

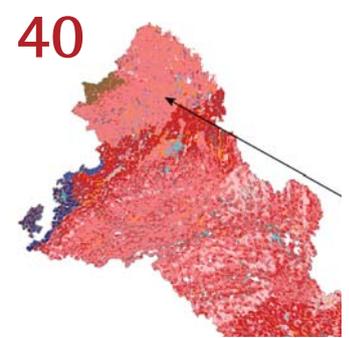
T Research

Research and innovation news at Teagasc

Reducing salt in ready meals

- ▶ Farm fatalities in Ireland
- ▶ Forest productivity map
- ▶ Perfect strawberry plant

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European research funding success

The European Union's 7th Framework Programme for Research and Technological Development (FP7) is its main instrument for supporting collaborative research, development and innovation in science, engineering and technology. It is the largest public good programme in the world. The primary aim of FP7 funding in the area of food and agriculture is the creation of a European knowledge-based bio-economy.

Minister for Agriculture, Fisheries and Food, Brendan Smith, said recently that the level of funding secured to date by Irish researchers (€8.5 million) is very significant. The Minister also pointed to the key role research has to play in the future of our largest indigenous industry and in the wider 'smart' Irish economy. Teagasc has been very successful so far in securing the funds available for research under FP7 (and its predecessor FP6). Teagasc headed the list of Irish bodies, securing research grants worth €2.8 million of funding under Theme 2 of the FP7 programme. The research areas where funding has been secured are focused in three broad areas of activity:

- sustainable production and management of biological resources from land, forest and the aquatic environment;
- food, seafood, health and wellbeing; and,
- life sciences, biotechnology and biochemistry for sustainable non-food products and processes.

There are significant advantages arising from our involvement in the programme. For example, in 2009 Teagasc was involved in nine successful FP7 consortia that secured project funding of €24.7m. We will receive €1.94m of this but will have access to, and benefit from the full projects' resources and results. The new knowledge generated and procured through involvement in FP7 will support science-based innovation in the Irish and European agri-food sector. Therefore, Teagasc, in conjunction with its national and international partners, will continue to bid for further research funding from the programme up to 2012. We will be seeking to expand our international co-operation on research projects through innovative and co-operative approaches.



Dr Frank O'Mara
Director of Research

Maoiniú Eorpach faighte do thaighde

Is é 7ú Creat-Chlár an Aontais Eorpaigh um Thaighde agus Forbairt Teicneolaíochta (FP7) an phríomhuirlis a úsáideann sé chun tacú le taighde, forbairt agus nuáil chomhoibritheach sna réimsí d'eolaíocht, innealtóireacht agus teicneolaíocht. Is é an clár is mó ar domhan um an mhaith choiteann é. Is é aidhm phríomhúil maoiniú FP7 sa réimse de bhia agus de thalmhaíocht bithghéilleagar Eorpach eolasbhunaithe a chruthú.

Dúirt an tAire Talmhaíochta, Iascaigh agus Bia, an tUasal Brendan Smith, le deireanas go bhfuil méid an mhaoinithe a fuair taighdeoirí Éireannacha go dtí seo (€8.5 milliún) thar a bheith tábhachtach. I dteannta sin, luaigh an tAire go mbeid ról príomhúil ag taighde i dtodhchaí ar dtionscail dhúchasaigh is mó agus i ngeilleagar 'stuama' níos leithne na hÉireann.

D'éirigh thar barr le Teagasc maidir le cistí a chuirtear ar fáil do thaighde faoi FP7 (agus faoin gclár a tháinig roimhe, FP6) a fháil. Bhí Teagasc ag barr an liosta de chomhlachtaí Éireannacha a fuair deontais taighde de luach €2.8 milliún faoi Théama 2 den chlár FP7. Tá na réimsí taighde a fuarthas maoiniú dóibh dírithe ar thrí réimse gníomhaíochta leathana:

- táirgeadh agus bainistiú inbhuanaithe acmhainní bitheolaíochta ón talamh, ón bhforaois agus ón timpeallacht uisceach;
- bia, bia mara, sláinte agus dea-bhraistint; agus,
- eolaíochtaí beatha, biteicneolaíocht agus bithcheimic le haghaidh próiseas agus táirgí neamhbhia inbhuanaithe.

Baineann buntáistí móra le páirt a ghlacadh sa chlár. Mar shampla, in 2009 ghlac Teagasc páirt i naoi gcuibhreannas rathúla FP7 a fuair maoiniú tionscadal de luach €24.7m. Gheobhaimid €1.94m den mhaoiniú seo, ach beimid in ann teacht ar agus tairbhe a bhaint as acmhainní agus torthaí iomlána na dtionscadal. Cuirfidh an t-eolas nua a ghinfear agus a gheofar trí pháirt a ghlacadh in FP7 bonn faoi thacaíocht do nuáil eolaíochtbhunaithe in earnáil agraibhia na hÉireann agus na hEorpa.

Mar sin, i gcomhar lena chomhpháirtithe náisiúnta agus idirnáisiúnta, leanfaidh Teagasc ar aghaidh ag déanamh tairiscintí chun maoiniú taighde breise a fháil ón gclár go dtí 2012. Déanfaimid iarracht ár gcomhoibriú idirnáisiúnta i ndáil le tionscadail taighde a leathnú trí mheán cineálacha cur chuige atá nuálaíoch agus comhoibritheach.

An Dr Frank O'Mara
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Published on behalf of Teagasc by

ThinkMedia
PROFESSIONAL PUBLISHING SERVICES

The Malthouse, 537 NCR, Dublin 1.

T: 01-856 1166 F: 01-856 1169 www.thinkmedia.ie

Design: Tony Byrne, Tom Cullen and Ruth O'Sullivan

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IPFN symposium

The Irish Phytochemical Food Network (IPFN) holds a series of annual symposia focusing on examining phytochemicals from fruits and vegetables in a farm to fork approach (agronomic factors, levels in selected vegetables, effects of processing and storage, understanding of consumer attitudes) in an Irish context.

The second symposium took place in March at Teagasc Food Research Ashtown (TFRA) and was sponsored by the Department of Agriculture, Fisheries and Food and Mason Technology Ltd.

The aim of the symposium was to inform and promote dialogue between stakeholders (food scientists, food industry, community groups, etc.) on phytochemicals and their impact on human health in Ireland. In addition, it provided an update on current trends from an Irish perspective. It is open to members of the food industry, growers, producers and processors of fruits and vegetables, researchers, community groups and health professionals.

The event was opened by Dr Nigel Brunton, Co-ordinator of the IPFN, from TFRA. The presentation by Dr Juan Valverde, Network Scientific Officer of the IPFN, was based on phytochemicals in Irish plants and particularly on recent results on glucosinolates from different broccoli varieties. Dr Dilip Rai, TFRA, spoke on the uses of "state-of-the-art" analytical tools such as nuclear magnetic resonance and mass spectroscopy on identification, structure elucidation and quantification of several phytochemicals in Irish fruits and vegetables.

Dr Kim Reilly (Teagasc Kinsealy Horticulture Research Unit) spoke on the effects of agronomic factors on the levels of phytochemicals in Irish grown vegetables.



Some of the speakers at the 2nd IPFN symposium: Dr Juan Valverde, Network Scientific Officer, TFRA; Professor Nora O'Brien, UCC; Professor Elizabeth Jeffery, University of Illinois Urbana, Champaign, USA; Dr Dilip Rai, TFRA; Dr Nigel Brunton, IPFN Co-ordinator, TFRA; Dr Kim Reilly, Teagasc Kinsealy; and, Micheal Gaffney, Teagasc Kinsealy.

Dr Douglas Sorensen (TFRA) gave an insight into the secrets to successful and sustainable functional foods brands. His talk generated a fruitful discussion on the future of functional foods and the acceptance by the consumer of this kind of product.

Links to all presentations are available at: www.ipfn.ie.

National soft fruit conference



Pictured at the National Soft Fruit Conference in Carlow in April are (from left): Jim O'Mahony, Head of Horticulture, Teagasc; Dr Eamonn Kehoe, Teagasc Soft Fruit Specialist; Michael Slawski, Bord Bia; and, Jimmy Kearns, Chairman of the Irish Soft Fruit Growers Association. The proceedings are available at: http://www.teagasc.ie/publications/2010/20100505B/soft_fruit_proceedings.pdf.

ICT-AGRI ERA-NET



Fourteen European countries, including Ireland, have come together under the auspices of the ICT-AGRI ERA-NET to launch a funding call for research projects in the area of ICT and robotics in agriculture and related environmental issues. The aim of this joint call, worth more than €3m, is to enable joint transnational research projects based on complementarities and sharing of expertise within ICT and robotics in agriculture. Projects are expected to apply a systems approach, addressing farm level integration of information technology, communication technology, automation and robotics. Projects must have a clear European added value by being carried out on a transnational level. ICT-AGRI is funded by the European Commission's ERA-NET scheme under the 7th Framework Programme for Research (FP7). Ireland is represented on ICT-AGRI by Raymond Kelly of Teagasc. Full details of the funding scheme are available at <http://ict-agri.eu/>.

FP7 meeting

The Framework Programme 7 (FP7) National Support Network met with Teagasc staff and management in Oak Park in April. FP7 is the EU's main instrument for funding research in Europe and has a total budget of €50 billion. The Irish network is led by Dr Imelda Lambkin of Enterprise Ireland and is composed of contact points for each of the different programmes and themes within FP7. The recently-appointed Director of Research at Teagasc, Dr Frank O'Mara, outlined Teagasc's strategic approach to FP7. Dr O'Mara acknowledged the great assistance that Teagasc has received from the network and, in particular, recent funding provided by Enterprise Ireland to facilitate the strategic approach to FP7. He also highlighted the contribution of Dr John Dardis of the Department of Agriculture, Fisheries and Food, who serves as the National Contact Point (NCP) for Food, Agriculture and Fisheries and Biotechnology. Dr O'Mara said that Dr Dardis had been "instrumental in Teagasc's success in FP7".

Dr Lambkin commended Teagasc's strategic plan for FP7 and stated that Teagasc was one of only five Irish institutions whose approach to FP7 had been financially supported by Enterprise Ireland. The meeting included presentations from each of the NCPs who highlighted funding opportunities in diverse themes such as agriculture and food, health, environment, ICT, energy, nanotechnology, research for SMEs, research infrastructure and researcher mobility.

The Department of Agriculture, Fisheries and Food recently published a report entitled 'Irish Success in the EU 7th Framework Programme', which features Teagasc researchers prominently. The report is available from: <http://www.agriculture.gov.ie/research/eu7thframeworkprogrammefp7/>.



The national support network for FP7 is pictured at a meeting at Teagasc Head Office, Oak Park, Co Carlow. Attendees included representatives from the Department of Agriculture, Fisheries and Food; Enterprise Ireland; the Environmental Protection Agency; the Higher Education Authority; the Irish Universities Association; Sustainable Energy Ireland; and, Teagasc.

Environmental efficiency in farming



A change in the EU agri-environmental policy is needed, away from the "less is more" philosophy, which assumes an inverse relationship between food production and environmental well-being, according to Teagasc environmental researcher Dr Rogier Schulte. He argues that a move towards a policy of environmental efficiency is needed, which would be based on meeting the production potential of efficient land.

Dr Schulte was speaking in Brussels in May, at a meeting of Members of the European Parliament organised by the Alliance of Liberal Democrats, on the topic of 'A Fairer and Greener Common Agricultural Policy for the New Century'.

Dr Schulte questioned whether the "less is more" philosophy is inadvertently damaging the global environment. He pointed out that producing less food in Europe may not be beneficial for the environment globally. He argued that it is leading to "environmental leakage", with Europe exporting its environmental problems, creating difficulties in other parts of the world. He warned that current EU policies are leading to "carbon leakage" and "water leakage" in certain parts of the globe.

He pointed out that in Ireland in the ten-year period to 2006, the number of

livestock has fallen, reducing greenhouse gas (GHG) emissions. However, he highlighted the fact that world food production has increased in the same period, leading to no net reduction in GHG emissions globally. He argued that Ireland is among the most efficient producers of beef and milk in terms of GHG emissions per kilo of beef or litre of milk produced. A recent FAO study has shown that temperate grassland-based milk production systems have a low carbon footprint.

Dr Schulte pointed to the use of scarce water resources in certain regions of the world to produce food to be exported to Europe. Describing it as "water leakage", he argued that it could be more environmentally efficient to utilise productive land in Europe where water is in greater supply, to produce more food, instead of producing food where water supplies are vulnerable. Again, he questioned this "exporting" of Europe's environmental responsibilities. He said: "If we want global trade and global environmental protection, Europe needs to move away from the 'less is more' philosophy, which influences current EU agri-environmental policy, and develop a new philosophy of environmental efficiency".

The Teagasc GHG working group is organising a major international environmental conference, 'A Climate for Change – Opportunities for Carbon-Efficient Farming', to address these issues (see events page).

Researcher profile



Dr Helen Grogan

Dr Helen M. Grogan is a Senior Research Officer at Teagasc, Kinsealy Research Centre, Dublin, and is responsible for the mushroom research programme as well as horticultural plant pathology diagnostics.

Helen has worked in the area of applied mushroom pathology for almost 20 years, initially at Horticulture Research International at Wellesbourne, Warwick, UK, returning to Ireland in 2005 to take up her current position.

Helen has conducted research into the epidemiology and control of all the major mushroom diseases including *Trichoderma* compost green mould, cobweb disease, *Verticillium* and, more recently, mushroom virus X (MVX). She managed a mushroom diagnostic clinic for many years in the UK serving the needs of growers at both national and international level, and was presented with the Sinden Award in 2005 in recognition of her "outstanding contribution to the control of mushroom diseases".

Helen's current research topics include: (1) the epidemiology and control of MVX; (2) measuring and managing dry bubble disease on farms; (3) health and safety aspects of handling spent mushroom compost; and, a new research project on (4) the epidemiology of *Trichoderma aggressivum* in Bulk Phase 3 compost – all run in close association with the industry and, where possible, in close collaboration with mushroom research groups in other countries.

Helen has published on a range of topics, including: dispersal of *Cladobotryum* spores in mushroom growing rooms; control of mushroom cobweb disease caused by benzimidazole-resistant strains; double-stranded RNA elements associated with the MVX disease of *Agaricus bisporus*; persistence of fungicides in mushroom casing soil; and, understanding and managing mushroom quality. She has also co-authored several technical fact sheets for the industry.

Helen grew up in Dublin and did not have much exposure to horticulture or agriculture apart from her father's vegetable garden. She developed an interest in fungi and mushrooms while studying botany at Trinity College Dublin, graduating with an MSc in 1982. She continued to study fungi in France at the Université Claude Bernard in Lyon in 1982-84, where an enduring love for all things French developed. Her PhD at University College Dublin was on mycorrhizal fungi, and a chance attendance at the 1991 International Mushroom Science Conference in Trinity College introduced her to the world of cultivated mushrooms, a subject that has kept her busy ever since.

Helen is a scientific representative on the UK Horticultural Development Council Mushroom Panel and is honorary secretary of the World Society for Mushroom Biology and Mushroom Products.

Science for All



David Daly, Teagasc Food Research Centre, Moorepark and the School of Food and Nutritional Sciences, UCC, is pictured at the 'Science for All' Postgraduate Student Public Presentation Competition at UCC, in which young scientists have to explain themselves "without the jargon" to a live audience. David gave a talk entitled 'Cracking the Cheese Problem'.

David grew up on a farm near Mallow and studied food science and technology at UCC, graduating in 2007. For the last two years he has been doing research in the cheese diversification laboratory in Teagasc

Food Research Moorepark in Fermoy, where he is particularly interested in Swiss-type cheeses.

Highly cited

A paper by Teagasc researchers is in the Top 10 Cited list (articles published in the last five years) in the journal *Trends in Food Science & Technology* extracted from Scopus.

http://www.elsevier.com/wps/find/journaldescription.cws_home/601278/description#description



The paper was co-authored by Dr Linda Reid, Teagasc Walsh Fellow now working at Bord na Mona; Colm O'Donnell, Assistant Professor, UCD; and Dr Gerard Downey, Adjunct Professor at UCD and Head, Prepared Foods Department, Teagasc Food Research Ashtown. The reference is:

Reid, L.M., O'Donnell, C.P. and Downey, G. (2006). 'Recent technological advances for the determination of food authenticity'. *Trends in Food Science & Technology* 17 (7): 344-353.

E-mail: gerard.downey@teagasc.ie.

T Commercialisation opportunity

Gel-encapsulation of probiotic bacteria

Teagasc is seeking partners within the pharma/medical foods industry to further develop a probiotic encapsulation technology with a view to licensing.

Summary

A novel method of gel-encapsulation with applications in probiotics has recently been developed in Teagasc, Moorepark, and a patent application filed. It was proven during *in vivo* trials that this technology can greatly improve the viability of probiotic bacteria during storage and gastric transit. This process would be of great interest to companies working with probiotics for medical food and pharma applications, as such high probiotic viability would improve cost efficiency and product shelf life.

Problem addressed

Health-promoting ingredients, such as probiotic bacteria, must be active and intact at the point of consumption to achieve a positive health effect on the host and to support health claims. However, bacteria can exhibit high mortality rates during storage and transit through the upper gastro-intestinal tract, which may result in a reduction in or complete loss of its health impact. This technology overcomes this problem through the use of gel-microbeads.

Solution

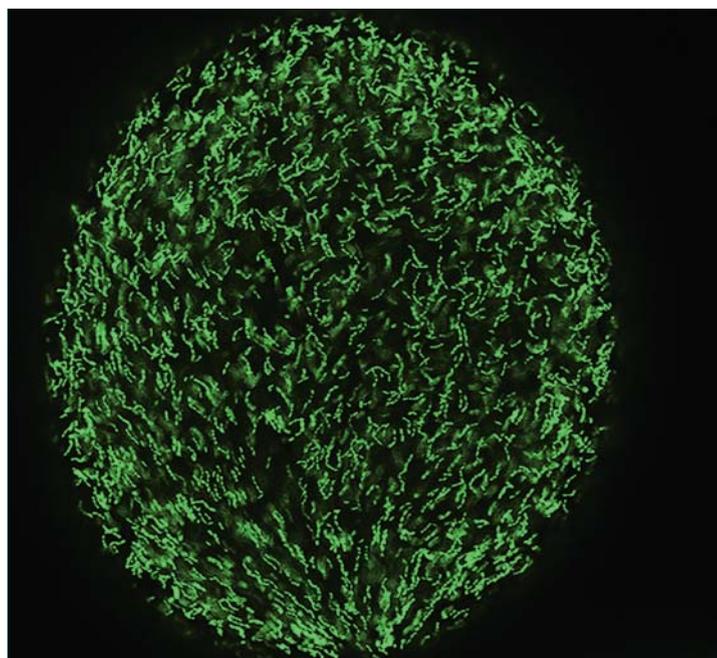
The use of gel-microbeads made of dairy protein matrices for entrapment of probiotics shows enhanced stabilisation of probiotic bacteria in liquid, non-dried form, so as to survive and remain functional during storage and gastric transit. These novel gel-microbeads show high stability during long-term storage and subsequent transit through the stomach, but disintegrate in the gastro-intestinal tract thereby overcoming the low stability problems of other commonly used polysaccharide-based encapsulation techniques.

Intellectual property status

A patent application has recently been filed by Teagasc covering process conditions for generating the gel-microbeads and application of the encapsulation method.

Competitive advantage of technology

1. High viability of probiotics during storage and gastro-intestinal transit; *in vivo* trials showed up to a 4 log cycle increase in viable probiotics in the porcine intestine.
2. Integration of a delayed release mechanism for targeted delivery of probiotics to the gut.
3. Platform technology for inclusion and protection of sensitive bioactive ingredients.
4. Exploitation of dairy proteins for gel-encapsulation.



Of interest to

This technology would be of interest to food/medical food, pharmaceutical and animal feed companies wishing to incorporate sensitive components including probiotics into their products. As some validation and optimisation is still required we are currently seeking partners for such commercialisation with a view to licensing.

Principal investigators

Dr André Brodkorb and Dr Catherine Stanton, Teagasc Food Research Moorepark, Fermoy, Co Cork.

How to proceed

For further information, contact Miriam Walsh PhD, Head of Intellectual Property, Teagasc. Tel: 059 918 3477; Mob: 087 911 3960. E-mail: miriam.walsh@teagasc.ie.

This project was supported by Dairy Levy Seed Funding.

BSAS Agricultural Research Forum

Over 400 agricultural scientists convened at Queen's University Belfast for the first joint meeting of the British Society of Animal Science and the Agricultural Research Forum on April 12-14. The conference theme was 'Food, Feed, Energy and Fibre from Land - a vision for 2020' and addressed future challenges for land use. There were well over 300 contributions. Here is a short summary of some of the many Teagasc papers.



Large dairy herds are using more dairy sires and fewer beef sires.

Dairy herd expansion

Speaking at the conference, Teagasc researchers Dr Jenny Jago and Dr Donagh Berry examined the association between herd size and herd expansion and breeding policy, reproduction and production performance of spring calving Irish dairy herds. Performance data from milk recording levels comprising over 1.6 million lactation records for the years 2004 to 2008 were studied. The results showed no difference in fat yield, protein yield, and fat percent, between herds differing in the rate of expansion. However, it was found that expanding herds had greater milk protein percent than herds that were not expanding. There was no association between herd size and milk production traits except for protein percentage, which increased with increasing herd size. The study concluded that rapidly expanding herds are increasing cow numbers by buying in more non-homebred replacement cattle. The proportion of dairy sires used in the breeding programme is increasing and there is more cross breeding, albeit at a low rate. Similarly, large dairy herds are using more dairy sires and fewer beef sires. Both large and expanding herds are calving heifers at a younger age.

