


T Research

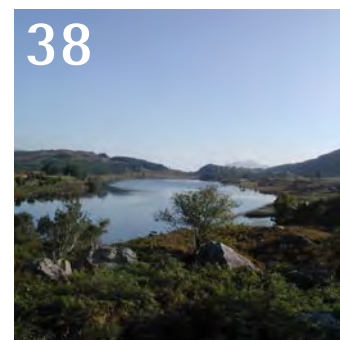
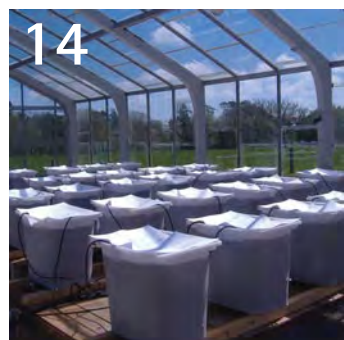
Research and innovation news at Teagasc

Molecular gastronomy



- The challenge of global food security
 - Reducing nitrogen loss using inhibitors
 - Shedding light on the milking routine
- 

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TResearch is an official science publication of Teagasc. It aims to disseminate the results of the organisation's research to a broad audience. The opinions expressed in the magazine are, however, those of the authors and cannot be construed as reflecting Teagasc's views. The Editor reserves the right to edit all copy submitted to the publication.

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EDITOR *Catriona Boyle* 059-918 3419 catriona.boyle@teagasc.ie

Teagasc's International Scientific Advisory Board

The Teagasc vision is to be internationally recognised for providing excellent science-based innovation support for the agri-food sector and the wider bio-economy. The organisation evaluates its progress towards achieving this vision, on an ongoing basis, through internal and external peer reviews of its four research programmes, scientific publications, external project funding and industry impact.

To enhance this process, Teagasc has established an International Scientific Advisory Board (ISAB) to provide advice and guidance on the strategic direction of its research programmes from an international perspective.

The specific objectives set for the Board include advice on emerging scientific trends, challenges and opportunities in a global context, and to ensure that Teagasc is adopting and incorporating international advances in science in its research programmes. The ISAB will also provide a review of the outputs of Teagasc's research programmes and compare these with international research organisations (e.g., publications, patents, licences, and industry links), and the allocation of resources across the research programmes. Based on this they will make recommendations to assist Teagasc in achieving its vision. The membership of the ISAB, which is chaired by Professor John Kennelly from the University of Alberta, Canada, includes international experts in our four programme areas from the UK, the Netherlands, France and New Zealand. It met for the first time on March 1 and 2, 2011. It has issued its first report, which is now being considered by Teagasc and its Authority. The ISAB notes that Teagasc is well positioned to set the agenda and provide international leadership in the areas of food security and environmental sustainability, especially in the area of grass-based animal agriculture and value-added dairy and beef product research. It recognises a strong "culture of engagement" with stakeholders and a positive impact on producers and the agri-food industry in general, in terms of industry competitiveness and innovation, as well as policy development and implementation. Following the internal review of the recommendations, Teagasc will undertake a series of activities to implement them. The next meeting is scheduled for the second half of 2012.



Declan Troy
Assistant Director of Research

An Bord Comhairleach Idirnáisiúnta Eolaíoch de Teagasc

Is í an aidhm atá ag Teagasc ná aitheantas idirnáisiúnta a fháil as tacaíocht nuálaíoch den scoth, eolaíoch-bhunaithe a thabhairt don earnáil talmhaíochta/bia agus don bhithgheilleagar i gcoitinne. Measann an eagraíocht a dul chun cinn maidir leis an aidhm seo a bhaint amach, ar bhonn leanúnach, tríd athbhr eithnithe piaraí eachtracha agus inmheánacha a dhéanamh ar a cheithr e chlár taighde, foilseacháin eolaíoch, maoiniú tionscadail eachtrach agus tionchar tionscail. Chun feabhas a chur ar an dul chun cinn seo, tá An Bord Comhairleach Idirnáisiúnta Eolaíoch (ISAB) bunaithe ag Teagasc chun comhairle agus treoir a thabhairt ar an treo straitéiseach dá gclár taighde ó sheasamh idirnáisiúnta.

San áireamh sna cuspóirí sainiúla arna leagan amach don Bord tá comhairle ar na treochoí eolaíoch atá ag teacht chun cinn, dúshláin agus deiseanna i gcomhthéacs domhanda agus chun a chinntiú go mbíonn Teagasc ag ionchorprú agus ag glacadh an dul chun cinn idirnáisiúnta san eolaíocht trína gclár taighde. Cuirfidh an ISAB athbhreithniú ar fáil maidir le torthaí na gclár taighde Teagasc agus cuirfidh sé iad i gcomparáid le heagraíochtaí taighde idirnáisiúnta (m.sh. foilseacháin, paitinní, ceadúnais agus naisc thionscail) agus an leithdháileadh d'acmhainní ar fud na gclár taighde. Bunaithe air seo, déanfaidh sé moltaí chun cabhrú le Teagasc a aidhm a bhaint amach.

San áireamh i measc baill an ISAB, ina bhfuil an tOllamh John Kennelly ó ollscoil Alberta, Ceanada, mar chathaoirleach air, bhí saineolaithe idirnáisiúnta ann sna réimsí dár gceithre chlár ón Ríocht Aontaithe, ón Ísiltír, ón Fhrainc agus ón Nua-Shéalainn. Thionóil sé don chéad uair riamh ar an gcéad agus an dar a lá de Mhárta 2011. Tá a chéad tuarascáil eisithe aige agus tá sé á mheas ag Teagasc agus a Údarás. Tugann an ISAB faoi deara go bhfuil Teagasc i seasamh maith chun an clár oibre a shocrú agus chun ceannasaíocht idirnáisiúnta a chur ar fáil sna réimsí de shláidáil bhia agus inbhuanaitheacht chomhshaoil, go háirithe maidir le talmhaíocht ainmhithe fhéarbhunaithe agus taighde táirge mairteola agus luach breise déiríochta. Aithnítear cultúr teagmhála láidir leis na páirtithe leasmar a agus tionchar dearfach ar dhéantóirí agus an tionscal talmhaíochta/bia go ginearálta, i dtéarmaí iomaíochas tionscail, nuálaíocht chomh maith le forbairt agus cur i bhfeidhm beartais. I ndiaidh an athbhreithnithe inmheánaigh de na moltaí, tabharfaidh Teagasc faoi shraith ghníomhaíochtaí chun iad a chur i bhfeidhm. Tá an chéad chruinniú eile beartaithe don dar a leath de 2012.

