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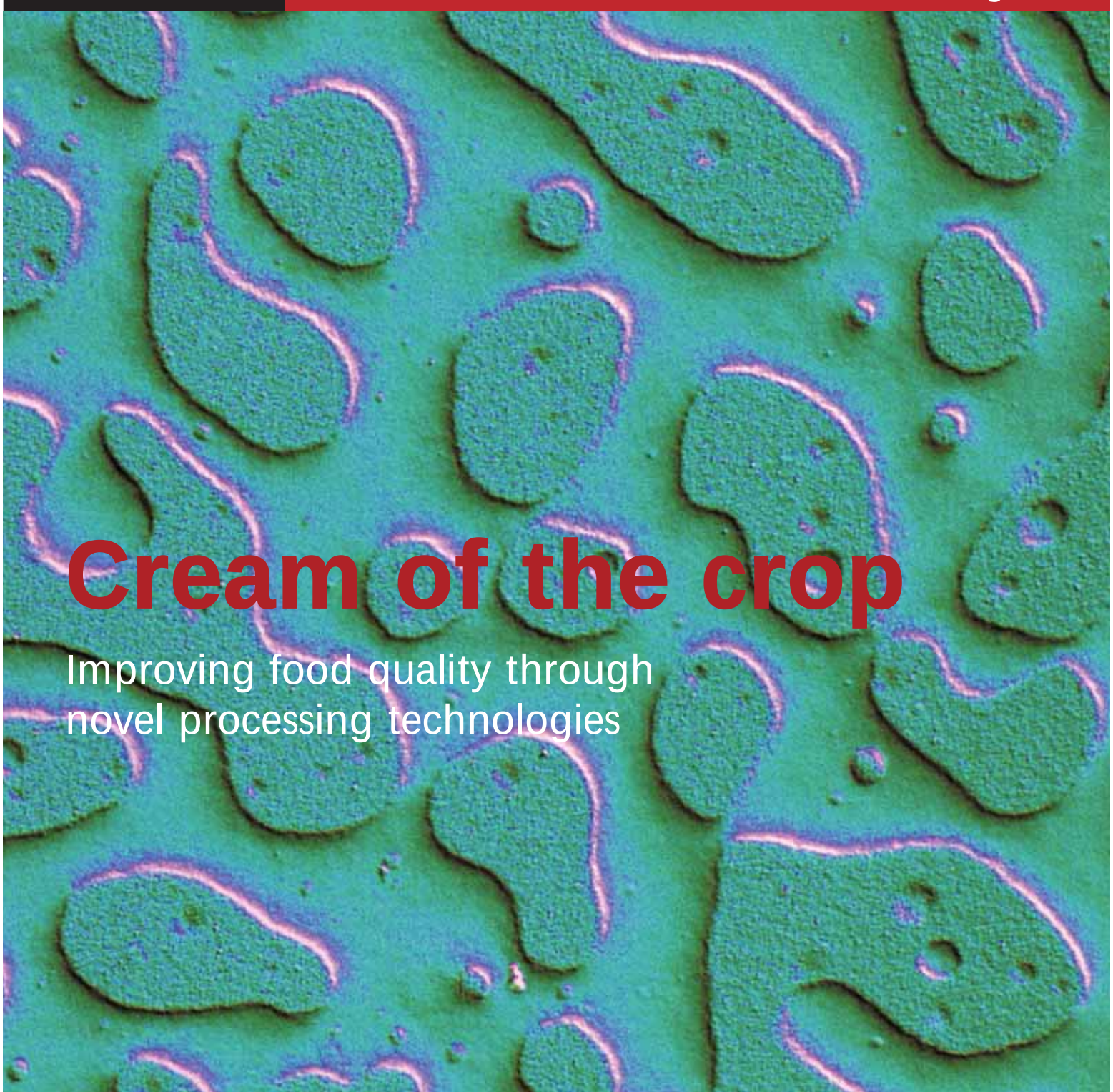
T Research

Research and innovation news at Teagasc



Cream of the crop

Improving food quality through novel processing technologies

Contents

Communicating science

Scientific research will be one of the key drivers of the knowledge-based economy in Ireland in the future. The need for effective communication of research and the promotion of science is more important than ever, if young people are to be attracted to study science and to pursue a career in research. *TResearch* aims to disseminate to a wider audience some of the important scientific work being undertaken in Teagasc and in other research institutions.

The planned increase in investment in science under the *Strategy for Science, Technology and Innovation 2006-2013*, aims to place Ireland firmly on the global map in terms of the excellence of our research and its application for the benefit of society. It is now more essential than ever that Irish scientists engage in a genuine dialogue with the public so that the latter can better understand, support, and indeed challenge, the science that is being undertaken while, at the same time, helping scientists understand public interests and concerns.

As the national body responsible for agri-food research in Ireland, Teagasc has a statutory responsibility to disseminate its research findings to key stakeholders. This we have done successfully over the years. However, as the nature of our programmes has changed to include more research in areas of concern such as food safety and the state of the environment, we have an additional responsibility to communicate effectively with a wider audience.

TResearch is a popular science publication aimed at meeting this need. While the primary aim is to communicate Teagasc research, the magazine also aims to improve the public awareness and understanding of agri-food research generally.

I wish the magazine well and trust that it will make a contribution to furthering public understanding of the science of agriculture and food.

Tom Kirley
Acting Director
Teagasc

Environment

New challenges for nutrient research 10

ROGIER SCHULTE explains how Teagasc has adopted a multi-disciplinary approach to the most efficient use of nutrients in the wake of the Nitrates Directive.

Food

Tracking food poisoning 20

GERALDINE DUFFY describes how molecular techniques are being employed to track food poisoning bacteria through the food chain.

Credits

TResearch
Teagasc | Oak Park | Carlow

TResearch is a Teagasc science publication, produced with the support of AIB Bank, to communicate scientific research to the agriculture and food industry.

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T News

Vision Programme

The development of world class competence is essential, not optional, for Ireland and Europe.

In March of last year, the Teagasc Authority approved a new programme known as The Vision Programme to underpin the long-term science and technology needs of the agri-food industry.

This new research strategy will expand the organisation's resources devoted to biotechnology, so that world class competence in selected key areas will be established. A key influence on the development of the new programme was the conclusion of the *Interdepartmental Group on Modern Biotechnology*. It found that biotechnology has the potential to deliver major benefits to individuals and societies in areas such as healthcare, agriculture and environmental remediation and that the development of world class competence is essential, not optional, for Ireland and Europe.

In agriculture, the programme focuses on identifying the developments that must take place in Teagasc so that the organisation can position itself to deliver the knowledge required to achieve the Government's vision for the industry in 2015. The strategy is to develop specific theme areas - animal science, crop science, environment and land use and rural research. The aim is to establish research teams with critical mass that will result in centres of excellence. The achievement of a high level of integration within and between the centres of excellence and with other national and international institutions is an integral part of this proposal. The programme proposed has four elements: animal science research, crop science research, environment and land use research and rural research.

In food, it is proposed that Teagasc embarks on a major expansion in its programme of research on 'food and health'. The objective is that Teagasc, in its own right, and in collaboration with UCC and other institutions, becomes an international leader in this area, with a clear focus on the creation of opportunities for commercial exploitation by Irish food companies. The proposed programme has three elements: functional foods research related to obesity and colon cancer, a new research department focused on nutraceuticals, and a large animal facility for clinical trials using the pig as a human model.

Ireland tops for ag research

Between 2000 and 2004, Thomson Scientific indexed 14,266 papers that listed at least one author address in Ireland. Of those papers, the highest percentage appeared in journals categorized under the heading of agricultural sciences. The citations per paper figure for agricultural sciences papers from Ireland exceeded the world average by 42% (3.42 citations per paper for Ireland versus a world mark of 2.40 citations). Ireland's citation performance was also notably strong in molecular biology/genetics (Ireland-based researchers contributed to just 317 papers in this field during the five-year period, but clearly this number included at least a few very highly cited reports).

Major meat conference

Dr. Anne Maria Mullen addressing delegates from the recent ICoMST conference at a visit to Ashtown Food Research Centre.

Teagasc Ashtown recently hosted a major international conference at the O'Reilly Hall in UCD. The 52nd International Congress on Meat Science and Technology (ICoMST) attracted over 450 leading meat scientists from all over the world. Speaking at the conference, Dr. Anne Maria Mullen, Head of the Meat Technology Department at Teagasc's Ashtown Food Research Centre, said that the benefits of advances in understanding of the human genome have helped scientists in their understanding of the cattle and pig genome. There is now a growing realisation that the molecular basis underpinning beef and pork quality is highly complex. Dr. Mullen, whose team is researching meat quality through the application of genomic and proteomic approaches, said that a lot of progress had been made in our understanding of the biological processes that contribute to the delivery of consistent quality meat. "Through the application of genomics and proteomics, we are gaining a deeper insight into these processes and their interaction with environmental factors. Knowledge gained from these approaches can be beneficial in defining and optimising management systems for quality, providing assurance of meat quality and in tailoring quality to suit market needs," she said.

T News

Science Week 2006

Science Week takes place during November 12-19. The launch of *TResearch* forms part of Teagasc's Science Week programme.

The annual Walsh Fellowships seminar takes place on November 14 at the RDS. Professor Patrick Wall, Associate Professor of Public Health in UCD, will address the seminar as guest speaker.

In addition, a number of events have been organised at Teagasc research centres. Ashtown Food Research Centre, Athenry Research Centre, Grange Research Centre and Moorepark Food Research Centre, are holding open days for local secondary schools.

Science Week takes place during November 12-19.

The Rural Economy Research Centre is holding a debate in conjunction with NUI-Galway on the environmental consequences of air travel. Staff from Oak Park Crops Research Centre will speak to students at Carlow IT about post-graduate opportunities in Teagasc, particularly in the area of biotechnology. For more information contact: Catriona.Boyle@teagasc.ie.

BGS best presentation

Nigel Young, British Grassland Society president, presents Isle Geijzendorffer with her prize for best presentation.

Ilse Geijzendorffer, a Walsh Fellow based at Teagasc Johnstown Castle, was awarded a prize for best presentation at the 8th Research Meeting of the British Grassland Society at the Royal Agricultural College, Cirencester, UK, with her presentation on "Quantifying the compatibility of grassland species".
Ilse explains: "Due to changes in legislation in Ireland (such as the Nitrates Directive, decoupling and agri-environmental schemes), there is an increase in interest in botanical diversity of the sward. Farmers are also becoming more interested in the potential agricultural benefits of a diverse sward (additional nitrogen via nitrogen-fixing legumes, extended grazing season, and additional nutrients to the diet). The easiest way to increase the botanical diversity is via seed mixtures. In this project, we're trying to determine which species can coexist in the long term. This is done by determining how similar species are and how much competition they experience from each other."
Ilse's project is supervised by Rogier Schulte and John Finn at Teagasc Johnstown Castle Environment Research Centre and Gordon Purvis (UCD). This project is part of the Ag-Biota project (an Environmental Research, Technological Development and Innovation programme funded under the National Development Plan by the Environmental Protection Agency).

Foresight Study

Teagasc is embarking on a Foresight Study of the science and technology needs of the agri-food sector in order to develop a medium- to long-term vision for the sector. The purpose is to identify the science and technology required for the sector in the next 10 to 20 years and to help guide the development of the organisation to ensure that it can meet this need.
The study will embrace the entire Teagasc organisation. It will be led by a steering committee, which will have the support of an expert working group. The existing Teagasc commodity teams and advisory committees will lead in providing the input for the areas that the organisation services.

Fulbright awards

The Irish–US Fulbright Commission's annual Scholar Awards Programme enables post-doctoral scholars and established leaders of professional, academic and artistic excellence to undertake advanced research/lecturing at a recognised US institution. Applicants must be in a position to outline a clearly defined programme and must obtain their own placements in the US.
Teagasc sponsors two awards each year in Agriculture and Food Science. The closing date for applications is 5pm on Friday November 17, 2006. For further information see: www.fulbright.ie.

Agricultural Research Forum

A first call for papers has been issued for the Agricultural Research Forum 2007. The objective of the meeting is to provide an opportunity for the presentation and publication of new scientific information relating to agricultural science (including animal and crop science, molecular biology and biotechnology), environmental and soil science, food science, agri-economics and forestry. The forum will provide an opportunity for scientists, specialists, advisors and others working in the above areas to interact and exchange views.
A one-page summary is required by December 11, 2006. Contact Michael Diskin (michael.diskin@teagasc.ie) for further details Tel: 091-845 841.

Appointments

Professor Frank O'Mara has joined Teagasc from University College Dublin (UCD) where he was a researcher and lecturer in animal nutrition. He has been appointed Assistant Director of Agriculture Research in Teagasc, where he will play an important role in ensuring the organisation provides innovative research to the agriculture and farming community.

Dr. Miriam Walsh has filled the new position in Teagasc of Intellectual Property (IP) Officer. Miriam previously worked for Trinity College Dublin as an IP Officer. Her role is to ensure the establishment of systems and procedures for the management of intellectual property arising from Teagasc research programmes.