Genomic selection first year results

A paper by Dr Francis Kearney (ICBF) and Dr Donagh Berry (Teagasc) looked at the first year results since the introduction of genomic selection (GS) in Ireland. GS in Holstein Friesian cattle was launched in February 2009, making Ireland only the second country in the world to do so, and this study summarised the first year's results of its use in Ireland.

"The uptake of the GS bulls has been very encouraging, with farmers using several bulls as recommended to reduce the risk associated with the still relatively low reliability of proofs of individual genomically selected bulls. Initial results on how

the technology is working are promising and suggest accelerated genetic gain in the future. Research between the ICBF and Teagasc is currently underway to reduce the cost of genomic selection to the end user, thereby making it more appealing to commercial farmers and increasing its exploitation. Research on genomic selection in beef is also underway. The study concluded that overall the implementation of genomic evaluations in Ireland has been very successful," said Dr Berry.

Reducing methane emissions

Evaluation of methane emissions by spring calving Holstein Friesian dairy cows offered a grass-only diet or a total mixed ration was presented by Brendan O'Neill, Teagasc Animal & Grassland Research and Innovation Centre, Moorepark. This work, carried out at Teagasc and University College Dublin, showed that cows fed a total mixed ration had higher milk yield, milk solids yield, body weight, total dry matter intake, and methane emissions than the cows fed grass only. However, the cows on a grass only diet had higher milk protein content and lower methane emissions per unit milk solids and per unit body weight. "This 10-week study indicates that grazing dairy cows emit less methane per cow and per kilo of milk solids produced in comparison to cows offered a total mixed ration. Hence, feeding grass-only diets is a strategy for decreasing enteric methane emissions from dairy production systems," he said.

Performance of Suffolk and Texel sheep facing parasite challenge

Drs Seamus Hanarahan and Barbara Good carried out a study over two grazing seasons using 143 Suffolk and 151 Texel lambs from the purebred flocks maintained



Results showed that Suffolk lambs grew faster than Texel lambs when parasitic infection was low.



A budgeting model was used to calculate the returns from willow and miscanthus.

at Teagasc Athenry. Lambs were tested and compared on 'clean' versus 'dirty' pasture in relation to parasite challenge and lamb performance. The level of challenge was measured by faecal egg counts carried out at regular intervals.

The results showed that Suffolk lambs grew faster than Texel lambs when parasitic infection was low. The interaction between breed and level of parasite challenge shows that breed differences in lamb growth depend on the level of parasite challenge. The impact of parasitic challenge on the performance of Suffolk lambs increases as the grazing season progresses.

Ovarian dynamics

Sean Cummins, a Walsh Fellow based in Moorepark, presented the results of a Teagasc Moorepark–UCD study that investigated the effects of genetic merit for fertility traits on ovarian dynamics during the oestrous cycle in lactating dairy cows. The aim of the study was to characterise ovarian dynamics throughout a complete oestrous cycle in cows of divergent genetic merit for fertility traits but similar genetic merit for milk production traits. The group found some differences in ovarian follicular and corpus luteum characteristics. This would indicate that genetic merit for fertility traits may be manifested in measurable changes in ovarian function. Further work is necessary to characterise the reproductive hormone profiles associated with the recorded differences in ovarian follicular and corpus luteum dynamics.

Embryo survival

Mervyn Parr, a Walsh Fellow based in Athenry, presented the results of a Teagasc Athenry–UCD study investigating the relationship between plasma

concentrations of progesterone during the early luteal phase (days four to seven post AI) and embryo survival in dairy heifers. The study found that there was both a linear and a quadratic relationship between concentrations of progesterone on days four to seven and changes in progesterone between these days and embryo survival rate. Embryo survival rates increased with increasing concentrations of progesterone, but at high concentrations embryo survival rate declined. The repeatability of plasma concentrations of progesterone during the early luteal phase from cycle to cycle in dairy heifers was low, indicating that concentrations of progesterone are likely to be lowly heritable.

Planting biomass

Daragh Clancy from the Teagasc Rural Economy Research Centre (RERC), Athenry, along with researchers from Teagasc Kinsealy and UCD, presented results of a study that aimed to measure the degree of risk in the returns from biomass crops and compare that to the risk faced by conventional agricultural enterprises. A budgeting model was used to calculate the returns from willow and miscanthus. The results from the analysis showed miscanthus having a lower risk than willow. The value of the risk premium required to entice farmers to switch to miscanthus production is significantly less than that required for willow.

The full proceedings of the conference are available from:
<http://www.agresearchforum.com> or
www.teagasc.ie/publications/2010/20100416/index.asp.



Encouraging innovation

DR MIRIAM WALSH, Teagasc's Head of Intellectual Property, gives an overview of the Government's recently published Innovation Taskforce report and how it relates to encouraging innovation in Irish society.

In December 2008, the Government published its medium-term economic framework, entitled *Building Ireland's Smart Economy*, containing five key action areas to drive productivity growth across all sectors of the economy. These key action areas are:

- ▶ Securing the Enterprise Economy and Restoring Competitiveness;
- ▶ Building the Ideas Economy – Creating 'The Innovation Island';
- ▶ Enhancing the Environment and Securing Energy Supplies;
- ▶ Investing in Critical Infrastructure; and,
- ▶ Efficient and Effective Public Services and Smart Regulation.

Focusing on one of these areas, the Innovation Taskforce report, launched in March 2010, is concerned with positioning Ireland as an international 'Innovation Hub'. Following an extensive consultation process, both formal and informal, meetings with stakeholders and web-based survey, the Taskforce came up with recommendations and ideas to build the innovation component of the economy. Within this report, a list of all recommendations, along with associated timelines and responsibility for implementation, is set out, and to ensure follow through, a high level implementation committee will be responsible for regular monitoring and reporting on implementation, as well as ensuring that the appropriate structures and policy measures are in place.

Recent overviews given by members of the Taskforce include those by Tara MacMahon, an intellectual property (IP) lawyer, at a recent Licensing Executive Society IP seminar, and by Dr Chris Horn (co-founder and former chief executive of Iona Technologies), through an article in *The Irish Times* and his related blogs. While it is agreed that this report cannot provide all the answers to build economic growth, the Taskforce believes that it places innovation at the heart of enterprise policy and that Ireland can become a global innovation hub in Europe. According to Chris Horn: "Ireland has a great foundation, with an economy open to enterprise and innovation, so while innovation is indeed risky, Ireland is truly uniquely placed to enhance the likelihood of success".

Principles of innovation

The theme behind the six principles agreed in the report lies in the belief that an increase in the rate of job creation and new company start-ups is achievable through policy and investment decisions being centred on supporting and encouraging the entrepreneur and innovative enterprises. This would include all

aspects of Irish enterprise including Irish-owned and foreign multinationals located here, established SMEs, start-ups and companies with high growth potential. These principles are as follows:

1. The entrepreneurs and enterprise must be at the centre of all efforts.
2. Establishing, attracting, growing and transforming enterprises must be the focus of a coherent national effort.
3. Availability of smart capital to start, grow and transform enterprises.
4. An education system fostering independent thinking, creativity and innovation.
5. Encouragement of flagship projects and infrastructure provision.
6. Sharpened focus of national research system by targeting areas of potential strategic and economic advantage.

While all equally important at a national level, the fundamental principles most relevant perhaps to research performers such as Teagasc, include the focus on the education system, national research system and entrepreneurship to assist in strengthening the knowledge base, facilitating the transfer of knowledge, and supporting the entrepreneur. The other recommendations relate to attracting new investment and embedding existing foreign direct investors.

Research investment

In terms of research investment, a key recommendation is to deliver on the investment framework to achieve the goal of investing 3% of GDP in research and development (R&D) through an updated Strategy for Science Technology and Innovation (SSTI) for 2014-2020. This, according to the report, requires more co-ordinated public research investment and national prioritisation, as well as leveraging of more private sector investments. The 2009 Innovation Alliance between Trinity College Dublin and University College Dublin, which will engage with enterprises and government on specific initiatives, is an example of such co-ordination, while other similar strategic alliances are pending, following the report recommendations.

Encouraging entrepreneurs

In terms of entrepreneurship, a massive shift in culture is required in Ireland, according to the Taskforce, whereby appropriate incentivisation and support must be given to entrepreneurs. According to Chris Horn, while for some professions failure is not an option, business failures "result in experience, insight, [and] strengthening of

competences, with their subsequent ventures being more likely to succeed". In terms of funding entrepreneurship, transformation of the scale and nature of venture capital and business angels funding is recommended, with the proposal that Enterprise Ireland should become increasingly focused on start-up and early stage activities. The drive to increase the number of start-ups is a critical success factor according to Chris: "Start-ups can take raw academic intellectual property and convert it into commercially viable offerings, and by being successful, they inspire others to try their luck, thereby enlarging the pool of entrepreneurs and innovators". In short, entrepreneurship from our academics, overseas partners and indigenous companies needs to be supported and encouraged.

Knowledge transfer in PROs

Relating to facilitating knowledge transfer, the focus in the report is on strengthening the commercialisation function and generation of economic value from IP generated in public research organisations (PROs), which includes higher education institutions and state-supported research institutes. The report gives a number of recommendations on the variety of ways this can be done, including strengthening their entrepreneurial culture, assisting commercialisation through funding, and by clarifying mechanisms by which state-supported IP can be accessed and commercialised by enterprises and entrepreneurs.

Incentives for innovation

While there is an expectation that publicly funded research provides a direct return to the taxpayer, research may and does fail. Processes that can be put in place to recognise and reward entrepreneurial culture in PROs are proposed in the report. These include linking career promotions to innovation activities such as licensing of IP, collaborative work with industry and spin-out involvement, as well as facilitating staff who wish to provide their expertise to innovative companies through secondment. One recommendation is to reward researchers involved in technology transfer through a license or other mechanism by inviting them to apply for specific public funding to further their basic research, this having been piloted in the UK through the Realising Our Potential Awards (ROPA) scheme.

The Business Partners Programme was piloted in 2009 through Enterprise Ireland to give selected entrepreneurs access to a portfolio of state-supported IP, with the aim of producing a start-up company, and due to its success, this is being officially launched in 2010. This is indeed in line with the recommendations of the Taskforce, while further proposals include increasing placements of entrepreneurs into state-funded R&D laboratories and encouraging further access by industry to PRO specialist infrastructure.

National IP protocol

Similarly, appropriate IP, education and related supports are recommended, including initiatives to increase public awareness of IP issues, a more co-ordinated approach by various funding agencies, and consistent national policy and rules for ownership of, and access to, state-funded IP. With a number of industry experts involved in the Taskforce, a major barrier identified by industry in the transfer of knowledge is the access to IP issue and lack of clarity, predictability and efficiency relating to it, when engaging with PROs. The Taskforce acknowledged this by recommending the development and publication of a national IP protocol, which would establish the ground rules when agreeing terms around ownership of and access to all state-supported IP. It is believed that if parties get the same predictable and professional service every time through model agreements and protocols, it would facilitate

engagement, and may give Ireland a competitive advantage over many other countries as the place to go to innovate. Indeed, this advantage may be built on by marketing Ireland as an 'International Innovation Services Centre', offering global IP management, licensing and trading services, according to the Taskforce. However, key to this is a clear and standardised approach from funding agencies on IP management, which to date has not been the case. While some agencies have provided frameworks for IP management, others have given little or no guidance to researchers, leading to mixed and conflicting signals from funding agencies. If all funding agencies were to adopt and publish standardised requirements from the management of their IP, in accordance with the proposed IP protocol, this would lead to less misinterpretations and difficulties encountered between parties when negotiating.

While the Taskforce acknowledges that significant progress has been made in the area of IP management, through expansion of technology transfer offices, there is a general consensus that further improvement in terms of efficiency and effectiveness is possible. It is worth noting that Forfás recently conducted a consultation-based review of current supports for exploitation of IP from state-funded research, and the findings should be very useful in identifying gaps and possible areas for improvements, which the Taskforce will indeed support.

Global innovation hub

In summary, the Taskforce and, indeed, the Government believes that Ireland has many attributes that make it suited to becoming a global innovation hub, but acknowledge that more needs to be done. In order to encourage an entrepreneurial culture, academic-industry collaborations and transfer of knowledge to enterprises and entrepreneurs, a supportive environment in terms of education, training, legislation, infrastructure, awareness in innovation and creativity, and support for entrepreneurial activity is key. These themes addressed in the report aim to promote a strong high level focus on the overall innovation agenda, by assisting in the development of an ecosystem in which each element and interaction supports innovation across the economy and society.

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Lessons from New Zealand

Agri-food science and technology is underpinning recovery in the New Zealand economy. DR LANCE O'BRIEN reports on a recent fact-finding mission to New Zealand.



Twenty-two per cent of all R&D performed in New Zealand supports agriculture, forestry and fishing.

Investment in knowledge, intellectual assets and new technologies, as well as the adaptation of existing business practices and technologies, has always been the key to value creation in the New Zealand agricultural sector. Early on the country recognised the vital importance of building and retaining its own in-house scientific capability in order to underpin its comparative advantage in pastoral agriculture. It has managed to invest in the order of 1.5% p.a. of agricultural Gross Domestic Product (GDP) in agricultural research over a long period, resulting in a high level of innovation in the sector, the creation of new markets and ongoing efficiency gains.

Despite the long-standing national recognition of the important role of science and innovation in boosting economic performance, New Zealand's overall level of research and development (R&D) investment remains low and, arising from policy decisions in the early 1990s, its public science system has been subjected to massive upheavals over the past 20 years. These have led to considerable disquiet among scientists and science managers; resulted in ongoing job losses and loss of capability in key areas of science; led to high costs associated with competitive funding; led to a lack of collaboration between institutions; and, brought about a strong emphasis on short-term outputs to the detriment of a strategic programme focus in key institutions. Over the years, governments have attempted to address some of the adverse consequences of the original 1990 reforms, but it is only over the past two years or so that more significant reform steps have been contemplated. One outcome is a renewed focus on investing in agri-food science and technology.

Science funding – the primary importance of agri-food

A core difficulty with the science funding system is the low overall investment by the country in R&D. At 1.21% of GDP, New Zealand's investment in R&D remains well behind that of many other developed countries (Figure 1). For example,

Australia invested 2.01% of GDP in 2006, while the Organisation for Economic Co-operation and Development (OECD) average was 2.29%. This relatively weak performance mainly reflects the very low level of private sector investment in research. Public funding for research in New Zealand, at over 52% of total research expenditure, is much higher than the OECD average (30%).

Of particular interest is the fact that the primary sector is a major focus of research, with 22% of all R&D performed supporting agriculture, forestry and fishing. Moreover, much of the R&D in industry – which accounts for a further 22% – involves processing and value creation from primary products. New research funds created in recent years have enhanced research investment in primary production, while specific investment in 2010 in the new Domestic Centre for Agricultural Greenhouse Gas Research and in the Global Research Alliance, will further boost research expenditure on agricultural greenhouse gas emissions. (The Global Research Alliance is a major global initiative, designed to increase international co-operation, collaboration and investment in research activities to find ways to produce more food with fewer emissions. New Zealand is taking a lead role in promoting this initiative.)

In recent policy statements, the Government has reiterated its commitment to maintaining the largest share of its science investment in land- and food-based science. This represents a shift from earlier policies, which prioritised newer areas in biotechnology and ICT, and is a clear recognition of the fact that the primary industries account for over 60% of New Zealand's exports and represent the nation's core economic strengths.

Policy background

The near collapse of the New Zealand economy in 1984 triggered a series of fundamental reforms resulting in the complete liberalisation of the economy and its transformation into a highly deregulated and market-led economy. Deep

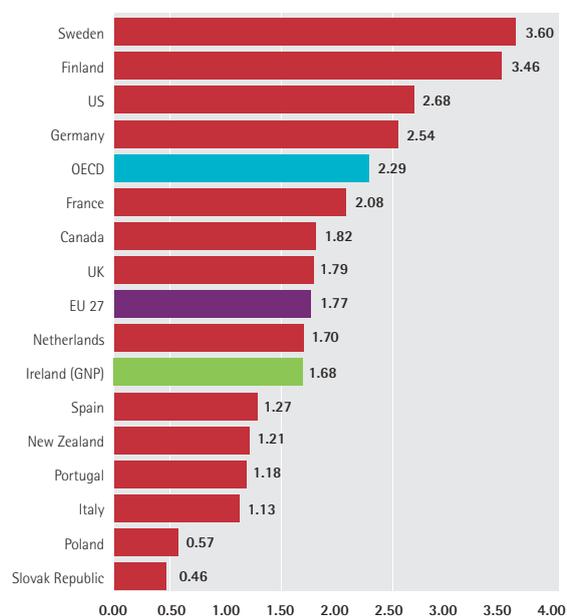


FIGURE 1: Gross expenditure on R&D (GERD) as a percentage of GDP/GNP – Ireland and selected countries.*

Sources: Derived from the Survey of R&D in the Business Sector, 2007/8 (CSO/Forfás); Survey of R&D in the Higher Education Sector, 2006 (Forfás); The Science Budget 2007/2008 (Forfás); and, Main Science & Technology Indicators, 2009/1 (OECD). *2008 or latest available data.

reform of the public sector, including a severe pruning of expenditure, was a key feature of the reform process. Over the period 1990-1992, the science system was significantly reformed as part of this process. The principle that policy advice, funding and service provision should all be carried out by different organisations, in order to avoid conflict of interest and capture by any particular group, was applied to the science system. Further, the notion that research should not be input-funded, but instead funded on the basis of desired outputs that could be contracted, was applied in the belief that the best science would be delivered if the funds were mostly contestable. The Ministry for Research, Science and Technology (MoRST) was created to be the provider of policy advice on research, science and technology to the government. The Foundation for Research, Science and Technology (FRST) was responsible for the allocation of the Public Good Science Fund (PGSF) to meet government-approved priorities formulated by MoRST. Finally, 10 Crown Research Institutes (CRIs) were formed to compete for contracts for this funding to deliver the promised research, science and technology. As companies under the CRI Act 1992, CRIs were expected to demonstrate "an adequate rate of return on shareholders' funds" (CRI Act 1992, Section 5.3(a)).

Impact of reforms

In the immediate aftermath of the New Zealand reforms, its model of competitive research funding was closely scrutinised by many other countries, although it would appear that none ever adopted the fully contestable system as introduced in New Zealand. Over the years, there has been much internal

criticism of its impacts and various *ad hoc* policy measures were introduced in an attempt to address some of the most critical deficiencies. In 2009, in response to the growing concerns, the government established a taskforce to recommend how CRIs could be better positioned to respond strategically to the needs of their end users and drive future economic growth (Crown Research Institute, 2010). Implicit in the recommendations set out in the taskforce's report is a recognition that the 1990s reforms had left these organisations with unclear objectives; suffering multiple lines of accountability; heavily dependent on short-term competitive contracts; and, discouraged from collaborating. The critical recommendation made is that the government should provide a significant proportion of CRI funding by way of long-term core funding and that a much smaller proportion should be allocated by way of competitive grants. This is a very significant recommendation from a country that placed such store over 20 years on competitive funding, and should provide food for thought for other countries that may be considering emulating the full New Zealand model.

Lessons for Ireland

From an Irish perspective, we have much to learn from the New Zealand experience. The efficient and highly productive and profitable farming sector of New Zealand is based on past research and innovation and all in the sector see its future well-being continuing to rest on ongoing investment in science. This has most notably been articulated recently by the Prime Minister, who has committed the government to supporting high quality innovation in the primary sector by investing the greater share of public research funding in land and food-based science (New Zealand Government, 2010). New Zealand believes that its primary sectors have a key role in its future economic growth and is staking its recovery from the current recession on export-led primary-based production. Asia is viewed as a major consuming power, requiring high quality, healthy food without seasonal restriction. New Zealand is positioning itself to take further advantage of these growth markets. The lesson for Ireland, as we finalise the Department of Agriculture, Fisheries and Food's 2020 strategy, is that we too must display a similar level of ambition for our agri-food sector.

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Gut feeling

DR CATHERINE STANTON outlines the highlights of the US/Ireland Functional Food Conference held in March.



Foods have an enormous role to play in keeping people healthy and many foods have properties that can enhance the health of those that consume them. A 'functional food' is one that serves a purpose beyond basic nutrition, promoting health or reducing the risk of certain diseases. The global market for functional foods is expected to increase to €14.7 billion by 2013. Indeed, in a recent foresight exercise undertaken by Teagasc, research in functional foods was seen as a priority to support the ambitions of Irish industry to compete in this market segment. The US/Ireland Functional Foods Conference took place in Cork on March 9-11, 2010, and was a key event in linking Ireland's large public research programme in functional foods with the top research performing food companies. The conference was jointly organised by Teagasc in conjunction with University College Cork and the United States Department of Agriculture (USDA) under the theme of 'Dietary Optimisation of Gut Function and the Microbiota'. This Conference followed on from a very successful landmark conference in 1997 entitled 'Functional Foods – Designer Foods for the Future', which was again jointly organised by Teagasc with the USDA under the auspices of the US/Ireland Co-operation Programme in Agricultural Science and Technology. The 2010 conference was unique as it brought together top scientists from both

inside and outside food research who are active in metabolic or clinical research of relevance to functional food development. The speakers, leading scientists and researchers working in Ireland and abroad who are recognised leaders in their field, with some coming from a medical/medical science background, presented on topics of vital importance for the validation of health claims for functional foods, which are seen as a key area of development for Ireland's food industry.