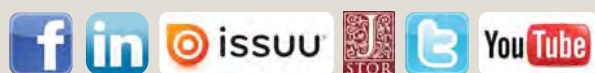
Declan Troy
Stiúrthóir Cúnta Taighde

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Editorial: Ann-Marie Hardiman and Paul O'Grady

Researcher profile



John Spink

John is Head of the Crop Science Department, Teagasc, Crops, Environment and Land Use Research Programme, Oak Park, Carlow.

John's career has concentrated on the agronomy and physiology mainly of the major arable crops, but also of minor and novel crops, as well as systems research and, more latterly, crop genetic improvement.

Key areas of research include: wheat physiology, development, seed rates, sowing dates, lodging control, take-all control and variety choice; oilseed rape physiology, canopy management, Plant Growth Regulator use, nutrition and disease control; systems research; and, identification of key traits for crop improvement. As well as leading research in these areas, he has been heavily involved in the dissemination of the findings to industry through conference presentations, farmer groups, press articles, audiotapes, videos/DVDs and online software.

After completing a BSc Agricultural Science (Crops) at Leeds University, John joined Rothamsted Research in the UK as a crop physiologist, investigating the impact of crop management on yield and seed quality in oilseed rape.

In 1990 he joined ADAS (the largest agricultural consultants in the UK) in Hereford as an agricultural advisory officer. He remained with ADAS until 2009, working successively as a research scientist, senior research consultant and principal research scientist. His final post with ADAS before moving to Teagasc was as a sector manager for agronomy, crop protection and renewable energy, with responsibility for setting strategy, scientific leadership, budgeting and achievement of revenue targets for ADAS.

Before taking up his current post with Teagasc, John worked as a research agronomist at Oak Park, providing research direction and leadership to the crops research programme.

John's publications include: 'Effect of sowing date on the economic optimum plant density of winter wheat' in *Annals of Applied Biology*; 'Agronomic implications of variation in wheat development due to variety, sowing date, site and season' in *Plants, Varieties and Seeds*; 'Quantifying the contributions and losses of dry matter from non-surviving shoots in four cultivars of winter wheat' in *Field Crops Research*; and, 'A physiological analysis of oilseed rape yields: past and future' in the *Journal of Agricultural Science*.

John's motivation for his work is a tremendous interest in how and why things work: "If we can understand that, there is more chance of predicting what will be the right thing to do in the future – the basis of sound advice". His interests are motorbikes and hill walking, usually in the Wicklow Mountains.

First ISAB meeting



Teagasc has established a seven-person International Science Advisory Board (ISAB) to advise on science strategy and direction. The ISAB held its first meeting in Teagasc Moorepark in March (see editorial on page 3).

Process analytics in cheese making

A new Irish study evaluating the effects of milk composition has shown up the need for increased automation and control to ensure greater efficiency in industrial cheese making, according to the lead researcher, Dr Donal O'Callaghan, Teagasc Food Research Centre, Moorepark. Donal says that the findings flag up the importance of milk standardisation in the manufacture of cheese, regardless of type.

He notes that on a per country basis, some cheese making factories adopt milk standardisation, while others follow a more traditional process.

"This is the first study to document experimental data to investigate the effects of milk composition, stir-out time and pressing duration on curd moisture and yield," said Dr O'Callaghan in relation to the benefits for industry of the research results.

The paper 'Effects of milk composition, stir-out time, and pressing duration on curd moisture and yield' appears in the *Journal of Dairy Science* 94 (6): 2673-2679. Authors: C.D. Everard, D.J. O'Callaghan, M.J. Mateo, M. Castillo, F.A. Payne and C.O. O'Donnell.

Teagasc supporting the infant formula sector

Teagasc Food Research Centre, Moorepark has generated a research programme that has a central role in supporting the technological development of the infant milk formula sector in Ireland.

In April, over 70 industry representatives attended a RELAY workshop held in Teagasc Food Research Centre, Moorepark. Among the topics discussed were the opportunities to grow the infant milk formula sector, the technical capability within Teagasc and UCC, and the research facilities underpinning the sector.

The global market for infant milk formula is estimated to be worth in the region of \$5-6 billion and Irish-based companies trade approximately 15% of the infant milk formula tonnage internationally.

IRCSET video launch



Dr Theodora Lola-Luz, a postdoctoral fellow working with Dr Michael Gaffney at Teagasc, Kinsealy, funded by the Irish Research Council for Science, Engineering & Technology (IRCSET), shares a seaweed cocktail with Minister for Research, Sean Sherlock, TD, at the launch of a new video series that celebrates successful collaboration between enterprise and Irish-based postgraduate and postdoctoral researchers. Theodora is working with Oilean Glas Teo (OGT), a small company based in Kilcar, Co. Donegal. OGT develops specialised seaweed extracts for application in agriculture and sports turf (golf courses, football pitches). OGT exports its products to 20 countries around the world. Theodora is helping OGT to understand the benefits of its products and providing the knowledge for the development of new products. (<http://vimeo.com/ircset/ogt/>)

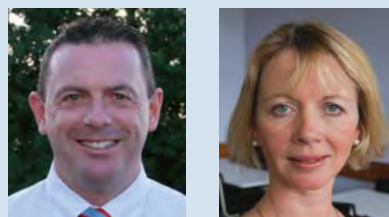
The proof is in the poo

Teagasc scientists have discovered a new biomarker for methane production in the faeces of cows. Researchers from the University of Bristol and the Teagasc Animal & Grassland Research and Innovation Centre, Grange (funded by the Leverhulme Trust), have found a link between methane production and levels of a compound called archaeol in the faeces of several fore-gut fermenting animals including cows, sheep and deer. The compound could potentially be developed as a biomarker to estimate the methane production from domestic and wild animals, allowing scientists to more accurately assess the contribution that ruminants make to global greenhouse gas emissions. The paper, 'Analysis of archaeal ether lipids in bovine faeces', is published in the journal *Animal Feed Science and Technology*, and is available online from doi:10.1016/j.anifeedsci.2011.04.006. Teagasc researchers involved in this project were: Emma McGeough, Walsh Fellow (now at Lethbridge Research Centre, Alberta, Canada); Dr Richard Dewhurst; and, Dr Padraig O'Kiely.