Science Events

November

12-14 *O'Reilly Hall, UCD, Belfield*

BioIreland 2006

BioIreland 2006 is the third in a series of conferences profiling the island of Ireland as a location of choice for the development of the biotech sector.

www.bioireland2006.com hazelheggie@eircom.net

12-19 *Locations nationwide*

Science Week

Science Week is part of the Discover Science & Engineering (DSE) initiative, which aims to increase interest in science, technology, innovation and engineering among students, teachers and members of the public. DSE is managed by Forfás on behalf of the Office of Science and Technology at the Department of Enterprise, Trade and Employment.

www.scienceweek.ie info@science.ie

20-22 *Seven Oaks Hotel, Carlow, Co. Carlow*

European Association for Research on Plant Breeding/European Association for Potato Research joint section meeting

Teagasc Crops Research Centre hosts the triennial joint section meeting of the EAPR Breeding and Varietal Assessment and EUCARPIA Potato Sections "The Science of Selection: Potato Breeding Methodology for the 21st Century".

www.teagasc.ie potato@oakpark.teagasc.ie

23 *Teagasc Environmental Research Centre, Johnstown Castle, Co Wexford*

National Soil Database project workshop

Teagasc presents this workshop in conjunction with the EPA.

www.teagasc.ie. sarah.lacey@teagasc.ie

January 2007

25 *Teagasc Environmental Research Centre, Johnstown Castle, Wexford*

AGMET "Making Science Work on the Farm" workshop

The AGMET Joint Working Group on Applied Agricultural Meterology presents a workshop on decision support systems for Irish agriculture.

seamus.walsh@met.ie

28 *Institute of Technology, Carlow, Co Carlow*

ESAI Environ 2007 colloquium

The Environmental Sciences Association of Ireland (ESAI) colloquium provides a forum for postgraduate students to present their research findings or ongoing projects. Students will also have the option of submitting a paper for publication by ESAI following peer review.

www.environ2007.ie environ2007@itcarlow.ie

March 2007

12-13 *Tullamore Court Hotel, Tullamore, Co Offaly*

Agricultural Research Forum 2007

Provides an opportunity for the presentation and publication of new scientific information relating to agricultural science (including animal and crop science, molecular biology and biotechnology), environmental and soil science, food science, agri-economics and forestry.

michael.diskin@teagasc.ie

August

26-29 *UCD, Belfield*

EAAP 2007

58th Annual meeting of the European Association for Animal Production. This meeting will be of interest to those working on animal breeding production and management issues.

www.eeap2007.com eeap2007@ovation.ie

September/October

29.09 - 04.10 *The Burlington Hotel, Dublin*

2007 International Dairy Federation World Dairy Summit

WDS 2007 will consist of concurrent conference symposia to cover a broad range of topics of interest to the dairy sector, e.g., primary production, technology, nutrition and health and dairy marketing and economics.

www.wds2007.com phil.kelly@teagasc.ie

T Feature

Obesity – the research agenda

LIAM DONNELLY, MARK FENELON, LINDA GIBLIN and CATHERINE STANTON of the Moorepark Food Research Centre outline the challenge posed to the research community by the obesity epidemic.

Obesity and accompanying health disorders, which form the condition known as the metabolic syndrome, including type 2 diabetes, hypertension and coronary heart disease, have reached epidemic proportions in many developed countries. Approximately 1.1 billion adults throughout the world are obese, making obesity one of the most pressing public health problems today. Childhood obesity is no less a problem in many western countries, and is now considered the most pressing health problem in childhood health in Europe. In the US, nine million children under six years of age are obese. Most people are unable to make voluntary life-long dietary changes needed for weight management and, therefore, it is important for public health that foods are developed which contribute to a decrease in energy intake or storage. Food choice can be influenced beneficially by food companies by offering a range of products of high quality that are designed to deliver a more balanced diet and to help the consumer with weight management. For the food industry, this provides many opportunities for product development, not least for the dairy industry, which is especially well placed to serve this need.

Technological innovation

Food technology has an important role to play in food innovation for obesity. Two strategies for product development for the obese market whose success depends on technological, rather than biological, innovation can be identified. These are foods of low caloric density and foods that are formulated to have a low glycemic index. Major challenges exist in creating food structures that meet the requisite sensorial properties, from the consumer perspective, and that show specific physicochemical behaviour during digestion.

Most people are unable to make voluntary life-long dietary changes needed for weight management and, therefore, it is important for public health that foods are developed which contribute to a decrease in energy intake or storage.

Low-fat foods

The demand for low-fat foods is increasing and, while the food industry has responded vigorously to this demand with a great variety of low-fat products, there is often a trade-off between perceived health quality and sensorial properties. A recent US study found that the number of consumers who say that taste is more important than health is increasing. Fat in food has a major influence on texture, mouthfeel and flavour and often the removal of fat changes the quality of these parameters in an undesirable way. Much research has been carried out on ingredient functionality aimed at reproducing the properties of fat in low-fat products and many formulation strategies are now available that replicate much of the quality of the full-fat equivalent. However, for the discerning consumer, a quality deficit still exists in many products and there are, therefore, still major technological challenges to be addressed in achieving full fat-mimetic properties in fat replacers. Creaminess perception is considered to be one of the most important contributions that fat makes to product acceptability and, therefore, lack of creaminess can be a significant barrier to acceptance of low-fat foods. Flavour is also greatly influenced by the presence of fat in food through the role of fat as a flavour solvent and in flavour perception, and flavour release during oral processing. Continued research is required on the microstructural, rheological and organoleptic factors that define the contribution of fat to food functionality and on the development of ingredients that can better replicate that functionality.

Low glycemic index

Economic success in the western world has been accompanied by an increase in blood glucose irregularities, which have been linked to diseases such as obesity, type 2 diabetes mellitus, glucose intolerance and cardiovascular disease. Of the latter conditions, the concurrence of obesity and diabetes, i.e., diabesity, has been increasing rapidly. Moreover, the market place is realising that the problem is not solved by reducing the caloric density of foods alone. Nutritional and medical research has shown that the quantity and source of carbohydrate and related

Opportunities for the development of foods targeted at obesity and 'diabesity' exist in new functional foods and in technologically innovative ingredients.

glycemic response in food is of significant relevance to health. Foods with a high glycemic index are metabolised quickly, resulting in large fluctuations in glycemia and demand for insulin, while foods with low glycemic index have slower and more consistent release of glucose, which is more conducive to extended feelings of satiety. Future research aimed at developing diabesigenic foods should, along with controlling caloric value and sensory properties, investigate the 'glycemic potential' and associated hormonal response of food components. Technological research is required on food structure/glycemia relationships. The structure of ingested food has a major role in regulating glucose absorption into the blood and, since proteins and carbohydrates (including starch) are the most widely used biopolymers in the food industry, it is probable that their interactions greatly contribute to control of the body's glycemic response. Guar Gum, for example, is used as an oral anti-diabetic agent in the treatment of mainly type 2 diabetes. More interestingly, studies have suggested that the body's glycemic response to carbohydrates when co-ingested with proteins is lower than that from ingestion of carbohydrate alone.

Product innovation

There is an identifiable opportunity for food formulators to adopt new strategies, based on technological approaches, to regulate glycemia through food structuring and alternative processing techniques. *In vitro* methodologies will be required to evaluate the techno-functional properties of protein–carbohydrate systems under simulated digestive conditions. The outputs of such bench-top studies should be linked to follow up *in vivo* studies to provide an opportunity to establish glucose absorption patterns and hormonal response of the biopolymer systems. The latter strategy can be adopted to study the behaviour of selected mixed food polymer systems pertaining to ingredient development for modulation of glycemia. Important elements of such a study would be an investigation of the stability of protein-carbohydrate ternary systems under simulated digestive conditions (i.e., pH, ionic strength, enzyme activities) and research aimed at understanding the thermodynamics of phase separation and subsequent micronutrient partitioning in mixed biopolymer systems. Ingredient systems from *in vitro* studies could then be evaluated in a monogastric animal model system, the pig being particularly suitable, from which postprandial metabolite and gastrointestinal hormone responses can be correlated with glucose response.

Ingredient opportunities

In summary, food manufacturers are looking for opportunities to engage in the rapidly growing added value 'food and health' category. To be successful in this field, requires the development of innovative ingredients and products that have been characterised for known health benefits. Opportunities for the development of foods targeted at obesity and 'diabesity' exist in technologically innovative ingredients. Targets for technological innovation are new techno-functional ingredients that improve the sensorial properties of low caloric density foods and that possess the necessary physico-chemical properties during digestion to modulate glycemia. Research is required on structure-function relationships of protein-hydrocolloid mixtures and on the development of *in vitro* systems to replicate the conditions of the GI tract. The ultimate requirement for all developments in foods for health is proper clinical validation in human clinical studies.

Dr. Liam Donnelly is Head of the Teagasc Food Research Directorate. Drs. Mark Fenelon, Linda Giblin and Catherine Stanton are Senior Research Officers at Moorepark. E-mail: liam.donnelly@teagasc.ie.




T Feature

Innovation at Ashtown

MICHAEL KYLE profiles the projects and personnel involved in innovation-related research at Ashtown Food Research Centre.

Work is underway to ensure that innovation is a central remit in the everyday activities that are carried out at Ashtown Food Research Centre (AFRC). The term innovation, in its common usage today, has become an overused one resulting in a vague concept, having many meanings. At Ashtown, we are defining what innovation means to us in terms of the research into meat science and technology, food safety, prepared meals and marketing. We are examining the best ways to introduce new ideas and to develop existing ideas, products, services, and practices in an attractive way.

Those involved in innovation activities at Ashtown meet regularly and have formed a working group in order to discuss the innovation-related work and ways to coordinate activities for the benefit of the centre. This article details the main roles and activities of those involved in projects designed to develop innovation at Ashtown.

Managing and co-ordinating

Ciara McDonagh is the manager of the innovation unit at AFRC. Her role is to manage food innovation arising out of research and development work originating from Ashtown and to provide focussed technology transfer and support services to the food industry.

She is responsible for the facilities within the development unit, which include a purpose-built product development plant, containing a meat development unit that is fully licensed, which houses an abattoir, boning hall, processing and packaging area and a cooked meats facility. There is a test bakery for the product development and testing of cereals. Additionally, there are two incubation units and a test kitchen available to food companies and entrepreneurs who may not yet have the facilities for developing new products.

Ciara has established strong linkages with agencies such as Enterprise Ireland, Bord Bia and Bord Iascaigh Mhara and offers assistance to companies looking for funding opportunities and collaborative partnerships with researchers.

Looking to the future, Ciara envisages attracting more industry to Ashtown to use the facilities and would also like to assist researchers in carrying out successful technology transfer at a commercial level.

Improving capabilities

Áine Curtin is a specialist trainer in food innovation and technology management. Her role is to improve innovative abilities in food companies and includes the development and delivery of training in food innovation and technology management. She also has a function in developing specialised training in support of technology transfer from research. Áine helps the Irish food industry to improve its research and development (R&D), innovation and new product development (NPD) capabilities. She works with colleagues on an AFRC- and Teagasc-wide basis.

Áine is working on a number of projects, including the development of a new product guide for food entrepreneurs, the piloting of FETAC-certified training courses in NPD, Producing Meat Products and in Writing Retailer Specifications. She is also involved in sensory analysis training and is conducting a review of innovation in the Irish food sector.

Technology transfer and public policy

Marie Buckley is currently carrying out work on a Toolbox project, the aim of which is to enhance the level of commercialisation and technology transfer from public-funded food research in Ireland. The overall coordinator of the project is Dr. Maeve Henchion, Head of the Food Marketing Research Group and project leader of the Toolbox project. The results of the project will support the successful transfer of results of research projects funded under the Department of Agriculture and Food's Food Industry Research Measure (FIRM) and other funding programmes. It will also provide an opportunity to put in place human resource development actions to prepare researchers for future research programmes, where there could be a greater emphasis on technology transfer and industry interaction. The study will identify the influence of publicly-funded research on industrial R&D in the Irish food industry and will seek to examine the absorptive capacity of the food industry, in terms of its ability to acquire and exploit public research.

The next stages of the project will involve an evaluation of the food innovation system, particularly in relation to technology transfer. The study will involve the use of stakeholder focus and industry and researcher groups to help identify the key factors influencing technology transfer.

Transferring technology

Briege Byrne is working on the 2xTRA (Technology Transfer Research Results Atlantic Area) project. It aims to promote economic activity based on research results and technologies developed in universities, research institutes and companies in the European Atlantic Area, by improving the technology transfer process and increasing the trans-nationality of technology transfer amongst key participants in the Atlantic Area. The project is being undertaken by a consortium of 13 partners engaged in innovation, technology transfer and business incubation activities in the United Kingdom, Ireland, Portugal, France and Spain, and is funded under the Interreg IIIB Atlantic Area programme. The project goals include the exchange of information and experience in technology transfer management, to promote the creation of new technology-based companies and to implement an Atlantic Network to support and promote the creation of technology-based companies.

The innovation team at Ashtown (from left): Marie Buckley, Dr. Briege Byrne, Áine Curtin, Ciara McDonagh, Dr. Michael Kyle and Dr. Maeve Henchion.

Developing meat innovation

Michael Kyle is working on a project, supported by the FIRM initiative, which analyses the technology transfer processes that occur in the meat sector. As the meat sector in Ireland and the EU is facing a number of threats, such as reform of the Common Agricultural Policy, imports from South American countries and increased consumer preference for non-meat products, an examination of innovation practices and methods is being produced to help improve competitiveness and work practices.

An important outcome of this project is the completion of a 'best-practice' technology transfer manual for use within the meat sector. International innovation systems have been examined in order to characterise and evaluate the different methods of technology transfer that are employed in Ireland and other European countries. Work is ongoing on examining methods of how best to extract ideas from meat research at Ashtown. Issues such as the development of research ideas, technology development, marketing, commercialisation and development of Intellectual Property will be dealt with.

Implementation

The next step will be a key one and will concentrate on the further development and practical implementation of the above projects.

Dr. Michael Kyle is an innovation specialist working on innovation and technology transfer issues at Ashtown Food Research Centre. For further information on these projects, E-mail: ciara.mcdonagh@teagasc.ie.

Most of Ireland's waterways are among the cleanest in Europe and boast a diversity of flora and fauna that is worth protecting.

Beyond the Nitrates Directive new challenges for nutrient research

ROGIER SCHULTE explains how Teagasc has adopted a multi-disciplinary approach to the most efficient use of nutrients in the wake of the Nitrates Directive.

The introduction of the Nitrates Directive from January 1, 2007, will bring changes to Irish agriculture, as it restricts the amount of nutrients that can be applied to land. Nutrients are the fuel that drive livestock production systems, but may also be lost to water and air and thus add to eutrophication, greenhouse gas emissions and soil acidification. For more than a decade, the Nutrient Research Programme at Teagasc has delivered nutrient management strategies that minimise nutrient losses to the environment without compromising productivity. The Nitrates Directive and its successor, the Water Framework Directive, are now posing new challenges to nutrient management. Teagasc's Environmental Research Programme is responding to these challenges and has initiated a cluster of innovative and collaborative research projects that will assist farmers with nutrient management in the post-Nitrates Directive era.