Understanding gut function

The conference was aimed at understanding the science of how the human gut functions, and the role that diet, nutrition and gut microbiota play in human health. The conference programme focused on: gut hormones and incretin release; gut microbiota for optimal gut function; diet and immune function; and, biomarkers for enhanced health through diet. While the health effects addressed at the conference were broad, they were naturally those that are diet-related and that connect to gut responses linked to such conditions as obesity and the metabolic syndrome. The metabolic syndrome is a clustering of risk factors (obesity, insulin resistance, dyslipidaemia/steatosis, inflammation and hypertension) that dramatically increase the risk of developing type 2 diabetes

and coronary vascular disease. In addition to fundamental science in this area, applied aspects, as well as regulatory and consumer issues were addressed, ensuring interest among academic and industrial personnel alike. This research is particularly relevant as obesity and the metabolic syndrome are increasingly becoming a problem in Ireland.

Keynote address

The keynote address was given by Professor Jeremy Nicholson of Imperial College, London, who is a world leader in human metabolomic studies, i.e., how metabolites in bodily fluids can be biomarkers of health, disease and wellness. Professor Nicholson's speech was dedicated to Professor Liam Donnelly, former Director of Food Research at Teagasc, in recognition of his significant contribution to innovation in food science during his career. Professor Nicholson's fascinating talk delved into the complexities of the human metabolome in terms of the myriad of substances in the body, arising from diet, from the use of drugs, and those being produced by the host and gut microbiota combined. This relatively new science is set to revolutionise our appreciation of the fate of dietary components in the body, particularly in relation to disease prevention. For example, components of the gut microbiota that act on dietary fatty acid substrates influence the fatty acid composition of host internal organs, such as the liver and brain. Given that fatty acids are involved in the production of important mediators and regulators of inflammation and immune responses, the metabolically active gut microbiota may impact on onset of diseases such as cardiovascular disease, inflammatory disease, obesity, cancer and certain psychiatric diseases such as depression.

Conference programme

The conference centred around four sessions on the theme 'Dietary Optimisation of Gut Function and the Microbiota', and each session started with a plenary presentation by an eminent scientist in the field of: gut signalling/hormones/incretins; gut microbiota; mechanisms and biomarkers as they relate to nutrient response; and, functional foods – from technology to regulatory aspects to consumer acceptance.

Gut signalling

Professor Graham J. Dockray from the University of Liverpool gave the plenary session in gut signalling/hormones/incretins, and spoke on how the gut sends signals in response to food. The session subsequently addressed the impressive range of signalling mechanisms involving the activation of intrinsic and extrinsic neuronal circuits and the release of regulatory peptides, biogenic amines and lipid mediators, which are triggered following ingestion of a meal.

Gut microbiota

Professor Fredrich Backhed from the University of Gothenburg, Sweden, gave the plenary session on gut microbiota, and addressed the gut microbiome and implications for obesity. He discussed how the gut microbiota is altered in obesity, some of the mechanisms by which it promotes disease development, and how pre- and probiotics may be used to improve treatment of metabolic diseases. The Irish contribution to this area of science was presented at this session by Professor Paul Ross, Head of Food Research at Teagasc. Paul presented findings from the Alimentary Pharmabiotic Centre (APC) collaborative project (UCC/Teagasc), looking at the impact of gut bacteria, including probiotics, on human health. He

highlighted the major opportunity to translate scientific discovery into new product opportunities for the food industry.

Collaborative research is being conducted within the APC, which is one of nine Science Foundation Ireland-funded 'Centres of Science, Engineering and Technology' (CSETs) in Ireland. The research undertaken at the APC focuses primarily on the area of gastrointestinal health. In late 2008, the centre was approved for second-term funding of more than €17 million from the Government, with industry contribution, to support its research programme for a further five years. In the period since its establishment, the centre has flourished, and now has a 100-strong multidisciplinary research team with a variety of funding sources, with staff based at both UCC and Teagasc Food Research Moorepark. Details of the ELDERMET project were presented by Dr Paul O'Toole, University College Cork. This joint research project, involving scientists from Teagasc, UCC and Cork University Hospital, is assessing the composition of the gut microbiota of elderly volunteers over 65 years of age in the Irish population, using state-of-the-art molecular technology. The samples collected are being screened for probiotic properties, which could help to produce functional foods for our ageing population.

Nutrient response

Professor Randy Seeley, University of Cincinnati, USA, gave the plenary session on nutrient response, and discussed the biological systems that regulate energy balance and body weight. Also in this session, Professor Rob O'Doherty of University College Cork focused on the biochemical and molecular mechanisms that link obesity, insulin resistance, dyslipidaemia and inflammation in the metabolic syndrome.

Regulation and consumer acceptance

Professor Tiina Matilla Sandholm of Valio International, Finland's largest food company, gave the plenary session on 'functional foods – from technological to regulatory aspects to consumer acceptance'. She said that food companies are focusing more on the sciences as they develop functional foods and bioactives with validated health claims. Furthermore, Jens Bleiel, Chief Executive of Food for Health Ireland (FHI), talked on functional foods from the perspective of the consumer and how to make them successful. Delegates were told that functional foods have become the cornerstone of innovation in the food industry, and that all big food companies are investing in functional foods because the mega trends in society require healthy food with added benefits to improve consumer health, wellness and quality of life.

A special issue of the International Dairy Journal (April 2010, Volume 20, Issue 4) was produced for the conference. The contribution of the organising committee is gratefully acknowledged.



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Reducing salt in ready meals

Researchers at Teagasc Food Research Ashtown, in collaboration with the University of Limerick and industry partners, have been looking at ways of reducing salt in ready meals without compromising on taste.



Photo courtesy of Bord Bia.

Today's busy lifestyles leave little time to prepare meals from fresh ingredients, resulting in the popularity of ready prepared meals. However, these meals contain relatively high levels of salt and health agencies throughout the world are recommending a reduction in non-discretionary sodium from salt- and sodium-containing additives used in the manufacture of these meals. In fact, reduction of salt (sodium chloride) in foods is now recognised as one of the top 14 challenges facing the food industry (Katan *et al.*, 2009).

Salt and health

Sodium, or salt, is essential for life processes and is quite simply something we cannot live without! However, a substantial body of evidence now exists to suggest that high dietary sodium intake is a key factor in the rise in blood pressure with age in industrialised countries such as Ireland (MacGregor, 2004). High blood pressure is the main cause of strokes and a major cause of heart attacks – two of the most common causes of death and illness worldwide (WASH, 2010). In Ireland, cardiovascular disease (CVD), including heart disease, stroke and related diseases, is the single biggest cause of death, accounting for 36% of all deaths (Irish Heart Foundation, 2010).

Salt and Ireland

It is currently recommended that Irish adults consume no more than 4g of salt

per day (FSAI, 2005). However, the average Irish adult consumes between 9 and 10g of salt daily (FSAI, 2005). In 2003, the World Health Organisation and the Food and Agriculture Organisation of the United Nations recommended the consumption of less than 5g salt (or <2g sodium) per day (WHO, 2003). These recommendations have become the cornerstone of health policies, reviews and recommendations on salt consumption targets across the globe. The Food Safety Authority of Ireland has endorsed these recommendations and aims to reduce the average intake of salt to 6g per day (FSAI, 2005).

Salt and ready meals

A survey in the UK by the Food Standards Agency (FSA) indicated that many popular ready meals are high in salt, with some meals containing almost all the recommended dietary allowance (RDA) of salt in one serving (FSA, 2003). At Teagasc Food Research Ashtown (TFRA), we conducted a survey of salt levels in ready meals on the Irish market in 2006. The results of this survey were very much in agreement with those from the UK, with the average Irish ready meal containing 71% of the RDA for salt. In fact, 58 out of the 67 ready meals surveyed contained 50% or greater of the RDA (Figure 1). An identical survey carried out in 2010 has revealed that 35% of the meals have the same levels of salt as four years ago, while 20% have slightly reduced salt levels. While this may seem like good news, 20% of the resurveyed meals have increased their salt levels and 25% have removed this information from their nutrition labels.

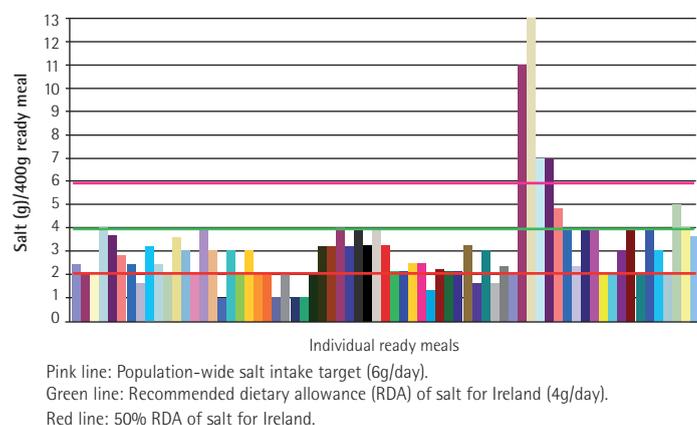


FIGURE 1: Salt content (g/400g) of ready meals on the Irish market in 2006.

Reducing salt in ready meals

In conjunction with the University of Limerick (UL), and industrial partners Dawn Fresh Foods and AllinAll Ingredients Ltd, researchers at TFRA are using herbs and spices as substitutes for flavour lost through removal of salt from three popular chilled ready meals. Herbs and spices contain potent antioxidant compounds, and thus can also improve the health-promoting profile of the meals. Work at UL is focused on assessing the impact of reducing salt levels on microbial stability. Initial work at TFRA used a trained sensory panel to conduct flavour profile analysis of popular commercial ready meals and their low salt equivalents to identify flavour differences arising from salt reduction. In a chilled vegetable soup, panellists reported that reducing salt levels by 52% resulted in a significantly weaker carrot aroma and a significantly weaker overall flavour when compared to its full salt counterpart. This was mainly due to the low salt meal having a significantly less salty and a more pronounced sweet taste. The overall acceptability of the reduced salt vegetable soup was also significantly lower. This was also the case for a reduced salt cottage pie and a chicken supreme ready meal.

With the key attributes negatively affecting acceptability identified, the next step was to address these flavour defects through reformulation with herbs and spices. In conjunction with project partners at UL, six herbs and spices with high antioxidant and antimicrobial activity were identified. These spices, namely clove, sage, pimento, oregano, garlic and rosemary, were then incorporated into each of the three low salt meals at four different concentrations and their acceptability determined using a nine-point hedonic scale.

Clove, the most potent spice in terms of antioxidant and antimicrobial activity, was unacceptable in all meals even at the lowest concentrations and therefore was not incorporated at higher levels. Pimento was also found to be unacceptable at all concentrations in both the vegetable soup and the chicken supreme ready meals; however, at the lowest concentration it was found to be very acceptable in cottage pie ready meals. Based on these results, acceptability scores were used to identify the most acceptable spices and addition concentrations for each meal, and this information was used in the invention of several spice combinations. Further sensory analysis was conducted to identify the most acceptable spice combination for each meal. A final confirmation test

was conducted comparing the most favoured spice combination with both the low and full salt meals to see how it performed in terms of overall acceptability. Results revealed that the different spice combinations added into the cottage pie and the chicken supreme ready meals were found to be more acceptable to taste panellists than both their low and full salt ready meal equivalents. Little difference in terms of acceptability was seen between the low, full and added spice vegetable soups, with the full salt meal found to be the most acceptable of these three meals.

Benefits to industry

In summary, sensory analysis was used to identify flavour defects resulting from significant salt reduction in three ready meals. This information was used to selectively address these defects using a combination of herbs and spices, resulting in three ready meals with acceptability scores comparable with their full salt counterparts. Results from this study can be used to significantly reduce salt levels in ready meals without influencing consumer acceptability from a flavour viewpoint. As a result of this study the production of low salt ready meals has been implemented on-line by Dawn Fresh Foods.

This research is funded by the Department of Agriculture, Fisheries and Food under the Food Institutional Research Measure.

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Gluten-free bread research

Pseudocereals are being investigated as possible functional ingredients in gluten-free breads by researchers at Teagasc Food Research Ashtown.

Greater public awareness and improved diagnostic procedures have combined to highlight the prevalence of coeliac disease (CD) and gluten intolerance in the general population. The estimated mean prevalence of CD is 1% of the general population. The only accepted treatment for CD is a strict, life-long elimination of gluten from the diet. Many widely consumed staples, such as bread and pasta, are made using gluten-containing grains such as wheat, which must be avoided by coeliac patients. Although gluten-free alternatives are readily available in the market, these products are often characterised by a crumbly, brittle texture, and are perceived as being of inferior quality compared to the wheat products they are intended to replace. In addition to quality defects, gluten-free foods are also characterised by an inferior nutritional quality. They have been reported to contain lower levels of essential nutrients such as B vitamins, iron and fibre, than are contained in wheat products. This is mainly due to the fact that gluten-free products are generally formulated with starches and refined flours, and are not usually fortified.

Research at Teagasc Food Research Ashtown (TFRA) has addressed some of the nutritional needs of coeliacs by formulating palatable, gluten-free breads with enhanced nutritional properties. It has focused on using the so-called 'pseudocereals' amaranth, quinoa and buckwheat to replace wheat in bread formulations. In botanical terms, these are not true cereals; they are dicotyledonous plants as opposed to most cereals (e.g., wheat, rice, barley), which are monocotyledonous. They are referred to as pseudocereals as their seeds resemble those of the true cereals in function and composition. They are, however, gluten-

free, and are also rich in nutrients; therefore, their incorporation in the gluten-free diet could not only add variety but also improve nutritional quality. Other characteristics of these seeds, such as their high protein, fibre and mineral content, as well as the presence of many bioactive components (compounds with beneficial effects on the body), make them attractive alternatives to traditional gluten-free ingredients (such as rice, potato and corn flours/starches) in the production of high quality, healthy gluten-free products.

Research approach

A gluten-free bread recipe similar to commercially used formulations and based on rice flour and potato starch was used as a control. One of the pseudocereals (amaranth, quinoa or buckwheat) replaced the potato starch in each of the experimental formulations.

Improved baking characteristics of breads with pseudocereals

Initially, the baking characteristics of the resulting breads were assessed. Dough rheology, specific loaf volume, textural properties, crumb grain/imaging and sensory analysis were completed. Some of the results are shown in **Figure 1**. Loaf volumes were significantly increased for buckwheat and quinoa breads in comparison with the control. Loaf volume is an important determinant of bread quality. A good loaf volume, coupled with a good crumb texture, indicates proper dough formation and a high quality product. No significant difference in volume was found between the control breads and those containing amaranth. In relation to the crust colour of the baked breads, the pseudocereal-containing gluten-free breads were significantly darker (lower L^* values) compared to the gluten-free control. The darkening of crust colour brought about by the replacement of potato starch by a pseudocereal flour is desirable, as gluten-free breads tend to have a lighter crust colour than white wheat breads and can sometimes appear artificial.

In breadmaking, a desirable crumb structure is characterised by a large number of small, thin-walled cells and a soft, spongy texture. In the present study, the largest number of cells was found in breads containing buckwheat and quinoa (**Figure 2**). All pseudocereal-containing gluten-free breads had a softer, more desirable crumb than the gluten-free control. A similar trend was found for crumb cohesiveness, with all of the pseudocereal-containing breads producing a more cohesive crumb than the control product. In sensory studies, the differences observed in the acceptability of the baked breads were not statistically significant, showing that pseudocereal flours may be introduced into a gluten-free bread formulation to

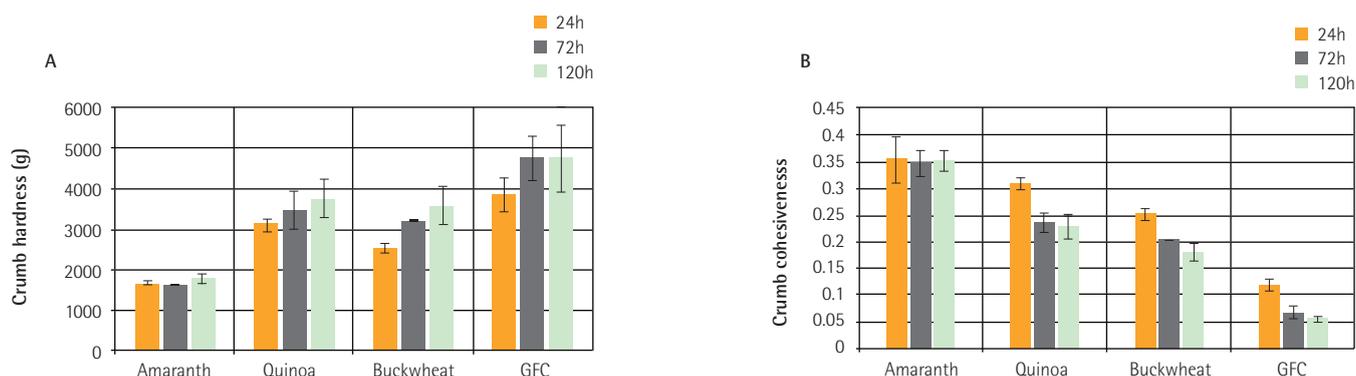


FIGURE 1: Texture profile analysis of the breads 24, 72 and 120 hours post-baking: (A) crumb hardness: a softer crumb is more desirable; (B) crumb cohesiveness: a more cohesive crumb is more desirable; GFC = gluten-free control.

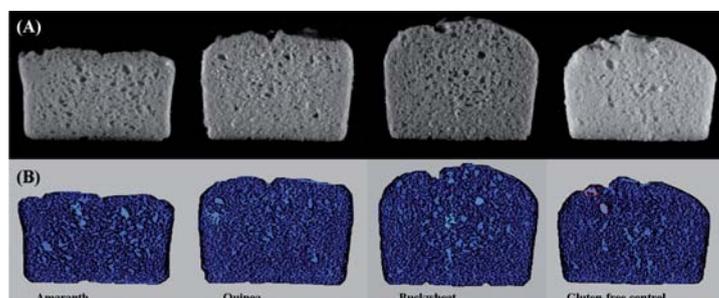


FIGURE 2: Above: Raw (A) and cell (B) images of amaranth, quinoa, buckwheat and gluten-free control breads. Right: The bread loaves: 1 = gluten-free control, 2 = quinoa, 3 = amaranth, 4 = buckwheat.

enhance crumb softness and cohesiveness without adversely affecting the sensory properties of the loaves. Confocal microscopy of the bread crumb revealed a more homogenous structure in the pseudocereal-containing gluten-free breads, with a more even distribution of fat, protein and starch.

Enhanced nutritive properties

The inclusion of pseudocereal flours produced breads that were characterised by a significantly higher content of protein, fibre, antioxidant capacity and total phenols (Table 1). The protein content in these breads was, in all cases, at least twice the value of the control bread. Dietary fibre content also increased significantly. In particular, the fibre content of buckwheat bread, at 23.3%, was more than three times that of the gluten-free control (wheat bread has a fibre content of approximately 4%).

Antioxidants prevent food oxidation during cooking and storage, and can also protect the body from degenerative diseases such as cancer and heart disease. It was found that the antioxidant capacity, measured by both DPPH and FRAP assays, was increased by the presence of the pseudocereals in the breads, compared with the gluten-free control, with the buckwheat bread having the highest overall result.

General conclusions

This project evaluated the nutritive properties of the pseudocereals amaranth, quinoa and buckwheat, and their application as functional ingredients in a gluten-free formulation. All pseudocereal-containing gluten-free breads had a significantly softer crumb in comparison with the gluten-free control. Nutritional studies revealed that gluten-free breads containing pseudocereals had significantly higher levels of protein and dietary fibre in comparison with the gluten-free control. The nutritional value of these breads was also in line with the existing nutritional recommendations for CD diets and CD products. Also, all of the pseudocereal breads showed significantly higher antioxidant activity and polyphenol content compared with the gluten-free control.

Further developments

In an ongoing collaborative project between Ashtown and Moorepark, researchers are investigating the conditions required to produce a dairy-based ingredient with properties similar to gluten in a gluten-free dough system. So far, the researchers have found that under optimum conditions of pH and calcium concentration, casein aggregates and forms a protein network capable of retaining gas in gluten-free dough, similar to wheat dough. This work is still in progress.



Table 1: Chemical composition, antioxidant capacity and phenol content of the gluten-free and wheat breads.

Bread type	¹ Protein	¹ Dietary fibre	² Antioxidant capacity
GF control	4.18 ± 0.0	7.6 ± 0.9	47.59
Amaranth	11.6 ± 0.0	17.2 ± 0.8	60.6
Quinoa	10.1 ± 0.1	16.1 ± 0.6	71.42
Buckwheat	8.4 ± 0.4	23.3 ± 0.7	147.66
Wheat bread	11.9 ± 0.1	13.4 ± 0.8	81.67

¹ (% dry-weight basis) ² (mg Trolox/100g DW)

Benefits to industry

The ingredients, formulations and technologies that have been studied and developed in these projects have yielded novel information, which will help to provide the industry with healthy, viable alternatives to the more traditional approaches in gluten-free formulation and baking.