Supplier Development Programme

Teagasc will again participate in the 2011 Enterprise Ireland SuperValu Supplier Development Programme, launched recently by Minister for Jobs, Enterprise and Innovation, Richard Bruton, TD. The programme will see ten Irish food start-up companies receive customised training and one-on-one mentoring support. In 2010, Teagasc provided individual mentoring through in-company visits and a workshop on meeting food assurance technical standards for businesses supplying the food retail group for each business on the programme. The mentoring role was provided primarily by Dr Gerard Barry, Teagasc, Limerick.

Teagasc scientists world leaders in probiotic research



Ireland's scientists are punching above their weight on a global stage. This is according to the independent international ratings agency Thomson Reuters Science Watch global analysis, which tracks trends and performance in research disciplines according to scientific publications. University College Cork weighs in at number two in the world for probiotics research, due primarily to publications from researchers in the Alimentary Pharmabiotic Centre (APC – a Teagasc/UCC/CIT alliance), a research centre funded by Science Foundation Ireland (SFI). The report, based on overall citations of APC research publications over the past 10 years, was published on <http://sciencewatch.com/ana/st/probiotics/institution/>. The report also indicated that six present and former APC researchers ranked in the top 20 of more than 15,000 authors globally, namely Professor Fergus Shanahan, Professor Gerald Fitzgerald, Dr Liam O'Mahony and Professor Kevin Collins, from UCC, and Professor Paul Ross and Dr Catherine Stanton (pictured above) from Teagasc Food Research Centre, Moorepark, Fermoy, Co Cork.

Professor Doug Cook from UC Davis



Professor Doug Cook from the University of California, Davis, recently visited Teagasc's Crops, Environment and Land Use Research Centre in Oak Park, Carlow, to speak on 'Straddling the divide between basic legume science and applications in agriculture'. Professor Cook provided guidance in the setting up of the legume genomics research programme at Oak Park in 2002.

EFSA appointment



Dr Declan Bolton, Food Safety Department, Teagasc Food Research Centre, Ashtown, has been appointed to the European Food Safety Authority (EFSA) Working Group of the Panel in Biological Hazards on the Safe Production of Skin-on Sheep Products.

Dutch/Irish co-operation on food research



Closer strategic links between Ireland and the Netherlands in the area of food research are being developed, particularly in the fields of food technology, and food and health. As part of this initiative, the Dutch Ambassador to Ireland, Mr Robert Engels, visited the Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, in April.

Teagasc Director, Professor Gerry Boyle, said: "The benefits of enhancing co-operation are many. The food innovation landscapes in Ireland and the Netherlands are very comparable. In both economies the food industry plays a central role. The Irish and Dutch Governments and businesses are committed to expanding the sector by investing in food innovation. In some areas, Ireland and the Netherlands will be primarily competitors, but that said, businesses in both countries have a lot to gain from enhancing their co-operation".

Pictured are (from left): Professor Paul Ross, Head of Food Research; Robert Engels, Dutch Ambassador; and Maarten Gehem, Economic and Trade Officer at the Royal Netherlands Embassy in Dublin.

Ireland Norway Day

The APC (Teagasc/UCC/CIT Alliance funded by SFI) and the Norwegian University of Life Sciences recently held an Ireland-Norway Research Day in UCC, with 20 presentations from the APC and Norwegian researchers on their research in lactic acid bacteria, bacteriophage and antimicrobials. This visit by Norwegian researchers from the Biotechnology Laboratory of Microbial Gene Technology, Norway, stems from a memorandum of understanding between the APC and the Norwegian University of Life Sciences (UMB). In addition to this, Professor Ingolf Nes, Professor of Biotechnology, has just completed a research sabbatical at the APC. Ingolf is generally acknowledged as a global leader in bacteriocin research and has published many seminal papers in this area over the last few decades. "The Ireland Norway Research Day proved to be a mutually beneficial day for all the researchers concerned and allowed us to explore further opportunities for collaboration," said Colin Hill (UCC), Principal Investigator (PI) at the APC and co-organiser of the symposium. APC PIs Paul Ross (Teagasc), Paul Cotter (Teagasc) and Colin Hill (UCC) have also undertaken separate trips to UMB to develop these links even further.

National bioenergy conference



Economists in the Rural Economy and Development Programme in Teagasc, along with bioenergy specialists from Teagasc Oak Park, examined the economic case for the growing of biomass crops in Ireland at the Teagasc National Bioenergy Conference in April. This analysis included a comprehensive comparison of the potential costs and returns of these crops with the costs and returns from conventional agricultural production systems. Using data from the Teagasc National Farm Survey for conventional agricultural systems, a Discounted Cash Flow (DCF) investment analysis for willow and miscanthus was conducted.

Dr Fiona Thorne, economist with Teagasc, said: "In terms of converting land from conventional agricultural systems, it seems that beef farms appear to be the most likely farms to convert to biomass production based on comparative economics. However, due to the level of risk involved in growing a novel crop such as biomass, widespread adoption by cereal farmers is unlikely unless we see cereal prices of around €120 per tonne or lower. At current market prices for conventional agricultural commodities, a 10% to 15% price increase for biomass crops would be necessary before cereal farmers would consider switching."

Future land use options



Teagasc biofuels researcher Dr John Finnan shows a willow crop planted in 2008 to Minister of State with responsibility for Food & Forestry Shane McEntee on a recent visit to Teagasc Crops, Environment and Land Use Research Centre, Oak Park. Minister McEntee, together with Department of Agriculture, Fisheries and Food officials, met with Teagasc staff to discuss future land use options.

Conserving farmland biodiversity



Photographed at the Teagasc Biodiversity Conference on 'Conserving Farmland Biodiversity' in Wexford are (from left): Dr John Finn, Teagasc Crops, Environment and Land Use Research Centre, Johnstown Castle; Dr Guy Beaufoy, European Forum For Nature, Conservation and Pastoralism; Professor Nick Southerton, Game Wildlife Conservation Trust; Dr Andy Bleasdale, National Parks Wildlife Service; and, Catherine Keena, Teagasc Countryside Management Specialist.

Dr John Finn, Teagasc environment researcher, Johnstown Castle, said: "Research by Teagasc and our research partners is helping to guide the most appropriate management for the protection of farmland wildlife in the wider countryside and in high nature value farmland. Measuring and demonstrating the successful provision of farmland wildlife as a public good will be an important justification for the long-term delivery of agri-environment schemes and payments".