Nutrient research to date: a success story

Nutrient management became a pivotal part of farm operations when excess phosphorus fertiliser applications were associated with eutrophication. This involves the enrichment of surface waters with nutrients, which leads to deterioration of aquatic ecosystems. Extensive studies at Teagasc's Environmental Research Centre at Johnstown Castle led to the introduction of the Phosphorus Soil Index in Teagasc fertiliser advice. The objective of this advice was to build up soil phosphorus to optimum levels that facilitated optimum productivity of grass and crops, with low associated risks of phosphorus loss to water. There are few sectors of the economy in Ireland that have responded so well to environmental advice: the new phosphorus advice was quickly adopted by farmers and use of chemical phosphorus fertiliser has decreased from 62,000 t to 39,000 t per year in the last decade, without reductions in grassland productivity. These reductions in phosphorus use coincided with a halt to the decline in water quality of rivers and lakes, and the most recent Environmental Protection Agency (EPA) report suggests that eutrophication levels have since been stabilised.

New challenges to the environment

More recently, nitrogen has increasingly been associated with a range of pressures on the environment. Of these, the risk of nitrate leaching to drinking water has received most attention to date, even though current nitrate concentrations in groundwater exceed the 'safe' threshold of 50 mg nitrate per litre in only 2% of samples. However, there is increasing evidence that nitrate may already add to eutrophication of ground and surface waters at concentrations well below this threshold. Of particular concern here is the eutrophication of estuarine and coastal waters, of which only 40% were classified as 'unpolluted' in the latest EPA report. Whereas the Nitrates Directive was primarily targeted at the quality of drinking water, the more arduous task of achieving and maintaining good ecological water quality in rivers, lakes and coastal waters will be the objective of the Water Framework Directive.
In addition, nitrogen may be lost to the atmosphere in the form of nitrous oxides and ammonia. Nitrous oxide is a greenhouse gas 310 times more powerful than carbon dioxide, and regulated under the Kyoto Agreement. It is invariably emitted following nitrogen fertiliser application as a by-product of the nitrogen cycle, particularly when soils are wet. Ammonia is an acidifying trans-boundary gas that is mainly lost from animal excreta, and agriculture accounts for 98.5% of ammonia emissions in Ireland. The EU National Emission Ceilings Directive is likely to further reduce the emission ceilings for Ireland after 2010.

Maximising nutrient efficiency

The challenge for nitrogen research is that, unlike phosphorus, there is no simple 'optimum' level of nitrogen input that guarantees optimum production without any significant losses to the environment. Most inorganic nitrogenous molecules are highly mobile and easily lost to air and water. In fact, it has been estimated that to date, as little as 10 to 25% of nitrogen fertiliser brought onto the farm has been recovered in milk and meat, with the remainder unaccounted for. However, the Green Dairy project, an on-farm research initiative by Teagasc Moorepark, is demonstrating that such efficiencies can be significantly improved on in many cases. The Nitrates Directive is now demanding that nutrients must be recycled much more efficiently, and currently this does not always sit easy with the economic imperative that costs of animal production be reduced. The implications are even more severe for pig farms: the law now stipulates that

Grass makes efficient use of fertiliser when applied at correct times and rates. Can we now also make better use of recycled nutrients from animal manures?

from 2010, the spreading of pig slurry on grassland will be increasingly restricted, which means that pig slurry may have to be exported to tillage ground.
There are more good reasons to review our fertiliser use, which are of direct relevance to farmers. The manufacturing of nitrogen fertiliser is an energy-guzzling process: for every kg of fertiliser nitrogen produced, more than 3 kg of carbon dioxide is emitted. Not only does this amount to a large proportion of the total greenhouse gas emissions from agriculture; in addition, this energy-dependency ties the price of nitrogen firmly to the price of oil, which is likely to move in only one direction in the long term - upwards. Similar trends are forecast for prices of phosphorus fertiliser; at the recent International Symposium on Phosphorus Dynamics in Brazil, it was predicted that world phosphorus reserves will be exhausted within this century.

Meeting the challenges: new nutrient research in Teagasc

In response, Teagasc has launched a large cluster of research projects that aim to provide answers for farmers to rise to these challenges. This research programme involves over 15 Teagasc researchers from all major research centres, and is

T Environment

Johnstown Castle boasts a world-class field lysimeter laboratory, which allows us to continuously measure nutrient uptake, and losses to water and air from three contrasting soil types.

Johnstown Castle has developed new research equipment to evaluate slurry spreading strategies, combining splash plates and trailing shoes on a single tanker. This allows for a direct and accurate comparison of both spreading methods.

conducted in close collaboration with the Department of Agriculture and Food and many national and international universities. The main goal is to develop strategies to improve nutrient efficiency on farms, i.e., to maintain production levels (meat, milk and crops) with reduced fertiliser inputs, thereby reducing emissions to the environment. In order to achieve this, Teagasc has developed three parallel research approaches detailed below.

Finding the main leaks of nitrogen

Since 2001, we have been tracing the main leaks of nitrogen from Irish farming systems. We now have increasingly convincing evidence that fertiliser nitrogen can be utilised relatively efficiently by the grass crop, but that a large share of nitrogen lost can be traced back to animal excreta, whether it is in the form of slurry, dirty water, or urine and dung. For example, it is estimated that only 5 to 25% of nitrogen in slurry is utilised by growing grass and that large quantities are lost through ammonia volatilisation. In addition, some of the excreta may end up in dirty water. To date, this has largely been considered a waste product, and has been disposed of through irrigation systems or landspreading; its nutrient value has rarely been considered. Even though nitrogen loads in dirty water are low compared to slurry, it is applied with large quantities of water, readily providing pathways for nutrient loss.

Similar risks of nutrient loss occur when animal excreta are deposited directly onto the field, in the form of urine and dung during grazing in autumn, when grass growth slows down and nitrogen uptake is reduced. Urine patches are particularly vulnerable to nitrogen loss, as very large loadings of nitrogen are deposited on small areas, at rates that are equivalent to more than 400 kg per ha. In recent years, Teagasc, Johnstown Castle, has built a world-class field-lysimeter

facility, in which we are studying the fate of urine nitrogen over time in three contrasting soils. This consists of 72 undisturbed 1 metre soil columns that have been inserted into a grazed pasture, and allows us to quantify how much nitrogen is utilised or lost from urine patches on different soil types.

Prevention: milking the nutrients on the farm

Most of the new research programme is now aimed at developing strategies to plug these nitrogen leaks, and to make better use of the 'free' nitrogen that is already present on the farm in the form of slurry, dirty water, or urine, or that made available from the use of clover.

For example, Teagasc Johnstown Castle is now leading two multi-disciplinary research projects that will change manure management practices on Irish farms. Together with UCD and Wageningen University in the Netherlands, we are evaluating and refining the use of low-emission slurry spreading techniques to increase our slurry nitrogen efficiency to at least 40%. If we can achieve this, this would mean that we can simultaneously cut back on fertiliser costs and ammonia emissions. Meanwhile, our partners at Oak Park and in the Spatial Analysis Unit are evaluating the potential and costs of exporting pig slurry to tillage farms.

For the management of dirty water, the goal posts have now been changed by the Nitrates Directive, since any liquid with a biological oxygen demand (BOD) over 2,500 mg/l is now considered to be slurry. As a result, the distinction between slurry and dirty water is fading. New research at Teagasc, Johnstown Castle, in conjunction with UCD, NUI-Galway and Teagasc, Athenry, aims to turn the risks associated with dirty water into a strength, by making use of its nutrient value.

Meanwhile, a new project is being undertaken by Teagasc Moorepark, in collaboration with Johnstown Castle and UCD, to examine nitrate leaching from grass-based milk production systems. Two large scale projects were established on a free draining soil type to study the impact of stocking rate, fertiliser nitrogen rates and grazing season length on nitrate leaching, as well as on-farm productivity. The objective is to establish a protocol for sustainable grazing management that maximises animal output, but does not result in unacceptable losses of nitrogen to water.

In a parallel study, research at the Teagasc Moorepark experimental farm at Solohead is demonstrating that nitrogen fertiliser inputs can be reduced through the management of white clover, while maintaining stocking rates up to 170 kg organic nitrogen per hectare. Although nitrogen fixed by clover may also be vulnerable to loss, biological nitrogen fixation does not consume the large quantities of fossil energy required for fertiliser production, giving clover-based systems an environmental edge, with estimated reductions in greenhouse gas emissions of over 15%.

Catching the nutrients that got away

The third approach in our new nutrient research involves remediation, i.e., catching the nutrients that got away, and were not recycled on the farm. We have circumstantial evidence that soils have an inherent capacity to clean up nitrates through denitrification at deeper depths (since nitrate levels in groundwater are much lower than expected on the basis of the quantities of nitrogen lost from the rooting zone). We are now uniquely investigating these deep denitrification processes with innovative research methodologies on a range of soil types, and we are trying to establish the end-product of this denitrification: how much of the nitrates is denitrified to nitrous oxides (a powerful greenhouse gas), and how much is further denitrified to dinitrogen (a harmless gas).

In addition, we are investigating novel on-farm technologies to further stimulate the denitrification capacity of soils. This involves the insertion of carbon-sources, e.g., woodchip, into the soil to provide energy to denitrifying bacteria. International research experience shows that these may become viable technologies to stop nitrates from reaching vulnerable areas, e.g., drinking water reservoirs or sensitive ecosystems. Our longer-term research objective is to integrate nutrient remediation technologies, crop production and biodiversity on farms. One example is the use of willow buffer strips, to provide coppice for bioenergy, a physical environmental buffer to prevent nutrients from reaching watercourses, as well as a habitat for farm wildlife. On tillage land, we are investigating the use of catch crops on tillage land during winter. This work is being carried out in collaboration with Oak Park and Trinity College Dublin. Crops such as mustard can take up nitrogen during autumn, thus preventing it from being leached, and carrying it over to be utilised by the next crop sown in spring.

Keeping an eye on the future

As the results of all these initiatives begin to roll in over the next four years, this concerted nutrient research programme will make a tangible difference to Irish agriculture: if we can make better use of the nitrogen and phosphorus that are freely available in the form of slurry/dirty water, urine, dung, and clover, we are not only reducing nutrient losses to the aquatic and atmospheric environment, but also cutting back on fertiliser requirements, thus putting money back in the farmer's pocket.

In addition, the new research will provide us with a more detailed understanding of nutrient dynamics on Irish farms. This should assist policy makers in dealing with the review of the Nitrates Directive in four years' time, as well as the imminent Water Framework Directive. An important development in this context is the new Mini-Catchments project: this multidisciplinary collaboration between Teagasc's research and advisory sections aims to implement our nitrogen and phosphorus research at the spatial scale of small river catchments, i.e., the scale at which water quality indicators operate. This will span all of the three research approaches mentioned above.

From a research perspective, we will increasingly aim our future projects at finding innovative solutions to environmental challenges. This will involve 'outside-the-box' thinking and the development of novel methodologies to conduct research and to disseminate the latest information efficiently to farmers and advisors.

Acknowledgements

The author is grateful to Drs. Noel Culleton, Owen Carton, Karl Richards, Deirdre Fay, David Bourke, James Humphreys, John Murphy and Deirdre Hennessy for their input and review of this article.

Most of the new nutrient research projects at Teagasc receive substantial funding from the Department of Agriculture and Food Research Stimulus Fund.

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Species-rich winterage in the Burren is of high conservation value and can be mapped using satellite imagery.

Mapping the Burren

JOHN FINN, SHARON PARR and GRACE O'DONOVAN describe a joint Teagasc-UCD project that used satellite imagery to map the broad habitats of the Burren.

Satellite imagery was used to survey and map the extent and spatial distribution of broad habitat types within the Burren, Co. Clare. This map is the first to show the area and distribution of the different habitats of the Burren, and we provide the first estimate of the area of the Burren affected by scrub encroachment – this being one of the most significant threats to the EU priority habitats in the region.

Comparisons between this survey and those in the future will permit a measurement of changes in habitats in the Burren. The Burren represents one of the more complex and demanding areas within which to apply this methodology; the outcome strongly indicates that the methodology is appropriate for national-scale use of remote sensing for habitat mapping.

High nature value habitats

National and international commitments increasingly require decision-makers in the rural environment to conserve and protect high nature value habitats, which are commonly found on farmland and other areas throughout Ireland. But where do such habitats occur? Often, there is surprisingly little knowledge available on the extent and distribution of high nature value habitats, and such knowledge is an essential prerequisite for informed decision making. High quality information on the quality and distribution of habitats allows more local scale (e.g., county-level or townland-level) prioritisation of habitats that are of very high quality, or are severely threatened. In turn, such information can facilitate more targeted conservation management. Traditionally, habitat mapping has occurred on a field-by-field basis, which is very labour-intensive. Here, we use the Burren as an area for the implementation of a methodology that uses satellite remote sensing to produce images that can be related to different habitat vegetation types.

The Burren, Co. Clare is an internationally important landscape, containing over two thirds of Ireland's native vascular flora and a mosaic of important habitat types (EU Habitats Directive). Much of this area is designated as a Special Area of Conservation (SAC) for its limestone pavement and limestone grassland. There has been increased concern about changes in the extent, distribution and quality of habitats of conservation value, particularly in the karst region of the Burren. A number of threats are perceived to be affecting the extent, distribution and quality of ecological habitats in the area. The main threats include farm intensification and changes to grazing management. These produce a variety of specific threats, particularly under-grazing, which is facilitating scrub invasion and is compounded by the feeding of silage. Increased feeding of silage may also contribute to enrichment of the grasslands by localised increased inputs of nutrients via dung and urine.