This research was funded by Enterprise Ireland and the Food Institutional Research Measure (FIRM). The authors would also like to thank Dr Laura Alvarez, whose Walsh Fellowship formed the basis of the pseudocereal trials.

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New cheese technology platform

Researchers at Teagasc Food Research Moorepark have developed an innovative new way of manufacturing cheese, which will better enable the inclusion of functional ingredients.

Growth in ingredient cheese sector

Ingredient cheese for food service and industrially prepared foods is a rapidly growing sector (Gira, 2006). The required functional attributes, which differ in intensity with specific application, typically include customised degrees of taste, fracture properties, hardness/softness, mouthfeel, chewiness, shreddability and cooking properties (e.g., melt, flow, stringiness, free oil exudation, succulence, browning). In many cases, ingredient cheeses are frequently produced to functional specifications set out in business-to-business relationships, with a strong emphasis on competitiveness or some technological advantage (e.g., controlled fat release on cooking, heat stability, melts at lower temperatures, pumpability, compatibility with superimposed filling application technologies and novelty).

Cheese products for this market are supplied in many different formats:

- natural named-variety cheeses (e.g., Mozzarella, Cheddar, Emmental);
- natural customised generic cheeses (e.g., high moisture cheese);
- processed cheeses (PCs) and analogue/imitation cheese products (ACPs); and,
- blends of the latter.

Natural named-variety cheeses must comply with specific national and/or international standards (e.g., Codex Alimentarius, Code of Federal Regulations) for manufacturing protocols, ingredients used, and composition. In contrast, natural generic cheeses, while having to comply with the Codex Alimentarius definition of cheese, are not limited by these standards and can be made to customised levels of fat, moisture and functionality. Although PCs and ACPs can be easily formulated to give specific functionality, they are generally considered inferior to natural cheeses as they lack some quintessential characteristics (e.g., chewiness, stringiness) and have high levels of sodium because of the inclusion of disodium phosphates/citrates during formulation. Hence, natural cheese is the most desired choice in cheese ingredient applications, provided its cost is competitive.

Conventional cheese manufacture

Conventional cheese manufacture is an age-old technology, involving the manufacture of numerous varieties from milk, starter culture, coagulant and salt. At its simplest, conventional cheese manufacture may be described as a three-step process involving: the gelation/coagulation of milk by added rennet (rennet substitute) and/or acid; dehydration of the gel to a curd (a concentrated protein-based matrix), accounting for about 10% of the milk weight, and the simultaneous expression of whey (about 90% of milk weight); and, ripening of the curd under defined conditions of temperature and humidity, resulting in its conversion to cheese with the desired varietal characteristics.

Limitations of conventional cheesemaking technology include:

- the expression of a large volume of whey (about 90% of milk volume);
- the contamination of whey with various materials solubilised and/or expressed during cheesemaking, including fat, bacteria, acid, and solubilised minerals;

- the loss of materials added to milk to improve nutritional status (e.g., bioactive peptides, prebiotic materials such as β -glucans), yield/component recoveries, and/or physical (functional)/biochemical properties of the resultant cheese (e.g., hydrocolloids, enzymes, flavours);
- few opportunities to include new functional ingredients in cheese; and,
- restricted scope to evolve cheese from its original status (calcium-phosphate gel modified by superimposed operations).

These limitations hinder our potential in innovating ingredient cheese by precluding the addition of texturising biopolymers and necessitating constraints on gelation conditions (e.g., temperature, time) and sequence of ingredient addition (e.g., starter culture prior to gelation and dehydration).

Considering these limitations, and the requirements of the expanding ingredient cheese market, the question arose: can cheese be made in a new way? The idea of reversing conventional cheese manufacture occurred: that is, concentration prior to gelation, as opposed to gelation followed by concentration and whey expression.

Moving cheese technology forward

NCTP and its advantages

The new cheese technology platform (NCTP) is a novel approach to cheese manufacture based on the gelation of concentrated reassembled milks with dry matter levels, which are essentially the same as the finished cheese in the case of 'cast' cheese variants (with $\leq 50\%$ dry matter), or slightly less in the case of 'structured' cheese variants (with $\geq 50\%$ dry matter) (Figure 1). The reassembled milks are prepared by dispersing fat and specialised dairy proteins in water-salt solutions. The dairy proteins are designed to endow the reassembled milks with the functionalities required for cheese manufacture and end product characteristics, and include *inter alia* dispersability to high protein content (e.g., 40% in moisture), capacity to gel, and confer the resultant cheese with quintessential 'cheesy' characteristics (e.g., chewiness), clean flavour and opaque colour.

The NCTP offers several advantages over conventional cheese manufacture in the systematic design of new differentiated cheese and cheese-like products. The NCTP:

- extends the range of specific variables (e.g., protein concentration, pH, gelation time, etc.) currently implied in conventional cheese manufacture;
- facilitates the formation of composite gel systems, through the addition of non-dairy, structure-texturising biopolymers (e.g., hydrocolloids);
- gives more options over the degree of interaction of protein (e.g., casein), biopolymers, or protein-biopolymer, through manipulation of environmental factors at gelation;
- facilitates the retention of added materials such as bio-functional ingredients (e.g., pre-biotic materials), tastants, odourants, colours, and enzymes, especially in cast cheese types, while preventing or minimising their loss and associated contamination of whey;

- affords more systematic control over product composition; and,
- is very amenable as a model system for studying factors affecting the growth and survival of microorganisms or the activity of enzymes in cheese matrices under defined conditions (e.g., pH, composition).

While the dairy ingredients used enable the resultant cheeses to comply with the Codex Alimentarius Commission (FAO/WHO) definition for natural cheese, the reassembled milk can be extended to include other materials such as hydrocolloids and proteins from non-dairy sources for the manufacture of cheese-style alternatives.

The global target of the NCTP is to provide a repository of expertise to enable the commercial development of more innovative cheese products, especially non-standard of identity cheeses for the ingredient market (more diverse physical characteristics and in-built cost efficiencies) and functional foods market (e.g., cheeses with health-enhancing added components). Scientifically, the platform provides a more fundamental understanding of factors controlling protein aggregation in gel-based systems (e.g., cheese), and how these in turn affect the physical/functional properties of interest to cheese users.

Current status of the platform

A patent application on the platform concept was filed in June 2008. Research on the NCTP began in May 2008 with a project entitled 'Cheese 2030 – New Technology Platform for engineering cheese structure and function in model systems', funded by Enterprise Ireland under the Commercialisation Fund Technology Development Phase 2007. Research to date has concentrated on:

- design/manufacture of protein ingredients and studying of their dispersion, hydration, and gelation characteristics under different conditions in model systems varying in protein content;
- investigating the effects of ingredient type, manufacturing conditions, composition, gelation conditions, and sequence of material addition on the biochemical and physical properties of the resultant cheeses; and,
- establishing component recoveries (e.g., fat, protein, casein) during the manufacture of protein ingredients and cheese.

Several prototype cheeses have been produced under the categories of cast (smooth uniform structure) and structured (more homogeneous, curd-like structure typical of hard cheeses), giving a range of compositional, biochemical and physical properties. A manufacturing and marketing feasibility study is being undertaken in parallel with the technological programme, so as to determine the potential commercial opportunity of the NCTP and the most cost-effective product range. Using current prototype cast and structured cheese variants as a guide, the study will consider the NCTP under the following market opportunity parameters: market potential, competitiveness, developments, prices, and benefits.

Benefits to industry

A new platform technology for cheese manufacture has been developed. Contrary to conventional cheesemaking, cheese is manufactured by gelation of reassembled milks that are prepared from aqueous dispersion milk proteins and other ingredients, and that have dry matter contents similar to, or close to, that of the finished cheese. The platform, currently under validation at research-scale at Moorepark, is capable of delivering cheeses with a range of compositional and functional properties. A cost-benefit analysis of the technology using

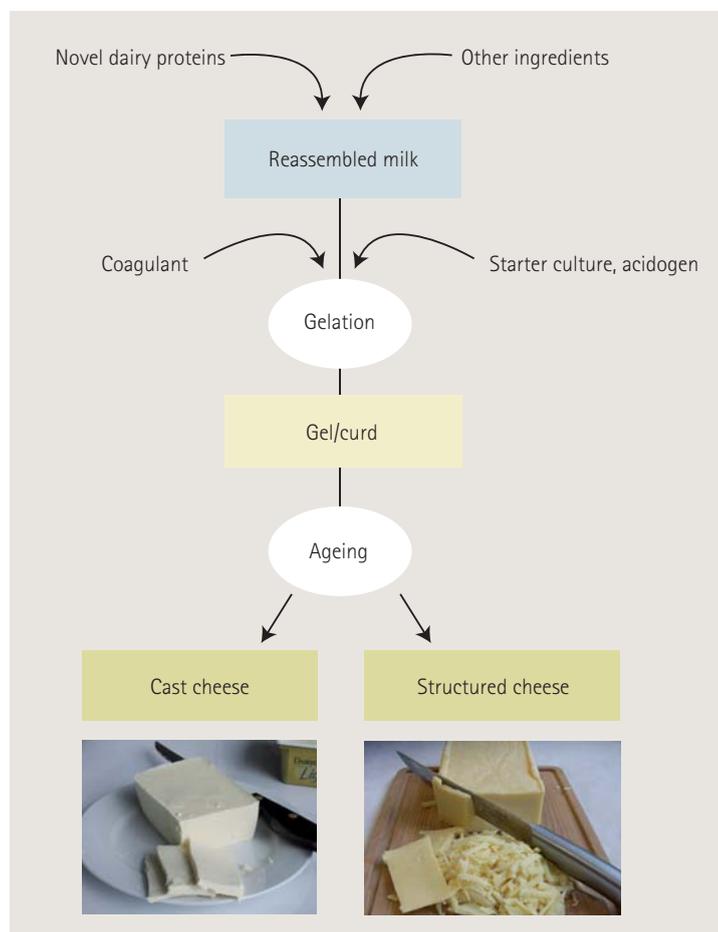


FIGURE 1: New cheese technology platform: schematic of manufacturing process and prototype cheeses.

cheese variants with dry matter contents of about $\leq 50\%$ or $\geq 60\%$ is being undertaken by an independent consultant. However, the technology is still nascent, requiring further research for characterisation and optimisation.

This research is funded by Enterprise Ireland.

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Designing the perfect strawberry plant

The Irish soft fruit industry is booming. The shining star is the strawberry. But what is the science behind the effort to produce the perfect Irish strawberry? DR EAMONN KEHOE describes a project at Teagasc Kinsealy Research Centre aimed at producing such a strawberry plant for the Irish strawberry grower.

The fruit-growing season in Ireland has changed fundamentally over the last decade. In the past, the strawberry season lasted from June to July. Today, through new technology, the season has been extended from April to November. In fact, the strawberry growing business in Ireland is now worth an estimated €35 million per year. The industry is expanding in volume terms at a rate of about 10% per annum, making it a highly valuable sector of Irish commercial horticulture. The most popular strawberry grown in Ireland is still the Dutch cultivar 'Elsanta'. No cultivar has yet matched Elsanta's success.

Strawberry plant imports

Irish strawberry growers used to import the vast majority of their Elsanta strawberry plants from both the Netherlands and the United Kingdom each year. This was because the Irish strawberry propagators could only supply field-grown 'bare root' plants and only for the early part of the season. However, things have now changed for the better. A number of growers have invested heavily in an attempt to stop the importation of plants and to produce their own. From a starting point in 2005, the 'tray plant' industry (i.e., plants are grown in trays outdoors for the entire production process) has expanded rapidly and is now worth an estimated €4 million per year. This should at least double over the next few years. The ultimate goal, when Ireland has satisfied its own market demand, is to export strawberry plants.

Tray plant production

Strawberry tray plants are used especially in protected strawberry production. They have gained in popularity and have formed an important part of the growing system among growers in the Netherlands, Belgium and countries such as France, the UK and Italy. They are more suited for glasshouse cropping than bare root plants. This is because the tray plant is able to cope with the hotter conditions experienced in a glasshouse environment. Tray plants are also produced from runners,

which a mother plant produces in the spring. Runner tips are cut from these runners and are stuck into modular peat trays. They offer many advantages compared to field-grown bare root plants. Runners and cuttings are grown on substrates, reducing the risk of infection by root diseases to a minimum. Plant nutrition can be controlled completely, plants can be more easily lifted during frost and wet conditions and the roots remain intact in comparison to bare root plants. This improves plant storability and establishment after cold storage. Tray plants also produce 10–20% more large fruits than bare root plants, which also reduces picking costs substantially.

Tray plant research

Applied research has been undertaken at Kinsealy to establish and test a tray plant production system for the Irish strawberry propagators. The main cultivar being tested is Elsanta. This system is aiming to help both those growers who are already propagating this type of plant and also those who may wish to set up such a plant production system in the next few years. As well as establishing a system for the propagators, a large part of the project is concentrated on trying to better understand strawberry plant flowering. Strawberry flower induction is sensitive to temperature and photoperiod, and to several agronomic and nutritional factors. The aim is to improve the cultural knowledge and understanding of the physiological control of axillary meristems (flower structures), which can enhance strawberry fruit production. It is also possible to programme axillary meristems to a particular grower's requirements and, even more crucially, for a particular part of the growing season. The quality and stage of flower development within the strawberry plant can also be checked by taking some plant samples at plant harvest time and dissecting them under a stereo microscope. The aim of the first experiments was to study the effect of runner size, date of runner harvest and two peat types (coarse and fine) on subsequent fruit yield characteristics. There was no significant difference between the yield recorded



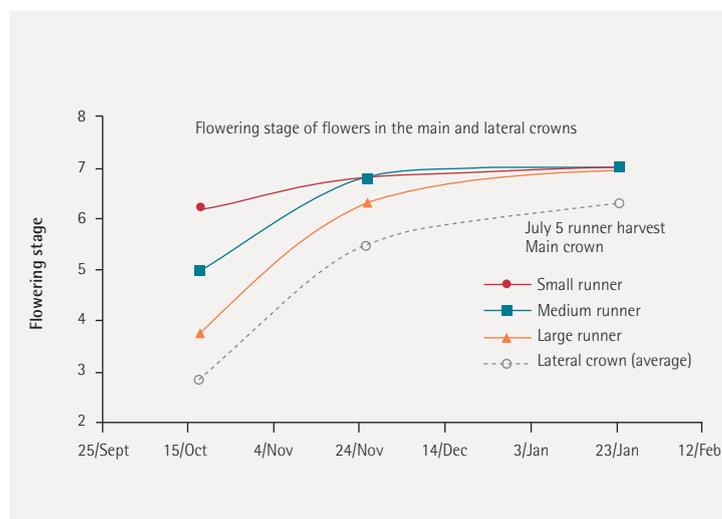


FIGURE 1: The flowering stage of the primary flower and lateral crowns for the July 5 runner harvest and three runner grades.

for season one or two for any of the treatments. However, the yields at our planting density of 10 plants per m² were very high for Ireland. The lowest and highest average yield recorded over the two seasons was 11.33 and 12.73kg per m². Most Irish growers struggle to get a yield of 9kg per m² at the same planting density. This was most likely due to the fact that we were using very high quality plant material.

The average fruit weight was also higher from plants propagated from the large runner grade when grown in the fine substrate. However, the large runner grade grown in the finer peat resulted in a smaller fruit size when it was propagated at the later date in July. This is the first indication that the timing of taking the runner cuttings could have a significant effect on fruit yield parameters. Further work is currently being undertaken to further study the effects of runner harvest time and peat substrate type on fruiting parameters.

Strawberry plant dissection

Strawberry plants were dissected a number of times in the later part of the growing season. The flowering stage of the apical meristems shows a regular development of the flower from the time the plant samples were harvested in mid October through to the final plant harvest in late January (Figures 1 and 2). However, there was a small difference between the stages of flower development between the three runner grades from the July 5 runner harvest. As the growing season progressed this difference in flower stage development narrowed further (Figure 1). The flower stage recorded from crowns from the second runner harvest time (July 19) had very similar stages of flower development (Figure 2). It should be noted also that the flower stage development for the lateral crowns in all the treatments was always less advanced from that seen in the main apical meristems mentioned above (Figures 1 and 2).

Strawberry crown dissection resulted in a very clear picture of the various stages of flower formation the plant goes through. This could be used as a method to further determine plant flower quality characteristics throughout

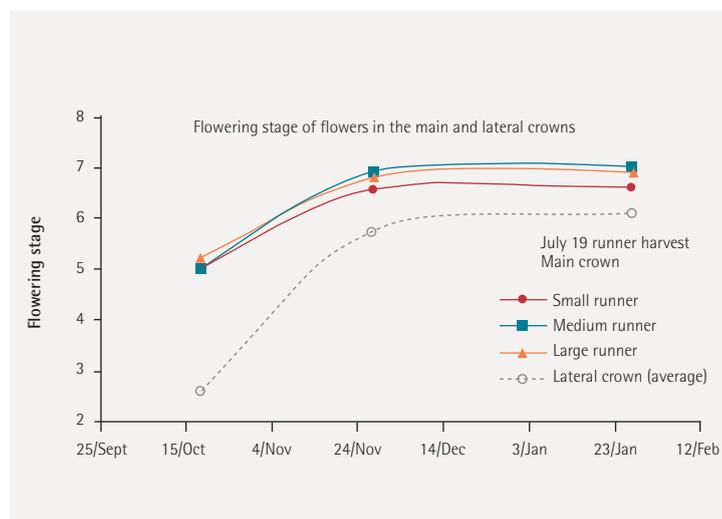


FIGURE 2: The flowering stage of the primary flower and lateral crowns for the July 19 runner harvest and three runner grades.

the whole growing cycle in the strawberry propagation nursery. It also gives the grower very useful information about the cropping potential of that plant for the following growing season and at what time of year that plant is best suited for production.

Expected benefits to industry

By successfully growing their own plants, growers would have less reliance on imported strawberry plants. The quality of these imports is sometimes poor and plant disease risks are also very high (e.g., *Phytophthora* spp., *Xanthomonas fragariae*). The knowledge transfer from this research should allow growers to grow and supply quality strawberry plants for the full length of the Irish season. Strawberry yields should also be higher than that of traditional bare root plants and with higher quality fruit. Labour costs would also be reduced because of faster picking times. There is also the potential to develop an export market in the not too distant future.

Further reading

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He has worked on this project in collaboration with Professor Davide Neri and Dr Gianluca Savini, Università Politecnica delle Marche, Ancona, Italy, through the EU-funded COST group 'Euroberry 863' (www.euroberry.it). He is also working on further aspects of this work with Gebremedhin Beyene, a Teagasc Walsh Fellow, and Dr Alan Hunter at the UCD School of Agriculture, Food Science and Veterinary Medicine.

Trends in winter wheat yield

JOHN SPINK, Teagasc Oak Park Crops Research Centre, describes winter wheat yield trends in Europe and the implications for Irish cereal research.



Demand for food, and cereals in particular, is widely predicted to increase dramatically over the next four decades due to global population growth and a change to more meat-based diets, particularly in some Asian countries. Increased demand for cereals is nothing new, and since the middle of the last century, increased demand has been met or more than met by increased productivity. However, there is now concern that the rate of productivity increase seen over the last 50 years may have slowed or even ceased.

In order to assess if these concerns are real, a statistical analysis of FAO (Food and Agriculture organisation of the United Nations) wheat yield data (<http://faostat.fao.org>) from 1961–2007 was undertaken to assess what has been happening to wheat yields globally and in more detail in Europe. Annual yield data were analysed to see at what rate yields have been increasing, and to see if there was any evidence that the rate of yield improvement had slowed and, if so, when the rate of yield change occurred.

Global trends

An analysis of global average wheat yield showed that wheat yield has been increasing by 41kg/ha/yr, with no evidence of a change in the rate of productivity improvement (**Figure 1**). The major production areas of the world (defined as areas with more than 10m ha of wheat production) were then similarly analysed and, in common with the global figures, no evidence could be found for a change in the rate of yield improvement in China, Canada or the Russian Federation. In contrast, however, the EU, India and Australia all showed evidence of declining yields, with the start of the decline occurring in 1998, 2000 and 2004 respectively. The USA did not show evidence of declining yields but of a reduced rate of improvement occurring in 1983. The only remaining large production area was Kazakhstan with 11m ha of wheat; however, its yields were so variable from year to year that there was no discernible improvement in yield over time.

The European Union

The EU was looked at in more detail as one of the areas with evidence of declining yields and where good production data exists. The analysis was restricted to 14 countries joining prior to 1995, with Belgium/Luxembourg treated as one country. Six of the 14 countries (Belgium/Luxembourg, Finland, Germany, Italy, Portugal and Spain) showed no evidence of a significant reduction in the rate of yield progress. Two showed evidence of a reduced rate of yield improvement (Sweden and the UK) and six of yields declining (Austria, Denmark, France, Greece, Ireland and the Netherlands). The date at which the rate in change of yield was predicted to occur ranged from 1980 for Greece to 2000 for Ireland. The rate of yield decline also ranged widely from only 2kg/ha/yr in Austria, to 70kg/ha/yr in France. The rate of yield decline in Ireland was predicted to be 23kg/ha/yr (from 2000–2007); however, the relatively recent predicted loss in yield improvement in Ireland must be treated with some caution as it may be due to normal year-to-year variation and a year or two of high yields could reverse the trend. It is also worth noting that until 2000 Ireland had the highest rate of yield improvement of any country in Europe, with annual increases of 159kg/ha/yr.

