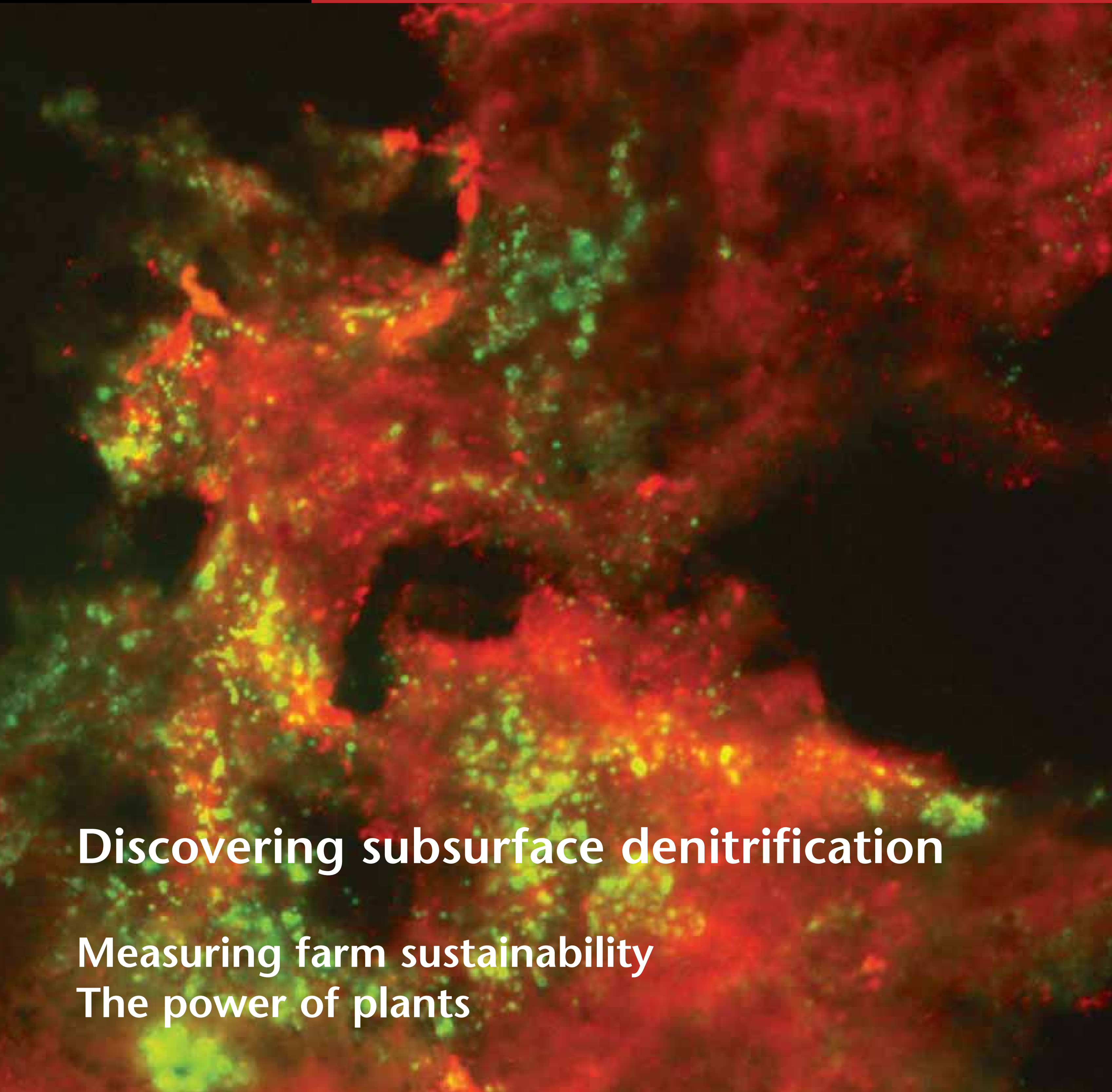
T Research

Research and innovation news at Teagasc



Discovering subsurface denitrification

Measuring farm sustainability
The power of plants

Volume 4: Number 3. Autumn 2009

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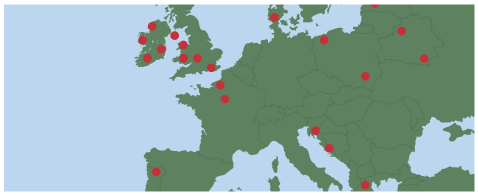
The future of food research in Teagasc

The food sector plays a critical role in the Irish economy and is our largest indigenous industry. It comprises a mixture of companies, from large co-ops to smaller, often highly innovative enterprises, important for development at both regional and national levels. There is tremendous scope in the food industry to develop more innovative and knowledge-based food products, which would undoubtedly have positive knock-on effects in terms of milk and meat price. We have seen this first hand in Finland and Japan, where emphasis has been placed on extracting an economic dividend from R&D in food, particularly in health. Teagasc food research occupies a very important strategic niche, spanning the academic research landscape and the industry itself. Indeed, the significant investment in food research funding over the last 15 years has resulted in the generation of a significant knowledge base within Teagasc centres and at a number of Irish universities. The current challenge is to capitalise on this shared intellectual resource in order to maximise economic return for the food industry. There are few organisations in the world like Teagasc, where true farm-to-fork type research can be performed. This includes everything from ensuring the safety and nutritive value of raw materials, to the application of biotechnology and new process technologies, to the development of new food ingredients. Our future direction, however, will have to be stringently aligned to the industry we serve to ensure competitiveness on national and international stages. In this respect, we intend to engage in new and inventive ways of integrating our research into an economic agenda that also includes partnering with key national and international companies. This not alone serves a foreign investment agenda, but will also yield unique opportunities for partnering with many of our own national industries.

To conclude, in an environment where the economic payback from national research investment is being questioned, the Teagasc food research centres have never been more essential to our food industry.

Professor Paul Ross
Head of Food Research

T Horticulture



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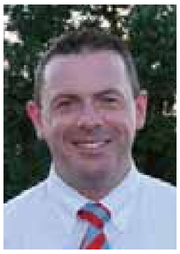
T News

New Head of Food Research



Teagasc has appointed Professor Paul Ross as Head of Food Research. In this role, Professor Ross will have responsibility for providing overall leadership for the Teagasc food research and innovation programme, which is delivered at the two food research centres – Moorepark in Cork and Ashtown in Dublin. The food research programme has a budget of €18 million and is designed to meet the research and innovation needs of the Irish food industry. It covers areas of food safety, foods for health, food ingredients, food cultures, meat research, dairy technology and prepared foods.

As well as leading the Teagasc food programme, Professor Ross has responsibility for the day-to-day management of Moorepark Food Research Centre. He also joins the board of Moorepark Technology Limited, a joint venture pilot plant that offers facilities and services to companies in the food industry to scale up research and new product testing.

Congratulating Paul on his appointment, Teagasc Director Professor Gerry Boyle said: "We are determined to build on the successful Teagasc food programme established by Professor Liam Donnelly, who retires later this year. Led by Paul, our researchers will work closely with our colleagues in industry and through our national and international research networks, to generate and apply new knowledge to develop the Irish food processing industry".

Top research paper

The Teagasc research paper:

Pang W.Y., Earley B., Gath V., and Crowe M.A. 'Effect of banding or burdizzo castration on plasma testosterone, acute-phase proteins, scrotal circumference, growth, and health of bulls' (*Livestock Science*, 2008, 117: 79-87)

was recently selected as one of the top ten in medicine and surgery of food-producing animals in 2008. The selection criteria included excellence in study design, statistical analysis and a high likelihood that the results will impact food animal practice.

The selection of this paper demonstrates the research to be internationally competitive, and reflects well on the quality of research conducted in Teagasc. The Teagasc research was carried out by a Walsh Fellow, Wanyong Pang, under the supervision of Dr Bernadette Earley, Teagasc, and Dr Mark Crowe, UCD. The selection of this paper indicates that their research is achieving excellence at an international level.

The selection of the papers was undertaken by Professor Constable, a leading US veterinary scientist and Head of the Department of Veterinary Clinical Science in Perdue University. He screened the top 50 veterinary journals and 40 animal agricultural journals as part of the selection process. The evidenced-based articles reviewed dealt with important topics likely to become "difference makers", and that serve as models for research that scientists should aspire to undertake. Professor Constable highlighted the papers at the American College of Veterinary Internal Medicine Forum in Montreal in June in a talk titled 'Top ten evidence-based papers in food animal medicine and surgery for 2008'.

Researcher profile

Dr J.P. Hanrahan

Dr J.P. (Seamus) Hanrahan (BAgrSc, MS, PhD) is Head of the Sheep Production Department at Teagasc, Animal Production Research Centre, Athenry, Co. Galway.

Dr Hanrahan received his BAgrSc (Animal Production) from University College Dublin and an MS in Animal Breeding and PhD in Quantitative Genetics and Statistics from North Carolina State University, USA. He joined An Foras Talúntais as a Senior Research Officer in 1971, became a Principal Research Officer in 1981 and Senior Principal Research Officer in 1984. In 1985 he was appointed Acting Assistant Director. He has been Head of the Sheep Production Department since 1981, and from 1990 until 2005 served as Officer in Charge, Teagasc Research Centre, at Belclare (1989-1997) and Athenry (1997-2005).

Dr Hanrahan's main research interests are: genetics of reproduction in sheep, with particular emphasis on genetic control of ovulation rate and embryo survival; identification of major genes affecting ovulation rate; genetics of disease resistance; artificial insemination in sheep; and, genetic variation in lamb growth and carcass composition. The research programme on genetics of reproduction led to the development of the Belclare breed, which was released to the industry in the mid 1980s with further modifications being released through the 1990s.

Seamus worked as a part-time lecturer on experimental statistics at University College Galway between 1973 and 1978. He was the invited lecturer on genetics of reproduction at the International Centre for Advanced Mediterranean Agronomic Studies, Zaragoza, Spain, between 1984 and 1990. He was visiting scientist at the Commonwealth Scientific and Industrial Research Organisation in Armidale, Australia, from July 1980 to June 1981, and at Invermay Agricultural Centre Mosgiel, New Zealand, from June 1981 to July 1981.

From 1994 to 1998 he was a member of a team involving the faculties of Agriculture and Veterinary Medicine at UCD and Teagasc for a European Community/Jordan Co-operative Project in Science and Technology concerning improvement of sheep production in Jordan. He has provided training courses in animal reproduction techniques for scientists from Hungary, Syria, Egypt and Iceland.

Dr Hanrahan has been Genetics Editor, *Animal Production* (subsequently *Animal Science*), Senior Editor, *Irish Journal of Agriculture and Food Research*, and an *ad hoc* reviewer for a number of eminent publications. He is the author of more than 60 papers in peer-reviewed journals and invited contributions to international conferences plus numerous papers to scientific meetings/conferences.

He is a member of the Society for the Study of Fertility, the British Society of Animal Science, and the New Zealand Society of Animal Production. In 2007 he was elected Honorary Life Member by the British Society of Animal Science.

T News

Agri-environment workshop

The agricultural ecology research programme at Johnstown Castle is developing the evidence base to support the design and delivery of agri-environment schemes. Dr Daire O hUallacháin recently held a workshop at Johnstown Castle to highlight different management methods for biodiversity of field margins and riparian watercourses. The event was attended by Teagasc researchers, Teagasc Advisory staff, and staff from the Department of Agriculture, Fisheries and Food, the National Botanic Gardens, UCC, UCD and the National Parks and Wildlife Service. Using a combination of seminars and visits to field sites, participants learned about best practice in field margin establishment and management, and management of the vegetation alongside watercourses.

Key messages from the workshop included the importance of suitable management of field margins and riparian zones, in particular the value of treatments such as periodic grazing, mowing and cutting of vegetation. The workshop also highlighted the biodiversity benefits of both vegetation diversity and structural diversity.

Attendees at the recent workshop held at Teagasc, Johnstown Castle.

2012 International Nitrogen Workshop

Johnstown Castle Environment Research Centre will host the 2012 International Nitrogen Workshop.

"We are now chasing the missing links in the nitrogen cycle at biogeochemical, farm and landscape level. This full understanding of all pathways of nitrogen is essential to develop cost-effective strategies to increase N-efficiency in agriculture". This was the message presented by researchers from Johnstown Castle at the 16th International N-workshop in Turin, Italy, at the end of June. This workshop, attended by over 300 scientists and extensionists from around the globe, focused on integrating our understanding of N-dynamics across spatial scales from soil to landscape. At the close of the conference, Dr Karl Richards and his colleagues accepted the honour of bringing the next International N-workshop to Ireland in 2012.

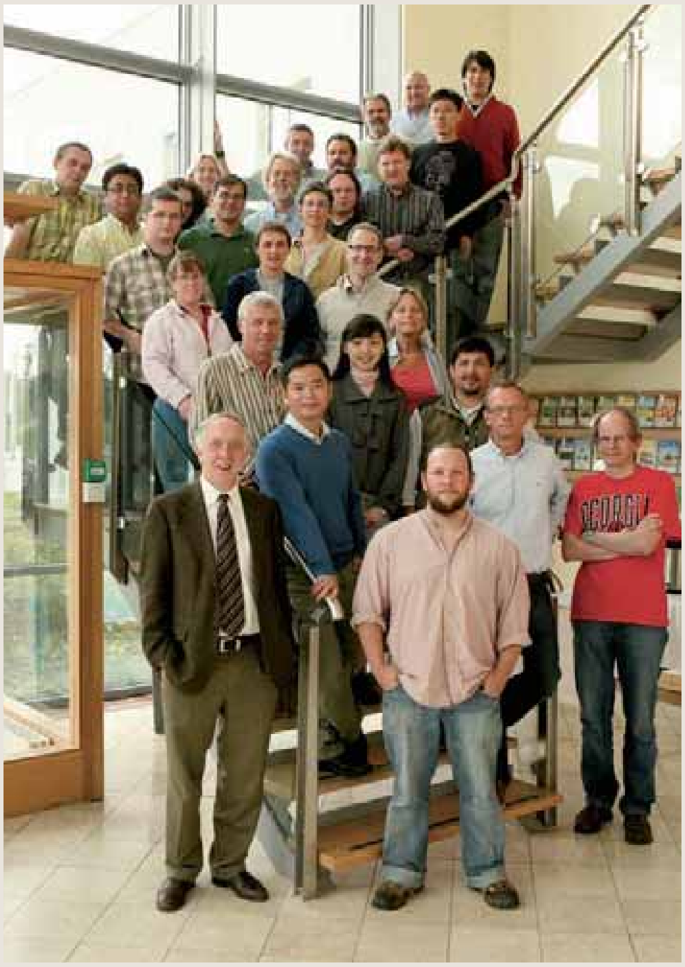
Wheat rust disease

Dr Jeff Ellis, CSIRO Crop Science Department, Australia, recently addressed researchers at Teagasc Oak Park on: 'The challenge of rust diseases for Australian and world wheat production' during a visit to the research centre. Dr Ellis has worked at CSIRO Plant Industry since 1982, researching gene regulation and host-rust disease interactions in plants. He is currently involved in the use of gene transfer technology to unravel fundamental aspects of plant biology application of molecular biology to crop plant improvement through disease and pest resistance. He has applied this technology to identifying and isolating genes involved in plant resistance to rust fungi. These genes include: host plant resistance genes of the nucleotide binding-leucine rich repeat class, and avirulence genes from the flax rust fungus that encode small secreted proteins.

His current research activities include: molecular basis of recognition of rust avirulence proteins by plant resistance proteins; route of entry of avirulence proteins from the fungus into the plant cell; and, biological function of rust-secreted proteins in disease. It aims to improve understanding of the biological basis of rust resistance and rust disease for improved control of these diseases in crop plants.

Dr Jeff Ellis, CSIRO Crop Science Department, addressing researchers at Oak Park.

International PGSC meeting



Professor Jimmy Burke and Dr Dan Milbourne (front from left) with members of the Potato Genome Sequencing Consortium at Oak Park.

The international Potato Genome Sequencing Consortium (PGSC) had a landmark meeting at Oak Park Research Centre this June. Nearly 30 scientists from 10 different countries came together at Teagasc Oak Park in Carlow to discuss the schedule for the release of a draft sequence of all 12 chromosomes of the potato genome. The group hopes to publish the draft sequence at the end of the year. The PGSC was welcomed to Ireland by Dr Dan Milbourne, whose group has been involved in the sequencing project from its conception, and by Professor Jimmy Burke, Oak Park Head of Centre.

Oak Park appointment

John Spink has joined Oak Park Crops Research Centre as part of the Teagasc Vision Programme. John comes to Teagasc from ADAS in the UK. His research focus will be on crop agronomy and crop physiology.

Teagasc activity highlights – April to June 2009

The following are some highlights of Teagasc activities and initiatives since the start of the year, aimed at supporting science-based innovation in the agri-food sector and wider bio-economy that will underpin profitability, competitiveness and sustainability:

- 62 new refereed papers and 202 other articles were published by Teagasc researchers and their collaborators.
- Three successful Open Days were held:
  –Moorepark Dairy Production Centre: 'New thinking for Challenging Times' – estimated numbers 7,000 (see p 8-9);
  –Moorepark Food Processing: 'Food Innovation in the Knowledge Economy' – estimated numbers 200 (see p 10-11); and,
  –Oak Park Research Centre: Tillage Crops Open Day, Knockbeg Research Farm – 'Responding to Challenges' – estimated numbers 500.
- A new website was launched during May that provides an up-to-date account of grass growth and animal performance on four different beef systems at Grange. It also gives an overview of the Teagasc/*Irish Farmers Journal* BETTER beef farms initiative – http://www.agresearch.teagasc.ie/grange/researchfarms/index.asp.
- The Teagasc Rural Economy Research Centre, in association with the Agricultural Economics Society of Ireland and the UK Agricultural Economics Society (AES), hosted the annual AES conference in Dublin from March 31 to April 1. Over 200 national and international agricultural economists attended. A pre-conference joint meeting focused on two themes: 'Balancing competitiveness and environmental sustainability: future challenges facing agriculture', and 'Understanding and promoting better rural development policy: UK and Ireland experience'.

Milking machines manual

A new manual on the installation and testing of milking machines has been prepared by Teagasc (Eddie O'Callaghan and Tom Ryan) under the umbrella of the Irish Milk Quality Co-Operative Society (IMQCS). The organisation was incorporated in 1989 with the aim of improving milk quality standards in Ireland, to ensure that Irish milking machine installation and testing standards exceed the best international standards. This manual combines IMQCS guidelines and new ISO (International Standards Organisation) standards (ISO 5707 [2007], ISO 6690 [2007] and ISO 3918 [2007]) into a reference guide for milking machine installers and advisers in the Republic of Ireland. The IMQCS guidelines and ISO standards have been developed to ensure best practice in the installation and testing of milking machines and are not a legal requirement. The basis of the manual is compliance with existing standards, directives and legislation, and agreed installation practices for the fitting of new milkline and recorder parlour plants for cows. Where possible and practicable the recommendations shall be applied to existing installations.

T Feature

Leading Europe – Finnish innovation policy

A delegation from Teagasc recently visited Finland to see what Ireland can learn from its progressive innovation policies. LANCE O'BRIEN reports on the important role of Public Research Organisations (PROs) there.

Over the past two decades economic and social progress in Finland has largely resulted from the development of high technology, its effective utilisation and determined efforts to increase exports, all within the context of a unique approach to innovation. Since the early 1990s, innovation policy objectives have been considered within the context of a national innovation system (NIS) approach, based on a high quality educational system, long-term investments by enterprises and the public sector in research and development (R&D), 'joined up' policies and well-functioning, networked institutions.