While there is considerable anecdotal evidence about changes in the habitats of priority conservation value in the Burren, there is relatively little evidence based on objective data that assess and research the nature and extent of the impacts of threats on the vegetation of the Burren. Efforts to understand habitat changes in the Burren are seriously curtailed by the absence of a large-scale baseline survey that makes data available in an accessible format. Due to the size of the area, a full field survey would be prohibitively expensive and time consuming. In a two-year collaborative study between University College Dublin and Teagasc, we aimed to address these issues by using satellite imagery to classify the broad habitats of the Burren.

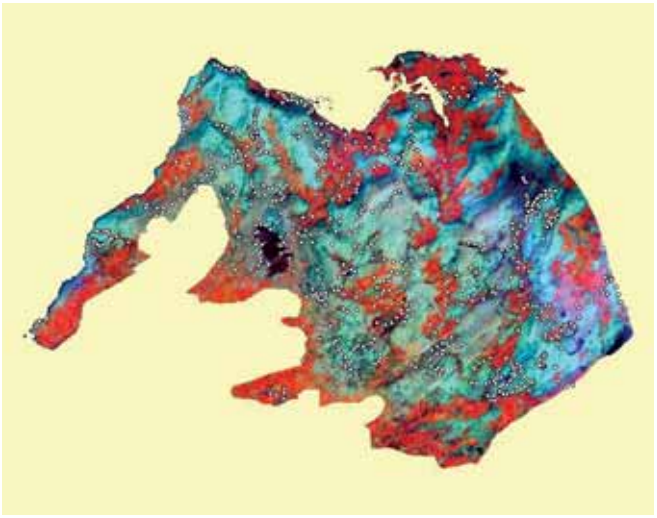

FIGURE 1: Vegetation data were collected from 850 sites (white dots). The site locations are superimposed here on a Landsat image of the study area. Note how small groups of dots form short lines that represent vegetation survey walks through the Burren.

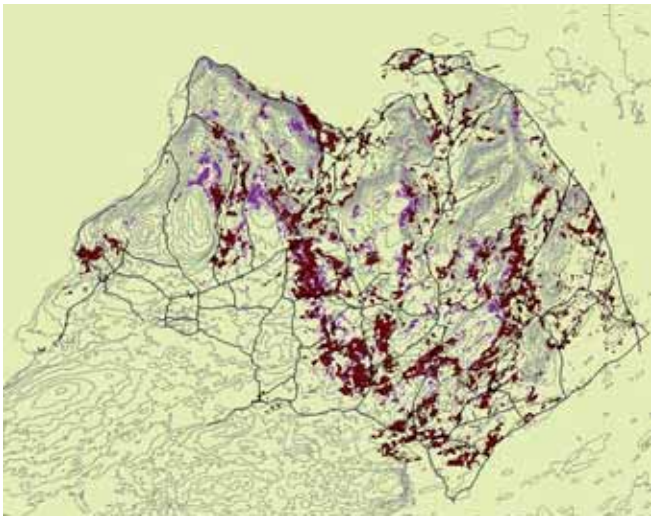

FIGURE 2: An example of habitats identified from satellite imagery in the Burren. Woodland and closed canopy scrub are seen here as dark brown. Calluna *heath and low open scrub are shown in purple.*

Mapping the Burren

The rationale for mapping the Burren area is to reduce the amount of field work required in the future for mapping habitat types and monitoring vegetation change in an area of conservation importance. The most useful, value-for-money imagery at this scale is the Landsat series, as it has the best range of infra-red (IR) bands most useful for mapping vegetation.

Extensive fieldwork was carried out in the field season of 2003, with habitat data being collected for approximately 850 individual points (see Figure 1) where we briefly described the habitat and the vegetation in the immediate vicinity. The vegetation and habitat types at these points could then be used to 'train' or ground truth the satellite images, and help us relate specific colours on the image to specific habitats. The habitat map was created by using a combination of two satellite images from April 2003 and August 2000.

An important aim of this study was to investigate whether we could use satellite imagery to map the location of scrub in the Burren. This category encompasses both scrub and ash-hazel woodland. Areas of mixed scrub including hazel, whitethorn, blackthorn and holly are most frequent on the north coast. The scrub category includes mature scrub with a more-or-less continuous canopy, mature scrub within a grassland matrix similar to a gladed wood pasture (scrub cover is usually greater than 50%) and immature scrub with a continuous or broken canopy that commonly ranges from approximately 1.5m to 3m in height. Various experimental approaches were used to try to boost the visibility of the scrub, which could then be used to map this habitat. The best approach involved mixing images from April 2003 and August 2000, after which the scrub and woodland became highly visible. Comparison of the areas classified as scrub and woodland with the combined image and GPS-referenced (Global Positioning System) vegetation data from fieldwork suggested that the resultant map was a relatively accurate representation of this habitat. It was not possible to separate woodland from scrub or to separate the different types of scrub (see dark brown areas in Figure 2).

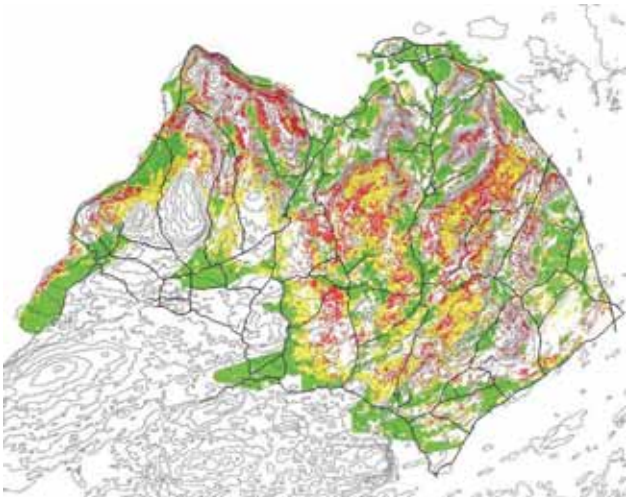

FIGURE 3: Habitat map of the study area showing improved grasslands (green), strong winterages (yellow) and weak winterages (red).

The extent and distribution of improved grasslands and those grasslands of high conservation (winterage areas) can be seen in Figure 3.

Satellite imagery and map creation

On the basis of the vegetation data obtained from ground truthing, a habitat map was derived with a number of broad habitat types being classed as: water bodies and associated aquatic vegetation, sand dunes, blanket bog and wet heath, tillage, plantation forestry, clear felled forestry, improved grasslands, strong winterage (more productive winter-grazed pastures with both calcareous

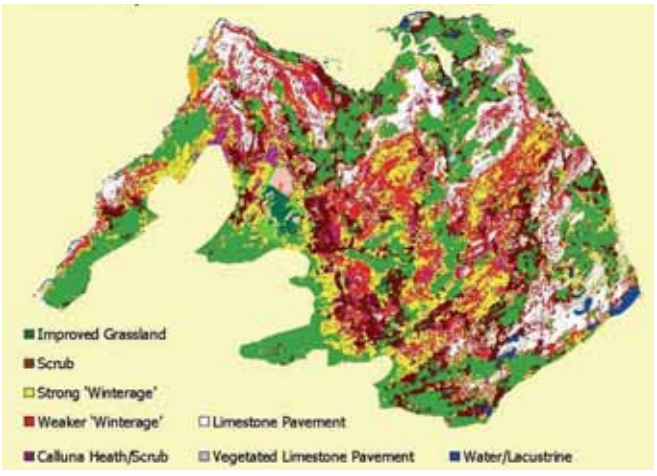

FIGURE 4: Habitat map of the Burren produced from a composite of multiple GIS images.

Dryas *heath is an internationally important habitat for rare arctic-alpine plants and animals. This habitat occurs on lime-rich soils and contains short, usually grazed, species-rich mixtures of mountain avens (*Dryas octopetala*).*

TABLE 1: Estimated area of broad habitats identified in the Burren study area.

Broad Habitat	Area (% cover)
Total unimproved grassland	31%
Strong winterage	17%
Weaker winterage	14%
Improved grassland	28%
Total Limestone pavement (LP)	20%
Bare LP	10%
Vegetated LP	10%
Scrub	14%
Calluna heath & open scrub	3.4%
Others	3.6%

and mesotrophic vegetation), weak winterage (less productive, calcareous winter-grazed pastures), scrub, limestone pavement, vegetated limestone pavement, *Calluna* heath/open scrub, drying turloughs and rushy pastures. The final habitat map was created using a variety of techniques as described above in an attempt to improve the level of accuracy obtained solely by a supervised classification. The methods used to classify the habitats meant that the end result was a composite of multiple images rather than a single one containing all the relevant habitats (Figure 4). A summary of the area (in percentage cover terms) associated with different broad habitats of the Burren is shown in Table 1.

Possibilities for GIS (Global Information System)

This study demonstrated that satellite imagery is a useful technology for creating habitat maps of the Burren. However, while a fair representation of the broad habitat types in the Burren has been produced, it must be recognised that the habitat classifications are more generalised than those that could be achieved by field-by-field walking and mapping methods. In addition, the resolution of the imagery at 30m, the complex topography of the Burren and, most importantly, the fact that habitats in the Burren do not exist within distinct boundaries (whether natural or artificial), but interdigitate in a series of complex mosaics, means that the map has its limitations. Using satellite imagery does, however, provide a means of mapping a large and complex area in a relatively short period of time. To map the habitats on foot would take many person-years and would not necessarily be more accurate due to the complexity of habitats, and the amount of time required for such a task to be completed. When finite resources are available, deciding between field-by-field and GIS-based approaches effectively involves a trade-off between collecting a moderate amount of information with a little uncertainty across a large area (predictive GIS-based approach) and having a large amount of information with a lot of certainty across a small area (field-by-field mapping).

Looking to the future, there is very significant potential for the combined use of high-resolution satellite imagery, aerial photography and ground truthing to complete a detailed national habitat and land use survey of Ireland. This would support more effective implementation of the agriculture sector's obligations under the Habitats Directive, and agri-environmental schemes with wildlife objectives. The outputs provided by such mapping approaches on a national-scale could inform the targeting of agri-environmental objectives, and increase the efficiency of detecting areas of high conservation value for monitoring by more conventional methods. The detailed land use descriptions offered by such imagery are also of high relevance to modelling approaches and risk assessment for implementation of land use policies such as the Water Framework Directive and Nitrates Directive.

Acknowledgements

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The WTO and Irish agriculture

TREVOR DONNELLAN, KEVIN HANRAHAN, THIA HENNESSY and FIONA THORNE explain the results of their research into the likely impact of the latest round of WTO talks on producers in Ireland.

The current round of World Trade Organisation (WTO) talks, known as the Doha Round, is currently suspended but is likely to be restarted following the mid-term congressional elections in the US this November. A successful outcome to the negotiations is not certain. However, any agreement that might be reached will bring changes to the rules governing the export and import of agricultural products and government support to agricultural industries across the globe.

Teagasc researchers from the Rural Economy Research Centre (RERC), working with colleagues from the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri, USA, have examined the impact of the WTO talks on Irish agriculture and farming by looking at different possible outcomes that might come about from the negotiations. The research conducted examined the impact of a possible WTO agreement using the FAPRI-Ireland aggregate model of the EU and Irish agricultural sectors, and the RERC-FAPRI-Ireland farm-level models of Irish farm businesses.

Any WTO agreement will involve the elimination of export refunds, the lowering of tariffs (taxes) on agricultural imports and further restrictions on the use of production distorting domestic subsidies.

Stark outcome

The results from the RERC-FAPRI-Ireland aggregate model of a possible WTO agreement indicate that Irish agricultural exports would decline, leading to lower Irish agricultural commodity prices. Irish milk prices are projected under a WTO agreement, to be over 11% lower by 2015; while Irish cattle prices would, when compared with a continuation of current policy, decline by over 10%. Such reductions in agricultural output prices are projected to lead to lower agricultural production and a fall in Irish agricultural sector income of €200 million in 2015, when compared to the projected level of Irish agricultural sector income in the absence of a WTO agreement.

The lower agricultural commodity prices that would result from a WTO agreement would also have large effects at the farm level. Research published by RERC economists using the RERC-FAPRI-Ireland farm models indicates that approximately 13% of cattle farmers and 35% of tillage producers would be unable to return a positive gross margin in 2015. The research indicated that such farmers would find it more profitable to retain their land only to claim their decoupled payments.

The abolition of export subsidies and resultant lower milk prices, as part of a WTO agreement, would also have serious consequences for dairy farmers. The research conducted in RERC found that the average gross margin per cow is expected to fall by over 40% as a result of WTO reform, and that this is likely to have serious consequences for producer numbers. The RERC-FAPRI-Ireland farm-level model predicts that economically viable dairy farm numbers could fall to less than 8,000 in 2015.

The RERC research found that a large number of the economically non-viable farm businesses may be sustainable due to the presence of other income in the farm household. It's predicted that 70% of cattle farmers and nearly half of tillage farmers will have an off-farm job by 2015. Nevertheless, the RERC research found that there will be a significant number of farming households that will be economically vulnerable because the farm business is not economically viable and there is no other income source in the household. This category of farm household includes 15% of dairy farming households, 21% of cattle farming households and 27% of tillage farms.

Conclusion

The findings of Teagasc WTO research illustrate the impact that a WTO agreement would have on Irish farmers. While a WTO agreement may bring benefits to developing countries by allowing them to expand exports to the EU, these reforms would also create significant challenges for producers in Ireland.