Listeria conference



Over 80 representatives from large and small industry, public health, regulation and research gathered in May at Teagasc Food Research Centre, Moorepark for a conference on Listeria, a food-borne bacteria that causes the disease listeriosis. Listeria is found widely in the environment and, through vigorous efforts, must be controlled in food-processing environments. The conference was supported by safefood and the aim was to bring together all those that are interested in Listeria to share knowledge on its control and regulation. The latest updates on regulation, the disease-causing ability of different strains and novel control mechanisms were presented. In order to assist with studies on epidemiology and strain transfer in Ireland, a new national database of sub-typed *Listeria monocytogenes* has been developed with the support of a project funded under the Food Institutional Research Measure, supported by the Department of Agriculture, Fisheries and Food. Speakers from Australia, Switzerland and England presented the latest information on international strategies for Listeria control. The conference was part of the activities of the safefood Listeria Network.

Pictured at the Teagasc national conference on Listeria monocytogenes in the Teagasc Food Research Centre, Moorepark, are (from left): Dr Rene Imhof, ALP, Switzerland; Dr Kieran Jordan, Teagasc; Doug Eddy, Dairy Food Safety, Australia; and, Mairead McCann, safefood (sponsor).

Teagasc event proceedings and presentations can be found online:
www.teagasc.ie/publications/.

IPFN



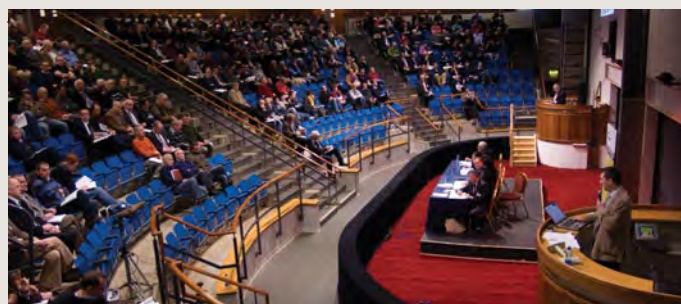
Some of the speakers at the 3rd Irish Phytochemical Food Network Symposium (from left): Dr Juan Valverde, Scientific Officer of the IPFN; Dr Nigel Brunton, Teagasc Food Research Centre, Ashtown; Professor Jose Vina, Faculty of Medicine of the University of Valencia, Spain; Dr Laura Alvarez-Jubete, Dublin Institute of Technology; and, Ashish Rawson, National University of Ireland, Galway.

Alternative uses for pig manure



Pictured at the Pig Development Department Research Dissemination Day on 'alternative uses for pig manure' in Teagasc Moorepark are (from left): Dr Xinmin Zhan, NUI Galway; Peter Frost, AFBI; Peadar Lawlor, Principal Research Officer, Pig Development Department; and, Kathy Carney, Teagasc Moorepark. In the foreground are woodchip biofilters for treating piggery wastewaters.

Beef conference



Delegates at the National Beef Conference 'Achieving Profitability from Beef at Farm Level' at Cillín Hill, Kilkenny.

The challenge of global food security

Two recent Foresight studies highlight the need for a different approach to global food production, explains DR LANCE O'BRIEN.

Despite the growth in global agricultural productivity over the past half-century, one of the most important challenges still facing society is how to feed an expected population of some nine billion by the middle of the 21st century. To meet the expected demand for food without significant increases in prices, it has been estimated that the world will need to produce 70-100% more food in 2050, and to do so with far less impact on the environment and biodiversity, and in the context of the growing impacts of climate change and concerns over energy security.

Two recently published Foresight studies address this priority challenge from slightly different perspectives (SCAR, 2011; GSO, 2011).

The SCAR report focuses on the expected environmental and resource issues impacting on long-term food security and the implications for future agricultural research in Europe. This study involves a meta-review of regional, national and international policy documents, scientific publications and Foresight studies published mainly since 2009. The key focus of the study is on those scar cities of natural resources – land, water, energy, nutrients, climate, biodiversity – which will seriously impact on future food security, and on those actions, both in terms of production and consumption, needed to ensure a smooth transition towards a more sustainable use of scarce resources.

The UK Foresight study (GSO, 2011) draws on existing work, as well as on over 100 peer-reviewed commissioned papers and the input of hundreds of experts and stakeholders, to explore the pressures that will impact on the global food system up to 2050, and to highlight the policies that need to be implemented to ensure that there will be sufficient food to feed the increasing population in a sustainable and equitable manner.

The SCAR report

The SCAR report concludes that many of today's food production systems compromise the capacity of the Earth to produce food in the future. Globally, and in many regions, food production is exceeding environmental limits or is close to doing so. For example, nitrogen synthesis exceeds the planetary boundary (see panel) by a factor of four, and phosphorus use is close to the boundary. Land use change and land degradation, and the dependence on fossil energy, contribute to about one-quarter of global greenhouse gas emissions. Agriculture, including fishery, is the single largest driver of biodiversity loss. Regionally, loss of water through irrigation exceeds the replenishment of water resources. The various scarcities and their causes are characterised by many similarities and interlinkages. Therefore, an integrated approach, which encompasses natural sciences, social sciences and improved governance, is required to enable a transition to a sustainable world economy and society.

The report identifies a set of principles upon which our food system should be based:

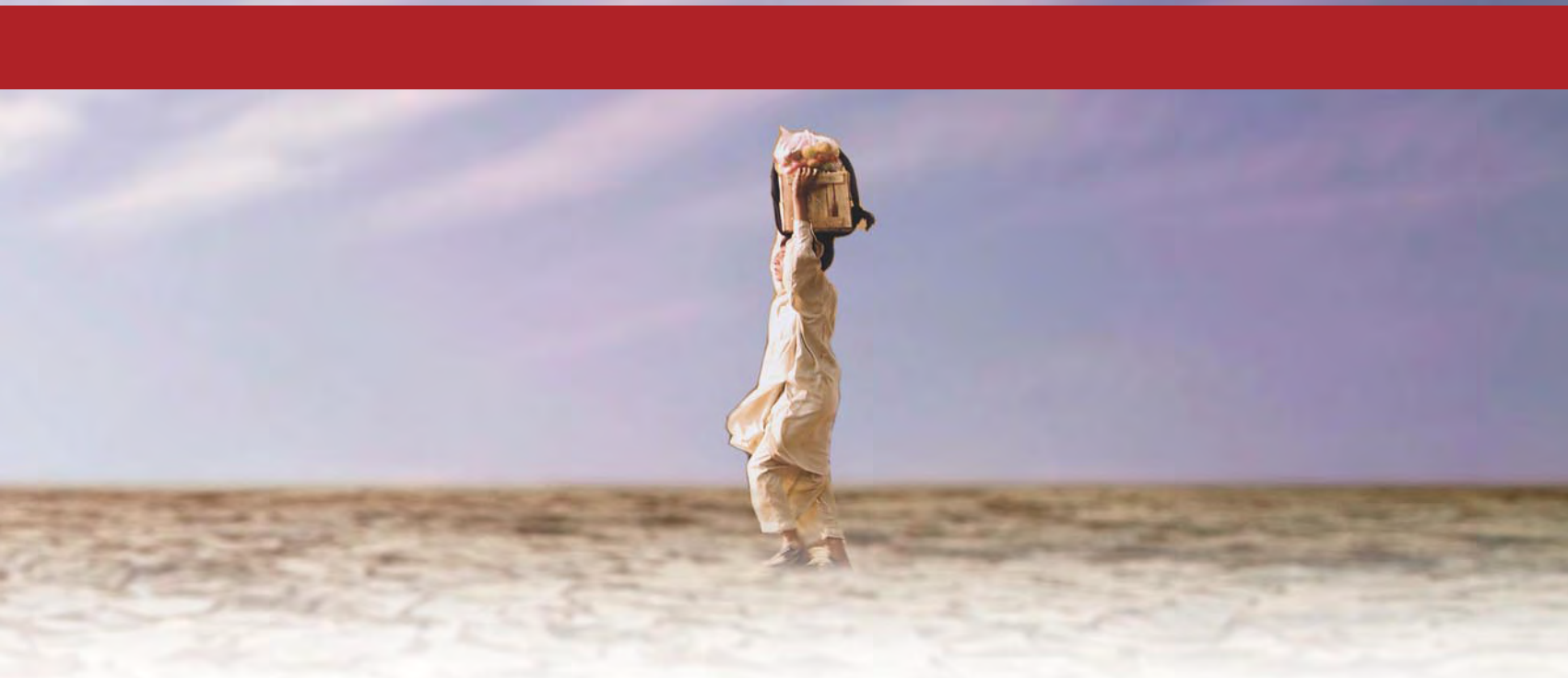
1. Well-being and high quality of life of all stakeholders involved in food and agricultural systems, from producers to consumers.
2. Resource use efficiency and optimality: by avoiding waste, promoting recycling and reducing our footprint, and by applying the cascading principle of resource contribution.
3. Resource conservation: critical natural resources, including biodiversity, land and water, should be maintained, taking into account the interaction between scarcities.
4. Diversity and inclusion: food and agricultural systems should reflect the territorial diversity present within the EU and worldwide to ensure resilience and equity.
5. Transdisciplinarity: research and innovation underpinning future food and agricultural systems should fully integrate the various sciences, including the social sciences and humanities, but should also be transdisciplinary, that is, fully integrating the end user into research and innovation.
6. Public involvement: strong public investment in research remains crucial to safeguard all of the previous principles.

Continued and increased investment in relevant research and innovation at EU and national levels is critical in addressing the transition to new food consumption and production patterns that respect the interlinked global scarcities. In particular, the EU must prioritise the development of new research programmes that will place a primary focus on resource conservation and a sustainable and knowledge-based economy.

Planetary boundaries

The concept of planetary boundaries is explored in: **Rockstrom, J., et al.** (2009). 'Planetary boundaries: exploring the safe operating space for humanity'. *Ecology and Society*, 14 (2): 32
<http://www.ecologyandsociety.org/vol14/iss2/art32/>.

These are boundaries set for nine major global processes, such as climate change, ocean acidification, rate of biodiversity loss, and interference with the global phosphorus and nitrogen cycles. The boundaries set quantified limits within which the authors expect that humanity can operate safely. Going beyond one or more of these boundaries may be catastrophic because of the risk of stepping over limits that will trigger major environmental change.



The report concludes that a radical change in food consumption and production in Europe is unavoidable if we are to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and uncertainty. The European agri-food sector should now consider that there is an opportunity to positively address the challenge and be the first to win the world market for sustainably producing healthy food in a world of scarcities and uncertainty.

The UK Foresight report

The Foresight project 'Global Food and Farming Futures' has examined how a rapidly expanding global population can be fed in a healthy and sustainable way. The report's main findings are:

- Threat of hunger could increase: efforts to end hunger internationally are already stalling, and without decisive action food prices could rise substantially over the next 40 years, making the situation worse. This will affect us all: as more of the world suffers from hunger, social tensions will increase, as will the threat of conflict and migration. Wider economic growth will also be affected.
- The global food system is living outside its means, consuming resources faster than they are naturally replenished. It must be redesigned to bring sustainability centre stage: substantial changes will be required throughout the food system and related areas, such as water use, energy use and addressing climate change, if food security is to be provided for a predicted nine billion or more people in 2050.
- There is no quick fix: the potential threats converging on the global food system are so great that action is needed in many areas, from changing diets to eliminating food waste.

With the global population set to rise and food prices likely to increase, it is crucial that a wide range of complementary actions from policy makers, farmers and businesses are taken now. Urgent change is required throughout the food system to bring sustainability centre stage and end hunger. It is also vital for other areas, such as climate change mitigation. In particular, increased, sustained and co-ordinated investment in research is a priority. Three important areas for change include:

- minimising waste in all areas of the food system: the equivalent of about a quarter of today's annual food production could potentially be saved by 2050 if the current estimate of global food waste is halved;
- balancing future demand and supply in the food system: this could include helping businesses to measure the environmental impacts of food so that consumers can choose products that promote sustainability; and,
- improving governance of the global food system: it is important to reduce subsidies and trade barriers that disadvantage poor countries. The project's economic modelling shows how trade restrictions can amplify shocks in the food system, raising prices further.

Concluding comment

Global food production has, to date, maintained pace with population growth. However, the scale of this challenge will be exacerbated in the future owing to increasingly unpredictable weather events and the changing pattern of disease in crops and livestock caused by anticipated climatic changes. Impacts of further biodiversity losses or even collapse of marine food webs are potentially even larger and less predictable. This, combined with an increased level of competition for scarce natural resources, particularly for energy, land and fresh water, has the potential to bring about the scenario described by Professor John Beddington, the UK Government's chief scientific adviser, as the 'perfect storm'. "Navigating the storm will require a revolution in the social and natural sciences concerned with food production, as well as a breaking down of barriers between fields. The goal is no longer simply to maximise productivity, but to optimise across a far more complex landscape of production, environmental, and social justice outcomes" (Beddington, n.d.).