Finland consistently ranks as one of the leading countries in innovation, as measured in terms of growth, competitiveness and technological infrastructure. In 2008, Finland's innovation performance was above or close to the EU average in the individual indicators of the European Innovation Scoreboard (EIS) and the country belonged to the innovation leaders. Among EU member states, Finland ranks second out of 27 countries and third out of 37 countries covered by the Summary Innovation Index (SII), after Sweden and Switzerland. In 2008, Finland adopted a new 'broad-based' innovation policy that not only focuses on the development and reform of the knowledge-based competitiveness of business, national economy and regions, but also supports reform of the public sector and the services sector. In other words, policies aiming to enhance and promote innovation are not restricted to manufacturing and R&D-intensive technologies, but also take into account opportunities for innovation in all areas of the economy and society.

As a consequence, Finland can be considered to be a knowledge society as, in international terms, it is able to exploit to an exceptional degree opportunities arising through knowledge-intensive growth. It has moved from being an economy based on natural resources to a knowledge-based economy. However, the primary, natural resource sector has not been downgraded during this period of rapid change in industrial structure: products and production methods have become more knowledge-intensive in the economy overall, meaning that the country is better equipped to face future challenges.

Research and development

Finnish innovation policy recognises the primary role of research as a source of and precondition for innovation. The diversity of innovation in the country relies on a strong and diverse research base in both the public and private sectors. R&D investments in Finland in 2007 amounted to €5.7 billion, or 3.4% of GDP. (The Lisbon target for R&D in the EU as a whole by 2010 is 3% of GDP.) A particularly important goal is to increase R&D funding to 4% of GDP over the next few years. The very extensive and multi-faceted public sector research system (comprising a higher education sector of universities and polytechnics and a strong State research institute infrastructure) accounted for €1.7 billion (28%), while private enterprise invested €4.2 billion (72%). This level of public R&D investment places Finland among the leading countries of the OECD. The proportion of research personnel in the total Finnish labour force is the highest of all the EU and OECD countries. Finland is also one of the world's biggest science publishers, relative to population and GDP. Finnish science is at the leading edge of developments in a number of fields, including the forest, chemical and metal industries, ICT, software and electronics, new materials, environmental technologies, functional food, biotechnology and knowledge-intensive services.

Public Research Organisations

Unlike many other countries, where the focus of R&D and innovation policy is almost exclusively on university-based research, Finland also accords a significant role to Public Sector Research Organisations (PROs) in its system of innovation. The country possesses a particularly well-developed group of PROs in key sectors of the economy. Currently, there are 19 PROs operating in eight different sectors. In 2008, over 16% of the Government's total R&D funding, amounting to €282 million, was allocated to PROs. In addition, these organisations generated a further €227 million through external funding.
PROs were established in many countries following WW2 in response to perceived actual or potential market or systemic failures. Specifically, they were established to provide R&D, technology and innovation services to enterprises, governments and other clients. Traditionally, PROs were distinguished from university research on the basis of their clear economic/social mission and their primary role as instruments of technology transfer. A study of Finnish institutes concluded that their main aims are to: "Provide, produce and transfer knowledge in support of strategic decision making and social and economic development; engage in strategic research aimed at sustaining the high quality of the applied research, recognising the needs and challenges for future research and creating the capabilities to solve the problems in the future; and, perform specific sector and organisation functions defined in their enabling legislation" (Hyytinen *et al*, 2009).
More recently, in the past 20 years or so, the environment for PROs worldwide has changed, as has their position within that environment. In Finland, as in many other countries, their roles and functions compared to universities and private sector R&D are becoming blurred. In addition, they are being impacted by changing views of what constitutes 'public good' research, by new government research priorities and pressures on public spending. Such pressures have resulted in an increased requirement on institutes to generate more commercial income and, in many cases, have resulted in the privatisation of PROs or their complete disappearance. While all of these policies have been adopted in Finland, that country is also distinguished by the continuing priority accorded to a large body of PROs and a strong commitment to redefining their roles and responsibilities within the framework of ongoing State support.
The Finnish Government is committed to the promotion of sectoral research institutes as part of its commitment to upgrade the entire research capacity and utilise it more effectively. As part of the overall reform of publicly funded research, sectoral research institutions will be transformed into international research organisations, which will have a multidisciplinary focus and be expected to produce findings of greater social relevance. These institutions will be expected to work closely and innovatively with higher education organisations and regional centres of expertise, producing know-how that will support regional, national and global decision-making, ensuring the ongoing success of Finland's broad-based competitiveness.

Lessons for Teagasc

A key lesson from the successful Finnish experience is that innovation results from the input of a wide range of different actors in the public and private sectors working together in a well-managed system. In the case of R&D, Finnish success demonstrates the benefit of maintaining and supporting research organisations with different missions, while ensuring that these institutions work closely together. The lesson for Teagasc is that it cannot work in isolation. As was clearly stated in the report of the recent Teagasc Foresight exercise – *Teagasc 2030* – the complex challenges now facing agriculture, food and other bioeconomy sectors in Ireland can only be addressed on the basis of active and deep-rooted collaboration among all interested parties. Teagasc must, therefore, develop strategic partnerships independently of project and programme funding cycles. This commitment is being implemented through a planned series of discussions with university partners and with other State support agencies, with a clear view to enhancing the innovative activity of Ireland's agri-food industry.

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Teagasc 2030 Foresight Report (2008) [online] available from: http://www.teagasc.ie/publications/2008/20080609/ForesightReportVol1.pdf.

Dr Lance O'Brien is Head of Foresight and Strategy Development based at Teagasc Head Office. E-mail: lance.obrien@teagasc.ie.

Latest research results from the Moorepark Open Day

Moorepark recently hosted an open day to present the latest dairy production research results to the farming public. JOHN MEE discusses the highlights and presents the exit poll findings.

The Moorepark 2009 'New Thinking for Challenging Times' event attracted upwards of 7,000 visitors.

2009 is the 50th anniversary of the establishment of Moorepark. As part of its contribution to the development of the Irish dairy industry over the past 50 years, Moorepark has hosted annual thematic and bi-annual large-scale open days. Upwards of 7,000 visitors attended the most recent large-scale open day, where they could interact with researchers and advisors at research stands, villages, demonstrations, and in a farmer-led conference. The 2009 milk production season has put major pressure on dairy farmers to maintain income due to the large reduction in milk price, particularly on farms with a high debt-to-milk price ratio. Hence, this year the focus was on new approaches to profitable milk production, grassland management, dairy cow reproduction, animal health and grass-based genetics. In addition, the latest results from the milk quality and composition, alternative feeding strategies, Moorepark food research, and environmental sustainability and energy efficiency research programmes were presented.

New approaches to profitable milk production

Variable farm gate milk prices will necessitate the development of lower cost production systems so that Irish dairy farmers can remain profitable in low milk price years. The mindset and approach to milk production on Irish dairy farms must change after milk quotas are abolished in 2015. Post quota, profitability per hectare, not per cow, will be the core objective. This change in focus will be achieved by increased home-grown pasture production and utilisation, increased stocking rates, accelerated heifer and cow calving rates, reduced supplementary feed usage and a more efficient dairy cow. Recent research results demonstrate that considerable potential exists to increase profitability beyond historical levels through improved management practices in combination with appropriate animals. The production system will continue to be based on a predominantly pasture diet. Pasture eaten per hectare and control of costs are the two drivers of farm profitability post quota. This new approach will only be successful if farmers use animals capable of surviving and performing in higher stocking rate systems. These animals will be healthy, and have aggressive grazing behaviour, high milk solids production, a 365-day calving interval, and retain a satisfactory body condition score.

Pasture to profit

The results of a recent survey conducted by Teagasc Moorepark concluded that grazing practices are suboptimal on 90% of dairy farms. Hence, there is tremendous scope for dairy farmers to increase utilisation of grazed grass and reduce feed costs. This can be achieved by adoption and application of grassland technologies such as the spring rotation planner, strategic use of on/off grazing, grass measurement using 'pasture wedge technology', autumn grass budgeting and increasing the perennial ryegrass proportion of grazing swards. For example, every extra day's grazing in the autumn is worth €2.10/day. Work at Moorepark has shown that autumn closing management has the largest effect on early spring grass. Each day delay in closing from October 10 to December 11 reduces spring herbage mass by 15kg DM/ha/day. Research indicates that the first paddocks should be closed in early October, with at least 60% of the farm closed by the end of the first week in November. Farm profitability can be increased substantially (€250 to €350/ha) by the application of better grazing management practices such as these (Kennedy *et al.*, 2009).

Increasing cow fertility

Nationally, dairy cow fertility continues to be sub-optimal. Moorepark results show for the first time that cows with a high genetic merit for fertility take less time (28 days) to go back in calf and they had the same actual milk production as cows with low genetic merit for fertility. This shows that it is possible to breed for superior production and fertility. In addition to poor fertility, usage of artificial insemination (AI) remains low, with only 53% of heifers born sired by an AI bull. These two constraints to better herd reproductive performance need to be addressed before the true genetic potential of the national dairy herd can be exploited. A survey carried out by Teagasc Moorepark highlighted the inability to identify cows in oestrus (heat) as a major reason for the current low level of AI use. The recent fertility research programme at Moorepark has focused on strategies to increase heat detection efficiency and submission rate. This work has shown that automated heat detection using an activity collar could correctly identify cows in heat 82% of the time. Further trials are ongoing. Another study comparing oestrus synchronisation regimes with natural breeding demonstrated that, while treated cows had similar conception rates to control cows, their calving date was on average eight days earlier. Some of these synchrony protocols did not require heat detection (fixed-time AI schedule).

Controlling infectious animal diseases

Part of the recent animal health research programme at Moorepark has concentrated on the non-statutory diseases such as bovine viral diarrhoea (BVD), infectious bovine rhinotracheitis (IBR) and others. The latest results from a Teagasc survey of bulk tank milk samples have shown that there is widespread exposure (up to 90% for BVD and leptospirosis and 65% for IBR) to endemic infections on dairy farms. While dairy farmers and their local veterinary practitioners have responded to this threat to their livestock with vaccination programmes, survey responses indicate that there is underutilisation of biosecurity measures and novel diagnostic technologies. There are no national control programmes for these diseases. However, Animal Health Ireland (AHI), which was established in 2009, will co-ordinate research and dissemination programmes towards better control strategies on a national basis. Teagasc Moorepark staff are playing an active role in the Technical Working Groups of AHI.

Grass-based genetics

The ideal dairy cow for Ireland, irrespective of coat colour, is a healthy cow that will efficiently deliver high milk solids from grazed grass and continue to go back in calf year on year. Research at Moorepark, in collaboration with industry partners such as the Irish Cattle Breeding Federation (ICBF), is using tools such as the economic breeding index (EBI), active bull list, genomic selection and crossbreeding studies to improve dairy cattle breeding in Ireland. For example, the EBI is continually being revised in light of changing economic policies as well as availability of additional data and greater understanding of novel traits. Genomically selected sires are now available, though with a low reliability (approximately 50%). The crossbreeding work at Moorepark since 1996 has demonstrated significant animal performance benefits. Reproductive efficiency and survival of the crossbred cows is markedly improved compared to the Holstein-Friesian. These benefits compensate for any loss in the value of the cull cows or male calves. Recent trials have focused on the Norwegian Red and the Jersey breeds. These studies will greatly assist the development of an across-breed evaluation for Ireland.

Exit poll

A total of 156 visitors responded to the questionnaire, of which 49% found the event helpful and 51% found the day very beneficial. Apart from respondents who came to see all the exhibits (57%), the majority of visitors came to see the principles of grassland management (26%), turning grass into money (22%) and grassland science and technology exhibits (14%). Among the single exhibits that stood out for visitors, the top three were the grassland presentations and demonstrations (49%), the animal health presentations (14%), and the presentations on costs and profit (7%).

Moorepark '09 Irish Dairying – New Thinking for Challenging Times, the Moorepark Open Day, 2009, was sponsored by FBD.

Associated publications

Buckley, F. (Ed.) (2009) 'Moorepark '09 Irish Dairying – New Thinking for Challenging Times', Teagasc: Moorepark Dairy Production Research Centre, 140 pages [online] available from www.teagasc.ie/publications/2009.

Kennedy, E., van Bysterveldt, A. and O'Donovan, M. (2009) 'Grazing Notebook', Teagasc: Moorepark Dairy Production Research Centre and the *Irish Farmers Journal*, 49 pages.

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Building capacity in functional foods

Teagasc has recently been upscaling its investment in functional foods research, and in an open day to celebrate its 20th anniversary, Moorepark Food Research Centre showcased its research in this area.

Image courtesy of Bord Bia.

An industry-focused open day took place at Moorepark Food Research Centre recently, themed 'Food Innovation in the Knowledge Economy'. The open day celebrated 20 years of research at Moorepark with exhibitions on research in functional foods, food ingredients, dairy foods and food quality. The interaction with industry, for which the centre has achieved a strong international reputation, was also highlighted.

Details of a new Teagasc SME support service was also presented (*TResearch* 2009; 4 (3): 12-13). This service will be operated jointly between Moorepark and Ashtown Food Research Centres.

Functional foods

Functional foods are foods that are enhanced with health-promoting ingredients. The successful development of these foods requires an in-depth understanding of the components responsible for biological activity. Moorepark Food Research Centre has become a key player in mining natural resources for probiotics, prebiotics and novel bioactive molecules. The Research Centre is also heavily involved with detailed characterisation of the components responsible for bioactivity. In partnership with University College Cork and other institutes, this knowledge base has now been channelled into four major multi-disciplinary research programmes aimed at the development of functional foods in Ireland. The ultimate goal of each team is simple: to identify health-promoting ingredients, drawing on all acceptable food sources, including milk, plants, microbial and marine. These programmes fall under the headings: Food for Health Ireland; APC (Alimentary Pharmabiotic Centre); NutraMara; and, ELDERMET.

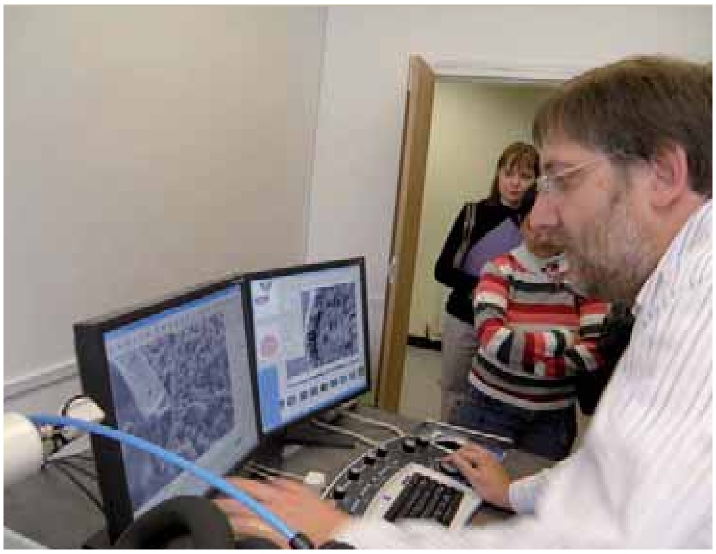
Food for Health Ireland

The Food for Health Ireland programme (Enterprise Ireland industry-led initiative) focuses on milk. Milk has evolved to be the ultimate food, containing all the nutrient requirements to support growth and development for children and young adults. Importantly, there is also an inherent 'intelligence' in milk beyond its nutritive value, which functions to programme health at a very early age. The major aim of Food for Health Ireland is to tap into this, by first systematically deconstructing milk to fractions and components including protein, fats and complex sugars, using conventional and bioinformatics-based technologies. These fractions and components will be thoroughly mined for health-promoting activities using a series of bioassays developed across Ireland in leading research institutions including UCC, UCD, UL and Moorepark. These results will be validated in animal models and human clinical trials, and will result in a series of dairy ingredients that can enhance the image of dairy foods and command a higher price through validated claims of improving consumer health.

Alimentary Pharmabiotic Centre

The Alimentary Pharmabiotic Centre (APC), established in 2003, is a Teagasc Moorepark–University College Cork initiative (Science Foundation Ireland CSET programme), and has become a key international player in understanding how intestinal bacteria influence health and disease. In particular, it focuses on gastrointestinal disorders and how they might be alleviated by functional foods, including probiotics. Knowledge generated within the APC plays a key role in the identification of commercial opportunities surrounding the exploitation of probiotics for food uses. As part of the APC, Moorepark is home to expertise in the field of novel fatty acid discovery, with a proven track record in the identification and isolation of several unique fatty acids with significant biological activities. The group has recently discovered that certain probiotic bifidobacteria can produce health-enhancing fatty acids like conjugated linoleic acid (CLA) in the intestine. *In vivo* studies have shown that this activity is associated with fatty acid changes in brain, adipose and even hepatic tissues. APC also has experts working in the field of antimicrobials. The team has built up a world-class in-house facility, which excels in the purification and identification of biological peptides and proteins. This group has already identified several bacteriocins (antimicrobial peptides) with commercial promise, exhibiting potent antimicrobial activity, such as lacticin 3147 and salivaricin, for food and pharmaceutical applications.

Professor Paul Ross describes Moorepark's research programme to visitors at the industry open day.



Dr Mark Auty explains food microstructure to visitors.

"One of the areas of greatest opportunity for knowledge-intense development is food ingredients, particularly nutritional ingredients and bioactives for the increasingly expanding food for health sector. In this area the scientific demands are greatest and an open innovation agenda is being pursued by the large branded food multinationals. Ireland can be an international leader in the development and manufacture of food for health ingredients where there is a very strong scientific capability in the research institutions, and building on the successes of Irish dairy companies in food ingredients manufacture."
Professor Liam Donnelly, Head of Moorepark Food Research Centre

"The current level of R&D spend in the Irish food sector is very low. On average, it spends 0.2% to 0.3% of sales on R&D. This low level is explained by the large incidence of SMEs in the sector, which do not have the resources, background or culture to engage in R&D, and this is why Teagasc, in partnership with Enterprise Ireland, is today launching a new SME Technology Transfer Service.
A small number of large Irish-owned companies do, however, have significant R&D activities. Nonetheless, it is now generally agreed that the science base underpinning the sector needs substantial development if it is to deliver its potential contribution to national economic recovery. Teagasc is prepared to play its role, along with all relevant putative partners, in realising this potential."
Professor Gerry Boyle, Teagasc Director.

NutraMara

Staying within the theme of bioactive discovery and validation, NutraMara (Marine Functional Foods Research Initiative) represents a consortium of scientists dedicated to the bioprospecting of marine resources such as seaweed and algae for functional food development. It is a Department of Agriculture, Fisheries and Food/Marine Institute research initiative. The island of Ireland has a huge marine resource, which is largely untapped as a source of high-value food ingredients. Many studies have shown that marine materials can contain a vast array of carbohydrates, proteins and lipid fractions, which can positively enhance human health. Despite this, there is only limited activity aimed at exploiting these resources as sources of functional foods or functional ingredients. Led from Ashtown Food Research Centre, this exciting initiative therefore aims to bioprospect marine materials (including algae, waste fish discard and products of our aquaculture industry) to generate new functional food ingredients. Importantly, this initiative, together with initiatives from the Marine Institute and the Department of Agriculture, Fisheries and Food, is generating a sustainable network of researchers dedicated to high-class innovative research in this area.