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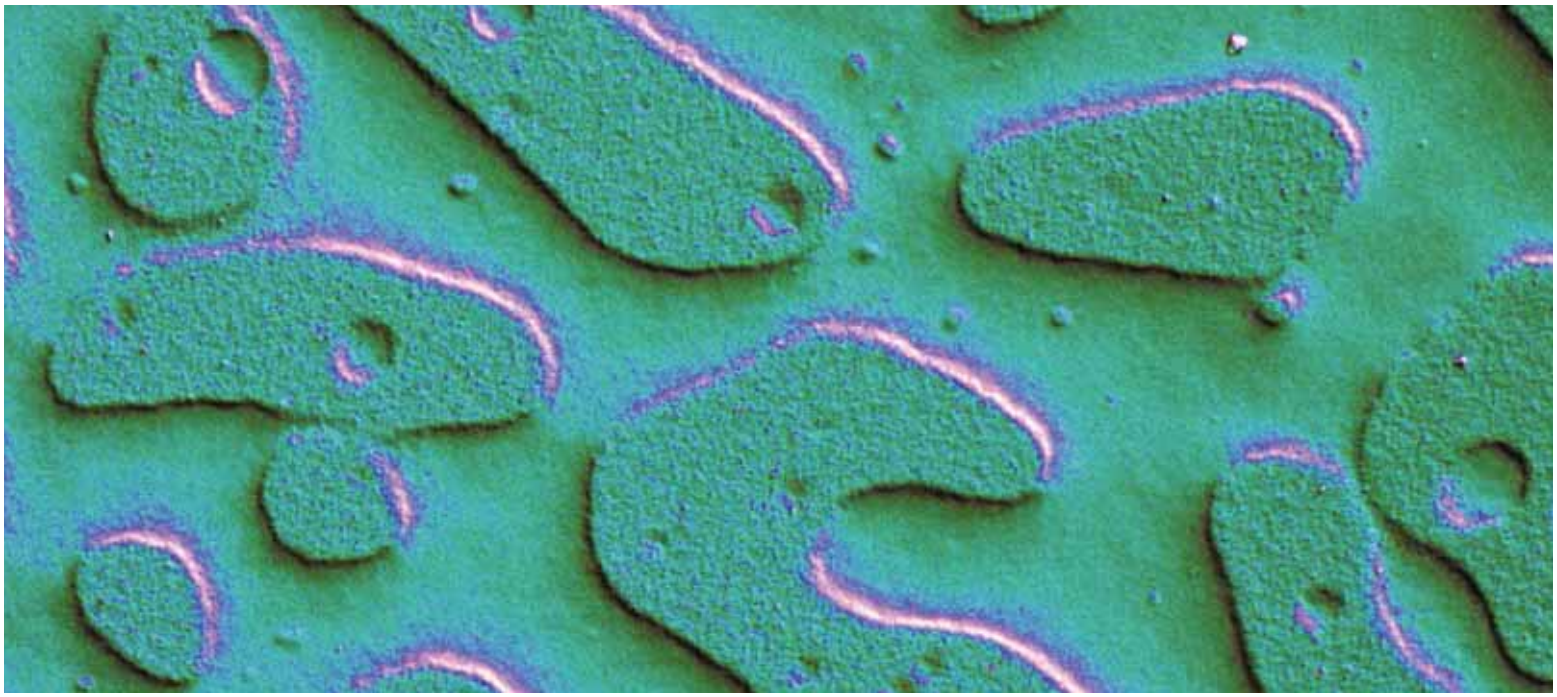
Full details of the research described are available from the Rural Economy Research Centre website www.tnet.teagasc.ie/rerc and from the FAPRI-Ireland website www.tnet.teagasc.ie/fapri.



Why do we like creamy foods?

MARK AUTY describes two new three-year projects that have begun at the Moorepark Food Research Centre. The projects form part of a strategic research programme to improve food quality through novel processing technologies.

Most people like foods that have a creamy texture. Creaminess implies richness and quality as well as carrying desirable flavour compounds. However, the availability of cheap, high-fat foods, coupled with a more sedentary lifestyle, has led to a massive increase in obesity in the western world. Consequently, reducing fat intake has a key role to play in reducing obesity. Creaminess perception is considered to be one of the most important contributions that fat makes to product acceptability and, therefore, lack of creaminess can be a significant barrier towards acceptance of reduced-fat foods. However, in spite of our preference for creamy foods, the exact nature of creaminess has yet to be clarified. Researchers at Moorepark are investigating the relationship between the food structure and a creamy mouthfeel.

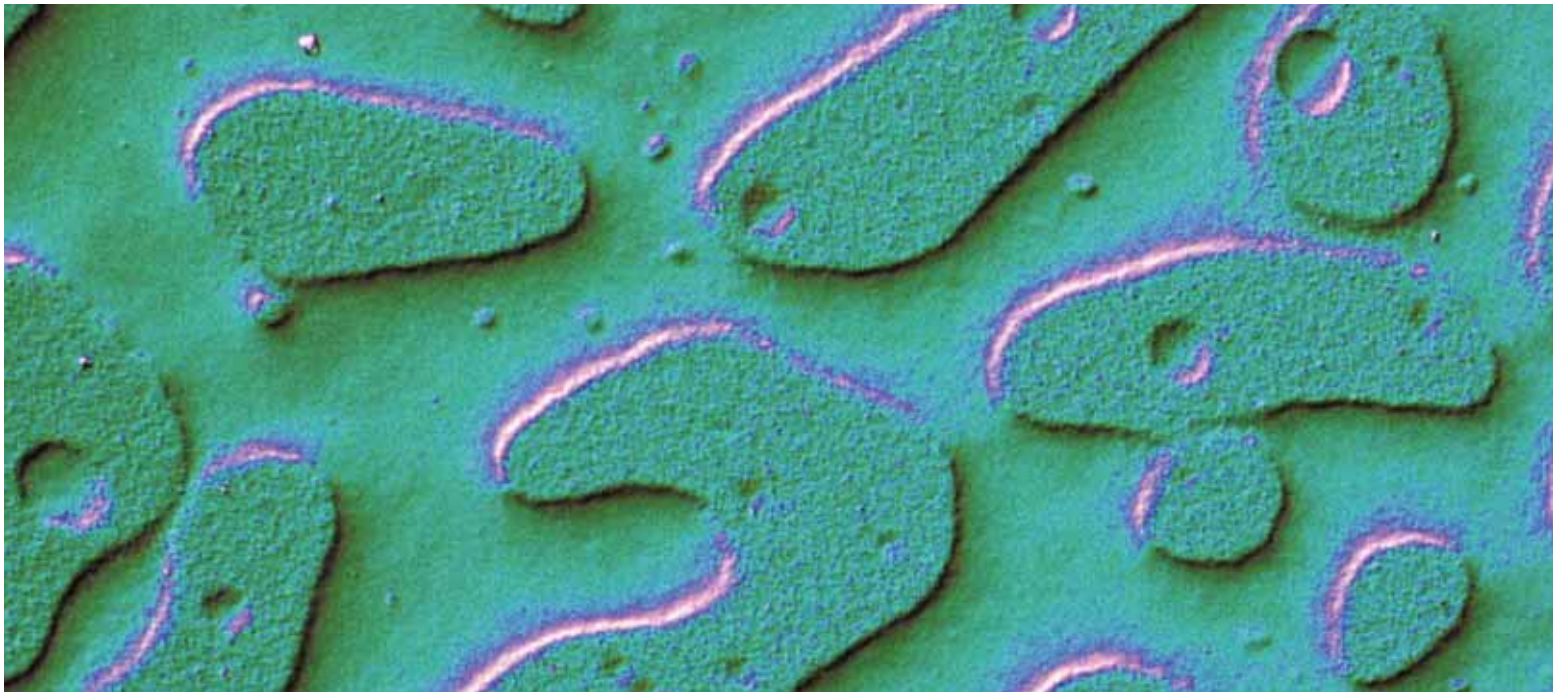
Polysaccharides and proteins are routinely used as fat-replacers. However, little is known of the effect of their physical chemistry and microstructure on creaminess perception. The consumption and enjoyment of food belies a complex series of inter-related mechanical, chemical, physiological and psychological events, which require a holistic approach.

This project will comprise a multidisciplinary team that will provide a scientific resource for future structure-function research. The objective is to study the mobility and perception of fat and fat replacers during oral processing. Product types such as yoghurt and cheese containing pre-defined sizes of either fat droplets or fat mimetics will be prepared. Deformation, rupture, coalescence and mobility of fat replacers that occurs during mastication will be modelled by state-of-the-art dynamic microstructure analyses. Mechanical properties of emulsions and gels will be characterised by dynamic rheometry and large deformation texture analysis, respectively. Results will be related to objective descriptive sensory analysis using creaminess as the main descriptor, but considering related textural and mouth-feel characteristics.

The replacement of fat with 'natural' alternatives, whilst maintaining sensory quality, is a technological challenge that requires an understanding of the complex events of oral processing on 'multiphase' or 'complex' foods. To maintain competitiveness, Irish food companies must develop innovative, added-value products that not only promote health, but have desirable sensory properties. It is hoped that this new research will help technologists to design innovative reduced fat foods.

Nanotechnology - the whey ahead

Nanotechnology is a rapidly emerging technology more often associated with semiconductors than food. Food applications of nanotechnology are at an



Light microscope image of a milk protein-polysaccharide mixture showing how the separate phases mimic a fat-rich food system.

embryonic stage in Ireland, but worldwide there is a growing realisation of the importance of nanotechnology, not just in the physical sciences, but in biotechnology and food applications. A comprehensive study by Helmut and Kaiser (Food Nanotechnology Report, 2004) has predicted that the market for food nanotechnology could exceed $20bn by 2010. A recent EU 'Nano2Life' expert survey provided a worldwide view on selected future developments in nano-biotechnology and the potential impacts and prospects in different domains, emerging from judgments of a large group of experts from academia and industry. This study confirmed that nanotechnology is seen as having a major scientific impact on life sciences in the medium term.

Increased global competition for commodities, including skim milk powder and butter, requires increased innovation by the Irish food industry to produce high added-value products and to maximise utilisation of waste streams such as whey. Milk whey proteins are versatile food ingredients added to foods to improve consistency, for example, by forming heat-induced gels, or as micro-particulate fat replacers. In many food systems, salt is necessary to promote whey protein aggregation. A recently discovered feature of globular proteins is their ability to self-assemble into extremely thin (<5nm) fibres or 'nano-fibrils' at low salt concentrations. The search for sources of non-meat protein, functional ingredients and the need to add value to existing protein waste streams requires an understanding of self-assembly processes. Nano-fibrils derived from whey proteins will supply a ready source of novel structuring agents for the food industry. Nano-fibrils could act as functional ingredients to improve product consistency, water-holding capacity, bio-adsorption and promote desirable textural attributes. The ability to fabricate nano-fibrils into larger structures such as hydrogels, globules and fibrillar bundles will provide novel food textures with low salt contents.

Little is known of the kinetics, dynamic re-assembly mechanisms and functional properties of nano-fibrils. The critical mass of expertise arising from this project will form the basis of a generic platform of nanotechnology research into self-assembled food macromolecules.

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These projects are funded by the Department of Agriculture and Food under its Food Industry Research Measure.

Tracking food poisoning

GERALDINE DUFFY describes how molecular techniques are being employed to track food poisoning bacteria through the food chain.

Food-borne microbial infections continue to cause a substantial public health and economic burden. Recognising this, the integrity and safety of the food chain is an absolute priority for the Irish agri-food sector. Key to assuring, and indeed improving, microbial food safety is the ability to track food poisoning bacteria along the 'farm to fork' chain. State of the art genetic tools are being applied at Teagasc, Ashtown Food Research Centre (AFRC) to track food poisoning bacteria, including *Salmonella* and *E. coli* O157:H7, along the food chain to identify the sources and routes of transmission.

Tools for tracking bacteria

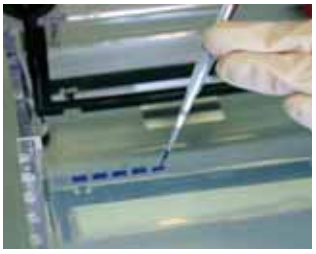
Within a group of food poisoning bacteria such as *Salmonella*, each individual strain of the bacteria has a unique genetic code or fingerprint. The genetic fingerprint for an individual *Salmonella* strain can be compared against the fingerprint of another *Salmonella* strain to determine categorically if the strains are identical and have come from the same source of contamination. The fingerprint can be generated using a number of different approaches. One of the main methods being employed in ongoing research at AFRC is Pulse Field Gel Electrophoresis (PFGE). PFGE employs restriction enzymes (endonucleases) to make a limited number of cuts in the bacterial chromosome providing chromosomal restriction patterns that form a unique 'fingerprint' for each individual bacterial strain. When the fingerprint is generated, computer software (bioinformatics) can be used to compare the fingerprints of different bacterial strains and will establish how closely they are related. The genetic fingerprints generated can be compared to those available on national and international databases. For example, 'PulseNet' is a North American database coordinated by the Centers for Disease Control and Prevention (CDC), which contains genetic fingerprints for food poisoning bacteria obtained using PFGE. These databases can be used to compare fingerprints for recently isolated bacterial strains with previously isolated strains. They can be used to establish relatedness between bacteria in a food poisoning outbreak and can also establish trends for the persistence or geographical spread of certain strains.

Food production

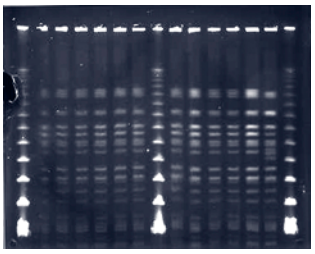
For the food industry, tracking bacteria gives scientific evidence about where food poisoning bacteria are entering a process, where cross contamination may be occurring, whether a particular strain is endemic in a factory environment and, most importantly, where controls should be directed. Ongoing research being undertaken jointly by AFRC and University College Dublin (UCD) in this area includes tracking *Salmonella* from pig herds through transport, lairage, slaughter, carcass dressing and boning into pork primal cuts. By tracking individual animals through to their derived pork cuts and by genomically comparing *Salmonella* isolated from the animal, meat or environment at key stages, it can be determined definitively whether the *Salmonella* isolate recovered from the meat has come from the pig's own gut or faeces; from the gut or faeces of another tracked animal slaughtered at the same time; or, if introduced from an environmental source such as the transport truck, the lairage or factory environment. This will yield essential data about transmission routes and also about the effectiveness of current process controls.