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Dr Lance O'Brien is Head of Foresight and Strategy Development in Teagasc and was a member of the SCAR Foresight Expert Group that prepared the SCAR Foresight Report. E-mail: lance.obrien@teagasc.ie.



China: the food security challenge

DR LANCE O'BRIEN, Head of Foresight and Strategy Development, Teagasc, explains how China is providing food security for its large and growing population through investment in agricultural R&D.

With less than 9% of global land, and with 20% of the world's population to feed, China faces a huge challenge in meeting the food needs of its citizens into the future. To keep pace with increased demands from projected population growth, food production in China will have to increase continually and adjust to the changing consumption patterns that will accompany a wealthier population. Up to now, China has succeeded in providing food security for its people. Along with policy reform and infrastructure development, agricultural technology is considered the key factor in driving this significant achievement (Huang *et al.*, 2003). Rising research investment resulted in a steady stream of productivity-increasing technology. China was the first nation to adopt semi-dwarf rice varieties, and drought- and pest-resistant wheat cultivars, in the 1950s. Its scientists also developed hybrid rice in the early 1970s. Several studies conducted by the Chinese Academy of Agricultural Sciences (CAAS) show that technology contributed to more than 40% of agricultural productivity growth. Recent studies on agricultural total factor productivity (TFP) confirm that agricultural productivity growth has mainly come from technology changes (Huang *et al.*, 2000; Jin *et al.*, 2007).

Agriculture in China

This success has been achieved despite the fact that China's agricultural production is almost exclusively derived from small-scale farming operations. According to the 2007 agricultural census, the country has 200 million farm households and an estimated 122 million hectares (494 million acres) of cultivated land – an average of 0.6 of a hectare (1.5 acres) per household. Farm households engage in intensive agricultural practices, including high levels of fertiliser application and raising two or three crops per year on a single plot (Figure 1). The country also relies heavily on irrigation to boost yields, with nearly 50% of its land supporting irrigation delivery facilities. The many crop varieties developed by its agricultural research institutes produce high yields with irrigation and fertiliser inputs. Some varieties are bred for a short growing season to facilitate multiple cropping.



Trends in agricultural production

China's agricultural production grew continually from the 1980s despite competition for resources, particularly for labour, from faster growing sectors of the economy, and competition from imports as trade policies were liberalised. Grain production (rice, wheat and corn) jumped from 247 million metric tons (mmt) in 1978 to 339mmt in 1984, and exceeded 470mmt in 2008 (Figure 2). Corn production grew faster than other grains to maintain exports for hard currency and to feed the growing livestock sector. Livestock production also increased, primarily for meat (mostly pork) and eggs, but in recent years, dairy production has also taken off (Figure 3). For many products, China's share of world production exceeds its share of world agricultural land and, for some products, its share of world production exceeds its share of world population.

China's agricultural research system

Since 1999, China's spending on research has increased by almost 19% each year. In 2007, it reached 371 billion yuan (US\$43.3 billion). Government policies play an important role in fostering this system. Agricultural research is overwhelmingly financed and undertaken by the public sector, although private-commercial research has grown rapidly in recent years. The country has the world's largest agricultural R&D system. Public investment in agricultural R&D increased rapidly following years of low growth during the 1990s (Figure 4). Total agricultural R&D funding increased from 3.3 billion yuan (US\$403 million) in 1986 to 12.3 billion yuan (US\$1.5 billion) in 2007 at 2005 constant prices.

The average annual growth rate was around 4-5% from 1986 to 2000, but this accelerated during the period from 2001 to 2007 to about 10%, which is on a par with national GDP growth during this period (Huang and Hu (2004); Lohmar *et al.*, (2009); Chen and Zhang (2011)).

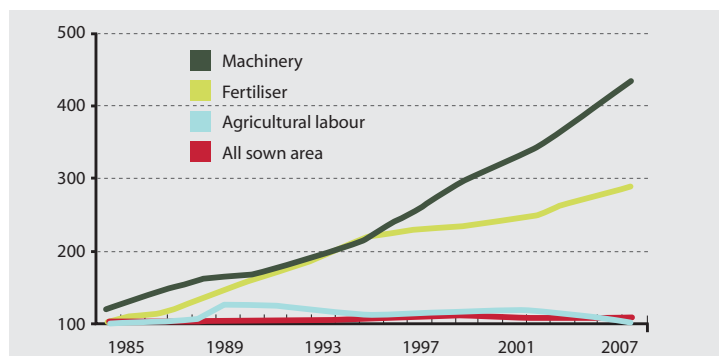


FIGURE 1: Indexes of agricultural use, China, 1985-2007.

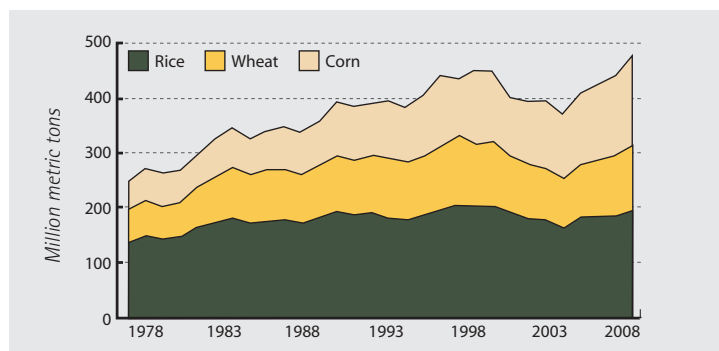


FIGURE 2: China's grain production increases, 1978-2008.