ELDERMET

Another area with growth potential is in the development of foods that improve the health of the elderly. ELDERMET is a collaboration between scientists and clinicians at Teagasc Moorepark, University College Cork and Health Service Executive hospitals, and is funded by DAFF and the Health Research Board.
It is estimated that the world's elderly (over 65) population will essentially double between 1998 and 2025. With this will come increased expectations on life quality, while there will be severe demand on our healthcare systems. The aim of ELDERMET is to determine the role of the gut flora in the health of the elderly. This project plans to determine the composition of the flora in 500 elderly people and to see how changes in the composition of the flora are related to age, diet and health status. The project is also isolating thousands of potentially probiotic cultures for future use in the elderly. This project is expected to be the genesis of a range of functional foods, which are either prebiotic- or probiotic-based, targeted at this rapidly growing and vulnerable sector. The range and level of research being conducted through these research programmes shows that world-leading standards exist and are focused on developing new competitive advantages for Irish products and for companies based in Ireland.

Genetic merit for growth

GERRY KEANE and DONAGH BERRY introduce some recent research showing that sire genetic merit for growth affects beef production and carcass quality traits.

Genetic merit for growth is being evaluated using progeny from Holstein-Friesian dairy cows and two beef sire breeds, namely Aberdeen Angus and Belgian Blue.

Key points

- Growth, expressed as expected progeny difference for carcass weight, is the most important genetic trait where animals are taken to slaughter and marketed as carcasses;
- compared with Angus, Belgian Blue animals had a lower intake per kg live weight;
- skeletal and muscular linear scores were greatly affected by breed but little affected by genetic merit;
- genetic merit for growth was more strongly expressed in early life and the breed effect followed a similar pattern;
- the overall genetic merit effect for carcass weight was close to that predicted but the effect for the individual breeds was not. It was considerably greater than predicted for Aberdeen Angus and less than predicted for Belgian Blue; and,
- the increase in fatness and decrease in muscle proportion that normally accompanies an increase in carcass weight did not occur in the higher genetic merit carcasses. Thus, the increase in carcass weight due to higher genetic merit was more beneficial to carcass quality and value than a similar increase due to better feeding or later slaughter.

The beef genetic index developed by the Irish Cattle Breeding Federation (ICBF) is estimated on an across-breed basis. It has a number of components, of which carcass weight, the measure of growth rate in the index, is the most important for dairy beef production. Carcass weight is the product of slaughter weight and kill-out proportion, and if differences in carcass weight were due entirely to differences in kill-out proportion, no live-weight benefit would be evident from using a bull of higher genetic merit for growth. In addition to evaluating effects on kill-out proportion, it is important to establish if the superior growth rate of high merit animals is evenly distributed throughout their lifetime, and/or if its expression depends on level of feeding. It is also important to determine if the composition of the extra carcass obtained from higher genetic merit animals differs from a similar carcass weight increment resulting from better feeding or later slaughter. A research project addressing these issues is being undertaken at Grange Beef Research Centre.

Genetic merit of sires used

Genetic merit for growth, or expected progeny difference for carcass weight (EPDcwt), is being evaluated using progeny from Holstein-Friesian dairy cows and two beef sire breeds, namely Aberdeen Angus and Belgian Blue, of high and low genetic merit for growth. The predicted differences in carcass weight (spring 2008 evaluation) were 15kg for low versus high genetic merit, and 25kg for Angus versus Belgian Blue. Other than in carcass weight, there were few differences between the two genetic merit sire groups.

Feed intake and linear scores

Intake per kg live weight was lower for Belgian Blue than for the Angus and a similar trend existed for the higher merit animals. However, there was no difference due to breed or genetic merit in efficiency of feed utilisation for live-weight gain. This was because date of slaughter was the same for all, and the Belgian Blue and high merit animals were heavier at slaughter than the Angus and low merit animals, respectively.

Table 1. Lifetime live weights (kg) of Aberdeen Angus and Belgian Blue steers of low and high genetic merit for growth.

	Genetic merit			Breed		
Stage	Low	High	Difference	Angus	Belgian Blue	Difference
Calf	71	73	2	67	77	10
Weanling	181	193	12	177	197	20
Yearling	283	300	17	279	303	24
Store	430	455	25	427	458	31
Finish	576	601	25	572	605	33

Table 2. Carcass characteristics of Aberdeen Angus and Belgian Blue steers of low and high genetic merit for growth.

	Genetic merit			Breed		
	Low	High	Difference	Angus	Belgian Blue	Difference
Carcass weight (kg)	308	324	16	299	334	35
Kill-out (g/kg)	534	540	6	522	552	30
Conformation+	6.7	7.1	0.4	5.8	8.0	2.2
Fatness+	8.3	8.6	0.3	9.6	7.3	-2.3

+15-point scale

Table 3. Carcass composition of Aberdeen Angus and Belgian Blue steers of low and high genetic merit for growth.

	Genetic merit			Breed		
g/kg side	Low	High	Difference	Angus	Belgian Blue	Difference
Hindquarter	457	459	2	450	467	17
Bone	192	194	2	194	193	-1
Fat	132	125	-7	157	99	-58
Muscle	676	681	5	649	708	59
High value meat	380	378	-2	369	389	20

Image courtesy of Bord Bia.

Sire genetic merit for growth affects beef production and carcass quality traits.

Average skeletal and muscular linear scores were superior for the Belgian Blue than for the Angus, but there was little effect of genetic merit. Ultrasound scanning showed clear breed differences for both muscle and fat depth (greater fat depth for Angus and greater muscle depth for Belgian Blue) but there was little effect of genetic merit on these traits.

Live weights

From about two months of age the high genetic merit animals were heavier than their lower genetic merit comrades (**Table 1**). The maximum weight difference of 25kg was reached at the store stage and there was no further increase during the finishing period. The higher growth rate of the high merit animals was not dependent on a high feeding level, as much of it occurred in the calf and weanling stages when feeding levels and average growth rates were lower than later in life when the genetic merit effects were less. The overall effect of genetic merit on carcass weight was similar to that predicted by EPDcwt for the two breeds combined, but not for the breeds individually. It was greater than predicted for Angus and less for Belgian Blue. As with the genetic merit effect, most of the live-weight difference between the breeds also occurred in early life, with over two-thirds of it (24 of 33kg) present by the yearling stage.

Carcass traits

The carcass weight superiority of 16kg for the high genetic merit animals (**Table 2**) was close to the predicted value of 15kg. Normally, an increase in carcass weight results in an increase in kill-out proportion and fatness but the heavier carcasses of the higher genetic merit animals did not have these traits. The carcass weight superiority of Belgian Blue over Angus was 35kg, which exceeded the predicted value of 25kg.

Carcass composition

Other than carcass grades, the beef genetic index does not estimate breeding values for carcass quality traits, but it is important to know if there are effects on these (**Table 3**). Generally, an increase in carcass weight results in increased fatness and reduced hindquarter, bone and muscle proportions. Such differences were not observed for the high genetic merit carcasses, which had similar composition to their lower merit counterparts. This implies that an increment of carcass weight due to higher genetic merit for growth is more valuable in terms of its beneficial effects on carcass composition than a similar carcass weight increment obtained from better feeding or later slaughter. The Belgian Blues had more muscle and high value meat cuts, and less fat than the Angus.

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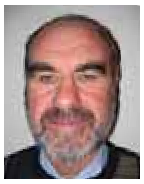

The appliance of science

KIERAN MEADE describes the new genomic technologies being used to identify animals with superior genetics for health.

An Illumina Next Generation Sequencer has recently been purchased by Teagasc to analyse the DNA and RNA sequences from disease-resistant and susceptible animals.

In economic terms, infectious diseases cost the livestock industries an estimated 17% of turnover in the developed world. Mastitis alone is estimated to cost €25 billion worldwide. However, there are also many hidden costs associated with animal disease through public perception of risks to the food chain and human health. **Table 1** lists the predominant bacterial and viral diseases that continue to limit the efficiency and profitability of the Irish agri-food industry.

The limited knowledge of and control strategies for these diseases in the national herd will have serious consequences for future international trade. Therefore, reducing the burden of disease at source (recognised as the best method for controlling transboundary, zoonotic infectious agents [Collins and Wall, 2004]) is critical. All livestock production systems are influenced by both environmental (management/feeding) and genetic factors. Considerable attention has been paid to biosecurity and optimised management (herd health) practices to minimise disease prevalence, but the role of genetics is only recently being appreciated. In this context, the Teagasc Animal Health Programme aims to identify and exploit natural mechanisms of disease resistance as a management and breeding tool for controlling disease into the future. Breeding genetically-resistant animals will provide significant benefits to animal production enterprises through increased profits, enhanced consumer confidence in, and demand for, Irish produce, and allaying fears associated with potential disease transmission.

Genetic variation in the immune response

Identifying genes that confer a more sensitive and efficient immune response in animals will enable rapid, widespread, economical screening of animals for resistance, so animals with superior natural immunity can be identified and used for breeding. Simply put, the set of genes that any animal carries determines whether it will put the energy it derives from food into making muscle (e.g., Charolais) or milk (e.g., Friesian). However, an animal's genes also determine how effectively its immune system can fight off infections and, just like milk and meat yield, some animals are better equipped than others (Morris, 2006). This is usually accounted for by differences in their DNA sequence known as single nucleotide polymorphisms (SNPs). The national cattle breeding selection index (known as the Economic Breeding Index – EBI, developed by Teagasc and the Irish Cattle Breeding Federation) now incorporates markers of disease to select for animals with increased resistance to lameness and mastitis. Genetic variation in resistance to disease has been demonstrated for over 50 animal diseases (Gibson and Bishop, 2005):

- one study found a 17.8% incidence of bovine respiratory disease (BRD) in Angus, as against a 7% incidence in Hereford;
- *Bos indicus* (humped) cattle have a generally higher genetic resistance to parasites and have been successfully used to overcome disease limitations in other breeds in both Africa and Australia;
- variation at the *CD18* gene in Holstein-Friesian cattle determines the animal's resistance to a genetic disorder known as bovine leukocyte adhesion deficiency (BLAD); and,
- variation at the *PrP* gene in sheep determines much of the variation in susceptibility to scrapie, with Suffolk breed being relatively resistant to disease.

In the examples above, selection against disease is facilitated by the fact that these traits are caused by defects in only one gene. Many other traits, and disease resistance in general, are affected by multiple genes. However, although more difficult to identify and select for, we have already had considerable success with other economically important traits (e.g., milk yield). Now we need to apply the same approach to health traits. However, selection for improved health is complicated by the absence of clear phenotypic markers for health. This is where genomics comes in.

Table 1: Non-government regulated infectious animal health challenges.

Disease	Prevalence in Ireland
Johne's disease (JD)	Medium
Bovine viral diarrhoea (BVD)	High
Leptospirosis	High
Infectious bovine rhinotracheitis (IBR)	Medium – increasing
Mastitis	High

New genomics technologies to identify animals with superior genetics for health

Whereas traditional methods may have analysed one gene or protein at a time, technological developments in genomics have facilitated the genome-wide analysis of all 30,000 genes in a high-throughput fashion. Examples of these technologies include:

Microarrays are small slides that have gene probes attached that bind to their corresponding gene (target), should it be present in the sample of interest. Using florescent probes, researchers can then identify what genes are turned up, down, on, or off, in response to a particular disease.

Potential result: Gene A is more highly expressed in response to infection with mastitis.

Next generation sequencing is a revolutionary technique used to sequence the DNA or gene transcripts present in any sample of interest. It not only allows the determination of gene expression levels (like the microarray) but also facilitates the identification of SNPs.

Potential result: Gene A is more highly expressed in response to mastitis by 1,000 copies, and there is an SNP present in this gene. This pathway may be important in controlling infection and this SNP may represent a potential biomarker to identify resistant animals.

SNP chips are similar to microarrays in that the probes on a fixed slide bind with higher affinity with targets (in your sample) that exactly match their DNA sequence, whereas a mismatch (SNP) will bind with less affinity. A lower affinity match will emit less fluorescence and so can be used to screen a population of animals. Current generation SNP chips facilitate the analysis of up to 500,000 SNPs spread across the entire bovine genome.

Potential result: Gene A SNP is present at a higher frequency in mastitis-infected animals than in healthy animals. This SNP may represent a potential biomarker to identify resistant animals.

Genome-wide association studies combine the power of traditional quantitative genetic approaches with molecular genetics (such as the results from an SNP chip study) to find an association between a gene and any trait for which detailed records are kept. In this way researchers can identify genes that associate with (or influence) any trait, such as mastitis susceptibility.

Potential result: The Gene A SNP, present at a higher frequency in mastitis-infected animals, is associated with reduced growth rate in these animals.

Genomics in animal health

Genomics is the study of the complete set of genes (or genome) that constitute an individual. Coupling this research at the gene level with traditional quantitative genetics (selecting animals on the basis of pedigree and phenotypic measurements) is contributing to a paradigm shift in animal genetic improvement. Molecular selection can also overcome some of the traditional limitations of quantitative selection where traits are not measurable in both sexes before reproductive age (e.g., milking ability). The net result of the use of these technologies will be the identification of genes that control the immune response to disease. Through the identification of genetic variants (SNPs) that are carried by disease-resistant animals, we can develop molecular diagnostic tests. Animals can then be identified shortly after birth, and selected for superior immunity, or managed accordingly. Furthermore, understanding the mechanisms regulating disease will allow the development of targeted therapies to fight disease.

Animal Health Programme

The new Animal Health Programme currently being established in Teagasc's Animal Bioscience Centre represents a multi-disciplinary approach for tackling priority health areas. A cross-centre approach will involve Athenry, Moorepark and Grange, in collaboration with leading researchers from Trinity College Dublin, University College Dublin and NUI Maynooth. Initially focusing on uterine and mammary immunity and, subsequently, incorporating infectious diseases (e.g., Johne's disease), animal health scientists seek to understand the mechanisms controlling immune response, identify differences between individuals and use this information to select animals with superior immunity.

We have already identified a panel of novel bovine antimicrobial peptide (AMP) genes that may have important roles in reproduction, fertility and immunity. These genes are currently being analysed across Irish cattle breeds. A primary interest is in important innate immune genes that control the activation and magnitude of the immune response (e.g., interleukin 8). Significant differences have already been detected between cattle breeds, and sequence variants have been associated with numerous diseases in other species. The cattle variants are likely to have significant implications for the immune response in these breeds, and functional characterisation is currently underway.

The central tenet of the EU Animal Health Directive, 2007-2013, is based on the principle that "prevention is better than cure". Proactive investment by Teagasc will help to develop the research platforms that will enable the Irish agri-food industry to increase the productivity of the national herd, target premium international markets and, ideally, position us to meet the health challenges of the future.

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Winter grass growth

DEIRDRE HENNESSY and WILLIE RYAN look at the effect of grazing closing date on herbage mass during winter and early spring.

Early spring grazed grass is the cheapest form of high quality feed available for milk production in early spring. To provide grass for grazing in early spring, grass has to be 'carried over' from the autumn period due to low grass growth rates during the winter period. Swards are generally closed in rotation from approximately October 10 until November 20 to allow herbage mass accumulation during late autumn and winter for early spring grazing. Grass growth rates during winter are low (0-10kg DM/ha/day, depending on location and climatic conditions) and, subsequently, net herbage mass may not increase substantially. However, during winter there is constant leaf growth and senescence. Tissue turnover, which is leaf and tiller growth and senescence, results in herbage mass accumulation and decline. Tissue turnover is determined by leaf extension rate, leaf senescence rate, leaf appearance rate and leaf area index (LAI – area of leaf over area of ground), all of which are influenced by a range of factors including date of final autumn grazing, quantity of herbage mass remaining on the sward at closing, and weather conditions, in particular soil and air temperatures.

Moorepark study

Recent research at Teagasc Moorepark Dairy Production Research Centre examined the effect of a range of autumn closing dates (September 29, October 13, October 27, November 10 and November 24) on herbage mass accumulation, tiller density and LAI to February 20. Over the winter months, herbage mass increased on all swards (**Figure 1**). The rate of increase varied depending on the length of the regrowth period. On February 20 herbage mass was only 4% greater than it had been on November 28 on swards closed in late September. Swards closed in October and November had on average 71% and 79% more herbage present on February 20 than in late November, respectively. Herbage mass on September 29 closed swards reached ceiling yield by January 9 and declined to February 20. It is likely that herbage mass on this treatment would have continued to decline after this unless herbage was removed by grazing (Hennessy *et al.*, 2006). Herbage mass continued to increase on the other treatments to late February.

Swards closed in November had considerably less green leaf present in late November and into December than did September and October closed swards due to recent defoliation. The green leaf proportion increased rapidly on November closed swards from a mean of 40% to 74% between late November and February 20, while the rate of increase on the September and October closing treatments was small. In general, the proportion of green leaf and green leaf yield in the swards was increasing and the proportion of dead material was decreasing by February 20, suggesting that leaf extension was still greater than leaf senescence.

Tiller dynamics

The changes in herbage mass and green leaf content can be explained by tiller dynamics. Tiller density increased from November to February, although it did fluctuate and was greatest at the end of January. Increases in tiller density usually have a positive impact on herbage production and LAI. LAI was least on November closed swards in late November and increased almost linearly on these treatments over the winter. LAI peaked in early January on September 29 closing date treatment, remained stable to January 30 and then declined by 22% to February 20. LAI peaked in early January for the October closing treatments and did not change significantly for the remainder of the experiment. There were strong relationships between herbage mass and LAI (R^2= 0.76) (**Figure 2**).

In this experiment, herbage mass generally increased in the measurement period following increases in tiller density. When new tillers become established their leaves expand, LAI increases and an increased level of light is intercepted, which in turn maximises the level of leaf production and sward growth. As sward growth rate increases, leaf senescence becomes progressively greater as LAI increases. High LAI results in increased herbage mass, which eventually restricts

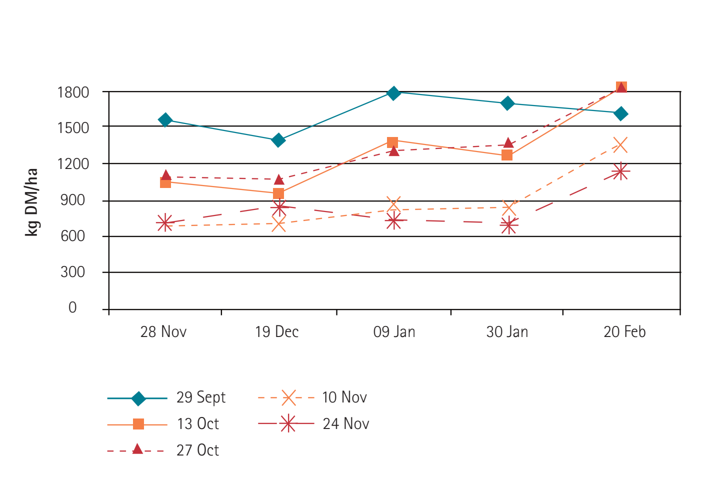

FIGURE 1: The effect of five autumn closing dates (September 29, October 13, October 27, November 10 and November 24) on herbage mass >4cm (kg DM/ha) measured on five occasions during winter (November 28, December 19, January 9, January 30 and February 24).