Generally, the countries with the lower yields (averaged over the last decade) and the lowest rates of yield improvement over the whole 47-year period, showed no change in the rate of yield improvement, with the exception of Greece, which has low and declining yields. Of the higher yielding countries only Belgium/Luxembourg and Germany showed no evidence of a decline in yield progress.

The reasons for declining yields

There are a number of possible reasons for this apparent reduction in yield progress: environmental yield potential has been reached, genetic progress has ceased, disease or rotation factors have reduced yield, or agronomy has been sub-optimal for maximising yield potential.

The fact that yields have been declining and are now lower in some cases than 10 to 30 years ago indicates that current yields are below potential, unless the

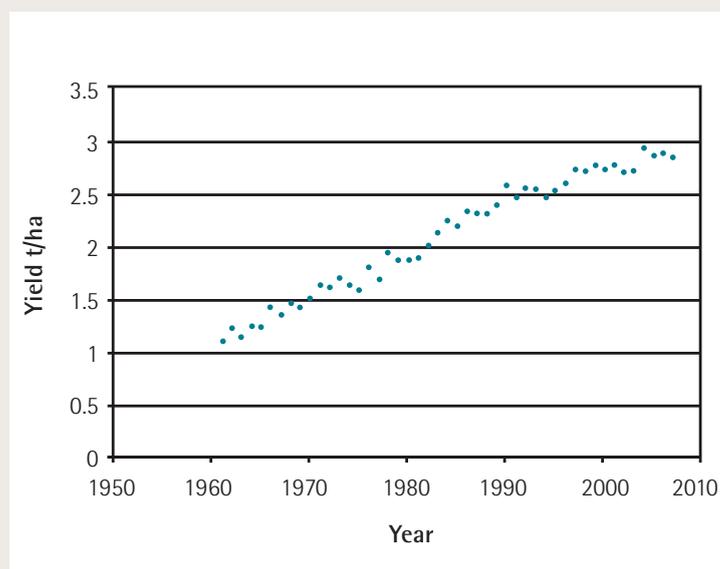


FIGURE 1: World wheat yield (t/ha) for 1961-2007 (Data from FAOStat).

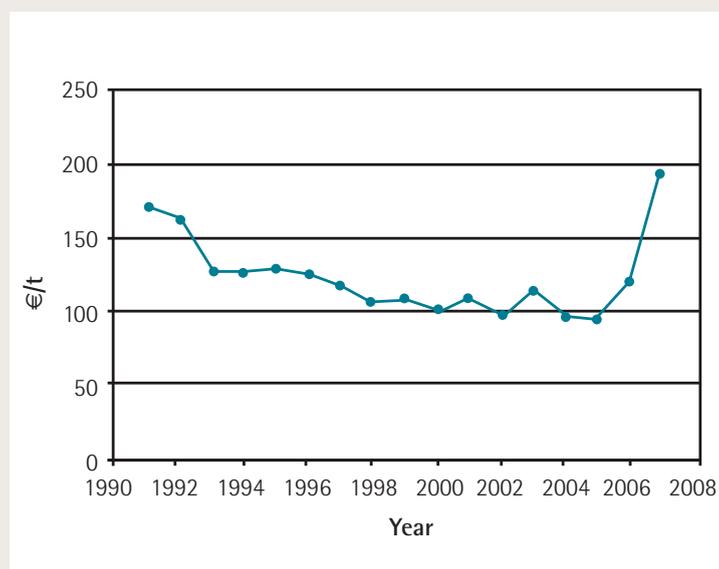


FIGURE 2: Average wheat price in France (€/t).

environmental potential has declined due, for example, to climate change. This theory doesn't appear plausible, however, as a number of studies have shown the potential yield, particularly in northern Europe, to be significantly above what is being achieved. For example, it has been estimated that based on standard light interception and radiation conversion efficiency, the theoretical yield potential of wheat in Ireland is 22.8t/ha at 15% moisture.

The rate of genetic progress in yield improvement has been studied by a number of authors who have shown, using official variety testing data and field experiments, that genetic progress has not slowed. An analysis of the performance of new varieties in the Irish recommended lists, however, indicates that newer varieties are not offering a significant yield increase over existing varieties. It is likely that this could be a result of breeders having to breed for characteristics such as disease resistance, and this is resulting in a drag on yield increases, particularly if the diseases for which resistance is being sought are not particularly important in Irish conditions; however, the yield potential of the varieties is not declining.

The most likely cause of stagnating or declining on-farm yield, therefore, seems to be sub-optimal agronomy. Agronomic practice that does not maximise yield could be a result of either increased environmental concerns driving policies that restrict the use of external inputs, or declining grain prices, which have caused expenditure on crop production on farm to be reduced. Grain prices were on a downward trajectory for most of the 1990s and 2000s until a spike in prices occurred in 2007 (Figure 2) as a result of concerns over food supply; these gains have subsequently been lost by two years of production outstripping demand.

Changes that have occurred on farm that impact on yield progress will vary to some extent between the various countries but the general trends will be similar. A review of the factors affecting productivity in the UK identified the following factors as important: reduced investment in plant and machinery and reductions in the total agricultural workforce (farm owners down 22% and paid labour down 44% between 1989 and 2005 in the UK), combined with difficulty in recruitment of staff, particularly with training in production agriculture. This has caused a decline in

management intensity per unit area, resulting in less accurate matching of crop inputs to requirement, adoption of reduced cultivations as a cost reduction strategy (sometimes in inappropriate conditions), and less accurate timing of inputs with consequent impacts on crop yield. In summary, growers have responded to low and volatile prices by reducing fixed costs.

As well as reductions in fixed costs there has also been a trend to reduced variable cost inputs, including reduced fertiliser use and reductions in the use of crop protection products, as a result of lower economic optima driven by increased input and reduced output prices. In addition to the economic stimulus to reduce inputs, policy-driven reductions in the availability of products and the application rates allowed have had an additional effect. The combined effects of reduced management intensity and external crop inputs appear to be combining to increase the gap between yield potential and on-farm crop yields.

The future

While depressed and volatile markets have had a negative impact on yield progress, the need to improve efficiency, competitiveness and output continues. Irish research has underpinned tremendous improvement in farm cereal yields over the last 40 years. Starting in 2010 a new research project at Oak Park Crops Research Centre will seek to identify the most important yield limiting factors in Irish conditions, providing a signpost for future research direction. The refocused programme will continue to develop the most cost-effective production methods conducive to high yields.



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Decreasing trend of fertiliser use

Analysis of Teagasc National Farm Survey data shows a dramatic reduction in fertiliser use on Irish farms, which could have serious consequences for soil fertility and productivity if not addressed.

Dramatic decreases in the usage of chemical fertilisers in Ireland in recent years are reported in the Fertiliser Use Survey from 2004 to 2008, recently published by Teagasc (Lalor *et al.*, 2010). The analysis is based on Teagasc National Survey data for the period 2004 to 2008. Decreasing fertiliser usage during this period might have been expected due to nutrient regulations, increasing fertiliser prices, and declining farm product prices. On the face of it, decreasing fertiliser usage could be interpreted as a positive development, as it implies more efficient use of nutrients, representing reduced costs to farmers and reduced risk to the environment from nutrient surpluses. However, the role of fertilisers in the development and maintenance of balanced fertility levels in soils is essential, and remains a key concern in the future.

Major findings

The data on national fertiliser consumption (DAFF, 2009) show a steady decrease in the usage of fertiliser on a national level in recent years (Figure 1). National fertiliser sales of nitrogen (N), phosphorus (P) and potassium (K) decreased by 20, 40 and 37%, respectively, between 2003 and 2008. The total national usage of fertiliser P and K has decreased to 1950s levels, while N fertiliser usage has not been so low since the early 1980s (Murphy and Heavey, 1969; Murphy *et al.*, 1997; Coulter *et al.*, 2005).

There was a larger decrease in fertiliser usage on grassland than on tillage crops. The average usage of fertiliser nutrients applied to grassland in 2008 was estimated at 86, 5 and 14kg/ha for N, P and K, respectively. The mean N usage was 30% lower than that estimated for 2003. There has been a 55% decrease in P usage, and a 48% decrease in K usage since 2003. The decrease in usage of all nutrients was higher on grazed swards than on silage swards (Table 1).

The types of fertilisers used for grassland showed a continuing trend towards relying on high N fertiliser compounds (e.g., [N-P-K] 24-2.5-10 and 27-2.5-5) rather than high P, K compounds (e.g., 0-10-20 and 0-7-30) to supply the P and K for both grazed and cut swards. The dependence on straight N fertilisers (CAN and urea) has also increased. This has resulted in the relatively larger decrease in the usage of P and K than of N. This trend was also noted in previous surveys.

The average fertiliser usage over all cereal crops was 137, 20 and 48kg/ha for N, P



The usage of fertilisers, particularly of nitrogen, on grassland is highly dependent on stocking rate.

and K, respectively, representing a decrease in the usage of all three nutrients, by 10% for N, 20% for P, and 14% for K. The fertiliser usage on each individual cereal crop was lower on every cereal crop type, with the only exceptions being N on malting barley, and N and K on winter oats. The fertiliser N, P and K usage on the major tillage crops, and the percentage change in usage since 2003, are shown in Table 1. Fodder beet and forage maize were the only crops in the survey that showed an increase in all nutrients applied in 2008 compared with 2003. Comparing fertiliser usage in 2008 with Teagasc nutrient advice showed that usage rates were generally lower than advised rates for almost all crops, particularly in the case of P and K. For example, the K usage rates on cereals crops were typically only approximately 60% of the rates advised. This indicates that farmers are relying more on soil P and K reserves to sustain crops, and are not fully replacing the nutrients being removed in crops. While this may be possible and will save money in the short term, it will lead to reduced soil fertility levels in the future.

Consequences of reduced fertiliser usage

The decrease in fertiliser usage was particularly apparent on grassland. The usage of fertilisers, particularly of N, on grassland is highly dependent on stocking rate. A crude estimate of the change in stocking rate between 2003 and 2008 based on organic N excretion equivalents and average numbers of the main categories of cattle and sheep showed a decrease in livestock numbers of 7% (CSO, 2008). The decrease in N usage of 30% seems high relative to this decrease in livestock numbers. This indicates that improvements in the efficiency of N utilisation are being achieved by farmers. Increased efficiency on farms means cost savings for farmers, and reduced risk of losses to the environment.

While the extent of this decrease was more dramatic on grassland than on tillage crops, the overall tendency towards reduced fertiliser inputs may have both positive and negative consequences in the future. While reducing nutrient surpluses in farm systems may be desirable in order to reduce the impact of agriculture on the rural environment, nutrient deficits will eventually compromise soil fertility levels, potentially restricting crop and animal performance.

The reduction in nutrient usage may be due to a number of factors in operation during this period. The improved efficiency of nutrient recovery from animal

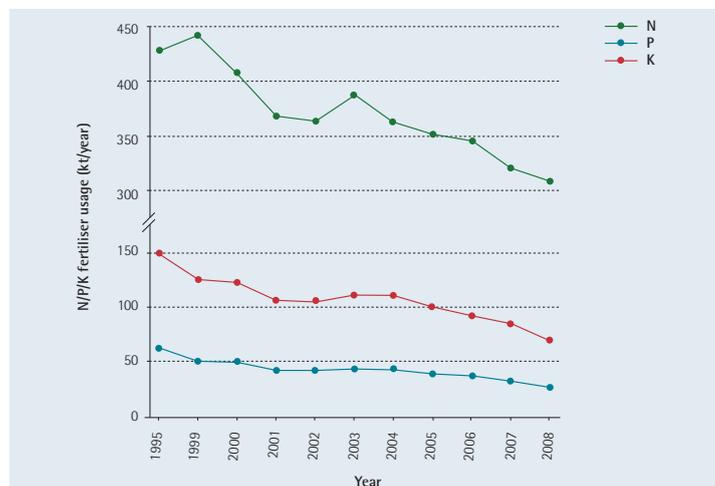


FIGURE 1: National usage of N, P and K fertiliser in Ireland from 1995 to 2008 (DAFF, 2009).

manures; increasing costs of fertilisers; decreasing product prices and farm income; and regulation of nutrient usage have probably all influenced nutrient usage during this period. While reduced fertiliser usage is a positive step in reducing costs to farmers, it should not be done at the expense of soil fertility and the future production capacity of soils.

The decrease in P and K usage is a particular cause of concern. Higher application rates were advised and adhered to in the past in the context of low soil fertility levels, and hence nutrient requirements were often in excess of crop uptake demand in order to correct and balance soil fertility levels. The increased fertility levels of a proportion of Irish soils in recent decades are a reward for these historic applications. As soil fertility has increased, the emphasis in nutrient advice and nutrient efficiency has become more focused on the guiding principles of: (i) balanced nutrient supply in accordance with crop-specific demands; and, (ii) soil fertility maintenance at agriculturally optimal and environmentally sustainable levels. It is appropriate to try to exploit the P and K reserves in our Index 4 soils. However, allowing Index 3 soils to fall into Index 2 and 1 must be avoided.

Getting the right balance

To maintain soil fertility, the agricultural system needs to be in balance, whereby nutrient removals are balanced by nutrient inputs. Recent estimates of national nutrient balances are scarce. In the case of P, Tunney (1990) estimated that the total P output for agriculture in 1988 was approximately 31kt. While a more recent estimate of national P balance combined with an assessment of trends in soil P levels is necessary in order to judge the current situation, this estimate indicates that some attention to maintain fertiliser input rates will be necessary in order to maintain soil P fertility in the future. The trend towards decreased K usage has followed the trend of decreasing P usage, largely because of the association between these nutrients through the various compound fertilisers commonly used. In summary, the reduced costs on farms arising from reduced fertiliser inputs is a major benefit to farmers, and may indicate that improvements are being made in how efficiently farmers are utilising nutrients on farms. However, ensuring that soil fertility levels are sustained and balanced into the future remains a key concern.

Table 1: Fertiliser usage on grassland and tillage crops in 2008, and percentage change in nutrient usage since 2003 (in parenthesis).

Crop	N	P	K
	kg/ha (% change from 2003)		
Grazing	65 (-38%)	3 (-63%)	9 (-50%)
Silage	101 (-16%)	7 (-46%)	24 (-41%)
Grassland overall	86 (-30%)	5 (-55%)	14 (-48%)
Winter wheat	179 (-12%)	19 (-17%)	52 (-5%)
Spring wheat	139 (-9%)	20 (-17%)	49 (-8%)
Winter barley	163 (-2%)	25 (-17%)	64 (-10%)
Spring barley	118 (-4%)	21 (-19%)	45 (-18%)
Malting barley	117 (4%)	16 (-20%)	48 (-9%)
Winter oats	141 (2%)	23 (-12%)	51 (6%)
Spring oats	75 (-34%)	11 (-56%)	23 (-53%)
Cereal crops overall	137 (-10%)	20 (-20%)	48 (-14%)
Forage maize	152 (30%)	41 (52%)	96 (57%)
Fodder beet	155 (20%)	51 (6%)	184 (14%)
Potatoes	93 (-19%)	73 (-28%)	170 (-24%)
Root crops overall	106 (-24%)	46 (-21%)	138 (-18%)

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Field margin biodiversity: wildlife on the edge

ROCHELLE FRITCH and colleagues explain how to establish species-rich field margins to create a place for biodiversity in intensive farmland.

Halting the loss of biodiversity by 2010 has been a priority environmental objective for the EU (and the Common Agricultural Policy) over the last decade; however, recent assessments indicate that this target has not been met and the EU is now strengthening its policy framework to halt biodiversity loss. This will likely prioritise increased conservation efforts for High Nature Value, but will also focus on restoring habitat areas outside of designated areas and in more intensively managed landscapes. Habitats within intensively managed landscapes provide undisturbed breeding and feeding areas for many species specially adapted to farmed conditions, and they also improve the ability of the landscape to connect wildlife across different habitats. Within intensively managed grassland, the protection and/or creation of field margin habitats offers one such restoration option to improve farmland wildlife. A major research project at Teagasc Johnstown Castle, funded by the Department of Agriculture, Fisheries and Food's (DAFF) Research Stimulus Fund, has focused on the development of a targeted, practical measure to increase the wildlife value of grassland field margins.

Why is biodiversity important on Irish farms?

The myriad of invertebrates, insects, worms, microorganisms and fungi that make up the vast bulk of biodiversity together perform vital functions that sustain the productivity of farmland. They mediate soil fertility, control pests, pollinate crops and recycle animal manures into soil nutrients. The function of biodiversity is important economically to Irish agriculture. For example, pollination by wild bees is estimated to be worth €85 million per year to the Irish economy. Measuring biodiversity is difficult but it is well known that farmland birds, such as the grey partridge and the yellowhammer, have declined sharply. Widespread declines of wild bees and butterflies are also well documented.

Field margins for biodiversity

Field margin habitats such as hedgerows, ditches and banks act as 'island' refuges in a 'sea' of intensive agriculture. These habitats maintain populations of wild plants and animals in the countryside and may facilitate the movement of wildlife through the landscape. In an Irish context, field sizes are relatively small, generally around four hectares. The establishment of large, long margins along entire field edges results in the loss of a relatively large proportion of productive area, and at the same



Wildflowers in sown experimental field margin plots.

time may not be the most efficient approach to creating sustainable field habitats. In this study, we explored the benefits of the alternative approach of creating fewer but wider margins on the farm. In this approach, resources are focused on areas with the greatest chance of successful field margin establishment. The three questions that this project aimed to address were:

- will desirable wildflowers re-establish naturally from the soil 'seed bank'?
- what width of field margin is best for wildlife?; and,
- what is the persistence of sown wildflower seed mixtures?

We compared three methods of field margins establishment at the dairy farm at Johnstown Castle: fencing of existing vegetation; rotavation followed by natural regeneration; and, rotavation followed by seeding with wildflower mixture. Two sward management methods were tested: grazing with the adjoining paddock or mowing annually in September. In addition, we tested the effect of margin width (1.5m, 2.5m and 3.5m) on wildlife abundance and persistence. Success of establishment was measured in terms of persistence of wildflower species richness, absence of noxious weeds and enhancement of insect diversity. We measured insect diversity within grassland field margins using a suction sampler, which acts like a large vacuum to collect insects from the vegetation.

To seed or not to seed?

On intensively managed farms, there may be few naturally occurring wildflowers remaining in the field or in field margins. The wildflower seed bank of dormant but viable seeds in soils can also become depleted over time. Our results showed that, on the dairy farm at Johnstown Castle, restoration of wildflower-rich grasslands was limited by seed availability; therefore, the addition of wildflower seed was required to re-establish plant diversity. 'Minimal change' management approaches currently adopted in agri-environmental schemes, such as withholding fertiliser inputs or simple fencing, did not achieve field margin swards of conservation value. We found that sowing seed mixtures produced the highest species richness and wildflower abundance in field margins over the seven-year experiment (**Figure 1**). Only appropriate native wildflower species from Irish seed sources should be considered and it is vital to match appropriate plant species with soil moisture conditions and fertility. On less intensive farms, where native species are available in the landscape,



The myriad of invertebrates, insects, worms, microorganisms and fungi that make up the vast bulk of biodiversity together perform vital functions that sustain the productivity of farmland.

plant biodiversity may be enhanced by fencing field margins during the growing season. This measure has been incorporated into the DAFF's Irish Agri-Environment Options Scheme (AEOS).

Width of margins is key

Our research found that wider margins promoted a higher abundance of wildflowers in sown margins, while reducing the amount of noxious perennial weeds, such as docks, thistles and ragwort. These results are important, as abundance of wildflowers within a sward is an indicator of the conservation value of the sward. A reduction in the amount of noxious weeds is highly desirable and reduces the need for weed management. New agri-environment measures for intensive grassland should target field margins with shorter overall lengths, but with greater widths. Thus, instead of putting narrow field margins on all fields, the establishment of wide margins on a few target fields should be given consideration.

REPS measures have prohibited the use of herbicide and fertiliser within 1.5m of field boundary features. While this is essential to protect plant biodiversity in existing field margins, our results found that it had limited value in terms of enhancing botanical diversity in low-diversity grassland swards over a seven-year period.

Increased insect diversity

To measure insect diversity, we used parasitic wasps as indicators of overall insect diversity. These wasps are a highly diverse group, with over 3,000 species occurring in Ireland. Each type of parasitic wasp can only develop in or on a specific insect or group of insects; therefore, diversity of parasitic wasps indicates the total insect

Main findings

- Field margins sown with a wildflower mixture had the highest plant diversity.
- Wider sown field margins supported a greater abundance of wildflowers and fewer noxious weeds.
- Cessation of nutrient inputs alone is not sufficient to restore plant diversity in intensive grasslands.
- Exclusion of grazing from field margins during the growing season increased insect diversity.