Similar collaborative research with UCD is commencing on verocytotoxigenic *E. coli* (VTEC - including *E. coli* O157:H7, O111, O103, O145 and O26) in beef and sheep and will involve tracking individual animals from lairage, through hide/fleece removal onto the carcass. Any VTEC recovered from the animal hide, faeces, carcass, lairage environment or process equipment will be genomically compared. Thus, the source of the VTEC strains recovered from the carcass will be established and scientific evidence generated about the contribution of hide/fleece to contamination of the carcass and how it may be controlled.

Geraldine in the food safety laboratory in Ashtown.



Loading an electrophoresis gel for genetic analysis of bacteria.



Pulse field gel electrophoresis profiles for 12 different isolates of E. coli O157:H7.

Human infection

In a food poisoning outbreak, the ability to track an individual bacteria from a human patient back to a food or environmental source provides essential information about the cause of the outbreak and can give the scientific basis for a product or batch recall. In more general terms, there is huge potential value from genomically comparing bacteria from human infection with those isolated from food, animal or environmental sources. In food poisoning bacteria, there are generally specific genes present that are linked to virulence. If the sequence of the virulence gene(s) in a particular bacterial species is known, they can be examined for the presence of these gene(s) and an assessment made about their likelihood to cause illness in humans. The question of whether all pathogenic bacteria detected from food are actually infectious for humans is an important issue to be answered by ongoing research. Equally, genomic comparison of bacteria from human and food animals will establish whether a particular species of food animal or commodity is more important than another in the carriage of human-disease-causing strains of a food poisoning bacteria. This data will enable focusing of resources most effectively to reduce the risk posed by that bacteria. Ongoing research in this area has genomically compared *E. coli* O157:H7 from human infection with isolates recovered from beef, sheep and pigs. It is known that *E. coli* O157:H7 can cause illness in humans ranging from mild diarrhoea, to severe bloody diarrhoea (haemorrhagic colitis) and kidney failure (haemolytic ureamic syndrome - HUS). *E. coli* O157:H7 that cause very serious illness in humans are known to possess genes linked to their ability to attach to the human large intestine (*eae* gene), and the production of a particular toxin called Verotoxin (encoded by the *vt*1 or *vt*2 gene). *E. coli* O157:H7 recovered from beef, sheep and pigs have been examined for these virulence genes. The virulence profiles of *E. coli* O157:H7 recovered from various stages of the beef chain are shown in Table 1. The majority of isolates (93.7%) contained the virulence profile (*eae, vt*2, *hlyA*) associated with very severe forms of the illness. Interestingly, there was much wider variation in the presence of the *vt*1 gene in the beef isolates from different parts of the beef chain with only 35% of isolates containing this gene. The *vt*1 gene is linked to virulence, but is considered to be associated with less severe illness in humans than the *vt*2 gene.
The profile of *E. coli* O157:H7 isolates recovered from sheep showed that 87% contained *vt*2, *eae* and *hlyA* genes. Only five isolates (15%) contained the *vt*1 gene. The prevalence of *E. coli* O157:H7 in pigs was very low and only four isolates were recovered from 1,710 pigs examined. However, three of these four contained the genes (*vt*2, *eae, hlyA*) indicating their potential to cause illness in humans.

TABLE 1: Virulence profile for *E. coli* O157 isolates from different parts of the beef chain.

		Virulence genes			
Source	No. of Isolates	*hlyA*	*eaeA*	*vt1*	*vt2*
Hide	62	+	+	-	+
Hide	29	+	+	-	+
Hide	0.9	-	-	-	-
Hide	5	+	+	+	+
Hide	2	+	+	-	-
Hide	1	+	+	+	+
Hide	1	-	-	+	-
Trimming	7	+	+	+	-
Trimming	5	+	+	-	+
Trimming	1	+	+	-	+
Trimming	1	-	-	-	-
Trimming	9	+	+	-	+
Trimming	6	+	+	+	-
Trimming	2	+	+	+	+
Trimming	1	+	+	+	-
Carcass	1	+	+	+	+
Carcass	2	+	+	+	-
Carcass	1	+	+	-	+
Head meat	3	+	+	-	+
Retail beef	42	+	+	+	+
Retail beef	1	+	+	+	-

Note: + Positive for gene - negative for gene

Impact on food safety

Tracking of food poisoning bacteria in the food chain and particularly establishing the genetic relationship between isolates recovered from humans, food, animals or environmental sources has enormous potential to direct and focus efforts to improve microbial food safety. Ongoing research at AFRC is expanding this area of research by employing an increasingly sophisticated range of genetic tools, including Restriction Fragment Length Polymorphism analysis (RFLP), Variable Number Tandem Repeat Analysis (VNTR), multi–locus sequence typing (MLST), gene sequencing and micro-array analysis to track food poisoning bacteria along the entire food chain. Bacterial isolates from different parts of the chain are being compared with a focus on genes associated with virulence/pathogenicity and fitness. Strains of food poisoning bacterial strains will be tracked through the food chain and examined to see if certain stresses, stages in the chain (environment, passage through the animal gut, food processing, etc.) induce any genetic changes (mutation, adaptation, etc.) that alter or enhance bacterial fitness or virulence potential. This will allow science-based control strategies to be developed and applied to enhance food safety.

Acknowledgements

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Progesterone and embryo survival

DERMOT MORRIS explains the relationship between progesterone and embryo survival in the cow and emerging research approaches at Athenry Research Centre.

Previous research at Athenry showed that early embryo loss accounts for 70 to 80% of all reproductive wastage in cattle and has a major depressive effect on the economic efficiency of both beef and dairy herd production. Factors that contribute to early embryo mortality include chromosomal defects of the embryo, deficiencies of the uterine environment and luteal deficiencies associated either with an early luteolytic signal or a delayed or weak production of interferon tau (IFN-τ) by the embryo. Moreover, in high yielding dairy cows, inadequate maternal nutrition and severe negative energy balance have been associated with an increased rate of early embryo loss.

The cow embryo spends its first three to four days in the oviduct and then moves into the uterus where it implants at around day 20. During this time, it is relatively free-floating and nutritionally and physiologically dependent on oviduct and uterine fluids for its growth and development. There is very little obvious change in embryo growth in the first few days after artificial insemination (AI). Between days 8 and 16, however, the cattle embryo undergoes a period of rapid growth characterised by a 250-fold increase in size and a 5,000-fold increase in protein content (Figure 1). It is during this period of rapid growth that most embryo loss occurs. Commensurate also with this rapid development the embryo has an increased requirement for energy substrates such as glucose and amino acids, the building blocks of proteins and nucleic acids. The embryo's dependence on the correct balance of essential nutrients necessitates a correct uterine environment for optimal growth and development. However, very little is known about the uterine environment at this time with respect to the biochemical composition and in terms of pH, ions, amino acids and proteins and how these are affected by environmental changes and changes in the concentration of systemic progesterone, arguably the most important reproductive hormone.

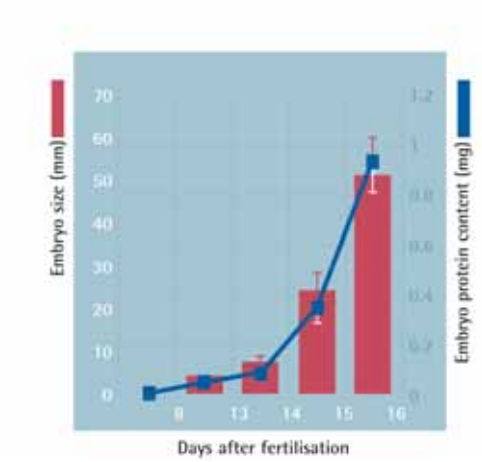

FIGURE 1: Cattle embryos undergo an exponential increase in size and protein content from days 8 through to day 16 after fertilisation.

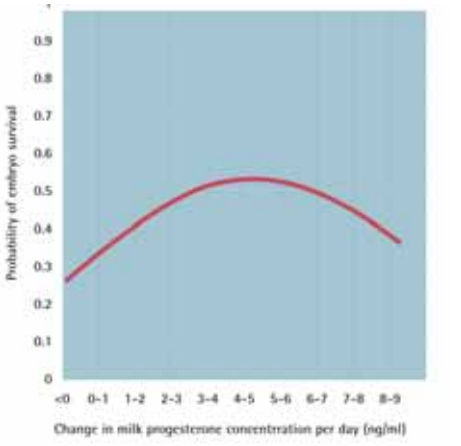

FIGURE 2: Relationship between the rate of change in milk progesterone between days 4-7 after AI and the probability of embryo survival.

Progesterone

There is substantial evidence for the role played by the steroid hormone progesterone in supporting embryo survival. Progesterone is one of the family of steroid hormones and is essential for the initiation and maintenance of pregnancy, including normal embryo development. Indeed, progesterone has been called the "hormone of reproduction" due to its many and varied roles in reproduction. Acting through its receptor and other co-factors, progesterone helps to orchestrate complex molecular, biochemical and physiological interactions in the uterus that affect embryo growth and development. It is known to increase uterine secretions, influence the rate of conceptus development and thereby influence the timing and strength of the luteotrophic signal.

Following ovulation, the granulosa cells lining the wall of the ruptured follicle undergo a process of 'luteinisation' and begin to synthesise and secrete progesterone into the ovarian vein and the peripheral circulation. It is this luteinisation process that gives rise to the corpus luteum or 'yellow body' visible on the cow ovary throughout the luteal phase of the cycle and it is the size of this corpus luteum that ultimately determines the concentration of systemic progesterone.

The concentration of progesterone in blood and milk increases rapidly during the early part of the oestrous cycle, reaching peak concentrations of about 8 and 40 ng/ml in blood plasma and milk, respectively, at about days 7-10, before declining precipitously at luteolysis, at 18-21 days after ovulation.

Progesterone and embryo survival

We have recently demonstrated a significant association between the concentration of progesterone in blood and in milk and embryo survival in both beef and dairy cows. Previous work at Athenry showed that low progesterone, or a low rate of increase in the concentration of progesterone in the first few days after AI, is associated with a low probability of embryo survival. While this is the case in heifers and cows, the problem is greatest in high yielding dairy cows (Figure 2), and this may arise from the cows' high metabolic rate as a result of

lactation. For example, in dairy cows, there is a clear positive relationship between feed intake and increased liver blood flow, which in turn results in an increase in progesterone metabolism, with a corresponding decrease in systemic or circulating progesterone. Clearly, alterations in the steroid balance, particularly progesterone, due to high feed intake, may have a direct effect on the developing embryo or may result in deleterious changes in the composition of uterine secretions essential for early embryo development.

In one UK study, administering exogenous progesterone to half of a group of cows with low progesterone effectively increased embryo survival compared to the control group. Possible solutions to addressing the problem of cows with low progesterone could be to administer additional progesterone to cows at risk or, alternatively, to remove cows with this trait from the herd. The first solution of progesterone supplements is not acceptable from the consumer's perspective and, because the heritability of low progesterone is effectively zero, the alternative of removing cows is not an option. What is required is a more fundamental approach to get a better understanding of the factors involved in both corpus luteum formation and progesterone production and in the relationship between progesterone and uterine fluid composition and embryo survival. By better understanding the mechanisms determining corpus luteum and uterine function, we may be able to devise new management or nutritional strategies to improve embryo survival, compatible with consumer demands and the practice of sustainable agricultural methods.

Research approaches

Despite the need for a better understanding of the fundamental mechanisms underlying these processes, there is little published information, particularly on the mechanisms underlying uterine function. Part of the research programme in animal reproduction at Athenry has been focussed on characterising for the first time, under physiological conditions, the biochemical composition of the oviduct and uterus throughout the oestrous cycle in cattle.

Progesterone and uterine biochemistry: using specially developed, customised miniature pH probes, we have measured both oviduct and uterine pH and have shown for the first time that, contrary to expectation, the oviduct pH at 7.6 is higher than the blood pH at 7.4, which in turn is much higher than the uterine pH at 6.96. These results show that not only is oviduct and uterine pH different, but that both are under active local control, maintaining the pH at a different level to that of blood. This also suggests that, for optimal embryo growth and survival, and to maximise the number of embryos deemed to be transferable *in vitro*, embryo production may need to use culture media with two different pH values. Similarly, we have characterised the biochemical composition of the oviduct and uterus in terms of the concentrations of ions, amino acids and metabolites and the results indicate that the composition of both oviduct and uterine fluid is different to that of blood and that the composition of the uterus is more dynamic. These baseline measurements demonstrate the dynamic nature of the uterine environment and how its fluid composition is affected by stage of cycle from day 6 to 14 - the period during which the embryo is undergoing exponential growth and when embryo mortality is greatest. During this period, the uterus is likely to be more susceptible to environmental changes capable of adversely affecting its composition to the detriment of embryo survival.

Progesterone and uterine gene expression: embryo growth and development is also dependent on the presence in uterine fluid of a wide range of proteins, including growth factors and transport proteins. Many of these proteins and the genes encoding them are known to be regulated by progesterone in some species. Using the latest developments in molecular detection technologies, we have been examining the effects of changes in systemic progesterone and stage of cycle on uterine gene and protein expression. Using genomic approaches, we have identified, amongst others, that the expression of genes encoding retinol binding protein (RBP) and folate binding protein (FBP) are sensitive to small changes in systemic progesterone, especially in the first few days after AI when progesterone *per se* is low (Figure 3). These transport proteins are functionally essential and their expression needs to be tightly regulated in order to maintain an optimal supply of vitamin A (RBP) and folic acid to the developing embryo. Ultimately, it is the expression of the proteins such genes encode that is functionally important for optimal embryo survival. As changes in gene expression are not always translated into changes in the corresponding proteins, we are currently adopting a complementary proteomic approach in order to determine how the protein composition of the uterus is affected by stage of cycle, changes in the steroidal environment and changes in dietary composition. Using approaches such as these, we can gain an insight into the fundamental mechanisms affecting uterine function and ultimately describe a uterine milieu that is commensurate with optimal embryo survival. In this way, we can better establish the relationship between nutrition, progesterone, uterine protein expression and embryo development and facilitate a nutritional approach to addressing the problem of early embryo loss.