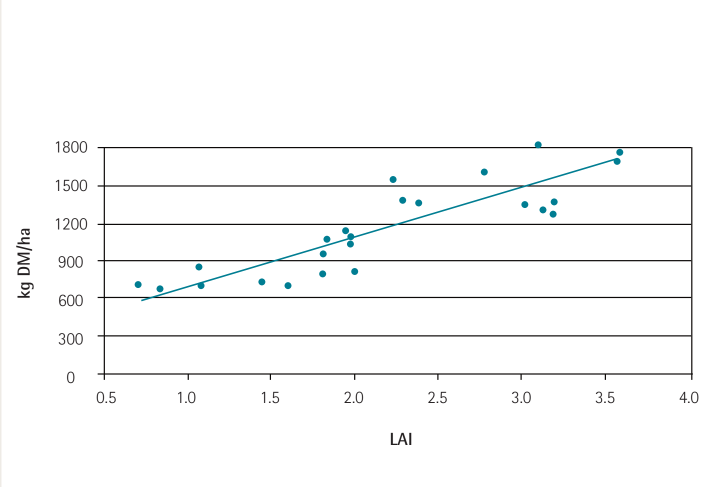

FIGURE 2: Relationship between herbage mass (kg DM/ha) and LAI on five occasions between November 28 and February 20 on swards closed from grazing on five dates in autumn (September 29, October 13, October 27, November 10, and November 24). The relationship is described by the equation $y = 393.7x + 315.51$, $R^2 = 0.76$.

the quantity of light reaching the lower leaves of tillers and the tiller buds, resulting in reduced tiller production and increased senescence. Hennessy *et al.* (2006) reported that tiller density declined as ceiling herbage mass was achieved. In this experiment herbage mass accumulation was not sufficient to restrict growth through loss of tillers: although tiller density decreased from January 30 to February 20 the reduction did not have a negative effect on herbage mass.

Growth cycles

A period of slow growth rates occurs following defoliation and is followed by accelerated growth rates, and finally a period of decreasing growth as the sward matures. The swards defoliated in November experienced a prolonged lag phase due to reduced photosynthetic area, and low temperatures and daylight hours, which reduced the energy available for leaf growth. This lag phase continued until growth conditions were more favourable (higher temperatures and increasing daylight hours) in late February. Swards closed in late September and October had a shorter lag phase and a greater LAI by late November than November closed swards. This was due to more favourable conditions for initial re-growth following defoliation. Generally, as herbage mass and green leaf yield increased, LAI increased. LAI can be considered as an indicator of production potential. Optimum LAI and sward growth is achieved when the lowest leaves of the sward are only just able to maintain a positive carbon balance; beyond this point the lower leaves will become an unproductive burden to the plant and die.

Swards that experience a long regrowth interval prior to spring grazing accumulate large quantities of herbage mass, develop high LAI and have high levels of senescent material in early spring (Hennessy *et al.*, 2006), resulting in reduced spring growth potential (Hennessy *et al.*, 2008). In contrast, swards closed late in winter will have an inadequate regrowth period and fail to accumulate sufficient herbage mass to meet livestock feed requirements in early spring. Tiller density and LAI, which are the two primary sward constituents influencing spring growth potential (Hennessy *et al.*, 2008), were not significantly affected by autumn closing date in this experiment; tiller density was not significantly reduced by closing earlier in the winter period and LAI was not in significant decline at the end of the winter measurement period (February 20). However, if swards with high herbage mass accumulations were not grazed in February/early March it is likely that spring growth could be reduced.

Acknowledgements

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Processing pig manure

BRENDAN LYNCH, Moorepark, asks if technologies used elsewhere are a viable option for the processing of pig manure here.

The term 'processing' when applied to pig manure covers a range of activities from energy generation to changing its handling characteristics. Inevitably, any process will add cost from capital investment in plant and running costs. Therefore, the processed product or products must generate extra revenue compared with application of the manure to land as a replacement for chemical fertiliser. Technologies in use in other countries may be effective and economical under their operating environments (input costs, climate, farming practice, cropping, stocking, legislation) but not in the Irish situation. Two widely discussed processes are manure separation and anaerobic digestion. Separation of manure into solid and liquid fractions partitions most of the dry matter and phosphorus (P) into the solid and most of the nitrogen (N) into the liquid.

Manure separation

While pig manure will have an N:P ratio of about 4:1, the separated solid fraction can have an N:P ratio of 2:1 and the liquid can have an N:P ratio of 20:1. These figures will vary with the separation method and the composition of the diets fed to the pigs. The most efficient separation systems will have up to 90% of the dry matter and P, and up to 30% of the N in the solid fraction.

Pigs excrete surplus P and N mainly through urine in water-soluble forms. Provided that the diets are adequately balanced to support good pig performance, feeding minimal levels of dietary protein and P results in less water soluble N and P in the manure and a greater percentage of the amounts of both in manure being partitioned into the solid fraction after separation.

Separation of manure into solid and liquid will have a role where the only outlet for the P is a distant tillage farm and the N-rich liquid can be utilised close by as a replacement for chemical fertiliser. In Brittany, France, a large number of pig farms practise separation, followed by composting of the solid and long-distance haulage of the compost over several hundred kilometres to tillage land. Also in Brittany, the surplus of organic N is so serious that the separated liquid is treated to remove up to 80% of the N, which is released to the atmosphere as N gas.

Meanwhile, adjacent farms are using chemical nitrogenous fertiliser derived by removing N from the atmosphere to grow crops. In terms of energy use, greenhouse gas emissions, economics and common sense this practice is nonsensical, but it does allow the pig producers to continue to function in compliance with environmental legislation. With the current emphasis on conservation of resources, especially fossil fuels, and recycling of co-products, a reappraisal at EU level of the Nitrates regulations would appear to be overdue.

Separation methods

There are a number of methods of manure separation, which vary in complexity and cost. Simple systems include various screens, presses and the Geotube – a porous sack that retains the solid while the liquid seeps out. The decanting centrifuge is the most effective in terms of P removal to the solid fraction but is the most expensive to install. Only large farms could justify purchase of an installation but there are a number of contractors who separate sludge from municipal and industrial sites using truck-mounted rigs. These will cost upwards of €10 per cubic metre of manure but provide the plant and, more importantly, the expertise. Since the volume of pig manure produced per sow and progeny to sale will range from 12 to 20 cubic metres, a decision to separate must not be taken lightly.

Very effective separation requires the addition to the manure of conditioner and coagulant, which causes the solid particles to aggregate or clump. However, addition of chemicals means using a substantial amount of water, which adds to the volume

Table 1. Volume and manure composition.

	Manure volume (m^3/sow)			
Variable	12	16	20	24
Manure dry matter (%)	6	4.5	3.5	3
Manure P (kg/m^3)	1.3	1.0	0.7	0.6
Manure N (kg/m^3)	6.5	4.9	3.8	3.2
Manure K (kg/m^3)	3	2.2	1.7	1.5

Table 2. Effect of volume and distance from manure store to field on manure handling cost (€/sow/year).

	Distance (km)			
Variable	1	5	10	20
Volume = 12m^3	19	34	51	81
Volume = 24m^3	31	62	97	156

*Based on hire of tractor and vacuum tanker (12m^3 capacity; €40 per hour).

A decanting centrifuge installation used to separate pig manure at Moorepark.

Clear liquid seeps from a Geotube filled with pig manure at Moorepark.

of separated liquid to be hauled and landspread or treated. The added water may be from 10% to 30% of the manure volume. It follows that 100 cubic metres of raw manure, with an added 20 cubic metres of water, will yield about 20 tonnes of separated solid manure and 100 cubic metres of separated liquid. There will be exactly the same amounts of N and P to be managed and therefore the same amount of land required.

Costs and logistics

The cost of managing pig manure depends on: (1) volume; (2) nutrient content; and, (3) distance from the pig unit to the land where used. In a project at Moorepark, the logistics and cost of manure handling were studied.

Volume of manure (most conveniently expressed in cubic metres per sow in the herd per year and including contribution of progeny to slaughter) depends on: (1) water use (drinking, spillage, washing); and, (2) amount of extraneous water entering the manure, e.g., rain water. Volume will vary from about 12 to over 20 cubic metres per sow per year and is minimised on dry feed systems, low-waste drinkers, good washing technique, plumbing supply maintenance and control of roof and yard water.

Amounts of manure nutrients depend on: (1) feed composition; and, (2) efficiency of use. Low manure volume means a higher concentration of nutrients in the manure (**Table 1**), but in the case of N there is some drop in efficiency of use by the crop.

The main options for hauling manure are: (1) vacuum tanker-spreader for local application; and, (2) haulage by truck with spreading by a separate vehicle on the customer's farm for longer distances. The effect of haulage distance and volume on manure cost is shown in **Table 2** for tractor-drawn tanker and in **Table 3** for a truck. In all cases, the cost includes land application.

Separation will greatly increase the cost of manure handling and is attractive only in exceptional circumstances. The data in **Table 4** assumes that the separated solid is hauled 100km and the liquid is used within 1km. Longer haulage distances for solid have only a marginal effect on total manure handlings costs in a separation scenario.

It is clear from the above that control of manure volume must be the priority. Returns from pig production will not sustain expensive processing options. Generation of biogas from pig manure and using the biogas to produce electricity sounds attractive at first. However, investment in these plants is not economically attractive at present start-up, labour and energy costs. Critically, from the operation of a pig unit, the volume of liquid from the digester and the amounts of N and P remain unchanged so the cost of land application is not reduced.

In conclusion, minimising manure volume and using the untreated material to replace chemical fertiliser is the only feasible use for pig manure at the present time and for the foreseeable future.

The Department of Agriculture, Fisheries and Food is currently supporting two research projects on pig manure management at Moorepark under the Research Stimulus Fund progamme.

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Table 3. Effect of volume and distance from manure store to field on manure handling cost (€/sow/year).

	Distance (km)			
Variable	25	50	75	100
Volume = 12m^3/sow/year	78	104	130	156
Volume = 24m^3/sow/year	155	207	259	316

*Based on hire of truck (27m^3; €72 per hour) and tractor and vacuum tanker (12m^3 capacity; €40 per hour).

Table 4. Effect of separation on manure handling cost (€/sow/year).

	Distance solid is hauled (km)			
Variable	25	50	75	100
Volume = 12m^3	190	197	204	211
Volume = 24m^3	286	294	300	307

*Includes separation by contractor; haulage and spreading of the fractions on land.

Measuring Irish farm sustainability

How do we measure agricultural sustainability? EMMA DILLON, THIA HENNESSY and STEPHEN HYNES are involved in research to develop indicators that will do just that.

The principle of sustainability is firmly enshrined in the objectives of the Common Agricultural Policy and is one of the forefront issues in European agriculture. Indeed, part of the mission statement of Teagasc itself is to improve the sustainability of Irish farming. The notion of sustainability has many dimensions and deliberation on these has further highlighted its complexity. A widely adopted definition was included in the 1987 report of the World Commission on Environment and Development, 'Our Common Future' (the Brundtland report): "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept of sustainability remains difficult to define and measure. Multidimensional aspects – economic, environmental and social – must be taken into account; however, this can prove difficult in practice at the farm level. Nonetheless, a meaningful measure is required if it is to guide policy.
This research develops indicators of economic, environmental and social farm sustainability in Ireland using National Farm Survey (NFS) data, generating these annually and projecting them under different policy scenarios, with a view to determining whether specific policy proposals do in fact improve the sustainability of Irish farming. We are currently in the process of assessing future trends in sustainability, taking a number of policy scenarios into account.

Towards a composite indicator?

Sustainability indicators should allow us to judge whether a certain development contributes to movement in 'the right direction'. However, in reality, the interpretation of a set of multidimensional indicators can prove difficult and it can therefore sometimes be useful to aggregate a multidimensional set of indicators into a single index or composite indicator. There is some debate, however, as to the usefulness of these indicators; they are helpful in that they can summarise complex or multi-dimensional issues and are easy to interpret, but they may lack accuracy if poorly constructed. In our analysis, the amalgamation of indicators into one composite indicator proved not to be very useful. The economic and environmental results were highly negatively correlated and, in effect, cancelled each other out, meaning that the social indicators were the main drivers of the composite indicator.

Sustainability indicators

Farm-level indicators are calculated here over a ten-year period (1996 to 2006). The advantage of using NFS data alone is that sustainability can be measured for the same farms across years; however, it should be noted that the dataset is somewhat limited in relation to biodiversity and social sustainability. Examples of some indicator types are summarised in **Table 1**.

Table 1: Sustainability indicator types.

Economic indicator	**Economic viability**
Description	An economically viable farm is defined as having: (a) the capacity to remunerate family labour at the average agricultural wage (or, in the absence of an average agricultural wage, the minimum wage for agricultural workers, as set by the Labour Court); and, (b) the capacity to provide an additional 5% return on non-land assets. The contribution of non-farm income is not taken into account here.
Result	Only between 28 and 41% of all farms were classified as economically viable between 1996 and 2006. Dairying and tillage systems tend to have a relatively higher proportion of viable farms compared to other systems. Generally speaking, the cattle and sheep systems appear less viable than all others throughout the decade.
Environmental indicator	**Methane emissions**
Description	Methane emissions (kg per hectare) can be calculated based on livestock emission factors for the different types of livestock recorded in the NFS (see O'Mara *et al.*, 2007). Emission factors represent the quantity of gas produced by an animal over a specific period of time. By multiplying emission factors for animal type by herd size, total emissions from a particular source category are generated for each farm.
Result	Methane emissions were found to be, as expected, much higher for dairying than for other systems. Overall, there was very little change across systems throughout the decade, indicating that perhaps, going forward, a more visible reduction across systems is required. Interestingly, however, when market return (family farm income minus direct payments) is related to methane emissions (€ per kg), only the dairying and tillage systems generate a positive return per kg of methane produced in 2006. Cattle and sheep systems make a private financial loss as well producing a negative externality (i.e., a harmful effect of one economic agent's actions on another economic agent).
Social indicator	**Demographic viability**
Description	Given the general perception that the Irish farming population is ageing at a fast pace, we felt it necessary to evaluate the problem. We defined a household as demographically viable if it had at least one household member under the age of 45.
Result	A slight decline in demographic viability is found over the ten-year period across all systems, most notably in the cattle, sheep and tillage systems. This indicator can perhaps be thought of as an indicator of succession (with the likelihood of someone taking over the farm worsening slightly over the period). However, it is important to note that perhaps not all family members are taken into account here; therefore, the true presence of a successor may be underestimated here.

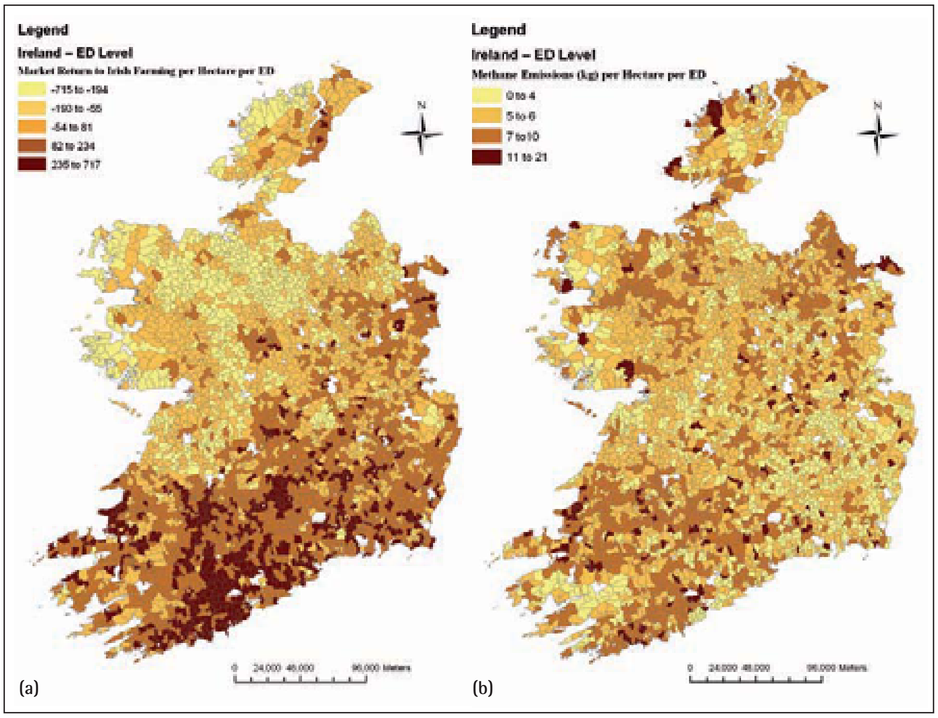

FIGURE 1: SMILE maps: (a) market return (€) to Irish farming per hectare at electoral division level; and, (b) methane emissions (kg) per hectare at electoral division level.

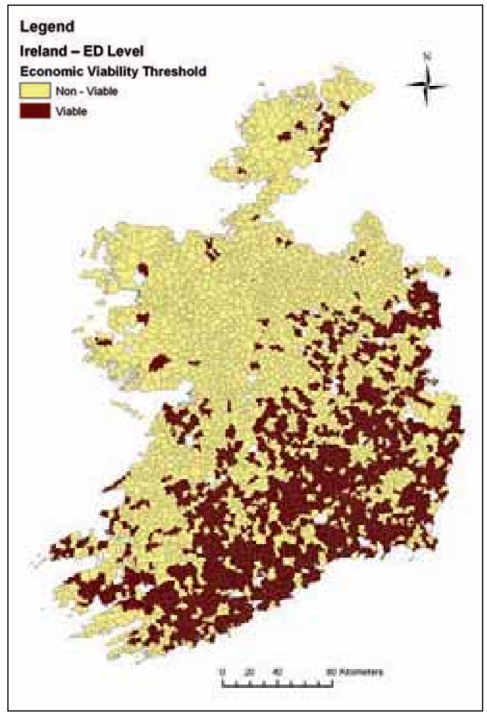

FIGURE 2: SMILE map of economic viability at electoral division level.

SMILE model

A spatial micro-simulation model, the Simulated Model for the Irish Local Economy (SMILE) is also utilised to produce a synthetic farm population representative by size, system and soil type at electoral division (ED) level. The SMILE model was developed by the Rural Economy Research Centre, Teagasc, and aims to simulate statically the population of Ireland. A technique called simulated annealing is used to match Census of Agriculture data to the NFS. Indicators are then presented using GIS (Geographical Information System) mapping techniques. A number of examples are outlined in **Figures 1** and **2**.

Market return (per hectare) and methane emissions (kg per hectare) for each ED are displayed in **Figure 1**. The lighter areas in map (a) represent low levels of market return, generally found in the west and midlands. On the other hand, the darker areas represent those EDs with relatively higher levels of market return (generally in the south and south east). In map (b) the lighter areas are representative of those EDs with relatively low levels of methane pollution, whereas the darker areas represent higher levels of pollution. Interestingly, but perhaps unsurprisingly, some correlation is found between those EDs with higher market returns and higher emissions.

The economic viability of Irish farms at the ED level is illustrated in **Figure 2**. It can be seen that the more economically viable farms are located towards the south of the country where the more intensive farms are situated (brown colour). This is reflective of the long recognised divide above and below the Limerick to Dundalk diagonal, with those farms lying below this generally performing better than those above.

Conclusion

The sustainability of farming is without doubt an emerging research area and an important policy goal. This research develops a number of farm-level measures of sustainability using NFS data, and while this research attempts to provide policymakers with some insight into the current sustainability of Irish farming, the results also highlight the complexity of the concept of farm sustainability and the difficulty of providing a comprehensive measure. It is important to measure sustainability if we are to test the effectiveness of policies; however, much confusion remains about how best to do so.

This research is kindly funded by the Department of Agriculture and Food Research Stimulus Fund.

Reference

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Estimating costs of production and returns in Irish farming

Given the current cost price squeeze that Irish farmers are experiencing, there is an increased need for all industry players to know and understand their competitive position.