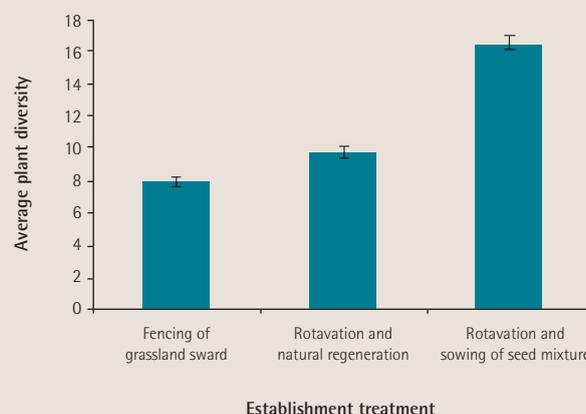


FIGURE 1: Effect of method of field margin establishment on plant diversity over a seven-year period.

diversity. We found that parasitic wasp diversity was higher when grazing was removed during the growing season. This can be explained by the fact that removal of grazing during the growing season allows vegetation to develop and form a more complex architectural structure, creating diversity of micro-habitats, which in turn facilitates insect diversity. Insect diversity was unaffected by the method of margin establishment.

The outcomes of this research suggest that targeting field margins with shorter overall lengths, but with greater widths, has benefits from both a biodiversity and financial viewpoint. Shorter, wider margins reduce the length and, hence, the cost of fencing required. In improved grasslands that have lost their native seed bank, sowing a wildflower seed mixture and exclusion of grazing during the growth season are required to enhance diversity. However, where appropriate native seed sources are available in the field margin and landscape, exclusion of grazing during the months alone may offer these benefits and research is currently ongoing to address this issue. Follow-up investigations at Johnstown Castle are evaluating the use of wide corners instead of linear field margin strips. If these corners prove to be equally beneficial to biodiversity, this would allow farmers to target field corners, further reducing fencing lengths and increasing ease of management.

This project was funded by the Department of Agriculture, Fisheries and Food under the National Development Plan 2006 Research Stimulus Fund.

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Soiled water is typically land-spread.



Soiled water is produced on dairy farms through the washing down of milking parlours and holding areas.

Positive management options for dairy soiled water

Researchers at Teagasc's Animal & Grassland Research and Innovation Centre at Moorepark, in collaboration with NUIG and UCD, are investigating alternative management options for dairy soiled water to maximise nutrient recovery and minimise risks of nutrient loss to the environment.

Soiled water is produced on every Irish dairy farm through the washing down of milking parlours and holding areas. This water contains faeces, urine, parlour washings and spilt milk. Like slurry, soiled water contains nutrients that are potentially available for herbage production, so that land application can supply some of the fertiliser requirement for grass growth. Nitrogen (N) availability from soiled water may be greater than from more concentrated slurries due to more rapid infiltration and, therefore, decreased ammonia losses. Indeed, many farmers report a grass growth response following soiled water application. Therefore, soiled water can potentially replace some of the mineral fertiliser requirement on dairy farms. This becomes increasingly important given recent fluctuating fertiliser prices, the need to cut production costs, and constraints on fertiliser use under the EU Nitrates Directive (91/676/EEC).

However, as with slurry, poor management can lead to losses of nutrients to the environment that can contribute to contamination of groundwater, eutrophication of surface waters, emission of greenhouse gases (nitrous oxide) and acidification. There has been some study of nitrate leaching from dairy soiled water in Ireland, but there is limited information on soiled water composition, production, management, nutrient availability and nutrient loss risks under the terms of the 'Nitrate Regulations' (Statutory Instrument 101 of 2009). The regulations require a ten-day storage capacity, limiting application rates to 50,000l/ha over six weeks and requiring farmers to take all reasonable steps to minimise soiled water production. Unlike slurry, there is no closed period for

spreading and the nutrient content is not accounted for in nutrient management. Currently, most farmers treat soiled water as waste and apply it to grassland as a means of disposal, without accounting for its nutrient content. Therefore, a collaborative research project involving Teagasc, University College Dublin and the National University of Ireland, Galway, is being undertaken to characterise soiled water and its management on Irish dairy farms, and to investigate management options.

Soiled water production and characteristics

Sixty dairy farms were surveyed across 18 counties in this study. The volume and composition of soiled water was monitored monthly, and farm systems and soiled water management practices were characterised. On average, 10,000l of soiled water were produced per cow per year. There was limited storage capacity on the farms analysed (mean tank size 66m³), so it was generally land-applied within three to four weeks. Mean storage capacity was 33 days. The Nitrate Regulations stipulate an upper threshold of 2,500mg/l biological oxygen demand (BOD) or 1% dry matter (DM) content for such wastewaters to be considered soiled water and not slurry. Seventy-one percent of samples were below the threshold for BOD and 88% for DM content. It is notable that the period of lowest soiled water production (in the winter months when most dairy cows are dried off) coincides with the period of highest risk of nitrate leaching. This is the opposite of the case for slurry, which is generated during winter housing. This temporal pattern simplifies management relative to slurry.

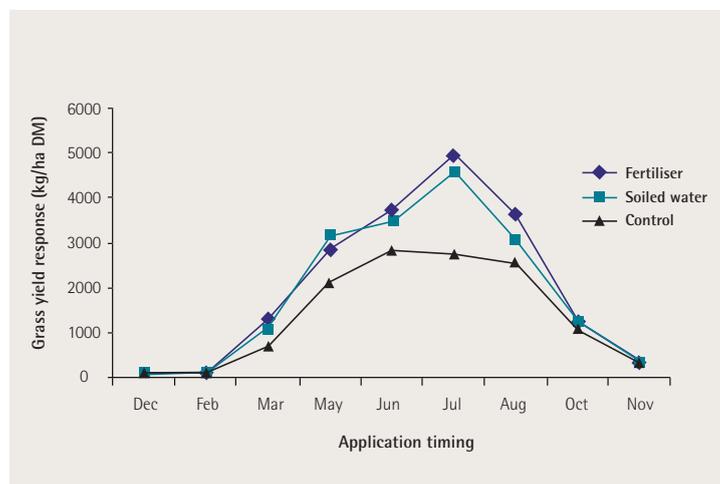


FIGURE 1: Grass dry matter yield response (eight weeks growth) to soiled water or fertiliser applied at six-week intervals over a year at Moorepark.

Mean total N (TN) concentration was 587mg/l, equivalent to 0.6kg/m³ N, in contrast to the 5kg/m³ N assumed for cattle slurry in the Nitrate Regulations. Roughly one-third is rapidly plant-available NH₄-N and the balance is mostly organic N. Mean phosphorus (P) content was 80mg/l and K was 568mg/l. Therefore, soiled water represents a potentially significant source of nutrients. The 10,000l produced per cow per year could supply 6kg of N, 6kg of potassium (K) and 0.8kg of P. However, quantities and concentrations varied widely and this presents a challenge for nutrient management.

Management strategies for soiled water

Two management options are being investigated. The first is application to grassland. The second is treatment with a woodchip filter to remove organic matter and nutrients, followed by re-use of water to wash down yards and eventual land application of woodchips. The focus of both management strategies is to recycle nutrients and/or water as efficiently as possible while minimising environmental losses.

Application to grassland

A field plot experiment was carried out to assess the fertiliser potential and nutrient availability of soiled water when applied to grassland. Experiments were laid out on two contrasting soil types: a free-draining acid brown earth and a poorly drained gley soil. Application timing (season), rate (0, 15, 22, 30kg N/ha) and concentration of soiled water are being investigated for their effect on grass growth and N uptake. Preliminary DM yields indicate that soiled water, while less effective than fertiliser N, offers a potentially significant source of nutrients for grass production (Figure 1). Cumulative yield response to soiled water over the whole year was between 60 and 90% that of fertiliser N. Therefore, soiled water would appear to have a high fertiliser replacement value and it may be beneficial to incorporate N in soiled water into farm nutrient management planning.

Filtration through woodchip

Laboratory woodchip filters (30cm in diameter and 0.5m, 1m and 1.5m in height) were constructed to test their potential for treating soiled water. Two concentrations of soiled water were applied: 210mg/l TN and 500mg/l TN. The

hydraulic loading rate was 28l/m²/day. There were three replicates of each treatment and height. Results suggest that woodchip filters are effective. Substantial removal of TN (92% at high concentration and 90% at low) and chemical oxygen demand (COD) (94% at high concentration and 92% at low) was found. Woodchip filters appear to have potential for treating soiled water so that it can be re-used to wash down yards. Farm-scale woodchip filters have been constructed at Moorepark to test effectiveness and feasibility. Filters are 10x10m in area and 1m deep. There are three replicates, each designed to treat soiled water from 100 dairy cows. Initial results are positive. Sand filters and lime are also being investigated as secondary treatments to further clean the water.

Assessing risks of loss to the environment

The risk of nutrient loss to the environment from soiled water applied to grassland is also being investigated using soil lysimeters. A lysimeter is an isolated column of soil that allows drainage water to be collected and analysed. Lysimeters have been established using the same two soils of contrasting drainage as were used in the plot experiment. Intact soil cores (30cm diameter by 70cm depth) were extracted and installed as lysimeters at Moorepark. There are four treatments, consisting of a control receiving no soiled water, and soiled water applied at the maximum legal rate (50,000l/ha every six weeks) at three different time periods (May to August, September to December and January to April). The optimum time (season) for soiled water application to minimise pollution risks is being investigated. There are four replicates of each treatment, giving a total of 16 lysimeters per soil type. Mineral fertiliser N is being managed on all lysimeters so that they all receive the same total N application over the year (200kg/ha N), replicating realistic farming practice. N and P losses in drainage and emissions of nitrous oxide are being measured.

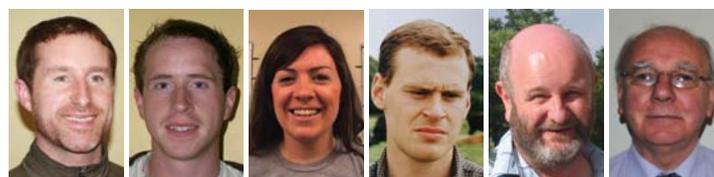
Further research and benefits to industry

The final stage of this project will involve an economic and environmental assessment of a range of management options for soiled water. Recommendations for best management practices will be made in due course.

Acknowledgements

This work has been funded by the Research Stimulus Fund of the Department of Agriculture, Fisheries and Food.

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The development of a potential forest productivity map for Ireland

Targeting certain soils and land with previous agricultural usage will result in increased forestry production, increasing profitability and competitiveness for growers, not to mention increases in carbon sequestration capacity and energy supply into the future. NIALL FARRELLY, MICHAEL BULFIN and TODDY RADFORD explain the development of the national forest productivity map.

Irish Government support measures for the establishment of new forests have seen a dramatic rise in afforestation in the private sector, increasing from 100,000ha in 1981 to 339,000ha in 2009, and now representing 45.5% of the total forest estate in Ireland. Annual planting is predicted to grow to 10,000ha per annum over the period 2007–2013, with the overall aim to develop the forest sector to a scale and in a manner that maximises its contribution to national economic and social wellbeing on a sustainable basis, and which is compatible with the protection of the environment. In this context, the development of a national forest productivity map can serve to guide forest policy so that productivity is maximised in a sustainable manner. The role of highly productive forests planted since 1990 has resulted in forests sequestering some 2.1 million tonnes of CO₂ per annum during the first Kyoto commitment period (2008 to 2012), predicted to almost double in the period to 2020, with the contribution of forestry to the national energy supply potentially increasing from 0.8PJ (peta joules) in 2006 to 2.6PJ in 2020, all indicative of the potential future contribution of forestry to climate change and energy needs. The forest soils and productivity study undertaken by Teagasc has succeeded in identifying preferred areas for forestry development, where increases in forestry productivity can be achieved, resulting in increased profitability and competitiveness, and ensuring that forestry will play a further significant role in meeting national and international targets in the future.

Forest survey

A national productivity survey examined over 600 sample plots of Sitka spruce (the reference species) located across a broad range of soil types throughout Ireland. On each site the performance of the crop was measured by assessing the height growth and age of trees to calculate the general yield class of the crop.

Soils sampled in the field were re-classified into the national soils classification, used in the production of a national soils and subsoils classification project based in Teagasc, Kinsealy, Dublin (see article on p 40). Production figures for each soil class were provided across a range of 150m elevation intervals and for different vegetation types on peat soils.

Good production on Irish soils

Results of the survey indicate that the productive potential of Sitka spruce in Ireland is very high, with average yield classes for all soils ranging from 12 to 26m³ha⁻¹yr⁻¹. The most productive stands (>24m³ha⁻¹yr⁻¹) of Sitka spruce occurred on free draining grey-brown podzolics and calcereous brown earths. Production on acid brown earths and brown podzolics was also high. Average production on marginal agricultural soils was also impressive; average yields were in excess of 20m³ha⁻¹yr⁻¹ on gley soils and cutaway basin peats. Results also indicated that the potential of forestry production was increased on land with some form of previous agricultural usage.

Mapping productive potential

A forest productivity model based on soil type, elevation class and habitat type was applied in a geographic information system (GIS). Digital datasets of the national soils classification map, digital elevation model and a habitat map were combined to create a new productivity surface on which the productivity model was applied (Figure 1). The map was then classified into productive and non-productive areas (rock outcrops, etc.); productive areas were then classified into yield class designations of 2m³ha⁻¹yr⁻¹ to create a national forest potential productivity map (Figure 2).

Benefits to the forest industry

The development of the forest productivity map provides an indicative assessment of the potential of forestry in any particular region and can be used as a tool for locating new forestry development in order to achieve maximum productivity. It will aid in increasing the contribution of forestry to meeting climate change, bioenergy and wood supply requirements. The productivity map is used as a key GIS layer in the Forest Inventory and Planning System (FIPS) by the Forest Service, Department of Agriculture, Fisheries and Food, in the development of an Indicative Forest Strategy (IFS) for forestry in Ireland. Further research is ongoing in Teagasc to look at the combined effect of environmental factors on forest production in order to identify factors that will result in increased forest productivity. Further refinement and information will increase our knowledge of forestry potential in Ireland.

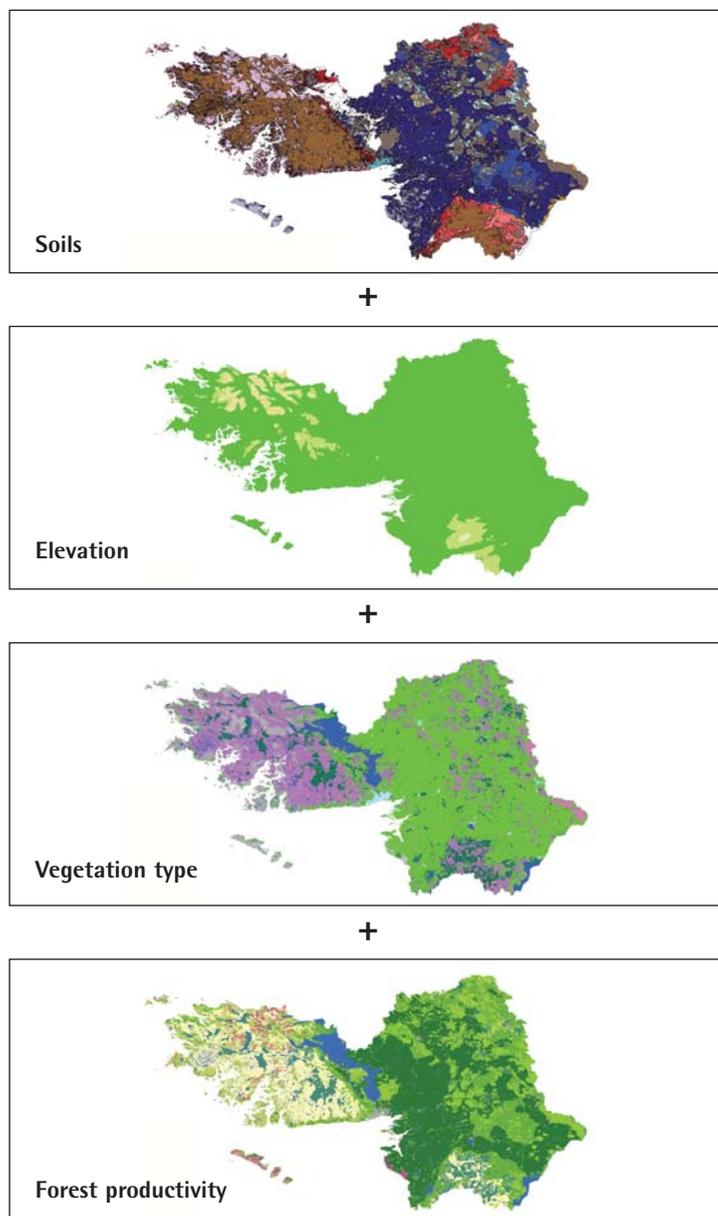


FIGURE 1: The development of the forest productivity map involves the merging of spatial datasets of soils, landcover and elevation in a GIS.

Acknowledgements

This study was funded by the Forest Service, Department of Agriculture, Fisheries and Food under the National Development Plan.

The authors would like to particularly acknowledge the members of the multidisciplinary project team, Mr Réamonn Fealy and Mr Stuart Green (Spatial Analysis Unit, Teagasc), Dr Monty Loftus, Dr Robert Meehan, Collette Cronin and Marie Doyle.

Thanks to Mary Ryan for provision of background information. Special thanks to Coillte Teoranta for access to forests to record growth data.

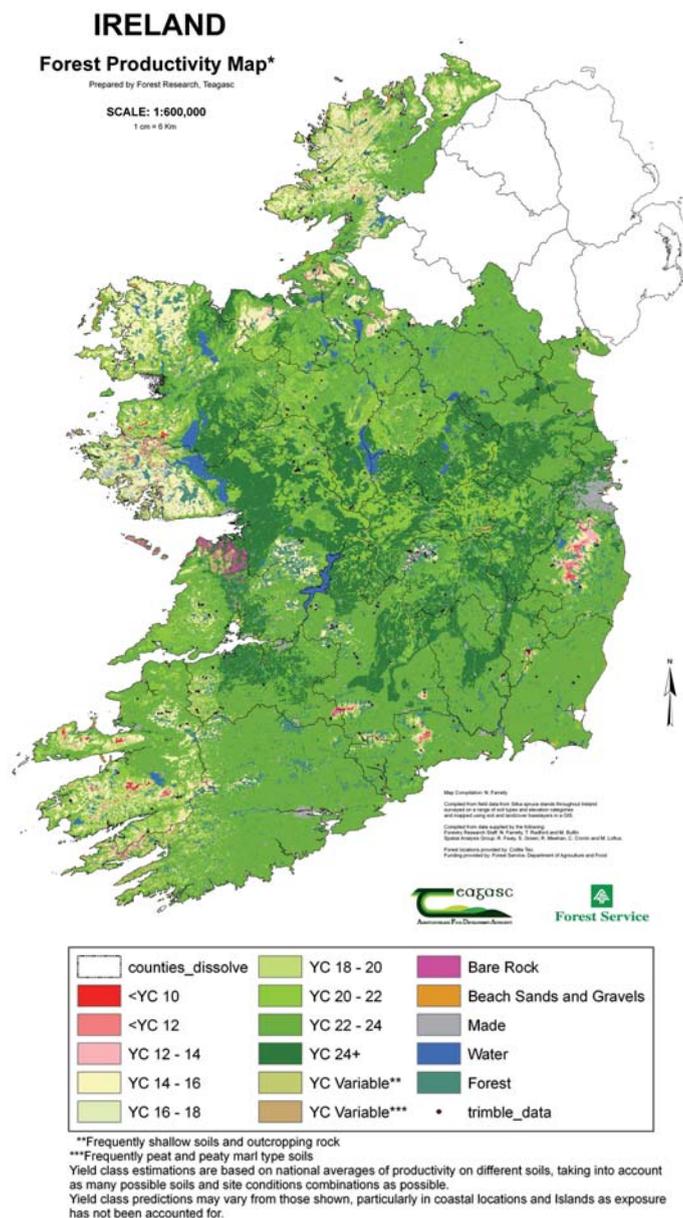


FIGURE 2: A map of potential forest productivity in Ireland.

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Feed utilisation: markers, proxies and components

Researchers at Teagasc Animal & Grassland Research and Innovation Centre (Grange and Moorepark) are developing improved techniques for estimating feed efficiency.

Feed costs

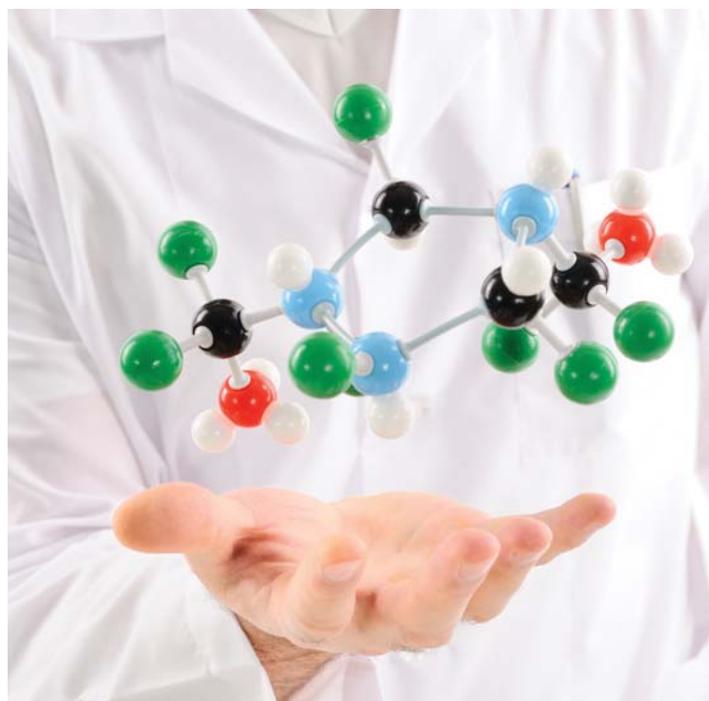
Feed represents 50-75% of production costs in pasture-based dairy and beef systems, and there is renewed interest in identifying animals that are more efficient at converting feed into milk or meat. A 1% improvement in feed conversion efficiency is worth around €30 million annually to the dairy and beef industries in Ireland.