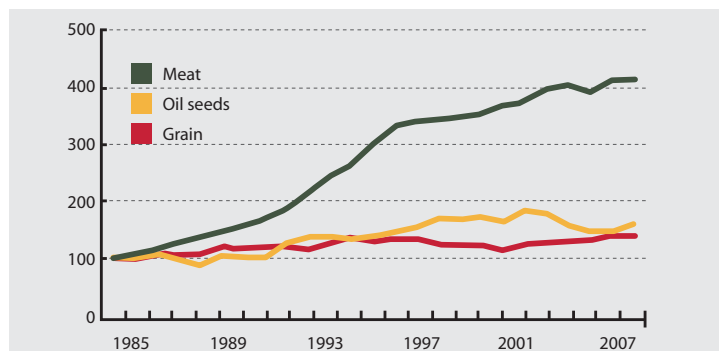
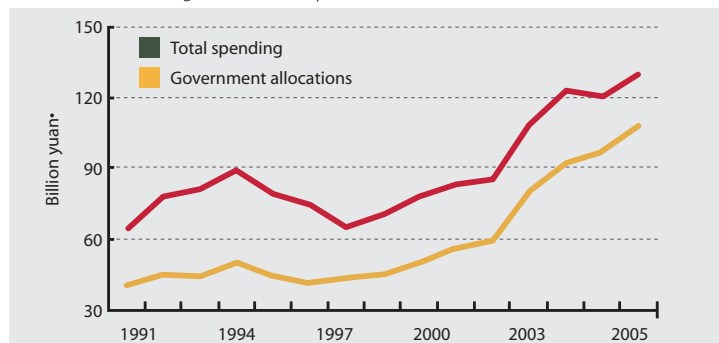


FIGURE 3: Indexes of grain and meat production, China, 1985-2008.



*Constant 2005 Chinese yuan (CNY)—total spending does not include private enterprises, but includes funds raised by universities and Government research institutes outside of direct Government outlays.

FIGURE 4: Agricultural research expenditures in China.

Source of Figures: Lohmar et al., 2009.

Agricultural research priorities

Grain security is the key goal for public agricultural R&D, with more than 50% of public investment in this area. There has also been a rapid rise of R&D investment in food processing, with 7.6 billion yuan (US\$928 million) invested in 2007; the average annual growth rate in R&D investment in food processing was nearly 20% during the period 1995-2007. In view of the increasing challenges for the environment posed by the high level of production, Chinese agricultural R&D has increasingly begun to pay attention to sustainable development.

Concluding comments

Despite the progress made in its agricultural development, China's agricultural industry is still facing enormous challenges. It has the largest population in the world – about 1.33 billion people – and the constraints on natural resources are severe: per capita arable land and water resources are lower than the world average, and are declining with urbanisation. At the same time, excessive use of fertiliser and pesticides results in new pressures on the environment and ecology. Agriculture is facing a drier and warmer future due to climate change. On the other hand, with the increase in population, urbanisation and household income, the demands for agricultural products are growing, and this represents a major new opportunity for Ireland to help achieve the targets for increased food exports set out in the *Food Harvest 2020* report. The case of China represents a microcosm of how the world as a whole will need to tackle its food challenges. Ireland, with its plentiful supply of food, is not immune from this challenge. We too must learn from the example of China by continuing to invest in agricultural R&D to ensure that we continue to produce sufficient safe food in a sustainable manner to meet our own needs and contribute to enhancing global food security.

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



Reducing N loss using inhibitors

A cross-disciplinary team of researchers from Ireland and New Zealand is looking at the use of inhibitors to reduce nitrogen losses to the environment.

The steady increase in the cost of nitrogen (N) fertiliser on farms has resulted in a renewed interest in methods to improve the utilisation efficiency of N sources such as: fertiliser, manure and faeces/urine from grazing animals. Fertiliser costs are one of the largest variable costs on Irish farms, accounting for over €400 million in 2009. Improving N efficiency reduces both farm cost and the losses of N to the environment. N can be lost to the environment through a number of processes, as seen in **Figure 1**. The main losses (highlighted in yellow) with negative impacts on the environment are: nitrate (NO_3^-) leaching to surface and groundwater, and gaseous losses of ammonia (NH_3) and nitrous oxide (N_2O).

Inhibitors

Nitrification inhibitors

Losses of N through NO_3^- leaching and denitrification occur when NO_3^- is present in the soil. NO_3^- is produced in the soil through nitrification, which is the enzymatic conversion of ammonium (NH_4^+) to NO_3^- by soil microorganisms. The rate of NO_3^- formation in soil can be reduced by using a nitrification inhibitor to reduce the activity of the enzyme ammonia monooxygenase. There are a number of commercial sources of nitrification inhibitors, with dicyandiamide (DCD) being commonly used on grassland. DCD has been investigated in New Zealand as an environmental tool and is available commercially. Nitrification inhibitors are effective when applied directly to the soil or in combination with organic or ammoniacal N sources (i.e., non-nitrate fertilisers). In Ireland, trials are currently being completed evaluating the effect of DCD incorporation in slurry applied three times in the year at Johnstown Castle, Hillsborough (Northern Ireland) and Moorepark. Further trials are being undertaken at the Johnstown Castle lysimeter facility to evaluate the effect of DCD on simulated urine patches.

Urease inhibitors

Globally, urea is the most common form of N fertiliser applied to agricultural soils as it is the cheapest form of solid N fertiliser available and it has a high N content. When urea is landspread it is hydrolysed to form NH_4^+ in soil through the enzyme urease. Elevated levels of NH_4^+ in soil can result in high volatilisation of NH_3 under certain weather conditions. This is why Irish farmers traditionally switch from using urea to

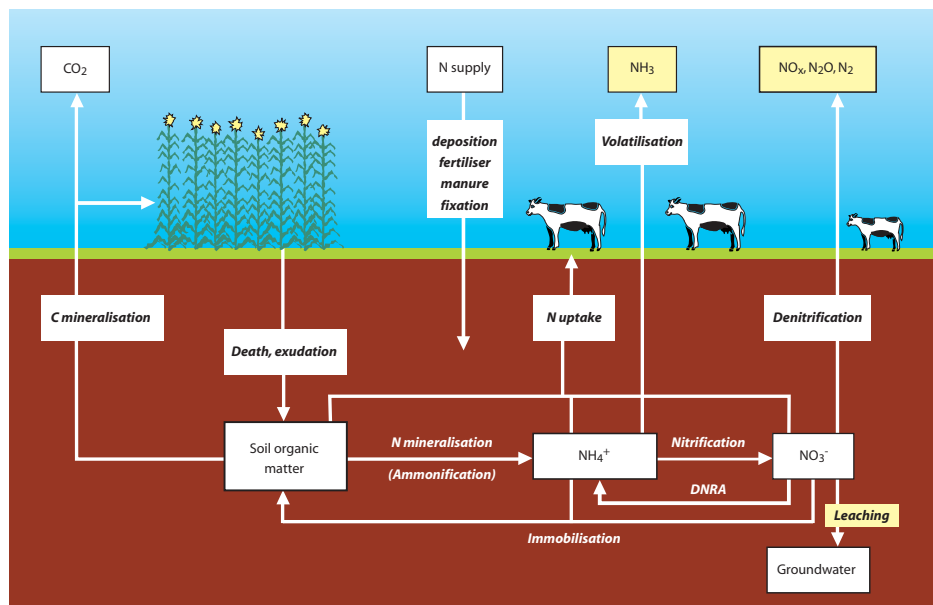


FIGURE 1: Nitrogen cycle.