As managers of businesses, farmers in Ireland are concerned with the incomes they receive and the factors affecting their farm efficiency and development. To plan and survive in a future, more volatile, marketplace, it is essential that relevant cost and return data are understood and used. Data on costs and returns in farming are readily available from a number of different sources. However, it is crucially important that the users of that data (farmers, advisers and others) are fully aware of the source and methods involved in computing such data. They also need to be aware of the usefulness and limitations of data from alternative sources for answering different questions.

Evaluating farm viability and competitiveness

For the purpose of examining costs of production and determining a farm's competitive ability on an intra-country or inter-country basis, it is important that both cash and economic costs are considered. Total cash costs include all specific costs directly incurred in the production of a given commodity, for example, fertiliser, feedstuffs, seeds, etc., plus external costs such as wages, rent and interest paid, plus depreciation charges. Total economic costs include all of the cash costs identified above, except interest charges, plus imputed resource costs for family labour, equity capital and owned land.

Data sources

Although there are numerous alternatives for generating data for costs of production and return estimates, three of the most commonly used methods are discussed here.

Farm survey data

The main source of costs of production and return data on Irish farms collected using survey methods is the Teagasc National Farm Survey (NFS). The NFS data is collected on a random, statistically selected sample of 1,200 farms on an annual basis by a team of full-time farm recorders. It is selected to represent Irish agriculture and the various farm systems. The main objective of the survey is to collect technical and financial data to develop population weighted average costs of production and return data for Irish farms. In addition, all direct costs of production on the NFS farms, e.g., fertiliser, concentrate, veterinary fees, chemicals and feed, are accurately allocated to each specific farm enterprise, enabling direct costs of production and gross profit per unit output of each enterprise to be calculated. The survey provides data that are useful in examining a variety of farm-level issues such as efficiency, viability, income, financial structure and competitiveness. These estimates include a complete costing for all inputs and captures the actual financial position of farms annually, representative of the full distribution of the farming population, unlike the budget or benchmarking data discussed below. The sample is collected on a stratified random sample basis and reflects the distribution of population attributes such as managerial ability, farm size and regional location. Each observation is intended to be representative of a number of similar farms and so can be weighted to represent the overall farm population. Simple sample averages provide inaccurate results for representing a sector or enterprise. The NFS is the only unbiased representative source of costs of production recorded on a system basis in Ireland.

In addition to providing information on the distribution of purchased inputs/costs of production across the population and between individual farm enterprises, the NFS also collects data on owned resources used in the production of output. This level of detail is extremely important in calculating the viability and competitive position of individual farms and farm enterprise.

Comparative farm benchmarking data

Benchmarking data is yet another source of costs of production and return data on Irish farms. The Teagasc Profit Monitor system is an example of a benchmarking system that collects individual financial and technical data on farms with the objective of examining enterprise profitability and whole farm profitability. The Teagasc Profit Monitor farms are individually selected by Teagasc and represent the more efficient farms for each system. The data is entered online by the farm operator. The main objective of farm benchmarking systems is to provide participants with the necessary management data to compare and contrast their own individual performance with other participants in the system for the purpose of identifying their own competitive advantages and disadvantages. Like all management accounts, the trends apparent from the results over a number of years become important reference data for decision-making, monitoring progress and the expression of planning objectives. For the participants in the system and their advisers, the availability of such data and their relative efficiency is extremely useful for planning purposes and decision-making. The availability of benchmarking data such as Teagasc Profit Monitor data to local discussion groups, monitor farm discussions, and individual farmer/adviser discussions is of paramount importance.

However, while noting the distinct merits of benchmarking data for the objectives as listed previously, an important shortcoming exists in the use of benchmarking data for the purpose of estimating the viability and competitiveness of the farming population because farms included in these data sets do not proportionately represent the entire farming population. Furthermore, the inclusion rate in benchmarking studies of farms differs by farm type and size. By construction, the sample upon which the Profit Monitor is based is subject to serious sample selection bias. Thus, inferences to sizeable portions of the farm sector are problematic, and no conclusive statements can be made concerning those populations.

While no direct comparison is available in terms of the performance of a matched panel of farms that appear in the NFS and the Profit Monitor versus the remainder of the NFS sample, it is possible to conclude, because of the selection process, that participants in the Profit Monitor programme tend to be larger farms, which are also more actively engaged with the advisory service, when compared to industry averages. Furthermore, recent research published by Teagasc's RERC has shown that productivity and technical efficiency levels tend to be higher on larger farms and also tend to be higher on farms that have contact with the Teagasc Advisory Service. Hence, it is most accepted that farms participating in the Profit Monitor programme have higher efficiency levels than industry averages represented by the average NFS sample of farms.

In terms of comparing the output results from the sample of NFS farms and Profit Monitor farms, while acknowledging the differences in sampling approaches, this exercise is still fraught with difficulties. The definitions of costs and returns in the NFS and the Profit Monitor programme are not based on the same accountancy principles and are not what is referred to as harmonised accountancy data.

Traditionally, the main use of the data generated through the benchmarking process has been for extension and education purposes. More recently, however, researchers and industry stakeholders have utilised the data to examine a wide range of issues. Reflecting the increased use of the benchmarking data for varied purposes, it is important to outline a number of key points related to its application, which will be useful in ensuring that resulting data are not misinterpreted:

- the use of the data should never occur without reference to the source of the data, hence highlighting to the target audience the usefulness and limitations of such data;
- the user of the data should be fully aware of the nature of the group standards. Some farm type groups are, inevitably, more heterogeneous than others and in no event is the data assumed to represent industry averages; and,
- when interpreting the results of benchmarking data for the purpose of individual farm planning, the full range of comparative information available should be consulted.

Farm management budget data

One of the most common uses of commodity cost of production and return data is as production guidelines, which are regularly published by extension agencies, such as the Teagasc Advisory Service. These guidelines are intended to be used by farmers for planning purposes for the coming production year. This type of data is frequently referred to as 'budget data' because of the forward-looking nature of its use. Given the nature of this data, management practices are often formulated and standardised by specialist agricultural advisers and are not necessarily based on actual farm financial or technical data. This type of data is often replicated based on different assumptions of technical efficiency. An example of this type of data is the enterprise budgets produced by Teagasc on an annual basis and published, e.g., 'Management data for farm planning', 'Crop costs and returns', and 'Various cattle system budgets'.

Clear thinking required of data users

To conclude, it is important for any user of costs of production and return data to be very clear in terms of the research objective associated with the analysis of the data. If the objective of the user of the data is to set goals for their own farm during the coming year, it may be appropriate to use profit monitor results or farm management budget data. If the objective is to examine the relative performance of their individual farm against the performance of a very defined set of producers, such as other farms in a discussion group, or locality, it may be appropriate to use the results from the Profit Monitor for this purpose, and this is best done and interpreted by the local adviser or specialist. However, if the objective is to examine relative farm or enterprise viability, competitiveness or efficiency for the overall sector, the weighted results from the NFS will provide the user with the most reliable and accurate set of data.

The relative competitiveness of an individual farm is not only about the performance of the top performing farms, but is also about the distribution of costs and returns among all farms. In other words, competitiveness is fundamentally about surviving in the marketplace, and focusing on the top performing farms is inherently wrong. In this respect, data based on a statistically representative sample of producers is vitally important. Finally, viability and competitiveness is about 'cash costs' and 'economic' costs. Adjustment in the farming sector in the long run will be about relative resource use, especially land, labour and capital and thus some indicator of relative resource costs are needed to understand and analyse this adjustment process.

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The onward march of potato late blight

A cross-border research study has been working on the control of the plant pathogen *Phytophthora infestans,* cause of potato late blight.

Oospores of Phytophthora infestans *formed following sexual reproduction of the pathogen.*

Following its first appearance in Ireland in 1845, potato late blight caused by the plant pathogen *Phytophthora infestans* has helped to shape the nation we are today. Although it is over 160 years since its arrival, which signalled the start of the Irish famine, this ever-evolving pathogen continues to have the same destructive potential.

A global pathogen posing a global threat

Having once been confined to Mexico, the global spread of *P. infestans* in the 1840s was driven by a combination of man's desire to improve potato quality and yield, and the increased movement of people and goods around the world. Since emerging onto the world stage, its ability to produce vast quantities of inoculum within a matter of days and resilience in adapting to control measures have ensured that *P. infestans* has become the single greatest threat to global potato production. The development of chemical fungicides, resistant potato varieties and our increased understanding and awareness of the pathogen have all helped reduce crop losses. Our ability to combat the pathogen was helped by the fact that global populations were, until the 1980s, dominated by a single clonal lineage of the pathogen. The migration of new, more virulent, strains from Mexico into European populations in the late 1970s has upset this equilibrium, and started a new chapter in the pathogen's history, one that continues to unravel. The increased diversity in *P. infestans* populations that arose following these migration events now mean that our attempts at taming the pathogen are unfortunately often short lived. The dramatic emergence and spread of resistance to the phenylamide fungicides in European *P. infestans* populations (including the Irish population) in the early 1980s is an indicator of the problems these population changes can have at the field level. More recently, the emergence of a new strain of *P. infestans* – dubbed 'Blue 13' – in Continental Europe and Great Britain has further increased the threat posed. Combining phenylamide fungicide resistance, increased aggressiveness and cold tolerance, 'Blue 13' has rapidly come to dominate *P. infestans* populations wherever it is present.

Changing *P. infestans* populations from an Irish perspective

The rise of the 'Blue 13' strain in northern Europe prompted informal discussions between researchers in Teagasc Oak Park and the Agri-Food and Biosciences Institute (AFBI) on how best to manage this new development on an all-island basis. These discussions culminated in a successful application for a Department of Agriculture, Fisheries and Food Research Stimulus Fund grant, entitled 'An integrated biosciences platform for the future control of potato late blight on the island of Ireland'. Subsequently, the first detection of the strain in Northern Ireland was made in the summer of 2007 by Dr Louise Cooke of the AFBI in Belfast. This aims to tackle the *P. infestans* problem by investigating changes in the Irish population, and by using data on the potato genome, made available through Teagasc's involvement in the international potato genome sequencing consortium, to assist in the development of resistant potato varieties. First, the research team set about establishing a *P. infestans* collection representative of current populations both north and south of the border in 2008. Initial results demonstrated that dramatic changes are occurring to the Irish population.

The rise of the A2 mating type within the Irish population

The ability of *P. infestans* to undergo very rapid asexual reproduction with the formation of billions of sporangia and zoospores, together with its ability to reproduce sexually and produce long-lived oospores, are the keys to this pathogen's adaptability. While asexual spore production will occur wherever the pathogen is present, for sexual reproduction strains of opposing mating types (A1 and A2) must meet within the same plant. Previous studies conducted both north and south of the border showed that Irish *P. infestans* populations were dominated by strains of

Typical late blight symptoms on potato foliage. If left untreated, not only would it be likely that the crop would be quickly overcome by blight, but it would act as an inoculum source for further infections.

The devastating effects of late blight as seen in an organic potato trial at Oak Park during the summer of 2008.

the A1 mating type, so that sexual recombination was very improbable. Surprisingly, 25% of the strains assessed in the 2008 collection were of the A2 mating type. In a number of crops both mating types were identified, creating a situation where sexual reproduction may occur. The dangers of increased adaptability and aggressiveness that such sexual events pose for future blight control are further compounded by the fact that oospores are extremely robust and may survive in the soil for several years. Their possible presence creates problems in terms of crop management, with the risk of much earlier infections, and the worst-case scenario of complete crop destruction shortly after planting.

The rise of 'Blue 13'

Following its identification in Northern Ireland in 2007, together with its history in Great Britain, it comes as no surprise that this strain was identified in Ireland in 2008. Although predominantly detected in the east of the country, 'Blue 13' isolates were found in Donegal and Limerick towards the end of the 2008 season. 'Blue 13' is an A2 mating type and therefore the problems associated with possible sexual reproduction with our A1 population arise. Furthermore 'Blue 13' is resistant to phenylamide fungicides. While phenylamide resistance is not new to the Irish *P. infestans* population, previous resistant strains tended to suffer fitness penalties, and anti-resistance strategies developed by researchers in Oak Park in the late 1980s succeeded in ensuring that their presence was kept low within the population. These strategies were so effective that as recently as 2007, very low levels of resistance were detected in the southern population. Unfortunately, 'Blue 13' does not appear to have these fitness penalties. If this strain establishes itself in the Irish population as it has done elsewhere, the value of using these fungicides will be questioned. In addition, 'Blue 13' has the ability to cycle faster and at lower temperatures than other strains, increasing the need for stringent fungicide regimes. Ascertaining exactly where this strain has come from may be difficult. It does appear to have all the attributes of a 'super' *P. infestans* strain, which might have originated in a sexual recombination event. Such a possibility highlights the need to monitor *P. infestans* populations. Genetic analysis of the 'Blue 13' strains within the Irish population has shown that a number of variants are present. This indicates that its arrival into Ireland was probably not via a single migration event, but involved multiple introductions at a number of locations.

Controlling this pathogen in future years will require strong integration of all aspects of disease control. Although we now have the ability to understand far more precisely the composition of our *P. infestans* population and tailor disease control programmes to suit, the basic principles employed for decades are still the foundation of any programme. The need to understand how this pathogen is changing is continual, for *P. infestans* needs no invitation!

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

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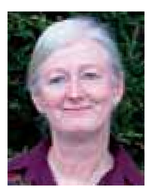

Discovering subsurface denitrification

Full denitrification has been notoriously difficult to measure, but now researchers at Johnstown Castle and Irish universities are opening the black box below the topsoil, to investigate how we can coax the responsible denitrifying microbes to work even harder for us.

Subsurface denitrification: friend or foe?

Full denitrification is a microbial underground process that silently cleans nitrates and nitrous oxides from our soil, and converts these to dinitrogen, a harmless gas. Nutrient research at Johnstown Castle aims to maximise the utilisation of nutrients by grass and crops, thereby reducing direct costs and risk of losses to the environment. Surplus nitrogen (N) may be lost to water through leaching as nitrate (NO_3^-), or lost to air as nitrous oxide (N_2O), a major source of greenhouse gas emissions. However, not all losses of N impact negatively on the environment; for example, dinitrogen (N_2) is an environmentally inert gas, comprising most of the air we breathe. It is the ultimate end product of complete denitrification, in which NO_3^- is sequentially stripped of its oxygen (O). Research at Teagasc Johnstown Castle aims to quantify full denitrification as a pathway for the control of NO_3^- and N_2O emissions.

Known knowns

N_2O emissions result from incomplete denitrification of NO_3^- to N_2, which is carried out by a range of soil microbes and fungi under low oxygen conditions. Under such anaerobic conditions, these microbes use the O in the NO_3^- ion as an O source for respiration; this process requires carbon (C) as a substrate. Under ideal subsurface conditions, i.e., low O concentration, a supply of C and a suitable pH, these microbes can strip the last O ion from N_2O, leaving N_2 as the end product. Predicting where these conditions occur simultaneously in space and time allows us to predict where N losses to water and air are likely to be low as a result of full denitrification.

Known unknowns

To date, science has struggled to understand the full complexity of the agricultural N cycle, because of the multitude of pathways and interactions; the full denitrification pathway has been particularly challenging to quantify. Conversion of NO_3^- to N_2 has challenged scientists for decades, since dinitrogen makes up 79% of the atmosphere; this is a major source of contamination for laboratory and field experiments. Therefore, most research has focused on N_2, which is much easier to measure. Even less is known about N_2 and N_2 emissions from subsoils, i.e., soil below the agriculturally important topsoil. However, subsoils may be many metres thick, and have potential to contribute significantly to the clean-up of NO_3^- and N_2O into N_2.

Our research programme

Since 2007, Teagasc and research partners have embarked on a major research programme to understand and quantify subsurface denitrification. This programme involves a multi-disciplinary team of soil scientists, microbiologists and hydrogeologists. Our goal is to quantify subsurface denitrification, and to understand the drivers of full denitrification. Building on this new knowledge, we aim to develop environmental technologies to enhance complete soil denitrification for the abatement of NO_3^- leaching and N_2O loss to the atmosphere.

We have measured soil and subsoil denitrification in laboratory and field studies for a range of Irish subsoils. Although total denitrification (N_2+N_2O)

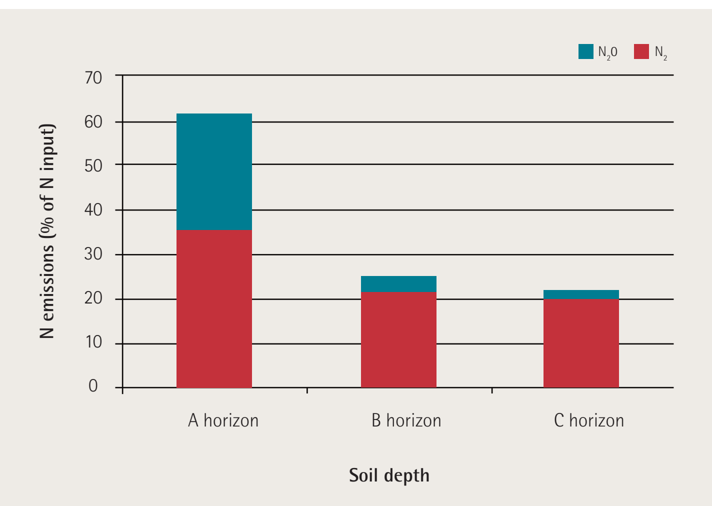

FIGURE 1: Proportion of N_2 and N_2O emitted as a percentage of the N applied. A horizon: topsoil; B horizon: subsoil; C horizon: parent material.

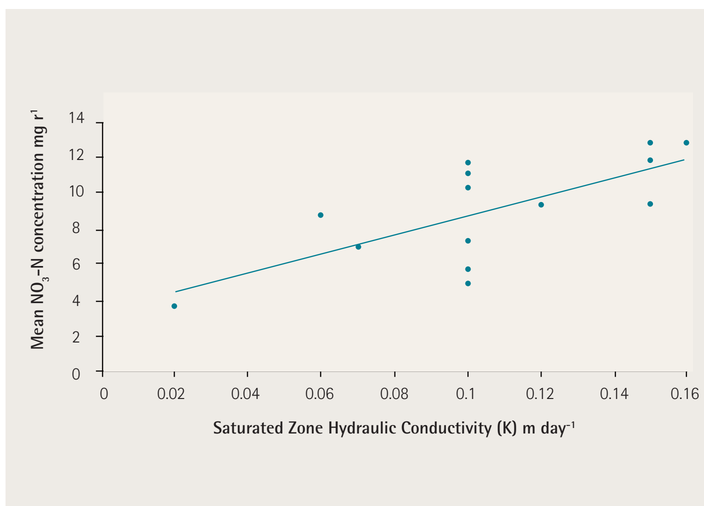

FIGURE 2: The positive relationship (p=0.003) between groundwater NO_3^- and the speed of groundwater movement (saturated zone hydraulic conductivity, K_{sat})(Fenton et al. 2009).

decreases with soil depth, possibly due to the greater substrate availability and prevalence of denitrifying microbes in the top soil, emission of environmentally benign N_2 was significantly greater in subsoil horizons compared to the surface horizon, accounting for about 90% of the total N_2+N_2O emissions (**Figure 1**), compared with 58% in topsoil (Khalil *et al*., 2009). This suggests that denitrification in subsoil occurs at lower rates, but produces mainly environmentally inert N_2.

Slower is better

Subsoils can be many metres deep, and percolating water may take months or years to migrate vertically through the subsoil profile. This potentially long residence time of water in subsoils is important, as it allows time for full denitrification to take its course. We have measured spatial variation in denitrification on a number of experimental sites, representing grassland, tillage and a range of soil/hydrogeological settings. Recently published results confirm our hypothesis that groundwater NO_3^- levels are lower with longer residence times in an aquifer (**Figure 2**).