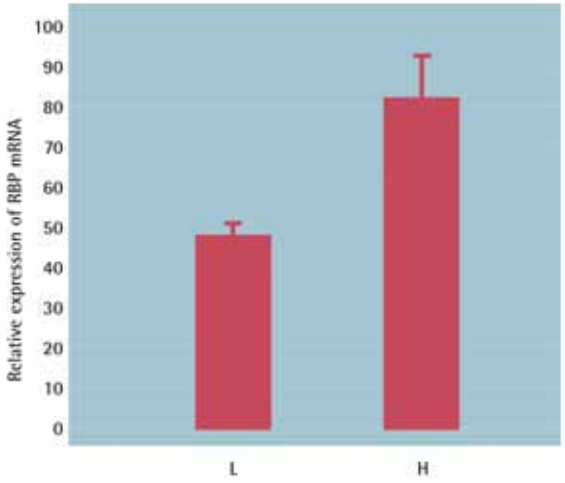

FIGURE 3: A 1ng/ml change in the concentration of blood plasma progesterone from low (L) to high (H) increases RBP gene expression by over 70% on Day 6 after AI.

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Breeding for profit

DONAGH BERRY describes the development of the Economic Breeding Index for the Irish dairy herd.

The Irish national dairy herd is primarily black and white and on the majority of farms is progressively being upgraded from the British Friesian to the Holstein breed. The importation of Holstein genetics into Ireland has historically derived either directly or indirectly from the United States, with bulls like Elevation, Chief and Ivanhoe Bell, having a major influence on the genetic makeup of the current Irish dairy cow population. For example, 55% of female Holstein-Friesian calves born in Ireland in 2004 could be traced back to the US bull, Ivanhoe Bell born in 1974. The Holstein germplasm imported into Ireland was typically derived from breeding programmes that aggressively selected on milk production, as US farmers strived for greater milk yields. This has led to deterioration in genetic merit for health and fertility over time within the Holstein-Friesian breed.

Nonetheless, several dairy breeds, most notably of Scandinavian origin, have been able to simultaneously improve milk production, health and fertility, suggesting an 'uncoupling' of the milk-fertility/health association within some families. The ability of these breeds to simultaneously improve health and fertility is owing to their breeding programme, where animals received positive scores for superior genetics for milk, health and fertility, the extent of the scores being dependent on the degree of improvement expected. In such a system, the scores are cumulated across the characteristics of interest, with the highest ranking animals generally being favourable in each characteristic. This is called a 'balanced breeding objective'.

More than half the milk in the Republic of Ireland is produced during the months of April to July, inclusive. To achieve this, cows calve in the spring time, when the farmer tries to maximise the amount of grass in the cow's diet; grass is by far the cheapest available feed source. In order to maintain this system, a cow must calve approximately every 365 days. However, the farmer would also like the cow to produce high quantities of protein and fat, and to do so with minimal fuss. This therefore suggests the requirement for a balanced breeding objective in Ireland that scores animals positively for high production, good fertility, good health and minimal fuss.

Development of the EBI

Until the year 2001, dairy farmers were advised, like most of their international counterparts, to select for high milk production. The side effect of this was deterioration in genetic merit for health and fertility of our cows. Although the effect of the unfavourable genes could be partially overcome by management changes, such as hormonal intervention or the acceptance of late calving cows, these managerial antidotes were unsustainable. Collaboration between the Irish Cattle Breeding Federation (ICBF - a body set up to improve genetic gain in profitability for Irish dairy and beef cattle), Teagasc and international scientists, led to the development of the economic breeding index (EBI) in 2001. The EBI replaced the previous index called the relative breeding index (RBI), which was only interested in increased milk output and composition. The difference between the EBI in 2001 and the RBI was that the former gave higher scores for animals with good fertility and survival, simultaneous with high fat and protein yield. The scores, which are called 'economic values', are derived from models simulating the costs of production and prices obtained within a typical Irish farm system. For example, the score, or economic value, on protein yield is the extra profit per cow a farmer will get if he improves his protein yield genetically by 1 kg. In order to include a characteristic of a cow or bull in a balanced breeding objective that characteristic must fulfill three criteria:

- It must exhibit genetic variation which means that we must be able to see differences in, for example, milk production between two animals identically fed and managed. This makes sense since we cannot identify animals with better genes if all animals have the same genes;
- It must be important either economically, environmentally or socially (e.g., welfare). Any business person would have serious difficulty in investing in something without a return. Purchasing a genetically superior animal or semen straw is an investment within a farm; and,

TABLE 1: Traits included in the EBI in 2006 as well as their economic weights and relative emphasis.

Sub-index	Trait	Economic weight	Relative emphasis	Relative emphasis
Production	Milk	-0.084	-14%	48%
	Fat	1.55	9%	
	Protein	5.27	25%	
Fertility	Calving interval	-7.17	-17%	31%
	Survival	10.80	14%	
Calving	Calving difficulty direct	-3.26	-3%	8%
	Calving difficulty maternal	-1.73	-1%	
	Gestation	-4.47	-3%	
	Calf mortality	-2.58	-1%	
Beef	Cull cow	0.04	0.2%	7%
	Carcase weight	1.38	5%	
	Carcase conformation	5.99	1%	
	Carcase fat	-4.49	-1%	
Health	Lameness	1.13	0.4%	6%
	Udder health	-55.48	-5%	

- The characteristic must be measurable. It would be difficult to identify higher producing cows if we didn't have information on what each cow was yielding.

Improvements in the system

It is the third point which limited the development of the EBI in its initial stages. However, Irish farmers, and bodies involved in Irish agriculture, are recording more and more and most are sending this information into a central database run by ICBF in Bandon, Co. Cork. For example, farmers now have the option to record whether or not they had to assist a cow at calving. In Ireland, we would like cows that cause minimal fuss, which means no assistance at calving. It is possible, through statistical analysis of daughters of bulls, to determine whether a bull has good genes or bad genes for each trait. The degree to which a sire will improve or worsen the genetics of a farmer's herd is described by his estimated breeding value, or EBV.

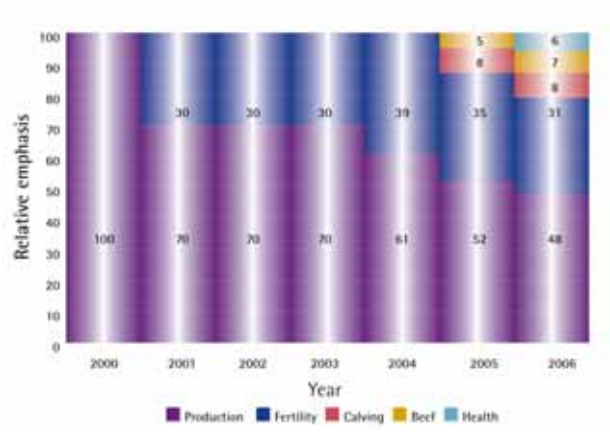

FIGURE 1: Change in relative emphasis on trait groups within the EBI over time.

Furthermore, the collation of data recorded from various sources has facilitated the development and diversification of the EBI in Ireland which is outlined in Figure 1. As can be seen in Figure 1, the traits included in the breeding objective are summarised into five groups or 'sub-indexes': production, fertility, calving performance, beef performance and health. Within each sub-index, are individual traits, which are outlined in Table 1. Figure 1 also clearly shows the change in emphasis in the traits with time, which is due to the introduction of new traits in the breeding objective as well as the impact of EU policies.

Selection on the EBI over time will increase genetic merit for fat and protein production, as well as improving fertility and udder health. However, the EBI is still under development and will be revised periodically in light of changes in costs of production, farm-gate prices and the traits that are important to Irish farmers.

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Biological control of

PAULA KELLY describes research into a suitable replacement for anthelmintics in controlling sheep parasites.

Infection of sheep with gastrointestinal parasitic nematodes (roundworms) is a constraint to production, particularly in young ruminants, and is capable of causing major economic losses if left unmanaged. Anthelmintics are the principal method of control. However, an alternative method for parasite control is required for a number of reasons. The worldwide upsurge in anthelmintic resistance is making many of the conventional treatments redundant, in turn leaving the animals vulnerable to large worm burdens. If a new anthelmintic product, or products, were introduced it is likely that they would meet the same fate, as resistance is expected to develop over time. A steady rise in demand for chemical-free food is also a contributory driving factor.

Considering these facts, the means of combating parasites in the future will require a multifaceted approach that will involve a more sustainable approach to using available anthelmintics, grazing management strategies and the use of resistant or tolerant animal breeds, bioactive forages and biological control agents. The whole principle of using a biological control agent is to significantly reduce the number of infective stages available to susceptible livestock, thus avoiding the negative consequences of parasitism.

Fungi as biological control

Nematophagous fungi have been investigated as a possible biological control of ruminant parasites. These fungi are natural enemies of parasitic nematodes and they are found worldwide. They attack and kill nematodes using them as a source of nutrients and can be divided into two major groups; predacious and endoparasitic. Previous work has mainly investigated the predacious fungi. These use adhesive or non-adhesive trapping structures, i.e., nets, constricting rings (Figure 1) to trap and kill the larvae. *Duddingtonia flagrans* is the most widely studied example and has been documented as being highly efficacious. They produce highly resistant spores (chlamydospores), which can survive the gastrointestinal tract to grow in the faeces and kill the larvae that emerge from the parasite egg. Investigations using this fungus have shown large reductions of larval challenge on pasture and overwintering of larvae. This reduction in larval challenge, and subsequent parasitism of the lambs, leads to more lambs being marketed earlier. Studies have shown that farmers considered this treatment to be of value. The fact that Chr. Hansen, a Danish company, is seeking approval from the European Commission for *D. flagrans* to be used as a feed additive does suggest that it may be available for commercial use in the foreseeable future.

Endoparasitic fungi

In contrast, endoparasitic fungi infect nematodes by producing spores that attach to the outside of the nematode (i.e., the cuticle) or are ingested by the nematode larvae. Some endoparasitic fungi also have the capacity to infect the nematode eggs (Figure 2). The fungus then grows within the egg or larva and uses it as a nutrient source. Previous work carried out on plant nematode eggs has yielded

sheep endoparasites

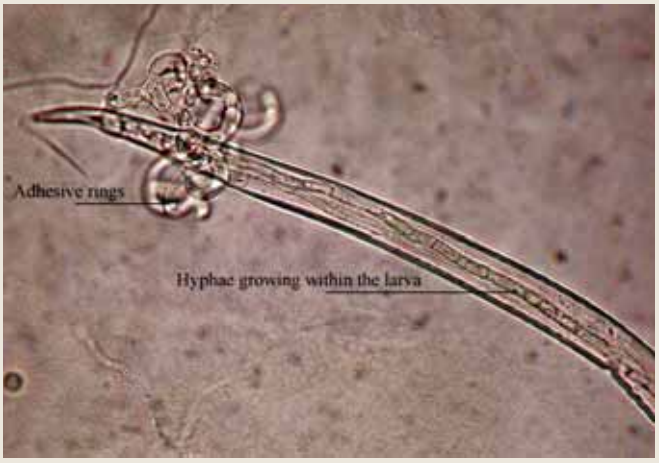

FIGURE 1: Adhesive rings of a predacious fungus attached to a larva. Hyphae of the fungus can be seen within the larva.

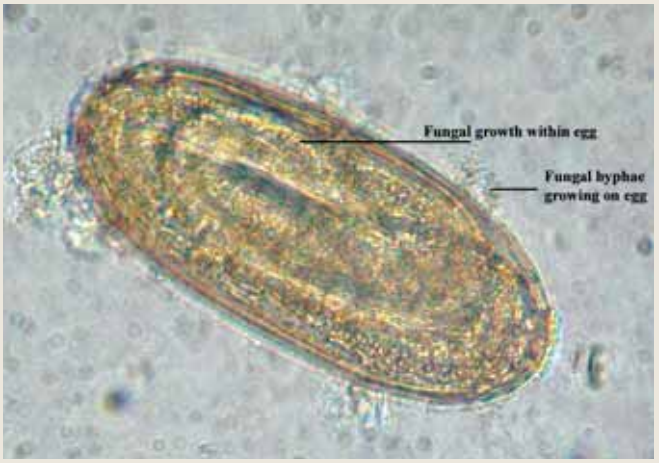

FIGURE 2: Fungal parasitised egg. Fungal hyphae can be seen growing in and around the nematode egg.

encouraging results. For example, one study demonstrated the efficacy of *Verticillium chlamydosporium* as a biological control of root-knot nematodes of kale, maize and tomato plants. In that study, over 90% of the eggs were parasitised. However, very little work involving endoparasitic fungi has been carried out on parasitic nematodes that infect sheep, and our research aims to address this. Under experimental conditions in the laboratory, we have investigated the effect of 16 endoparasitic nematophagous fungi that are known to be native to Ireland, or the UK, on two sheep roundworms common in Ireland namely, *Teladorsagia circumcincta* (formerly *Ostertagia circumcincta*) and *Nematodirus battus*. The effect of each fungal isolate compared to the control treatment (no fungus added) on egg/larval viability was examined over a series of time points. Twelve fungal isolates demonstrated nematophagous potential; with five clearly being predominantly ovicidal to *T. circumcincta* (Table 1).

TABLE 1: Percentage reduction of larval recoveries after fungal treatment compared to controls.

Fungal species	Reduction (%) of larvae recovered after fungal treatment	
Days	1 & 2	7 & 14
Harposporium anguillalae	95	97
Haptocillium sphaerosporum	96	99
Drechmeria coniospora	87	99
Fusarium coeruleum	75	86
Fusarium incarnatum	75	84

Essential criteria

For fungi to be considered useful candidates for biological control, they must ideally satisfy the following criteria: the fungus must produce a resistant stage, chlamydospores, which can survive passage through the gastro-intestinal tract; and, these spores must be easily and economically mass-produced and easily administered to the target animals. Four of these five 'egg attacking' fungi have the ability to produce chlamydospores and work is ongoing to produce large quantities of these chlamydospores in order to examine their survivability on passage through sheep.