Components of feed efficiency

Animal breeders have made substantial gains in feed efficiency through selection for increased production levels over the last century. Much of this gain has been attributed to so-called 'dilution of maintenance', in which the daily maintenance costs of animals are divided among greater daily production. While there is scope for further 'dilution of maintenance', attention is turning to efficiency gains at a given level of production. A wide range of animal characteristics may contribute to increased feed efficiency (Waghorn and Dewhurst, 2007). These include differences in animal activity, immune responses, rumen function and digestive efficiency, as well as cell processes such as protein turnover and ion transport.

Difficulties of estimating feed efficiency

The major constraint to selecting for new traits such as feed efficiency is that animal breeders need measurements from many thousands of animals in order to introduce such new traits into breeding programmes. The same constraint applies when looking for genome-wide associations. Measuring feed efficiency is costly, laborious and prone to errors. In spite of these problems, some countries are investing very heavily in making these measurements. For example, a joint project between Australia and New Zealand is measuring feed efficiency in growing dairy heifers as a first step towards identifying efficient dairy cows. A further impetus



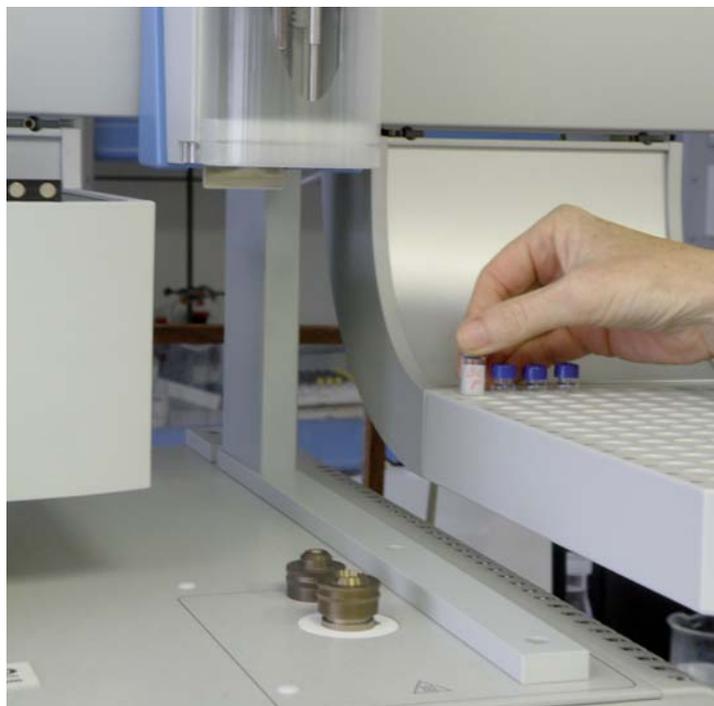
for work on markers that are easier to measure is the need for ongoing monitoring of traits that are incorporated into our breeding programmes.

New approaches to evaluate feed utilisation

Alternative approaches to study feed efficiency include breaking it down into components (e.g., using meters to monitor animal activity), using indirect estimates of energy expenditure (e.g., heart rate monitoring; infra-red thermal imaging), or the use of biochemical markers for processes that affect feed utilisation in the rumen or animal tissues. One approach being developed as part of the animal bioscience programme in Teagasc is the use of novel biochemical markers – one for the efficiency of converting feed protein into milk protein and another for energy losses as methane. Traditional animal science departments have been split between animal breeders studying few traits in many animals, and other scientists developing detailed knowledge about small numbers of animals. By developing marker approaches based on easily accessible samples we will be able to make measurements using the large numbers of animals, spread across the national herd, which will help to build efficiency into breeding programmes.

Previous experience with rumen markers

The impetus for developing a marker-based approach comes from previous experience with non-invasive methods to study rumen function. Rumen processes are fundamental to the success of ruminants in utilising fibre in forages, but they can also have profound negative effects in transforming protein and lipids. The efficiency of utilisation of protein in the rumen depends on achieving a balance of rumen degradable protein and available carbohydrates to maximise microbial protein synthesis (microbial protein synthesis should be maximised for efficient



A technician at Grange loads the GCMS instrument.

use of feed protein and energy). The early methods for estimating microbial protein synthesis in the rumen were difficult and prone to large errors. Alternative approaches to studying rumen function have been developed over the last 20 years, based on detailed measurements of 'markers' in samples that are easier to acquire – notably urine and milk. The most successful example of this type of marker has been the urinary purine derivative (PD) technique for estimating the flow of microbial protein from the rumen. Purine bases (adenine and guanine) are components of nucleic acids that are metabolised to PD (allantoin and uric acid), which are excreted mainly in urine. The main source of purine bases in the digesta flowing out of the rumen is in the nucleic acids of microorganisms, so there is a direct relationship with rumen microbial synthesis. Studies established relationships between the amount of microbial purine leaving the rumen and the excretion of PD in urine. A major constraint to the application of the urinary PD technique is the difficulty of collecting urine from cattle quantitatively over one or more days. While it is possible to use 'spot' samples of urine and evaluate ratios of marker compounds to creatinine (which is excreted at a predictable rate), this approach does increase errors. An alternative approach that has been used as a marker for a range of rumen function is to measure odd- and branched-chain fatty acids (OBCFAs) in milk, which are easier to collect and quantify. OBCFAs are distinctive components of microbial lipids and most are not found in feeds. A number of relationships have been identified between measurements of the rumen environment, as well as microbial protein synthesis and milk OBCFAs (Vlaeminck *et al.*, 2006).

N-use efficiency marker

The conversion of feed protein into milk protein is at the heart of a profitable and environmentally sustainable ruminant production system. Protein,

whether as meat or milk, represents the most valuable part of our products. The traditional way to measure this efficiency is to conduct a full nitrogen (N) balance study, which involves laborious measurements of all inputs and outputs from individually stalled animals. This approach also suffers from experimental biases, with a tendency to overestimate N intake and underestimate N losses. An alternative marker approach that is widely used is to measure urea concentrations in blood and milk. However, this approach does not distinguish between inefficiency in the rumen and tissues, and appears to be less reliable when dealing with high protein diets. We are investigating an alternative approach to assess N-use efficiency based on fractionation of naturally occurring nitrogen isotopes (^{14}N and ^{15}N). The fractionation occurs in certain biochemical pathways, notably deamination and transamination, as a result of the small mass difference between compounds containing ^{14}N or ^{15}N . The specific fractionation that interests us is the depletion of ^{15}N in urine and corresponding enrichment of ^{15}N in milk. This is a collaborative project with colleagues at Lincoln University (New Zealand) and will be described more fully in a subsequent article.

Methanogen marker

Methane losses from the rumen can represent up to 12% of gross energy intake and so represent a significant component of feed efficiency. Methane is also a potent greenhouse gas. Existing techniques to study methanogenesis, including the use of respiration chambers and the sulphur hexafluoride tracer method, are difficult to accomplish. Coefficients of variation in the range 15–25% have been recorded for the sulphur hexafluoride technique, highlighting the difficulty of achieving adequate replication.

We are investigating an alternative marker approach, based on the distinctive membrane ether lipids (such as archaeol) of the *Archaea*, the micro-organisms responsible for methane production in the rumen. This approach is analogous to our earlier work with urinary PD and milk OBCFAs, though in this case the marker is measured in faeces. This is a collaborative project with colleagues at Bristol University (UK) and will be described more fully in a subsequent article.

This research is funded by the Teagasc Core Programme, as well as an EU FP7 Marie Curie International Reintegration Grant – 'Nitrogen isotope fractionation as a marker for Nitrogen-use efficiency (NUE) in dairy cows'.

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Feed efficiency in suckler beef production

Researchers at Teagasc Animal & Grassland Research and Innovation Centre (Grange) are examining the potential for cost savings to farmers if feed efficient animals can be identified and selected for in a breeding programme.



The biological efficiency of producing beef from the suckler herd is relatively low with a very large maternal cost to production. For example, the cow herd accounts for approximately 85% and 50% or greater of the annual feed costs in suckler calf-to-weaning and calf-to-beef systems, respectively. Since about 70% of the total energy consumed by beef cattle goes towards maintenance requirements, this means that cow maintenance costs are a considerable proportion of the total feed costs of beef production systems. As feed is the largest single variable cost (70%+) in beef production, consequently, feed efficiency is central to economical and environmentally sustainable production systems.

Feed efficiency

Traditionally, feed efficiency was expressed as the ratio of weight gain to feed intake (feed conversion rate – FCR). However, because there is a negative genetic correlation between FCR and average daily gain and size in beef cattle, breeding selection programmes based on this measure lead to an increase in animal mature size. This means higher animal maintenance and feed requirements, with higher manure, methane and carbon dioxide production and greater associated costs. This has particular negative ramifications for the cow component of suckler beef production systems because of the proportionately higher costs associated with it. If an increase in the feed requirements of the breeding cow herd offsets the gains in growth efficiency, there will be no change in production system feed efficiency. There is evidence that individual suckler cow size has

increased over time. Consequently, improvements in efficiency in the entire beef production cycle (i.e., cow plus progeny) must be considered.

Residual feed intake

An alternative measure of feed efficiency that is genetically independent of growth and body size is residual feed intake (RFI). RFI is defined as the difference between an animal's actual feed intake and what its predicted feed intake should be based on body weight and level of performance. Therefore, efficient animals eat less than expected and have a negative or lower RFI value, whereas inefficient animals eat more than expected and have a positive or higher RFI value. In Irish beef bulls, the significant genetic variance and heritability (0.45) for RFI (Crowley *et al.*, 2010) suggests that selection of herd replacements from low RFI animals should permit the development of energy-efficient cows and offspring without increasing cow body size. Thus, because of its potential to improve both economic and environmental sustainability, interest in the RFI trait is increasing in the beef industry worldwide.

Phenotypic variation

For growing cattle, an animal's predicted intake is usually based on its weight and growth, and RFI is the variation in intake that remains after accounting for the requirements for maintenance and growth. Irish studies have shown that phenotypic variation (within breed type) for RFI in populations of growing beef heifers (McGee *et al.*, 2008; Kelly *et al.*, 2010) and suckler cows (Lawrence *et al.*,

Table 1: Productivity-related traits in pregnant beef heifers with low (bottom tertile) and high (top tertile) phenotypic residual feed intake (RFI) offered grass silage.

	RFI GROUP		Significance
	Low (efficient)	High (inefficient)	
Expected feed intake (kg DM/day)	7.8	7.8	NS
Actual feed intake pre partum (kg DM/day)	7.1	8.6	***
RFI (kg DM/day)	-0.7	+0.8	***
Live weight (kg)	559	565	NS
Daily live weight gain (kg)	0.46	0.46	NS
Body condition score (0-5)	2.9	2.8	NS
Ultrasonic fat depth (mm)	3.1	3.0	NS
Ultrasonic muscle depth (mm)	59.9	57.0	NS
Muscularity score (1-15)	5.8	5.2	*
Withers height (cm)	122	125	NS
Back length (cm)	116	113	NS
Pelvis width (cm)	52	52	NS
Chest depth (cm)	71	71	NS
Chest circumference (cm)	197	195	NS
Calf birth weight (kg)	43.8	44.7	NS
Calving difficulty (scale 1-5)	2.7	2.6	NS

Source: Lawrence *et al.* (2009) – Grange Beef Research Centre.

2009) is approximately 20%, and in pedigree beef bulls (Drennan *et al.*, 2005; Crowley *et al.*, 2010) is approximately 10% (Table 1). To date, our results indicate that there are no obvious negative associative effects on other economically important traits measured. Consequently, given the moderate heritability and lack of antagonistic relationships with other important traits, there is potential for cost savings to farmers if feed efficient animals (i.e., low RFI) can be identified and selected for in a breeding programme.

Variation in RFI

Even though differences among individuals have long been recognised, little effort has focused on the amount or causes of individual variation in efficiency of energy utilisation by cattle. Processes likely to contribute to variation in RFI are those associated with intake of feed, digestion of feed, metabolism, physical activity and thermoregulation (Herd and Arthur, 2009). Physiological mechanisms identified so far in the literature include body composition, feeding patterns, protein turnover, tissue metabolism and stress, heat increment of fermentation, digestibility, activity and other. However, this information is based on very few studies, some of which have used low numbers of animals.

There is very little information pertaining to RFI, and biological factors contributing to it, in cattle offered forage-based diets, especially grazed grass (the cornerstone of beef production in Ireland), and even less so in relation to the suckler cow where, arguably, RFI has the greatest impact. There is also a need for a better understanding of the relationships between feed intake and the

components of production at different phases in the animal's productive life. Finally, because the widespread measurement of feed intake and, as a consequence, feed efficiency, is precluded by the high cost of maintaining individual animal feed intake recording facilities, research is required to examine the relationship between RFI and markers (e.g., biochemical markers or genetic markers) of the trait (see article by our colleague Richard Dewhurst in this issue, p 34). In this context, a collaborative project between Teagasc and University College Dublin is examining the biological control of RFI in cattle, with a view to identifying some more easily measured indicators of the trait. Results to date have shown significant differences between efficient and non-efficient animals in the expression of genes controlling the synthesis of cellular energy. It is planned to further validate and exploit this information so that it could eventually be incorporated into the genomic selection programme currently being planned by the Irish Cattle Breeding Federation. Ultimately, this should facilitate the cost effective and early identification of genetically superior animals for feed efficiency and improve the long-term sustainability of the Irish beef industry.

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Milking the milk

When cows utilise more energy than they ingest, they are said to be in negative energy balance, and consequently compromise their own health as well as the type of fats they produce in milk.

As part of the EU study, RobustMilk, researchers in Teagasc's Animal & Grassland Research and Innovation Centre at Moorepark and collaborating EU institutes are developing techniques to routinely determine, at no extra cost, the energy balance status of cows and the relative proportion of different fats in the milk. The aim is to produce healthier milk from healthier cows.

In recent years, consumer concern over the impact of the food they eat on their own health and well-being has increased. Consumer concern over animal welfare in modern day dairy production systems is also growing. Consumers wish to consume high quality products from disease free, 'happy' and healthy animals. However, as dairy producers strive to increase milk production to meet revenue targets, there is often a consequential deterioration in product quality and animal health or robustness.

Bovine milk is often criticised as being a high fat product, yet many of the fats found in milk are actually beneficial for human health. In fact, bovine milk can be broken into two distinct groups of fats; saturated fats, which are deemed to be bad for human health; and, unsaturated fats, which are thought to be more favourable. For example, conjugated linoleic acid (CLA) is found in bovine milk and has been shown to have anti-carcinogenic properties. Dairy products only contribute about 15–25% of the total fat in the human diet; however, up to 35% of the total saturated (or bad) fat in the human diet arises from bovine milk fat. This is due to the relatively large proportion of saturated fatty acids found in dairy cow milk relative to the unsaturated fatty acids. In fact, the milk fat breakdown of the average dairy cow is approximately 70% saturated fatty acids (bad fats) to 30% unsaturated fatty acids (good fats).

RobustMilk project

The energy balance of an animal refers to the difference between the animal's energy intake and utilisation. Energy balance has long been considered an



important indicator of dairy cow health. Throughout lactation, energy balance status may change from negative (cow is utilising more energy than ingesting) to positive energy balance (cow is ingesting more energy than utilising). Not only does negative energy balance have implications for cow health and fertility, but it has also been shown that cows in negative energy balance produce an increased proportion of saturated fat in their milk.

RobustMilk is a European-wide project that brings together geneticists from six leading European agricultural research institutes, including Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark. The overall objective of the RobustMilk project is to use genetic and genomic tools to determine if we can breed cows to produce healthier milk for human consumption, while simultaneously ensuring that the cows producing the healthier milk are themselves healthy. Teagasc is the work package leader on developing phenomic tools to quantify animal robustness and product quality, as well as determining the impact of current selection practices on these characteristics.

How do we know if our cows are producing the right kind of fat?

Gas chromatography of milk samples in laboratories to determine the fat breakdown is costly and time consuming. As a result, the fat composition of milk is not routinely available. Currently in Ireland milk samples from over 400,000 milk recorded dairy cows are subject to mid-infrared spectrometry on average four times a year as part of a milk recording scheme. Bulk tank milk samples from Irish

dairy herds are also routinely subjected to analysis by mid-infrared spectrometry. Mid-infrared spectrometry involves shining a light source through the sample and the absorbance of the light at wavelengths within the mid-infrared range is determined. Because infrared spectroscopy exploits the fact that molecules absorb light at specific frequencies that are characteristic of their structure, our hypothesis was that analysis of the patterns of absorbance of light at different wavelengths may be used to determine the different types of fatty acids in the milk. The routine availability of infrared spectral data on all milk recorded cows implies that any favourable results obtained can be easily implemented into the national breeding programme at a minimal marginal cost. Milk quality at a herd level can be assessed by already collected bulk milk tank samples.

The experimental design involved collecting milk samples from cows of several dairy breeds including Holstein-Friesians, Jerseys, Normandes, Montbelliardes, dual-purpose Belgian Blues and Norwegian Reds from Ireland, Belgium and Scotland. A calibration dataset was created to develop algorithms to predict milk fatty acid content from the mid-infrared spectroscopy. The accuracy of prediction was determined in an independent dataset. In summary, the accuracy of predicting the saturated and unsaturated fatty acid content in the milk of 250 independent samples from Ireland and Scotland was 98% and 96%, respectively. The accuracy of separating the fatty acids into long chain, medium chain, or short chain fatty acids was greater than 90%. The accuracy of predicting the content of some individual fatty acids like C14:0 was high (91%), although it was lower for other fatty acids like C18:2 cis-9, trans-11 (67%). These results suggest that at least groupings of fatty acids can be accurately predicted using mid-infrared spectroscopy. Milk fatty acid content has already been shown to be heritable and to exhibit significant genetic variation, implying that breeding for improved milk fatty acid content will be fruitful. This research was lead by Gembloux University in Belgium.

Quantifying energy balance in dairy cows

Unfortunately, energy balance is also very difficult and expensive to measure. A true measure of energy balance can only be obtained in calorimetric chambers and therefore energy balance is predicted using measures or indicators of energy intake and expenditure. Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, is currently researching the potential use of mid-infrared spectrometry technology to also determine the energy balance status of cows at the time of milk recording. The ratio of fat to protein in milk is often used as an indicator of energy balance status. Since both fat and protein fractions of milk are predicted using mid-infrared spectrometry, it makes sense that the same technology could be used to predict energy balance directly without the accumulation of errors in the prediction process. Similarly, the fatty acid content of the milk changes depending on the energy status of the cow, and we now know that we can accurately predict milk fatty acid content from the mid-infrared spectrum.

Data from the Animal & Grassland Research and Innovation Centre at Moorepark, as well as the Crighton research farm in Scotland, will be used in this experiment. Although research into the prediction of energy balance from the mid-infrared spectrum has only recently begun, the initial predictive models developed show promise. The accuracy of prediction is not as high as for the fatty acids, but very high accuracies are not expected since energy balance itself, as defined in this study, is not exact. Instead, energy balance has been predicted using measures of intake and utilisation and so intrinsically contains error. Research on refining these prediction algorithms is continuing.



Teagasc, Moorepark, is currently researching the potential use of mid-infrared spectrometry technology to determine the energy balance status of cows at the time of milk recording.

Benefits to industry

Tools developed in this study are immediately applicable and can be implemented nationally at a low marginal cost. They have implications for both farmers and industry, including milk processors, breed societies and AI organisations. Teagasc and the Irish Cattle Breeding Federation (ICBF) are embarking on a new project to build a decision-support interface based on the results from this study to help farmers to make management and breeding decisions. Because the prediction equations can be applied to individual cow samples (>1.5 million samples annually), estimates of genetic merit for cows and AI bulls for different milk fatty acid type, and possibly energy balance, will be feasible. Milk quality will therefore make its way into the Economic Breeding Index (EBI) in dairy cattle. As well as facilitating management decisions at an individual cow level through individual milk samples, the developed tools can also be applied to bulk tank milk samples, facilitating herd management strategies as well as payment strategies for milk processors. Teagasc will also investigate the potential use of mid-infrared spectrometry at predicting other cow characteristics (e.g., cow disease), as well as developing prediction equations in the near-infrared region, which may lend itself more to in-line measurement.

The RobustMilk project is financially supported by the European Commission under the Seventh Research Framework Programme. The content of this article is the sole responsibility of the authors, and it does not necessarily represent the views of the Commission or its services (www.robustmilk.eu).

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Teagasc indicative soil and subsoil mapping

“I hope that my answer to your question is clearly indicated in what I have written. It is that the soil survey will never be completed because I cannot conceive of a time when knowledge of soils will be complete.”