Opening the microbial black box

To help us understand which soil conditions are limiting the denitrifying activities of microbes in the subsoil, researchers at the Department of Microbiology at NUI Galway are using advanced molecular tools to quantify the number of organisms related to N_2 and N_2O emissions, and to identify where exactly these are located in the subsoil and groundwater (**Figure 3**), and preliminary results confirm that abundance decreases with depth below soil surface (Barrett *et al*., 2008).

We are now using this new knowledge and understanding to develop innovative technologies to enhance full subsurface denitrification and to remediate groundwater with elevated NO_3^-, while simultaneously reducing N_2O emissions. Such technologies include the installation of reactive barriers that introduce carbon into groundwater as an available source of energy for the denitrifying microbes (Fenton *et al*., 2008). We are testing a variety of carbon sources for costs and effectiveness. In addition, we are evaluating technologies to manipulate the water table in buffer strips, in an attempt to control and extend anaerobic conditions over a larger part of the subsurface profile, thereby increasing the depth over which full denitrification can operate (Haria *et al*., 2009). Building on a deeper understanding of the processes that drive subsurface denitrification, these technologies help us to develop solutions where productive farming contributes to a sustainable environment.

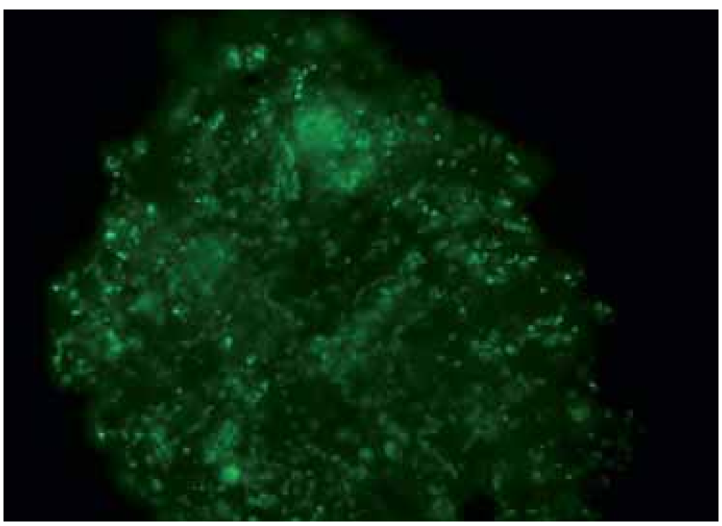

FIGURE 3: Epifluorescent micrographs illustrating the results of in situ *hybridisations carried out on soil profiles containing microbial biomass.*

Acknowledgements

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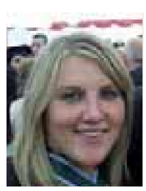

Agri-environment schemes for public good: a European perspective

Monitoring of the environmental effectiveness of agri-environment schemes has taken a back seat in their evaluation. JOHN FINN, LIAM DUNNE and DAIRE Ó hUALLACHÁIN explain that such monitoring is an investment in securing the future of these schemes and maintaining their contribution to rural livelihoods and society in general.

Policy background

Agri-environment schemes (AESs) in the EU are a major contributor towards CAP objectives to reverse biodiversity decline by 2010, achieve good water quality by 2015 and achieve the Kyoto targets for mitigating climate change. AESs are the only mandatory policy instrument for Member States within Axis 2 of the Rural Development policy. About 51% (~ €34 billion) of the Axis 2 Rural Development budget for the 2007-2013 period was allocated to AESs, which now cover nearly three million farms across almost 39 million acres. The Rural Environment Protection Scheme (REPS) is the Irish AES.

Agri-environment schemes aim to provide public goods

The payments associated with AESs are clearly linked to the provision of public goods; overall, these aim to deliver a rural countryside with environmental standards that exceed those achieved by cross-compliance (i.e., direct payments to farmers depend on complying with the legislation) alone. Achieving and demonstrating the delivery of these environmental standards is becoming increasingly important in order to satisfy EU agri-environment legislation, to demonstrate value for money to taxpayers, and to avoid accusations of trade distortion (e.g., in WTO negotiations).

There is an EU official requirement for Member States to monitor and evaluate AESs. Most of the recent evaluations of AESs have been criticised for insufficient consideration of the environmental impacts of the scheme. A Court of Auditors report highlighted an over-reliance on data on levels of uptake and expenditure as measures of scheme performance. It is important to emphasise that this does not mean that AESs do not deliver environmental benefits; it simply means that there is not sufficient evidence to demonstrate delivery of the benefits. As the Court of Auditors begins focusing on the environmental effectiveness of AESs, there will be more demands for schemes to be well designed and implemented, and to clearly demonstrate the environmental benefits. Teagasc research has been involved in a number of collaborative EU projects on AESs. Here are some of the lessons learned about the design and delivery of environmentally effective schemes.

The ITAES project

Teagasc researchers in the Rural Economy Research Centre and the Environmental Research Centre collaborated with other EU partners in the EU FP6 ITAES (Integrated Tools to design and implement Agro Environmental Schemes) project. Due to the absence of relevant environmental data, we developed a methodology that used agri-environmental experts to assess the environmental impact of AESs. The experts provided ratings and qualitative feedback on various criteria that reflect the effectiveness of practical measures for delivering specified environmental objectives. The results suggested significant opportunity for the environmental performance of AESs to be improved and to be better aligned with agri-environmental priorities (Finn *et al.*, 2009). Interestingly, across all case study areas, the experts indicated high levels of compliance by farmers in implementing their agri-environmental contracts. When experts considered that schemes did not fully deliver the intended environmental benefits, it was usually because of insufficient participation, insufficient targeting of participation in areas with agri-environmental problems, and implementation of measures that were not wholly appropriate to achieve the environmental objectives.

This methodology could help to prioritise resources for monitoring and evaluation by identifying where there is most to be learned about how to improve the environmental performance of a scheme. In this way, most benefit may be gained from the investment in monitoring and evaluation. For example, where experts' judgements indicate a very effective measure, then sufficient monitoring could be conducted to simply confirm this effectiveness. Where experts indicate doubt about a measure, then monitoring can help to identify relevant strengths and weaknesses. For measures that experts clearly identify as failing (e.g., due to deficient assumptions about how a management prescription will achieve an environmental objective), then it may be best not to invest in monitoring until the design is changed.

Looking to the future

Speculating a little on the future challenges and opportunities for AESs, we suggest a number of key issues. A primary challenge, of course, will be budgetary pressures on not just the EU contribution to the rural development budget, but also on the availability of national co-financing. Increasing the environmental effectiveness and economic efficiency of schemes will be vital for farmers to justify continued public financial support, especially in periods of budgetary constraints. For budgetary and international trade reasons, future agri-environmental payments can no longer be justified as a farm income system, and there will be clear demonstration that payments are for environmental services provided. Already, there are strong signs that the environmental objectives of EU policies will not be met, e.g., biodiversity loss in the EU will not be halted by 2010. This will likely result in even stronger strategic emphasis on the use of agri-environment spending to achieve these targets. As a consequence, future agri-environment spending may well be more targeted at specific issues and geographical areas.

Future changes are more difficult to predict. There is likely to be an increased emphasis on the design of cost-effective measures, and scope for sharing best practice in addressing common environmental objectives across Member States. In response to accumulating research evidence, future EU schemes will have an added scientific input at development stage to ensure improved scheme design, plus operational and payment structures that will result in better environmental outcomes for society. Possible examples include outcome-based payments, co-operative proposals among groups of farmers, and bidding systems for achieving specified environmental objectives. Future agri-environmental payments for farmers will be designed and financially justified for both direct and indirect costs incurred as a result of their supply of public goods.

The primary emphasis within AESs to date has been on maintaining and increasing the supply of environmental goods and services. In the future a greater prominence will be given to the marketing and utilisation of these goods and services arising. As a consequence, there may be a refocusing of the schemes themselves, with an added input by potential users into the overall scheme design, and a strengthening of the linkages between farmers and potential users of products and services. Recognition by consumers and society of the environmental services provided by farmers will also help to ensure the continuation of public funding for their provision. Consequently, the architecture of future schemes within the EU may become more diverse and focused on indigenous resource conservation in combination with local and regional priorities, while simultaneously conforming to EU objectives, standards and implementation criteria.

Conclusions

In summary, ensuring the environmental effectiveness of AESs will require a number of different approaches that include:

- ensuring a reliable evidence base to inform decision makers about the design of environmentally effective schemes;
- designing and implementing cost-effective programmes to monitor the environmental impact of schemes on air, soil, water and biodiversity; and,
- evaluating environmental impacts of schemes to better learn about which elements are effective, and which need to be improved.

The design stage is crucial for the achievement of environmentally effective and cost-efficient AESs. Ideally, monitoring and evaluation should confirm the good environmental performance of well-designed schemes, rather than highlighting weaknesses in poorly designed ones.

Thus, the imperative is that schemes should be well designed, which usually requires measures that are evidence based. This challenges ecologists, environmental scientists and economists to improve their transfer of relevant knowledge from their specialist disciplines to decision makers. Across the EU, AESs have been criticised for not sufficiently monitoring the resulting environmental impacts, which is the first step in demonstrating the environmental benefits that occur, and learning how to improve measures that are not as effective as intended. Both the costs and complexity associated with environmental monitoring (especially of biodiversity) are two prominent reasons for the lack of available budget for monitoring. However, such costs would be very small in comparison to the potential value of these schemes to farm and other rural livelihoods. More than ever before, we should view the costs of monitoring as an investment in securing the future of these schemes, and their contribution to rural livelihoods and society in general.

The ITAES project (Integrated Tools to design and implement Agro Environmental Schemes) was a Specific Targeted Research Project funded by EU FP6 (http://merlin.lusignan.inra.fr/ITAES/website). Otherwise, this research is funded by the Teagasc Core Programme.

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Bumblebee importation: balancing risks and benefits

With modern agriculture becoming increasingly dependent on pollination, researchers at Teagasc and IT Carlow have been assessing the costs and benefits of bumblebee importation in light of recent declines in our native bee populations.

"Flowering-the-earth"

Between 1961 and 2006, the percentage of cropping land devoted to pollinator-dependent crops in the developed world increased from 18.2 to 34.9%. This trend, commonly called "flowering-the-earth", suggests that modern agriculture is becoming increasingly pollinator dependent. Currently, of the 124 main crops grown for human consumption, 87 (70%) require insect pollination for seed production (e.g., carrots, onions, garlic) and to increase produce quality and yield (e.g., coffee, nuts, many fruits). Fundamentally, pollinator-dependent crops now represent 35% of global agricultural production, i.e., one-third of everything you eat has been pollinated by an insect.

Pollination as an ecosystem service

With an estimated 30,000 species worldwide, bees are by far the most important insect pollinators, pollinating over 90% of the world's 254,000 flowering plant species and thus providing an essential ecosystem service. Although bees are typically associated with honey production, their role as pollinators is far more valuable. For example, sales of Irish honey in 2008 were valued at €992,000, whereas bee pollination generated a minimum of €14.4 million of horticultural produce in the same year. Furthermore, the indirect benefits include the maintenance of sexual reproduction in a host of wild flowers and trees, which provide a myriad of other services such as habitat for other beneficial insects, nutrient cycling and soil stability. Current estimates of both direct and indirect benefits of pollination to the Irish economy range from €52 to €200 million per annum.

Worldwide declines in bee populations

Since the mid-1990s, scientists have become increasingly concerned about declines in pollinator populations worldwide. Data from regional studies conducted as part of the International Pollinators' Initiative (IPI) have confirmed that the abundance and diversity of wild bees, including wild honeybees, is now in decline and some species are close to extinction. These declines are primarily driven by fragmentation and loss of natural habitats. In Europe, Britain and the Netherlands have lost 52% and 67%, respectively, of their bee biodiversity since 1980; in France and Belgium, 25% of bee species are in decline and 23% could not be assessed as they are now too rare. In Ireland, 30% of our 101 bee species are considered threatened and three species have already become extinct. Honeybees, primarily the European and African species *Apis mellifera*, remain the most economically valuable pollinators of crop monocultures worldwide. Despite the widely reported regional declines of hives in Europe and the USA (27% and 57%, respectively), overall the global stock of commercial honeybee hives has increased by 45% since 1961, particularly in major honey exporting countries. However, the recent expansion in pollinator-dependent agriculture greatly exceeds that of the global stock of commercial hives and, particularly in Europe and the USA, commercial hives cannot satisfy the demand for agricultural pollination or compensate for losses of wild bees.

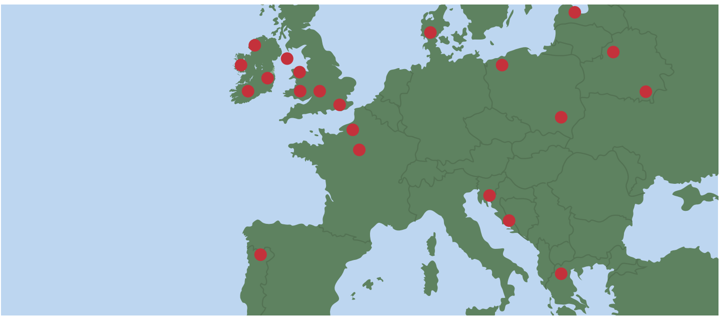
The global bumblebee trade

As the above illustrates, reliance on a single bee species for agricultural pollination is unsustainable. Fortunately, some 20 years ago the horticultural industry responded by domesticating an alternative group of bees, the bumblebees. The global trade in bumblebee hives is now worth over €55 million per annum, with over one million bumblebee hives exported worldwide each year. Unlike honeybees, bumblebees can vibrate their wing muscles while visiting flowers to rapidly release pollen from the anthers. This 'buzz pollination' allows them to pollinate a wide variety of crops for which honeybee pollination is poor. Furthermore, bumblebees work under less favourable weather conditions such as low temperatures, wind and light rain, and are less aggressive than honeybees. In combination with the decline in the numbers of Irish honeybee hives, these benefits encourage Irish horticulturalists to import about 1,500 bumblebee hives every year, primarily for strawberry, apple and raspberry pollination.

In Europe, the domesticated species of bumblebee is *Bombus terrestris*. Breeding and rearing facilities produce these bumblebees for year-round export. However, the *B. terrestris* consists of a number of recognised subspecies, including *B. terrestris audax*, which is found only in Ireland and Britain. The breeding stock of commercial bumblebees is not native to Ireland and unregulated importation could pose a risk to our native bumblebee subspecies. Studies in both Canada and Japan have shown that imported bumblebees have been responsible for spreading both diseases and parasites to native bumblebees. Imported bumblebees can also escape from glasshouses and compete with native bumblebees, eventually establishing in areas with frequent hive importation. Finally, imported bumblebees may interbreed with native *B. terrestris audax*, which, because of genetic dilution, could erode any unique physiological adaptations to Irish conditions.

Teagasc and IT Carlow bumblebee project

Research into the benefits and the potential risks of importing non-native bumblebees was initiated in 2006 in a collaborative project between Teagasc (at



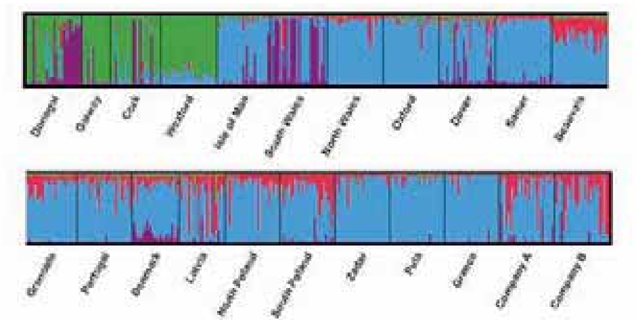


FIGURE 1: Locations of the B. terrestris *sampled for this study and a summary of the statistical clustering of genetic markers within each population. Note the 'green' genetic signature unique to Irish populations.*

Oak Park and Kinsealy) and the Institute of Technology Carlow. The research objectives are:

- to improve the management of imported bumblebees in order to increase pollination efficiency;
- to reduce drift between hives and escape from areas of importation;
- to determine the level of genetic differentiation between native *B. terrestris audax* and non-native *B. terrestris*;
- to assess the risk of hybridisation between native and non-native bees and the risk of establishment of non-native bumblebees; and,
- to determine the disease and parasite load of imported bumblebees and the risk of disease transmission to native bumblebees.

The project will conclude in 2009 with a comprehensive risk assessment of the bumblebee trade in Ireland and evidence-based recommendations for policy and legislation. The results from the pollination and population genetics studies are briefly summarised below.

Pollination of cv. Elsanta strawberries

'Elsanta' is the most widely grown strawberry cultivar in Western Europe, and it is currently the most economically valuable crop grown in Ireland that requires bumblebee pollination. Despite its popularity, the pollination requirements of Elsanta and the pollination efficiency of commercial bumblebees was unknown for this cultivar. In the absence of bumblebees, fruit weight dropped by 26% and the rate of fruit deformity increased by 41%. Furthermore, bumblebees only needed to visit flowers one to five times to achieve maximum pollination, making them 2.5 times more efficient pollinators of strawberries than honeybees.

Population genetics of European *Bombus terrestris*

Samples of *B. terrestris* (630), representing 20 populations from across Europe and two populations of commercially-reared bumblebees, were genetically screened at eight hypervariable DNA microsatellite markers. Overall, the greatest proportion of non-native queen and worker haplotypes were found within 500m of glasshouses. However, non-native males were most frequently recorded 2km away from the site of importation. Although levels of genetic diversity were relatively high, evidence of recent inbreeding was observed in almost all populations, indicating a decline in population size within the last few generations. Of significant importance was the confirmation that the native Irish and British *B. terrestris audax* is genetically distinct from continental European and commercially-reared populations. In addition, using a novel mitochondrial DNA marker, we determined that imported bumblebees can spread up to 10km from sites of importation and successfully overwinter under Irish conditions (**Figure 1**).

Conclusions

Our research has demonstrated that the Irish market for commercial bumblebees is continually expanding, largely due to the convenience afforded by commercial hives in securing pollination services, and the efficacy of bumblebee pollination, particularly in protected crop systems. However, we have also confirmed the genetic uniqueness of Irish *B. terrestris audax* and established that commercial bumblebees can easily escape from glasshouses and successfully overwinter in Ireland. Our parallel conservation campaign to inform horticulturalists of best practices to reduce commercial bumblebee escape have been successful, with recent surveys indicating that growers better understand the risks involved and are keen to act responsibly to improve management of imported hives. Teagasc's research on imported bumblebee management will facilitate and improve the use of imported bumblebees, while protecting our native bee populations using evidence-based recommendations for management and legislation. Furthermore, to maintain and improve current levels of agricultural pollination in Ireland, further research is needed on the current status of our pollinator populations and the provision of pollination in Irish agro-ecosystems.

This research is funded by the Department of Agriculture, Fisheries and Food under the Research Stimulus Fund and the programme for Conservation of Genetic Resources for Food, Agriculture and Forestry to investigate sustainable management practices for imported bumblebees.

Tomás Murray, Postdoctoral Fellow, Oak Park Research Centre, **Sérgio Moreira**, Walsh Fellow, Oak Park Crops Research Centre, **Eamonn Kehoe**, Crop Advisor, Teagasc Kinsealy Research Centre, **Thomais Kakouli-Duarte**, Lecturer and Principal Investigator, Institute of Technology, Carlow, and **Finbarr Horgan**, Research Scientist, International Rice Research Institute, The Philippines.
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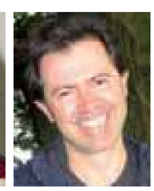

T Horticulture

The power of plants

MICHAEL GAFFNEY and KIM REILLY ask if changing agronomic practices can increase the phytochemical content of plants.