As these fungi are active at the earliest stage of nematode development, it does add to their effectiveness and enhances their potential as biocontrol agents. An attacking fungus would offer a possible control for liver fluke where there is not a predominant larval stage, and *Nematodirus*, where development within the egg stage occurs over a prolonged period. While much work remains to be done on field evaluation of these laboratory findings, the results do hold some promise for a biological option for the control of parasitic nematodes in the future.

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The not so humble spud

DAN MILBOURNE describes Teagasc's involvement in an international consortium that is sequencing the potato genome and how this could speed up the potato breeding process.

An international Potato Genome Sequencing Consortium (PGSC) has been established, with the goal of obtaining the near-complete sequence of the entire potato genome over the next two to three years. In order to make a significant contribution to this initiative, Teagasc will sequence a significant portion of potato chromosome 4, with a specific emphasis on a region that contains a number of genes that confer resistance to important diseases such as late blight and eelworm. The Potato Genome Sequencing Consortium (www.potatogenome.net) involves fifteen countries with a common interest in sequencing the entire genome of potato over the next five years; an endeavour currently estimated to cost a total of approximately €36 million.

Sequencing the potato genome

The potato genome comprises 12 chromosomes, with a combined length of 850 million nucleotides (letters of the genetic code) – this equates to a length of between one-third and one-quarter the size of the human genome – and results from other plant genome sequencing projects suggests that the potato could have anywhere between 40,000 and 60,000 genes. The proposed potato genome sequencing project is based on the recent development of a genetically anchored physical map of the potato genome. This physical map was produced by randomly breaking the potato genome into fragments of approximately 120,000 nucleotides each. These fragments are individually maintained as bacterial artificial chromosome (BAC) clones in *E. coli*. A library of 100,000 of these BAC clones has been produced in a diploid potato line called RH. This BAC library contains the entire potato genome broken up into fragments of 120,000 nucleotides. However, when a BAC library is constructed, the identity of the fragments, which chromosome they come from, and their order along the chromosome relative to each other, are all unknown. Physical mapping is the process of identifying the relative order of these BAC clones along the chromosome using a genetic fingerprinting methodology (Figure 1). A physical map of RH is now nearing completion. Sequencing the entire genome of potato will involve selecting for each chromosome the minimum number of BAC clones that spans that chromosome (this should be approximately 600 to 1,000 BACs depending on the size of the chromosome). Once this is done, individual BAC clones are further randomly broken up into fragments of 2,000 to 3,000 nucleotides (called subclones) and sequenced. To obtain the complete sequence of one BAC clone requires sequencing approximately one thousand subclones of that BAC. Teagasc has committed to sequencing approximately 200 BAC clones, which equates to between one third and one quarter of chromosome 4 (depending on the size of the chromosome).

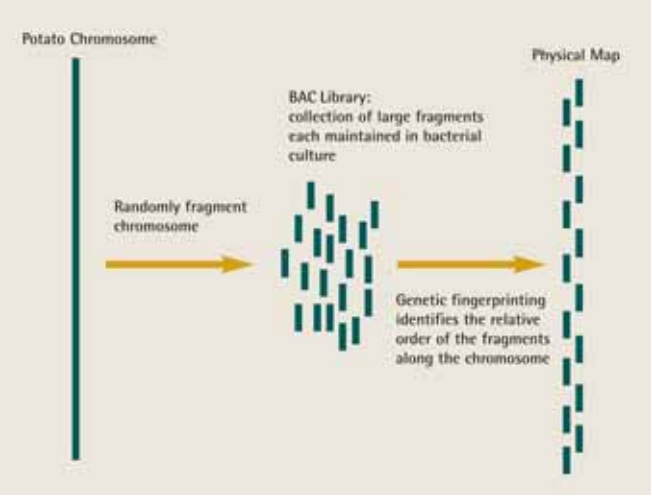

FIGURE 1: Sequencing is based on a physical map of the potato genome.

Faster breed development

Overall, the potential impact of this project on potato genetics and breeding cannot be overstated. The complete genome sequence will revolutionise our ability to find which genes are responsible for a whole range of important characteristics in potato, from disease resistance to yield. This information vastly improves the prospects for biotechnology-based approaches, such as marker assisted selection (MAS) to develop improved potato varieties. Many important characteristics in potato are based on the combined expression of multiple genes (between tens and hundreds), and combining all of the desirable genes for a trait in one individual by traditional crossing methods is a very challenging process (breeding a new potato cultivar takes approximately 12 to 15 years). MAS involves identifying which parents in a breeding programme possess naturally occurring variants of genes (called alleles) underlying important characteristics and using genetic fingerprinting approaches to allow breeders to track alleles of genes in crosses, and to choose progeny from these crosses with the most desirable combinations of alleles. Thus, MAS has the potential to make potato breeding faster, more efficient, and more targeted.

In addition to the practical benefits, sequencing the potato genome will contribute vastly to our understanding of the basic processes of evolution and biology in plant species, by allowing comparison of the potato genome to the sequenced genomes of other plant species.

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The truth about GM crops

EWEN MULLINS describes the GM risk assessment programme at Teagasc and the development of a website to make GM information freely accessible.

For centuries, farmers have been improving and modifying their crops. Through the process of selective breeding, specific traits are identified and a hybrid line is created that expresses the desired agronomic character (e.g., high yield, disease resistance). This conventional form of breeding has had great success but, by its nature, has also imposed many restrictions. Modern day biotechnology provides a means to accelerate this pace of discovery and, over the last decade especially, the application of this science to crop improvement has provided a tremendous insight into its potential.

Now, through recombinant DNA technology, a gene of interest that originates in bacteria, fungi, another plant or even an animal can now be inserted into a specific crop. As a consequence, certain crops now possess characteristics that previously would have been considered unattainable. Though potentially advantageous, the production of these transgenic or genetically modified (GM) plants has invoked public concern, in regard to the perceived risks associated with how GM crops can co-exist with conventional and organic crops.

Photograph courtesy James M. Bradeen.

Blight resistant GM potato (cv. Kathadin).

Risk assessment

To address these concerns, our programme of research is focused on assessing the potential benefit or risk GM crops could present; from both an agronomic and environmental context. More specifically, we are currently assessing the potential of blight resistant potato, stem-rot resistant clover and herbicide tolerant oilseed rape. In addition, we have commenced a two-year study to develop production measures that will facilitate the cultivation of GM herbicide tolerant (GMHT) oilseed rape in coexistence with non-GM oilseed rape cultivars. Employing the GeneSys™ gene flow modelling system, the goal of this study is to preserve the sustainability of existing non-GM oilseed rape systems in Ireland, should there be an uptake of GMHT oilseed rape in the near future. In addition, we are researching the potential impact future GM cropping could have on Irish biodiversity. Sponsored by the EPA, the goal of this study is to significantly improve our understanding of the actual rates of gene flow that could be expected from future Irish GM cropping systems and the likely consequence of such gene flow for biodiversity conservation.

Information resource

While no genetically modified (GM) crops are presently cultivated in Ireland, the lifting of the EU moratorium on the cultivation of GM crops in 2004, combined with the implementation of several EU regulations, implies that Irish farmers could soon be afforded the choice of being able to purchase GM seed for cultivation. It is important, therefore, to facilitate the transparent dissemination of research data into the public domain and ensure that key stakeholders are adequately informed in regard to all aspects of GM crop cultivation. To assist in this task, we have designed *The Information Resource for GM crops in Ireland* – www.gmoInfo.ie. Constructed to facilitate the transfer of data from the research programme to the farming community, and increase public understanding of the primary issues, gmoInfo is composed of five primary sections:

- *EU legislation* explains what organisations are responsible for the regulation of GM crops in Ireland and what legislation is in place to ensure the appropriate segregation of GM and non-GM crops.
- The *crops* section presents six crops (barley, wheat, oilseed rape, potato, sugar beet, maize) that are likely to be the probable targets for modification.
- *GM issues* contains a list of frequently asked questions relevant to the debate and presents case studies on *Bt* cotton, virus resistant papaya and *Bt* maize.
- *Risk assessment* is split equally into a description of the economic and environmental research that is currently underway within Teagasc.
- *Coexistence* explains the important issue of 'gene flow' (when a trait is transferred from one crop to an adjacent crop either through pollen or seed) and discusses the measures required to minimise the impact of this event, which occurs in both non-GM and GM crops.

So that the focus of gmoInfo remains central to the debate, a feedback option is available to visitors who can email comments and questions to the webmaster. In addition, separate links provide access to research updates from the Risk Assessment programme and additional internet resources that represent both sides of the GM debate.

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Producing bacteria-free Buddlejas

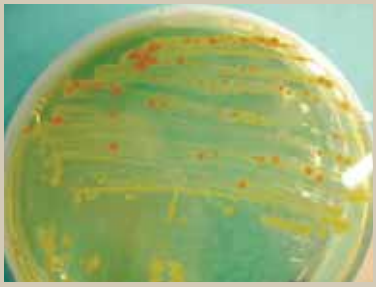
GERRY DOUGLAS and SINEAD PHELAN isolated 11 types of bacteria from buddleja, which may be contributing to die-back in this popular ornamental.

The ornamental shrub *Buddleja* stands out in any garden by attracting clouds of butterflies of all types in late summer. Buddlejas became an instant favourite in gardens when introduced from China over 100 years ago. Soon *Buddleia davidii* set seeds when grown in Europe and offspring with bigger flowers and a range of flower colours were noted. Nurserymen loved buddlejas too, because they found it was very easy to get rooting in cuttings and to build up stocks of new varieties for trading. Although there are now over 100 named cultivars of *B. davidii,* you will find a decreasing number of the good varieties in garden centres because of problems in production.

Die-back

Commercial growers have reported a blackening in *Buddleja* shoot tips as a problem in producing high quality plants. This blackening or 'die-back' can affect all varieties, and is most severe in 'Pink Delight', 'White Profusion' and 'White Ball'. At Teagasc Kinsealy, we have been studying the health status in the varieties mentioned above, as well as in 'Black Knight', 'Border Beauty', 'Lochinch', 'Nanhoensis', 'Empire Blue', 'Ile de France' and 'Royal Red' ,

It has been suggested that nematodes are responsible for dieback in buddlejas, but none were found in the 10 varieties examined at Kinsealy. We then detected bacteria within stems by culturing pieces of stem on nutrient agar. Eleven different types of bacteria were isolated. Four have been characterised fully from profiles of their DNA and their metabolic pathways. So far the bacteria identified are *Pseudomonas putida*, *Bacillus thuringiensis*, a rape rhizosphere bacterium and *Staphylococcus warneri*. Four different types of bacteria were found in common in all 10 varieties. Further tests are needed to confirm which bacterium, or combination of bacteria, are responsible for the disease die-back. This is done by inoculating healthy plants with suspect bacteria, reproducing the disease symptoms and then reisolating the bacteria from the plants. Some of the bacteria may be harmless components of the internal microflora that thrive within all plants. We found a strain of *Acinetobacter*, which is entirely new to science and it may be given a new species name. One suspect in causing die-back is *Pseudomonas putida*, because it was present in nine out of ten varieties. Another suspect is a possible species of *Burkholderia,* which is known to cause disease in other plants. *Staphylococcus warneri* was of interest because it was present in two different varieties. It is a common bacterium on human skin and is generally harmless. It is interesting to speculate that it may have been transferred to *Buddleja* varieties through routine handling of plants and cuttings. If this is the case, extra hygienic practises may be needed during the handling of cuttings to minimise bacterial spread and also during subsequent stages of production.



Bacteria isolated from Buddleja stems.

FROM FAR LEFT: Walsh Fellow Sinead Phelan checking Buddlejas from meristems at Teagasc, Kinsealy Research Centre.

Die-back disease in a shoot tip of Buddleja.

Flowering in bacteria-free Buddleja *varieties; varieties (from left): 'Ile de France', 'Empire Blue', 'White Ball' and 'Lochinch'.*

Bacteria-free buddleja

Our main objective was to produce plants that were free from bacteria that were suspects in causing die-back disease. Research began to see if healthy plants could be produced by using biotechnological methods of propagation. Plants were regenerated from the smallest possible piece of the shoots tips called meristems. Meristems are found in the growing shoot tip; they are less than half a millimetre in size and are not in direct contact with tissues that may harbour bacteria. After several months of culturing meristems, they developed leaves and eventually whole plants were produced and transferred to the glasshouse. The plants are now flowering at Kinsealy and their flower type and colours are true-to-type. More importantly, all 10 varieties of *Buddleja* are without any die-back symptoms. Furthermore, we have been unable to detect any of the original bacteria in the plants produced from the meristems. A secondary advantage in producing plants by biotechnological methods is that we can propagate them very quickly in large numbers. When all of the plants from this research are returned to the growers they will have stocks of healthy plants that can be used to produce crops of cuttings and liners for the future.

In the production cycle of many ornamental shrubs, it is common practice to take a crop of cuttings from plants that are almost ready for sale. This can have a benefit in giving the plant a light pruning which results in an attractive bushy plant. However, it means that there is a continuous cycle of cutting, collecting and handling which may lead to a build up of problematic fungi and bacteria (microflora), both within the plants and on the leaves. Breaking the cycle of continuous cutting-collecting by removing plants from the production cycle may help to re-establish a healthier microflora on stock plants. Alternatively, it may be necessary to take special measures, such as meristem culture with disease monitoring, to re-establish healthy stock plants.

Planting schemes

The availability of healthy material in the trade may encourage growers to produce and grow more buddlejas. Landscapers should give more attention to their value in planting schemes. They combine well in semi-natural settings and, if left unpruned, they will form small spreading trees that provide winter seeds for birds. Buddlejas can make a striking focal point in planting schemes when trained as a standard and they also go well in modern schemes with bamboos, ornamental grasses and sedges. The genus has a lot to offer - spring flowering *B. globosa,* a native of Chile and Peru, as well as *B. alternifolia,* which is native to Tibet and China. Best of all are the many varieties of *B. davidii*, with a flowering time of late summer and a fragrance to attract butterflies and other insects to their energy-rich nectar.

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