So wrote a certain R.S. Smith, Director of the Illinois Soil Survey, in 1927. Smith was writing in response to the Comptroller of the University of Illinois when he was asked to make an estimate of how much it would cost to complete the soil survey of Illinois. In many people's minds, like the Illinois Comptroller, there is a perception that there is only one soil map of any country. They may expect that the path to the production of this National Soil Map simply involves the establishment of a survey, a field campaign to see what soils there are and the production of a map. However, nature has a way of mocking the attempts of man to order its sometimes apparent chaos. Confirmation of this is easily found in the literature describing soils in Ireland and the efforts of the National Soil Survey to find and ascribe some systematic classification to these (Culleton and Gardiner, 1985; Gardiner, 1972).

In truth there is no such thing as any one national soil map of any country but rather multiple possible representations of soils at various scales. In reality it could be argued that there is a requirement for as many maps as there are different applications and scales at which these are needed. The requirement for soil map data ranges from national to local plot or field levels and covers nearly the entirety of the scale range in between. In some cases, such as the assessment of carbon budgets, it could be strongly argued that the requirement crosses the scale range, as in a best case scenario carbon density would be measured at plot level and then scaled to national level for budget reporting.

The key challenge to the production of soil maps in Ireland derives from the history and nature of our subsoils, which have been moulded, mixed, churned, transported and deposited by the action of glaciers as they ebbed and flowed across the Irish landscape during successive Ice Ages. As soils are formed in most cases directly from these underlying glacial deposits, we have inherited an extremely complex suite of soil landscapes in Ireland. In a pattern previously reported by a number of authors, and that we have all too often seen confirmed during extensive field mapping across the country, it is common to find a range of soil types, classified at great group level, coexisting over short horizontal ranges.

Despite this inherent natural variability or, it could be argued, because of it, the role of traditional soil mapping has been to describe and map soils in a meaningful manner, appropriate to the intended application. The original target for the Irish Forest Soils project, which began in 1998 and was NDP-funded through the Department of the Marine and Natural Resources, was the construction of a forest productivity map of Ireland to enhance the planning of our national forest resource. At the outset of this project in 1998, only 44% of Irish soils had been mapped. Initially, the development of national soil mapping that infilled the missing 56% of land area without previous mapping was seen only as pre-requirement for the

construction of the productivity map. However, on completion of the national subsoils and indicative soils mapping (based on predictive modelling), the potential of these intermediate products was recognised and they came to be valued as useful products in their own right. In the last edition of *TResearch* (Spring 2010, p14-15) the landcover and habitat project outputs were described. Here we describe in summary the development of the subsoil and indicative soils maps.

Parent material/subsoil mapping

Most of the surficial sediments in Ireland, which form our subsoils, were deposited during the Quaternary period, which stretches from 130,000 years ago to the present. Most Quaternary sediments owe their genesis in one way or another to the action or melting of ice. The last glaciation occurred between 73,000 years ago and 10,000 years ago and Ireland has a very rich legacy of glacial deposits and landforms relating to this recent glaciation, comprising approximately 90% of Ireland's land area. The mapping of Quaternary-derived subsoils initially involved the integration of a number of suites of pre-existing Quaternary information. Subsequent map development incorporated an advanced technology toolset provided by digital stereo photogrammetry techniques, which facilitated the visualisation and mapping of the landscape in a 3D software and hardware environment. The subsoil boundaries were interpreted and mapped using dedicated high end photogrammetric workstations with digital stereo-pairs of black and white photography acquired at a scale of 1:40,000. Subsequent fieldwork was carried out, which concentrated on areas within the boundary zones between differing subsoil types. The field mapping allowed checking of the ground for areas mapped during the photogrammetric analysis, and was therefore crucial in refining mapped boundaries and increasing the accuracy of the maps.

Soil mapping/soil modelling

The mapping methodology employed in this project was analogous to the survey methods and development of the mental models of the traditional soil surveyor. Key soil forming factors such as vegetation (landcover) and geology (parent material) were mapped and an expert rule-based classification applied to these datasets to predict the soils that might occur at any given location in the landscape. The core technologies involved in this process were based on geographical information system (GIS) and remote sensing techniques. This application of a software-based expert classification approach to develop the soil mapping has proved extremely useful in formalising the knowledge of previous soil surveyors and facilitating its integration into a classification process for areas where no or little previous mapping existed.

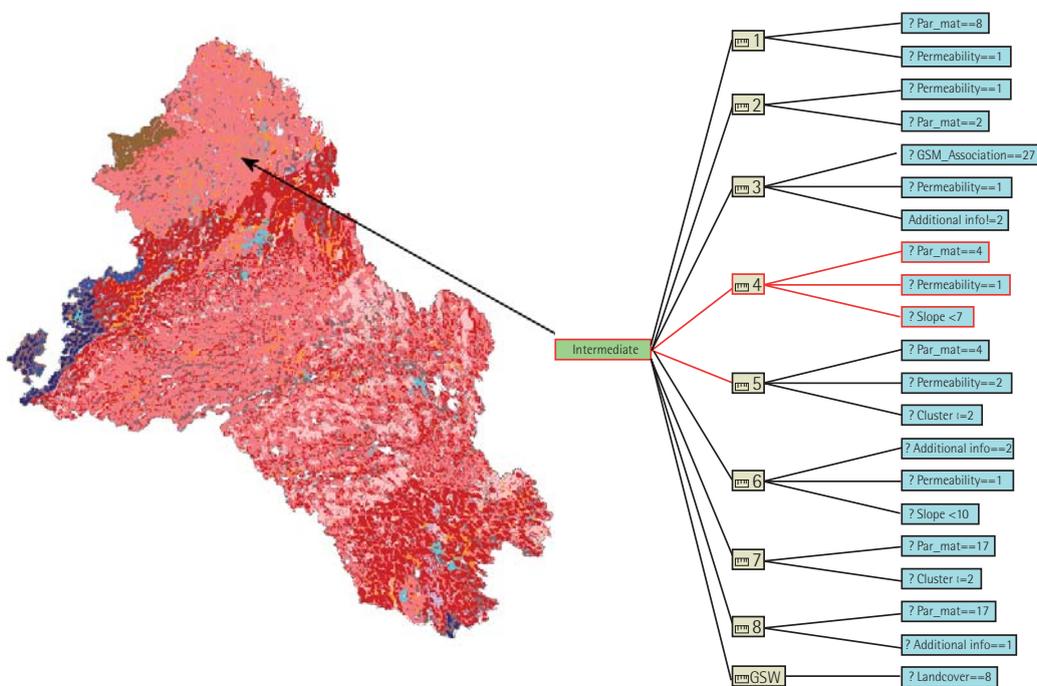


FIGURE 1: Application of the expert rule system highlighting a classification pathway in the knowledge engineer/classifier.

Production of the indicative soil map employed a classification scheme that differs from traditional soil survey classifications as used by the National Soil Survey in Ireland. A key difference is that the indicative soil map is based on a simplified classification of soil type and does not contain soil property information, which would have required soil sampling and laboratory analysis. The indicative soil maps are based primarily on a functional subdivision of soils. This is reflected in the legend, which differs from traditional legends used in soil mapping in Ireland, which employ the soil series (e.g., in Ireland, the Clonroche series among others...) as the basic unit of classification. Despite the differences, however, a key feature of the Irish Forest Soils classification scheme is that each of the classes has a very close relationship with the great soil groups that occur in Ireland. This classification scheme design facilitates broad level interpretation and comparison with previously mapped areas.

Benefits and further work

For the first time since the ending of the National Soil Survey in 1985, mapping now exists for areas in Ireland where previously the only map data available were highly generalised in nature. While the data products have been used in a range of applications to date, their primary importance is in serving as an extremely useful bridge between the pre-existing and incomplete mapping of Irish soils and the planned national map at 1:250,000 scale due for delivery by the Irish Soil Information System (ISIS) project in 2013.

In this manner, R.S. Smith's additional comment on the contribution that each generation of soil surveyors makes to their discipline provides a fitting conclusion: "Our expectation is that our successors will build on what we have done as we are building on the work of our predecessors".

Acknowledgements

The authors would like to particularly acknowledge the members of the multidisciplinary project team, Michael Bulfin, Dr Mortimer Loftus, Dr Robert Meehan, Colette Cronin, Marie Doyle and Niall Farrelly (Forestry Development Unit, Teagasc), and the many people who assisted in various ways towards the successful completion of this project. Funding was provided under the NDP through the Forest Service (DAFF) and Department of the Environment, Heritage and Local Government.

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Farm fatalities in Ireland

The incidence of farm accident fatalities in Ireland is rising with, until recently, a shift towards the older population. Researchers at Teagasc report on the changing demography of farm accident fatalities in the 1993 to 2009 period.



It is widely recognised that farming constitutes a dangerous occupation resulting in high levels of work-related injuries and fatalities.

It is widely recognised that farming constitutes a dangerous occupation resulting in high levels of work-related injuries and fatalities. A review of international studies concerned with farm fatalities found that there is a growing body of research covering the incidence and cause of injury and death among farm populations. Surprisingly, relatively little direct consideration has been given to the demography of fatalities. Where the age structure of fatalities has been considered, it is largely limited to the deaths of children on farms. While the emphasis on child injuries and deaths is not surprising, a major gap in our understanding of the age structure associated with farm fatalities persists in relation to the farm workforce.

This article looks at fatal accident trends using a five-year rolling average, using data made available from Ireland's Health and Safety Authority (HSA) covering the period from 1993 to 2009. The research aim is to analyse the relationship between age and farm fatalities. In the course of undertaking the analysis this article establishes the context of farm fatalities in Ireland. Data is presented describing the number of fatalities during the period and assessing how this has changed. The occupational fatality rate is then reported per 100,000 workers. The analysis moves to considering whether there is a relationship between age and fatal accidents. Finally, the article evaluates whether the age structure of fatalities has changed during the 1993 to 2009 period.

In the Republic of Ireland, the Safety, Health and Welfare at Work Act (1989) was introduced to modernise safety, health and welfare legislation and extend it to cover all work sectors including agriculture. It also provided a means of implementing the EU Framework Directive on occupational health and safety (89/391/EEC) and subsidiary directives, along with secondary legislative instruments by means of regulation and codes of practice. This legislation, which was modernised in 2005, makes it mandatory that all fatal workplace accidents are reported to the Health and Safety Authority of Ireland (HSA). The HSA is the national body with responsibility for overseeing health and safety at work. Their remit covers every type of workplace and every kind of work. Part of the HSA's

remit is to undertake or facilitate research that will assist in the improvement of their understanding of health and safety issues in the workplace.

In line with this remit the HSA made data relating to fatal incidences on farms available to the authors. The dataset contains the gender and age of those killed in farm accidents and the year and cause. These data were analysed using descriptive statistics to establish the incidence of farm fatalities in Ireland and how these have changed in recent years. As the number of fatalities is subject to considerable year-to-year fluctuations, a five-year moving average is applied to the data. This smoothes out such variation and allows the overall trend for the period to be discerned. The data were divided into two groups based on whether the victim was less than or aged 55 years and older. The odds and relative risk of experiencing a fatality were calculated. These analyses facilitated an assessment of whether the age profile of those dying in farm accidents has changed significantly during the 1993 to 2009 period.

Farm fatalities 1993 to 2009

In the period 1993 to 2009 there were 304 fatal accidents on farms in Ireland. The number of deaths varies widely from year to year, with 1995 recording the highest (25) and 2009 the lowest (11) number of fatalities. An analysis of the five-year moving average indicates that the number of deaths has consistently declined since the late 1990s. Comparative assessment of the change in the average number of fatalities from the highest level – 1997 to 2001 – to the lowest – 2005 to 2009 – indicates that fatalities have declined by 25%. However, this change took place against the backdrop of significant reductions in the numbers working on farms. Analysis of Census of Population data finds that the number of persons employed in the agricultural sector fell from 133,969 to 89,277, a decline of 33%, between 1996 and 2006. The number of persons employed in this sector stood at 89,500 at the end of 2009. These developments impacted on the fatality rate. In 1996, the rate stood at 15 per 100,000 workers, but this increased to 22 per 100,000 by 2009. This compares to two fatalities per

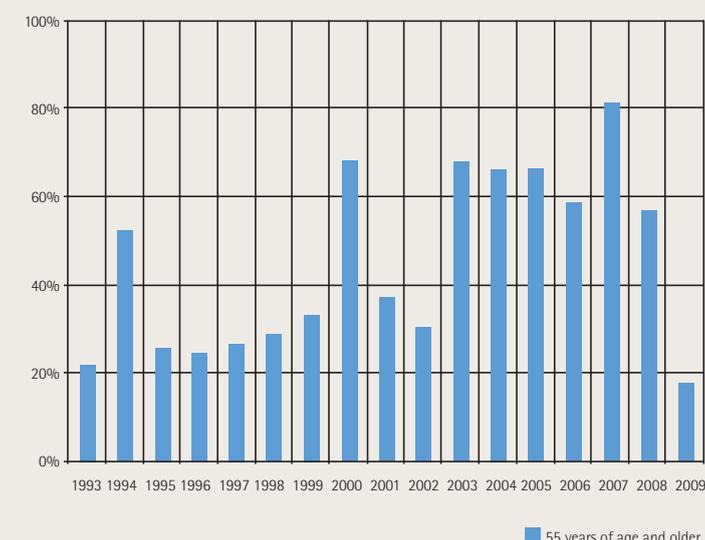


FIGURE 1: Number of farm fatalities on Irish farms over the 1993 to 2009 period.

100,000 in all other industrial sectors in Ireland. While the absolute number of fatalities in Ireland is small by comparison to the other countries, the fatality rate is comparable to those of Canada, the USA, Australia and New Zealand. In several European countries, the fatality rate is significantly lower. Great Britain (10.8), Germany (15.4), France (12.1), Italy (14.4) and Spain (4.2) all record fatality rates below those of Ireland. These data highlight the range of fatality rates recorded for the agriculture sector. It is notable that all of the European countries quoted have fatality rates below the Irish level. It is unknown why the fatality rates of the countries referred to above vary to the extent that they do. Comparing national fatality rates must be approached with considerable caution as different statutory reporting protocols prevail. Differences in how fatalities are defined for recording purposes will influence the fatality rate.

Changing demography of farm fatalities

Assessment of the age profile of farm accident victims indicates that fatalities are split between youth, those under 15 years of age, and those over 15 years of age. It is apparent from these data that there is a relationship between age and fatalities. Statistical analysis established that older farmers are more likely to die from farm accidents. Analysis was undertaken evaluating whether significant changes in the demography of those dying on farms between 1993 and 2009 has occurred. The data covers a period of 17 years. This is divided, on the basis of the total number of fatalities, between 1993 to 2000, and 2001 to 2009. Period 1 (1993 to 2000) accounts for 156 or 51% of all deaths, while Period 2 (2001 to 2009) accounts for the remaining 148 fatalities. Deaths of those less than 55 years of age accounted for 65% (97) of all fatalities in the first period. In the second period the proportion of fatalities accounted for by those less than 55 years of age fell to 45% of all deaths. Analysis establishes that, during the 1993 to 2000 period, a person under 55 years of age was twice as likely to be killed as a farmer 55 years of age and older. Between 2001 and 2009 this profile was reversed, with more farmers 55 years of age and older dying relative to Period 1. It is uncertain to what extent the



changing demography of fatalities is reflected in other countries as there appears to be relatively little published regarding this topic. As indicated in **Figure 1**, a trend of an increased proportion of fatal farm accidents among younger farmers has occurred since 2008. This was highlighted at a recent Teagasc/Institution of Occupational Health & Safety seminar (see www.teagasc.ie/news).

Conclusion

The changing demographic profile of farm fatalities in Ireland is related to a number of factors, including greater awareness of farm safety. This follows sustained promotion of the legislative requirement and higher health and safety standards and practices among farmers and farm households. Clearly this has contributed, with a fall in the number of deaths among younger cohorts. Unfortunately, these advances have been cancelled out by an increase in deaths of older farmers. Teagasc, as a member of the HSA's Farm Safety Partnership, will continue to provide research and training to farm households in an effort to reduce the incidence of fatal farm accidents.

This research is funded by the Teagasc Core Programme with data supplied by the Health and Safety Authority.

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T Events

JUNE

June 15 *Teagasc, Animal & Grassland Research and Innovation Centre, Grange*

Suckler Beef Day

Farmers will have the first opportunity to visit the new Suckler Beef Research Demonstration Farm "Derrypatrick Herd", which was set up in 2009. With an ambitious financial target of achieving a gross margin of €1,000 per hectare on the unit, the open day will provide an opportunity for beef producers from all over the country to examine and discuss the key technical steps for achieving this target.

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<http://www.agresearch.teagasc.ie/grange/researchfarms/sucklerdemo/updates/>

June 17 *Carlton Hotel, Tralee, Co. Kerry*

BioEnergy 2010 – Warming to Wood Energy

This conference is organised and presented by Teagasc, the Sustainable Energy Authority of Ireland and COFORD. One of the highlights of the day will be the study tour, providing the opportunity to visit a wood chip fuelled district heating system developed and managed by Tralee Town Council. The tour will also incorporate a visit to a local forest, demonstrating first thinning, the production and transport of wood chips, and processing of firewood to supply local markets. The conference is supported by a comprehensive technology exhibition, with Ireland's leading service and product suppliers showcasing the very latest in bioenergy innovation. At the same time the event will provide visitors with the perfect opportunity to get advice first hand from the experts actively involved in the wood energy and bioenergy sectors.

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www.teagasc.ie/forestry/events_diary/events/bioenergy_10.asp

June 24–25 *Mansion House, Dublin*

A Climate for Change: Opportunities for Carbon-Efficient Farming

Is the global debate on climate change a threat to Irish farming, or can we turn it into an opportunity? Can carbon-efficient farming give Ireland a competitive edge on the global food market? Which on-farm measures are practical and cost-effective in further improving carbon-efficiency on tillage, dairy and beef farms? These are the central questions being asked at this Teagasc Agri-Environmental Policy Conference.

Speakers include: Dr Hayden Montgomery, Senior Policy Analyst, NZ Ministry of Agriculture and Forestry; Dr James Humphries, Teagasc researcher, Moorepark Dairy Production Research Centre; Professor Pete Smith, Professor of Soils and Global Change, University of Aberdeen; and, Dr Philip O'Brien, Environmental Protection Agency.

This conference brings together scientists, policy makers, farmers, students and stakeholders to discuss first hand how we can transform the challenge of GHG emissions into an opportunity for Irish agriculture.

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June 26 *UCD Lyons Estate*

Sheep 2010

Sheep 2010 will take place in the UCD Lyons Estate research farm. The event is jointly organised by a number of the main service providers to the sheep industry including UCD, Teagasc, Sheep Ireland and Bord Bia, with the *Irish Farmers' Journal* the media partner for the day. It will comprise all of the different components that make up the national sheep industry in Ireland, in addition to several commercial exhibitors.

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JULY

July 7–8 *Teagasc, Food Research Centre, Ashtown*

Legal Labels Ireland – The essential guide to Irish food labelling

Legal Labels Ireland (presented by Leatherhead Food Research) is structured to function as a fully comprehensive review of current regulations and official recommendations. Presentations cover all major labelling considerations, including product-specific labelling for foods with compositional standards, nutrition and health claims, and new developments in general food labelling.

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SEPTEMBER

September 13–16 *Seven Oaks Hotel, Carlow*

EAPR Pathology Section meeting 2010 – Potato Pests and Diseases: Old Enemies, New Threats

The 2010 European Association for Potato Research Pathology Section meeting will be jointly hosted by Teagasc and the Agri-Food and Biosciences Institute (Belfast). The three-day meeting will deal with all aspects of potato pathology, with a special emphasis on new threats to potato posed by changes in the behaviour of existing pests and pathogens, as well as

by new species. The meeting will also include an excursion to the Teagasc Crops Research Centre in Carlow, home of the Teagasc potato breeding programme.

Speakers will include: Colin Fleming, AFBI Belfast, on 'Emerging nematode threats'; Jan van der Wolf, PRI, on 'New variants of *Dickeya* and *Pectobacterium* causing increasing problems with blackleg'; and, Lars Christoffersen, Head of Sector (Plant Health), Food and Veterinary Office, European Commission, on 'The importance of phytosanitary controls for sustainable potato production!'

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www.teagasc.ie/events/EAPRpathology2010

OCTOBER

October 14 and 15 *Silversprings Hotel, Cork, and
Teagasc Animal & Grassland Research and
Innovation Centre, Moorepark*

Grasses for the future: Perennial ryegrasses – current and future genetic potential

This is a unique opportunity for all stakeholders of the grassland industry (farmers, breeders, merchants, advisors, evaluators, scientists) to come together to discuss the future needs of the sector. The conference will focus on the livestock production requirements from perennial ryegrass as a feed source in temperate climates. The discussion on day one will focus on grass breeding and evaluation. Possibilities of influencing a more accelerated uptake of grass breeding progress at farm level will be explored. A workshop and site visits will take place on day two. This conference provides a unique platform for all stakeholders to participate in strengthening progress in the grassland sector. Visits to the Department of Agriculture, Food and Fisheries Crop Variety Evaluation Site at Ballyderown Farm and Teagasc Moorepark's Grassland Research Programme will take place following the workshop.

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NOVEMBER

November 7–14 *Nationwide*

Science Week 2010

Teagasc will host a series of Science Week events at its research centres nationwide.

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www.scienceweek.ie