In nature phytochemicals may play a role in a wide range of functions within plants, such as pest and herbivory deterrence (glucosinolates); prevention of UV-induced oxidative damage (flavanols); and, pigmentation (anthocyanins). A large number of studies have shown that several phytochemical compounds can exert a significant positive effect on human health. Indeed, phytochemicals have been defined as "non-nutrient chemicals found in plants that have biological activity against chronic disease". As part of the Irish Phytochemical Food Network (www.ipfn.ie), researchers at Teagasc Kinsealy are trying to manipulate the way we grow vegetables to increase their beneficial phytochemical content. They are focusing on areas such as nutrition, maturity, tissue type, variety and – the always contentious issue – comparing organic to intensive production. They hope to understand how vegetable crops can be grown to produce healthier food and food ingredients (functional foods).

Phytochemical profile

The phytochemical profile of a plant is strongly dependent on genetic components and there is clear evidence that the range, type and amount of individual phytochemicals and other bioactive compounds vary between different cultivars of the same species, and different species of the same genus. In broccoli, the predominant glucosinolates detected are glucoraphanin and glucobrassicin. In a detailed study using high-performance liquid chromatography (HPLC), which evaluated the glucosinolate profile of 50 broccoli accessions grown under uniform cultural conditions, the reported levels of glucoraphanin ranged from 21.7mmol/g DW in the cultivar Brigadier to 0.8mmol/g DW in the cultivar EV6-1. Less research has been carried out on the effect of cultivar on phytochemical accumulation in carrot and onion varieties. In order to identify the Irish situation, Teagasc researchers are carrying out field trials on Irish grown carrot, broccoli and onion. Analysis of key health-promoting phytochemicals in each crop (such as polyacetylenes in carrot, glucosinolates in broccoli and flavanols in onion) should allow us to better understand how much variation in phytochemical content occurs between different varieties and under different cultivation practices. At Kinsealy, over 40 varieties each of broccoli, carrot and onion are currently being grown in replicated field trials. In conjunction with Teagasc Ashtown Food Research Centre, we hope to identify varieties with higher levels of naturally occurring phytochemicals. The variety trials include most of the commercial varieties for each crop, as well as older, traditional varieties sourced from Horticulture Research International, Wellsbourne and Irish Seed Savers.

Nutrition

Decreasing nitrogen (N) application has resulted in higher accumulation of glucosinolates and phenolic compounds in brassicas, while increasing N levels has been shown to promote the formation of carotenoids and chlorophylls. A recent Australian study investigated the effect of applied N on phytochemical accumulation in the broccoli cultivar Marathon. N was applied at 0, 15, 30 or 60kg/ha. In this study, N application at levels above 30kg/ha caused an increase in glucobrassicin content of up to 44%, while levels of glucoraphanin declined by 18-34% and levels of the phenolic compounds quercetin and kaempferol declined by 20-38%. However, crop yields (floret weight) declined significantly (up to 40%) at N levels below 60kg/ha. Thus, low N regimes may only be commercially useful for growers producing mini broccoli heads for a niche health market. Current Teagasc recommendations for N application rates in broccoli are 90-120kg/ha depending on soil index. Few studies have examined the effect of phosphorus (P) or potassium (K) on phytochemical accumulation. Field trials running at Kinsealy Research Centre will enable assessment of the influence of major nutrients (N, P, K) on phytochemical accumulation in carrot, onion and broccoli.

Tissue type and plant maturity

The level and type of individual phytochemicals found can differ in different plant tissues and at different developmental stages. Levels of glucosinolates are frequently reported to be higher in un-germinated broccoli seed than in seedlings or in plant florets. Levels of the anti-carcinogenic phytochemical glucoraphanin are considerably higher in broccoli seedlings than in the mature

Autumn broccoli field trials at Kinsealy Research Centre in 2008.

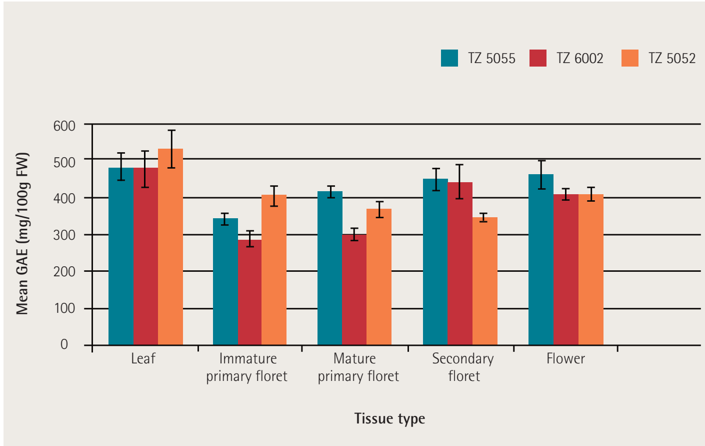

FIGURE 1: Determination of total phenolic content in three purple sprouting broccoli varieties (TZ 5055, TZ 6002 and TZ 5052). Total phenolic content is expressed as gallic acid equivalents (GAE mg/100g FW). Error bars indicate the standard error of the mean.

plant and a number of products based on sprouted broccoli seeds have been developed, patented and licensed by Johns Hopkins University. They include BroccoSprouts®, Brassica® tea and the supplement Xymogen Oncoplex SGS™. In a study on cultivated broccoli plants, levels of total glucosinolates declined during development; however, levels of glucoraphanin were unchanged during head development. In carrot, higher levels of total polyacetylenes are found in the outer part of the root. This is in agreement with the observation that peeled carrots contain up to 50% less falcarindiol, a polyacetylene compound with strong anti-fungal activity associated with bitter flavour in carrots. In onion, higher levels of quercetin and kaempferol are found in the outer dry skins, with lower levels detected in the inner edible rings.

Field trials will allow us to examine the levels of key phytochemicals in different tissues and different developmental stages in Irish grown field crops. Data (**Figure 1**) from an autumn 2008 broccoli trial has shown that tissue type has a significant impact on total phenolic content.

Organic versus conventional agriculture

A limited number of studies have compared nutritional content in organic and conventionally grown vegetables. Some studies have been carried out in fruit, with very few of these examining phytochemical content. In general, the evidence suggests little difference in the nutritional content of organically cultivated crops, with the exception that levels of nitrates are lower and levels of vitamin C and dry matter content are higher than in conventionally grown crops. Some data does suggest increased levels of phytochemicals in organically grown crops and some authors have suggested that levels of phytochemicals which can be considered as defence-related secondary metabolites, could be considerably higher in organic vegetables. Several studies have evaluated antioxidant levels rather than measuring individual phytochemicals and there is evidence that the antioxidant profile of organically grown crops may be higher. It is unclear to what extent these differences may be due to factors such as low N, use of disease-resistant cultivars, or to increased pest damage in organic systems.

A field trial to compare the effects of organic and conventional production systems on phytochemical accumulation has commenced at Kinsealy. This trial is a factorial systems comparison trial, which means that the systems to be compared are divided into component parts. Agronomic practices used in organic agriculture are divided into an "organic soil treatment" (i.e., crop rotation, use of organic fertilisers, winter cover crop, etc.), and "organic pest control" (use of certified organic or untreated seed, mechanical weeding, organic pest control). Similarly, conventional agriculture is divided into "conventional soil treatment" (e.g., mineral fertilisers, no set crop rotation) and "conventional pest control treatment" (chemically treated seed, chemical pest and weed control). Two varieties each of carrot, broccoli and onion are grown each year and each crop variety is grown under four possible treatment combinations. The trial is planned to run initially over four to five years to allow at least one complete rotation, and will be used to evaluate phytochemical content in onion, carrot and broccoli, and to examine the effect of, and any interactions between, the system components. It should help us to better understand how techniques used in either conventional or organic agriculture can affect phytochemical content in field grown vegetables.

Funding for this research under the Food Institutional Research Measure (FIRM) of the Department of Agriculture, Fisheries and Food is greatly appreciated.

Michael Gaffney is a Horticultural Development Officer and **Dr Kim Reilly** is a Research Officer with the Horticulture Development Unit, both based at Teagasc Kinsealy. E-mail: michael.gaffney@teagasc.ie.

Finding the right ingredients

A new dedicated Bio-analytical Research Centre at Teagasc Ashtown Food Research Centre will help to identify novel food ingredients, explains NIGEL BRUNTON.

NMR machine: NMR is one of only two techniques (the other being x-ray crystallography) that allow the user to probe into the three-dimensional structure of compounds.

Visitors to Teagasc Ashtown Food Research Centre (AFRC) will have noticed a new three-storey building currently under construction on site. The new building will be home to a new dedicated Bio-analytical Research Centre with facilities aimed at extracting, isolating and characterising new and novel compounds from natural sources for inclusion in functional foods. Given the current economic climate, the Bio-analytical Research Centre at AFRC aims to supply high quality, new and exciting ingredients for the Irish food sector to enhance competitiveness in the growing, and highly competitive, functional foods market. Research at AFRC will focus on three biological sources: terrestrial plants and foods; the marine environment; and, animal muscle.

The research strategy will focus on the following activities related to three different, but integrated, research routes, as illustrated in **Figure 1**:

- identification – screening for novel compounds that have high potential for commercial exploitation and that can be extracted from natural sources;
- bio-assay directed fractionation – identifying novel or improved properties for compounds in pure and mixture form by cost-effective and industrially feasible *in vitro* laboratory tests; and,
- extraction/purification – optimising the extraction/purification procedures at analytical and pilot scale with the aim of developing improved, feasible and sustainable industrial processes for the commercial exploitation of novel compounds.

Analytical scale recovery of new bio-molecules

A typical work-flow diagram for analytical scale extraction and purification of novel bio-actives from natural sources is illustrated in **Figure 2**. In some cases biologically-active compounds, such as peptides and carbohydrates, can only be extracted from source by chemical and/or enzymatic hydrolysis of the parent molecule. The process of hydrolysis must be carried out under tightly controlled conditions of temperature, pH and agitation. At AFRC, fermentations of this nature will be carried out in a dedicated bio-fermentation facility encompassing four units allowing four replicate fermentations to be carried out simultaneously. Fermentation will result in the generation of a heterogeneous mixture of bio-molecules differing in molecular weight. Since the biological activity of many molecules is related to their size, it is useful at this point to carry out an initial separation using tangible flow membrane filtration. It is essential that the biological sources of new and novel compounds are carefully catalogued and stabilised so they can be re-examined in cases where new or novel compounds are discovered. At AFRC, we are currently using a pilot-scale freeze dryer to stabilise our natural products and, following this, all samples are vacuum-packed and stored at -80°C. This strategy is allowing us to build up a natural product repository, which will serve as a source of biologically useful bio-molecules into the future.

Following stabilisation of either the raw natural product or a fermentate, the next step is to fractionate compounds on the basis of polarity by carrying out solid-liquid extraction utilising food-friendly solvents. At AFRC we use pressurised liquid extraction (PLE) to prepare these 'crude' extracts. This technique uses high pressures to allow the user to carry out extractions at temperatures above the boiling point of

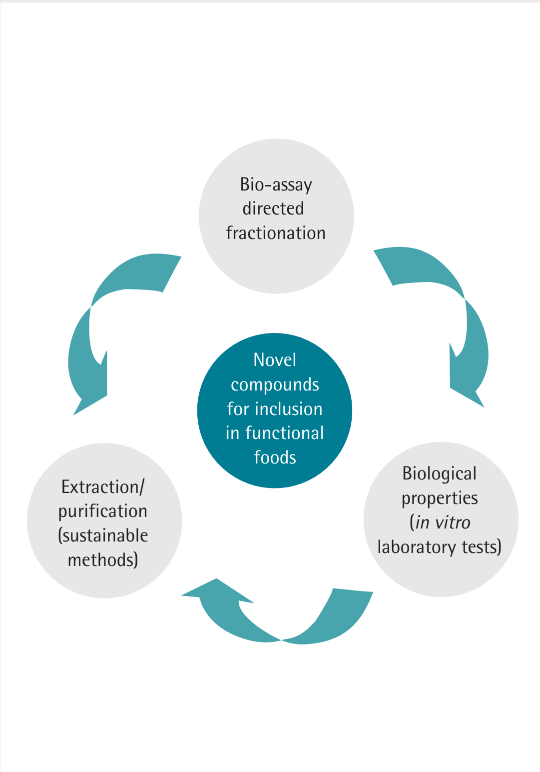

FIGURE 1: Bio-analytical Research Centre research routes and related interconnections.

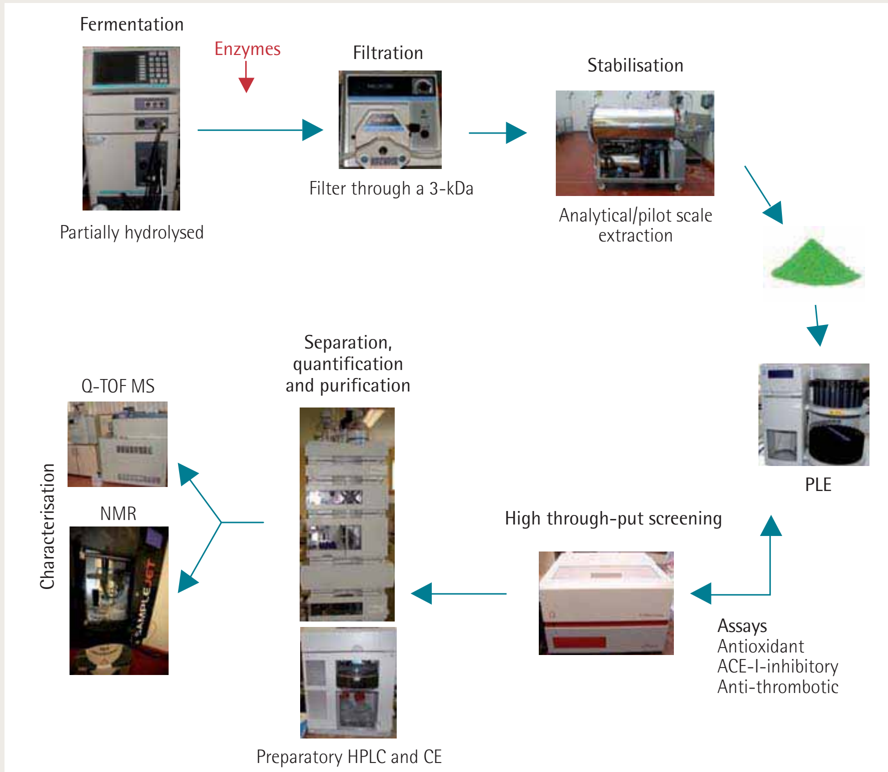

FIGURE 2: Work-flow diagram for analytical scale recovery of new and novel bio-actives from natural sources.

the solvent. This enhances analyte solubility and mass transfer rates, resulting in better recoveries of the target compounds than conventional solid-liquid extraction techniques. This means that the technique uses less solvent than conventional methods and thus could be considered a 'green' extraction technique. PLE can also be automated, thus decreasing sample preparation time. 'Crude' extracts from PLE can be further fractionated and purified using a combination of techniques such as flash and high-performance preparative chromatography. Both these techniques are available at AFRC. These fractions are then assayed for useful biological properties using high throughput plate reader based bioassays. Fractions exhibiting promising biological properties will be further purified at this point before progressing to more detailed chemical characterisation.

Chemical characterisation of novel compounds

As a result of generous funding from the Department of Agriculture, Fisheries and Food's Food Institutional Research Measure (FIRM) at AFRC, we have two highly sophisticated pieces of equipment, which, in tandem, will allow us to elucidate the structures of new and novel molecules with health-promoting potential. A quadrupole time-of-flight mass spectrometer with a tandem nano-HPLC facility will allow us to determine empirical formulae of target molecules. In addition, this facility incorporates a MALDI ionisation source, which is particularly useful for bio-molecules such as peptides and sugars, which tend to be too fragile for ionisation using conventional techniques. Final fine structure elucidation of molecules with health-promoting potential will be carried out using our high resolution nuclear magnetic resonance (NMR) facility. NMR is one of only two techniques (the other being x-ray crystallography) that allow the user to probe into the three-dimensional structure of compounds. For new compounds, fine structure determination is an essential step, both as part of the patenting process and to develop an understanding of biological efficacy.

Pilot-scale extraction

Up-scaling of extraction and purification protocols is an essential step towards commercialisation of functional ingredients. At AFRC, we are addressing this requirement by developing protocols that could be used to recover target compounds at pilot scale. Pilot-scale protocols will operate under the same principles as analytical-scale methods but will use techniques that can be used to extract and purify from a larger volume of natural product. For example, the new bio-analytical centre will incorporate a batch solvent extraction and de-solventising unit. This will allow us to carry out extraction and concentration of target compounds simultaneously and on a larger scale than is possible with techniques such as PLE. The programme will work in close collaboration with Moorepark Food Research Centre, where the emphasis will be on investigating health claims associated with nutraceutical components.

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Biopolymer interactions in foods

BRENDAN O'KENNEDY explains how research at Moorepark Food Research Centre is addressing common industry problems caused by biopolymer interactions in formulated food.

Image courtesy of Bord Bia.

The addition of LBG and/or guar to the ice-cream mix markedly improves the melt resistance of the frozen ice-cream.

Biopolymers are a class of polymers produced by living organisms. Cellulose and starch, proteins and peptides, DNA and RNA are all examples of biopolymers, in which the monomeric units, respectively, are sugars, amino acids, and nucleotides.

The most commonly used biopolymers in formulated food systems are starch, milk proteins, egg proteins, seed proteins and other carbohydrate-based polymers (starch, guar gum, carrageenan, alginate, etc.). In general, these biopolymers are synthesised in large quantities for the purpose of nutritionally sustaining the plant or animal species in question. It must be stressed that these biopolymers were never synthesised with the production of formulated food in mind, where heating regimes, pH and ionic strength can be severe. The structure and texture of formulated food is a direct effect of heating temperature/time, the pH of heating, the final pH and the ionic strength of the aqueous biopolymer phase. Ongoing research at Moorepark Food Research Centre approaches biopolymer interactions from a number of different angles as outlined below.

Effect of biopolymer interactions in heated milk on the properties of yoghurt and fermented milk products

The caseins in milk are a heterogeneous group of phosphoproteins that self-assemble, in the presence of calcium and phosphate ions, into discrete protein packages (casein micelles) with diameters in the region of 200nm. κ-casein (a glycoprotein) is regarded as the major stabilising influence for the casein micelle. They are generally stable to heat (i.e., they don't aggregate). The whey proteins, on the other hand, are globular proteins, which are susceptible to heat-induced unfolding and subsequent aggregation into particles. When bovine milk or casein/whey protein combinations with varying ratios are heated under certain temperature/pH conditions, the κ-casein can migrate from the micelle and interact with the denatured whey proteins. Under different conditions of pH, heating promotes the interaction of the denatured whey protein with the κ-casein on the casein micelle. So depending on the heating conditions (pH, temperature), different types of protein particles can be produced, each of which can have a different functional expression, which in turn can have a large impact on the structure and physical properties of the resultant yoghurts. Hence, the key to understanding the functional behaviour of heated milk, whether for yoghurt production or from a heat stability perspective, is to control the degree of interaction between the casein/whey protein biopolymers.

Biopolymer interactions in cheese

The recovery of whey proteins from milk to cheese has long been an aspiration of cheese manufacturers because of the potential increase in product yield. This has generally been achieved through heat denaturation/aggregation of the whey protein prior to renneting. It is well known that heat treatment of milk negatively affects its curd-forming properties. These heat-induced changes in the milk have been correlated to the denaturation of whey proteins and formation of both micelle-bound whey protein and soluble whey protein/κ-casein aggregates (as outlined above). Curd fusion and syneresis are also inhibited, leading to a reduced curd firming rate, soft, high moisture curds and impaired melting properties. The adverse effects of whey protein denaturation on cheese-making properties have been attributed to the interaction of denatured whey proteins with κ-casein. Controlling these biopolymer interactions by altering the environmental conditions during heating may provide a window for incorporation of these globular proteins into the cheese matrix with minimal effects on curd formation and cheese meltability.

Biopolymer incompatibility in ice-cream

The addition of guar and/or locust bean gum (LBG) (both neutral carbohydrate-based biopolymers) to the pasteurised homogenised milk in the manufacture of ice-cream leads to separation of the mixture into two liquid phases. One phase is enriched in the milk proteins while the other phase is enriched in guar/LBG. The volumes of the phases depend on the concentration ratios of the milk protein and the gums. This is an example of biopolymer incompatibility, an occurrence that has marked effects on the physical properties of ice-cream such as mouthfeel, hardness and melt-resistance. The phase volume ratios determine which phase is continuous (dominant) when the ice-cream mixture is pumped, aerated and frozen. The melt resistance is obviously an important commercial requirement of ice-cream, determining the quality of the product at consumption. The addition of LBG and/or guar to the ice-cream mix markedly improves the melt resistance of the frozen ice-cream. Research at Moorepark has investigated the interactions between milk proteins, homogenised fat and gums with a view to customising the physical properties of ice-cream. Our studies have shown that homogenised fat is stabilised by, and phase partitions with, the protein on addition of the gum. However, in the manufacture of low-fat ice-cream the phase volume of the combined protein and fat phase is significantly lower than that of full-fat ice-cream, resulting in an inferior low-fat product. It was also shown that the whey protein in the milk, or added whey proteins, will only phase separate with the casein and the fat if heat denatured. This observation should be taken into account when designing any ice-cream formulation.

Biopolymer interactions on interfaces (emulsions and foams)

Food formulations, in general, are a complex mixture of biopolymer, water, oil, sugars, salts and air, the concentration of each of the components determining the type of food (mayonnaise, low-fat spreads, cream liqueurs, chocolate, meringue, cappuccino). Stabilisation of oil droplets and air bubbles is often the primary function of proteinaceous biopolymers, such as caseinate. Consequently, the interaction between the biopolymers at the oil–water interface or the air–water interface becomes a key factor in controlling stability and quality of emulsion and foam-based products where food product quality and/or stability is required. A number of diverse food products with similar types of biopolymer interaction problems are currently under examination in Moorepark.

Cream liqueur is a dairy-fat based emulsion with an aqueous ethanolic/sugar/caseinate continuous phase (17% ethanol (v/v), 40% solids, pH 6.8-7). The fat content can vary from 5-16% (w/w) depending on the market and these emulsions can be stable to separation problems for up to two years. Most of the problems observed in commercial cream liqueurs revolve around the fat fraction, including creaming, cream plug formation, flecking and gelation, which are all manifestations of fat globule destabilisation. However, the fat globules are emulsified by a surface layer of caseinate, which confers the sought-after stability in the first place; hence, destabilisation in these products may be a caseinate problem. Cream liqueurs contain up to 3% sodium caseinate to aid in the emulsification of cream and provide body to the resultant emulsion. Stability of the liqueurs to time/temperature-dependent increases in viscosity is a necessary requirement for long-term storage of the product. Research at Moorepark is ongoing into the factors that cause the biopolymer (caseinate) to aggregate.

Chocolate is a fat continuous system (contains very little water [0.1%]) composed of cocoa butter with a dispersed phase of solid particles. The interactions between the dispersed particles determine the mouthfeel and rheology of the system. In milk chocolate, the milk powder (containing biopolymers such as protein) is dispersed in oil (cocoa butter). These powder particles are subject to aggregation in the oil phase even though the biopolymers are not hydrated. Our studies have shown that controlling the degree of aggregation of the powder particles is a key facet regulating quality attributes.

Cappuccino is a popular example of a frothed milk product that frequently experiences foam stability problems. In some cases the foam may be too strong, making pouring of the frothed milk difficult; however, more usually the froth is too weak. Since the casein and whey protein in the milk are the main agents responsible for the frothing efficiency of cappuccino, our work investigates the behaviour of these proteins at the bubble/water interface and how their interaction is affected by temperature.

Biopolymers in bakery type products

Other than wheat flour, the major sources of biopolymers found in baked products are eggs, milk and soy. Gluten is the main structure-forming protein in wheat flour, and is responsible for the elastic properties of dough. Gluten removal from bakery formulations results in major problems for bakers, and currently many gluten-free products available on the market are of poor quality, showing poor mouthfeel and flavour. Gluten contains the protein fractions glutenin and gliadin. The former is a rough rubbery mass when fully hydrated, while gliadin produces a viscous, fluid mass on hydration. Gluten, therefore, has both an elastic and a viscous component, which together give gluten the important properties of extensibility, gas holding ability and resistance to stretch, which determine the properties of dough.

An ongoing project at Moorepark aims to completely substitute the gluten biopolymer with a functional casein-based biopolymer. The principle behind this approach is that casein becomes a functional substitute for gluten by increasing the calcium concentration in the casein/caseinate ingredient to an optimum level under optimised conditions of pH and ionic strength. Under such conditions, the highly functional (covalent) S–S bonds in a gluten-based dough are replaced by calcium-induced casein–casein complexes.

This research is funded by The Department of Agriculture, Fisheries and Food under the Food Insitutional Research Measure (FIRM).

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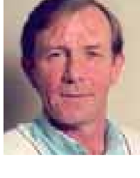


An apple a day

RONAN GORMLEY, CHRISTIAN RÖßLE and FRANCIS BUTLER have been looking at the nutritional content and eating quality of apples as part of the ongoing EU-funded ISAFRUIT project.

The five-a-day message and other initiatives aimed at increasing fruit and vegetable consumption are based on strong epidemiological evidence that populations with a high intake of fruit and vegetables are, to an extent, protected from cardiovascular disease, certain cancers, and some other so-called modern diseases (Denny and Buttriss, 2007). These health-promoting properties have been attributed to fruit constituents including antioxidants (such as flavonoids, anthocyanins, polyphenols), folic acid, dietary fibre, pectin (Gunning *et al.*, 2008), vitamins, minerals, and other phytonutrients/bioactives. Recently, antioxidants have received an extensive press on their role as quenchers of tissue-damaging free radicals (produced in profusion in our bodies). Participation by researchers at Ashtown Food Research Centre (AFRC) in the ongoing EU-funded ISAFRUIT project (see www.isafruit.org) is, therefore, timely and results are presented below on quality aspects and antioxidant status of apples purchased in a major Irish supermarket over a 12-month period. Nature's Best Ltd is also a partner in ISAFRUIT.

A changing scene

Changes in eating patterns are taking place, such as offering fruit as an alternative to scones and croissants at break times in workplaces, at conferences, and so on. Proactive initiatives have also been established, such as the 'Food Dudes' Programme in schools (national roll-out in Ireland in early 2007), which is a Bord Bia initiative funded by the Department of Agriculture, Fisheries and Food and supported by the Department of Education and Science. Bord Bia is also promoting (via a DVD available in September 2009) the concept of school gardens to give children a better understanding of how food is grown. This is complemented by the 'Incredible Edibles' programme, sponsored by Agri Aware in Ireland, which delivers a fruit and vegetable growing kit to every primary school nationwide.

Pioneering research at Teagasc

Today dietary intervention studies are commonly used to assess the possible beneficial effects of food constituents on human health. In 1977 such studies were not so commonplace; however, a study at the Kinsealy Research Centre (Gormley *et al.*, 1977) showed that two apples per day reduced serum cholesterol levels and raised the beneficial high-density fraction in humans (78 volunteers). Other researchers demonstrated that apple cell wall material had a similar effect, and also helped to control late-maturity-onset diabetes in humans (Mayne *et al.*, 1982). Since then, many other studies with fruit worldwide have shown similar results both in human intervention trials and in animal models. Ongoing ISAFRUIT trials at the University of Copenhagen (Dragsted, 2009) revealed that it takes just three to four weeks to lower cholesterol levels by 10% if fruit consumption is increased. Additionally, studies in rats indicate that while the whole fruit retains components beneficial to health, fractions of it, such as juice, may lose some of these characteristics. Early indications suggest that drinking cloudy fruit juices may be more beneficial for health as they include whole fruit components.

Apple quality – supermarket study

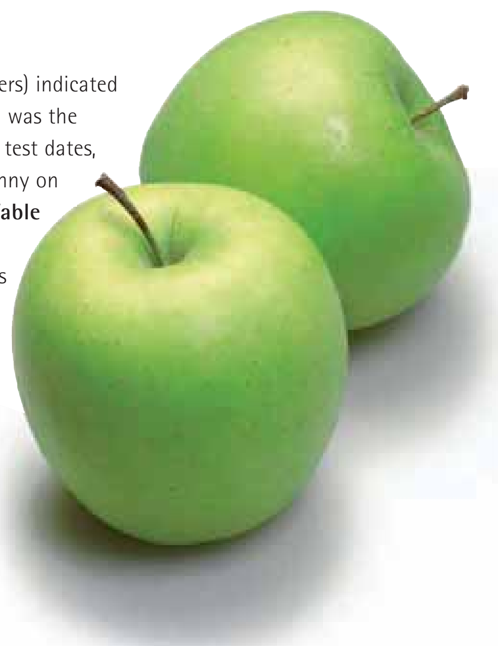
A consistent high quality supply of apples is essential if consumers are to benefit from their potential health-promoting properties. This study investigated the eating quality of Golden Delicious, Braeburn and Granny Smith apples, as these cultivars are big players in the marketplace. Representative samples (20 apples) were purchased in a major supermarket each month for one year (i.e., on 12 occasions), and were tested at AFRC for physicochemical and sensory properties using standard procedures. The antioxidant status and phenolic content of the fruit was also measured on each occasion in both skin-on and skin-off samples. Triplicate samples of each cultivar were obtained, i.e., 60 apples of each cultivar were tested each month.

Apple quality parameters

Soluble solids (mostly sugar) showed an appreciable degree of variation between cultivars – being highest for Golden and lowest for Granny. Soluble solids in excess of 13% indicate a good level of sweetness and influenced the taste panel response (**Table 1**). Acidity (highest for Granny, lowest for Golden) also influenced sensory response, with the lower acidity being preferred by most tasters. Flesh of Golden Delicious apples was yellowest (Hunter colour meter values) while Granny apples had the least yellow flesh. Apple texture (Kramer shear press) is important for consumers and, as expected, Granny slices were the firmest (some panelists said too firm), with lower values for the other two cultivars. There were large variations in physicochemical properties of the apples from month to month, due, presumably, to different countries of origin, different levels of maturity, and different lengths of time in storage and in the channels of trade.

Sensory tests

Sensory scores (18-21 tasters) indicated good acceptability; Golden was the preferred cultivar on eight test dates, Braeburn on four, and Granny on one of the 12 test dates (**Table 1**). However, tests using a large number of consumers by a Spanish ISAFRUIT partner showed that, within a population, a considerable number of consumers prefer a firm green apple. Therefore, this population segment must also be catered for in the marketplace.



A coffee break where a fruit choice is available.

Table 1: Mean values[1], and rank order[2] of the means, for the different test variables for Golden Delicious, Braeburn and Granny Smith apples.

Variable	Golden	Braeburn	Granny
Moisture content (%)	84.4 (3)[2]	85.7 (2)[2]	85.9 (1)[2]
Soluble solids (%)	13.8 (1)	12.7 (2)	12.2 (3)
Flesh pH	3.69 (1)	3.54 (2)	3.43 (3)
Hunter L (flesh whiteness)	74.1 (1)	69.5 (3)	70.9 (2)
Hunter 'b' (flesh yellowness)	17.7 (1)	16.7 (2)	12.1 (3)
Hunter L/b (white/yellow ratio)	4.23 (2)	4.19 (3)	5.99 (1)
Shear (texture) (kN)	1.68 (2)	1.55 (3)	2.27 (1)
Sensory acceptability[3]	4.32 (1)	4.15 (2)	3.57 (3)
Anti-radical power (skin-on)[4]	0.651 (2)	0.546 (3)	0.796 (1)
Anti-radical power (skin-off)[4]	0.499 (2)	0.482 (3)	0.613 (1)
Total phenols (skin-on)[5]	662 (2)	605 (3)	1107 (1)
Total phenols (skin-off)[5]	577 (2)	518 (3)	936 (1)

[1] Values are means over the 12 test dates

[2] Highest numerical value for each variable ranked 1; lowest ranked 3

[3] 6-cm acceptability scale of 0 (unacceptable) and 6 (very acceptable)

[4] Anti-radical power: ARP [1/IC50 $(g/L)^{-1}$]

[5] Total phenols (mg gallic acid equivalents/100g dry weight)

Antioxidant status

Like many fruits, apples are a good source of antioxidants, which could benefit consumers by scavenging free radicals, which have been implicated in the genesis of many diseases. The antioxidant status of the apples was assessed on the basis of: (a) anti-radical power (ARP), i.e., the ability of extracts to quench free radicals; and, (b) total phenol (TP) content. ARP (DPPH procedure) values for skin-on and skin-off samples were highest for Granny and lowest for Braeburn. Granny had the highest values on nine out of 12 test dates compared with two out of 12 (Golden) and one out of 12 (Braeburn). This indicates that Granny Smith apples may deliver more antioxidants to consumers than the other two cultivars examined in the study. This is in sharp contrast to sensory scores for these cultivars (**Table 1**). Data for the different test dates varied widely, presumably influenced by stage of maturity, source of the fruit (i.e., country of origin), and length of time in controlled atmosphere storage. The data pattern for TPs (measured by the Folin-Ciocalteu procedure) was similar to that of the ARP values. The higher values found for skin-on apple wedges compared with skin-off indicate the benefits of eating apples with the skin attached. Some consumers peel apples because they fear surface contamination. However, the Department of Agriculture, Fisheries and Food apply EU residue legislation (EU Regulation 396/2005) and conduct a comprehensive screening programme on pesticide levels in fruit and vegetables. They are also networked, and thus share information, with other screening centres Europe-wide to ensure consumer safety.

Conclusions

From a sensory acceptability point of view, Golden Delicious was the preferred cultivar in these trials, followed by Braeburn and Granny Smith. However, Granny Smith apples had the highest level of antioxidants, especially TPs, indicating that they may have better health-promoting properties than the other two. The results from this study will be further validated by measuring these parameters over a number of seasons. The outcome of this and the wider ISAFRUIT project will help in the development of new and innovative fruit-based products designed to deliver convenience and promote health.

Acknowledgements

Thanks are extended to the EU for supporting the ISAFRUIT project (European Commission; 6th Framework Programme).

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Professor Ronan Gormley is a Senior Principal Research Officer (recently retired and now located at the UCD Institute of Food and Health) and **Christian Rößle** is a Teagasc Walsh Fellow PhD student at Teagasc, Ashtown Food Research Centre. **Professor Francis Butler** is in Biosystems Engineering at University College Dublin. E-mail: ronan.gormley@ucd.ie.



T Events

September

September 1 *Teagasc, Athenry, Galway*

Inaugural Irish Rural Studies Symposium

Organised by the Innovation and Rural Development Unit, Rural Economy Research Centre, Teagasc, and the Irish Centre for Rural Transformation and Sustainability, NUI Galway, this symposium will provide a forum for the diverse community of researchers and postgraduate students who are involved in research with a rural significance.

david.meredith@teagasc.ie *www.tnet.teagasc.ie/rerc*

September 9-11 *Teagasc Johnstown Castle, Wexford*

Soil Quality = Environmental Quality?

The first joint meeting of the Irish and British Soil Science Societies is themed around the forthcoming EU Soils Framework Directive. As a taster before the main event, the CréBeo (Irish for 'Living soil') project will host their end of project workshop at Johnstown Castle on September 8, which is open to all delegates of the soils conference.

rachel.creamer@teagasc.ie *www.ucd.ie/sssi* *www.ucd.ie/crebeo/*

September 16 *Ashtown Food Research Centre, Dublin*

Food processing stresses and associated genomics of Gram-negative food-borne bacteria – International Conference

Topics to be covered include: 'Omic' technologies and signals associated with food preservation; and, contribution of antimicrobial resistance to the enhancement of resistance food preservation stresses.

sfanning@ucd.ie or clodagh.oneill@teagasc.ie *www.teagasc.ie*

September 17-18 *Ashtown Food Research Centre, Dublin*

Control and Management of Pathogenic *Escherichia coli* – International Conference

The Pathogenic *Escherichia coli* Network (PEN) conference aims to increase understanding of the role of biotherapies, risk management, HACCP and prerequisites, risk communication, and clinical intervention in the control and management of pathogenic *Escherichia coli.*

www.pen-project.eu

September 21-22 Moorepark Food Research Centre, Cork

***Listeria monocytogenes* conference**

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 8 *Silver Springs Hotel, Cork*

Teagasc National Rural Development Conference

The theme of this conference will be the impact of the recession on rural Ireland and what the enterprise development agencies, including Teagasc, can do to increase employment, wealth and incomes in rural Ireland.

gerry.scully@teagasc.ie *www.teagasc.ie*

October 14 *Hodson Bay Hotel, Athlone, Westmeath*

Artisan Food/Rural Tourism Conference

This conference will look critically at the artisan food products currently being manufactured in Ireland by small and medium sized businesses. It will examine the opportunities to improve and develop the product offering to meet the changing requirements of modern consumers.

gerry.scully@teagasc.ie *www.teagasc.ie*

October 15-16 *Moorepark Dairy Production Research Centre, Cork*

Forage legumes in temperate pasture-based systems – International Conference

At this conference, scientists will weigh up the beneficial and negative consequences of using forage legumes to meet the N requirements of pasture-based production, future challenges for research and possibilities for collaboration.

moorepark.dairy@teagasc.ie *www.teagasc.ie*

November

November 8-15 *Nationwide*

Science Week – Celebrating Creativity and Innovation

In this, the EU Year of Creativity and Innovation, Teagasc will host a series of events for second- and third-level students nationwide. The Walsh Fellowships Seminar has been scheduled for November 11 in the Royal Dublin Society. Johnstown Castle Environment Research Centre will hold a national 'Worm Week' workshop for primary schools.

catriona.boyle@teagasc.ie *www.teagasc.ie* *www.scienceweek.ie*

November 12 *Hodson Bay Hotel, Athlone, Westmeath*

Equine Conference

This conference will focus on the factors that impact on producing high performance sports horses that can compete on a global stage.

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November 18 (*Mullingar, Co Westmeath*) and 19 (*Killarney, Co Kerry*)

National Dairy Conferences

The Teagasc national dairy conference will feature two New Zealand dairy farmers, who will share their experiences. Managing Director of the Kerry Group, Stan McCarthy, is the keynote speaker at the conference in Killarney, and Teagasc speakers will focus on areas where technical performance can improve, such as increasing EBI and grass budgeting.

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November 26 *Johnstown Castle Environment Research Centre, Wexford*

Slurry Conference

The conference will be invitation only, and is aimed at DAFF, specialist advisors, farm organisations and researchers. It will provide a summary of the slurry research linked to Johnstown Castle (with Oak Park, Athenry, and UCD), and will also provide information on current and future research on the use of slurry nutrients.

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