calcium ammonium nitrate (CAN) in May, as the efficacy of urea decreases due to increasing ammonia volatilisation from urea applications in warmer and drier weather conditions in summer. There are chemical inhibitors that reduce urease activity in soil, slowing the hydrolysis of urea. One such product is nBPT (n-(n-butyl) thiophosphoric triamide), which has been shown to reduce ammonia emissions from urea fertiliser (Watson *et al.*, 2009). In our temperate climate, the reduction in the rate of NH_4^+ and NO_3^- formation in soil could potentially reduce losses of N_2O , NH_3 and NO_3^- . The use of urease inhibitors with urea could therefore decrease farm fertiliser costs and have positive environmental effects. Field trials are currently being conducted at Johnstown Castle to evaluate a number of urease inhibitors combined with urea, on grass growth and N_2O emissions, compared to CAN.

Slowing the release of inhibitors

Typically, urease and nitrification inhibitors are either used to coat fertiliser granules or else sprayed on the soil surface at different times of the year. Inhibitors degrade and break down over time. For example, DCD breaks down through microbial activity and is readily leached from soil, which necessitates repeated application. New research, in collaboration with NUI Maynooth, is evaluating the use of biodegradable hydrogels as a mechanism to slow the release of inhibitors in soil and slurry. Encapsulated inhibitors are released through the biodegradation of the hydrogel matrix.

Inhibitor efficacy in Ireland

Experiments examining the use of DCD with urine, fertiliser and manure N sources have been conducted at Johnstown Castle in collaboration with Lincoln University New Zealand, AFBI Northern Ireland and Teagasc Moorepark over the past five years. Recently, our research (Dennis *et al.*, 2011) has shown that DCD significantly reduces NO_3^- loads leached from urine patches by approximately 40%, and maximum drainage NO_3^- concentrations by 50% on the free draining soils (**Figure 2B**). Current legislation (Nitrates Directive) for acceptable NO_3^- levels in waters is based on concentrations, and thus the finding that DCD significantly reduces peak NO_3^- concentrations is important. Our research has also investigated the effect of DCD on N_2O emissions from soil amended with both urine and slurry. We have found that DCD can reduce N_2O

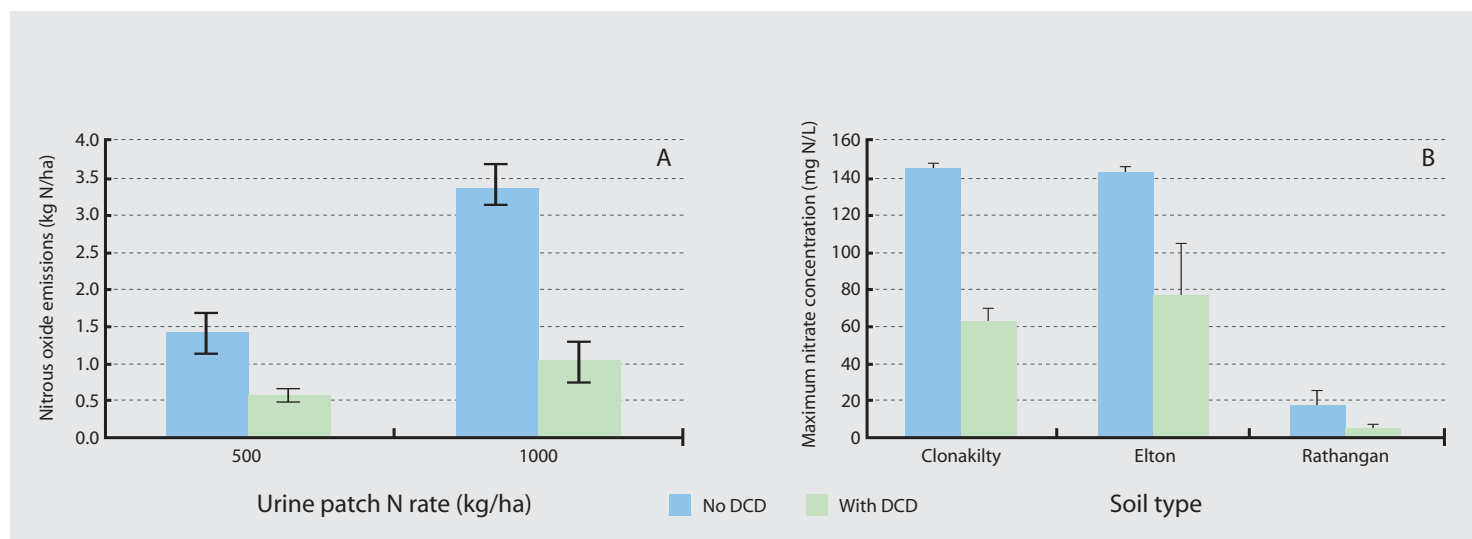


FIGURE 2: DCD decreases: **A.** Nitrous oxide (N_2O) emissions from urine with varying N concentration; and, **B.** Maximum nitrate concentration (NO_3-N) from lysimeters of three different soils, receiving cow urine patches at a rate of 1,000kg N/ha. Field scale losses will decrease when averaged with non-urine areas. Clonakilty and Elton are free-draining and Rathangan is poorly drained.

emissions from slurry applied to grassland by up to 66% on an imperfectly drained loam soil (Cahalan *et al.*, 2011a). Nitrous oxide emissions from lysimeters amended with urine patches (1,000kg N/ha equivalent) were significantly reduced by up to 70% (Figure 2A) with DCD (Selbie *et al.*, 2011). Our research has shown that the use of the nitrification inhibitor DCD can reduce environmental emissions of NO_3^- and N_2O . These N savings would be expected to result in increased herbage dry matter (DM) production, due to the higher N availability in the DCD treatments. Here our results have been conflicting. Although DCD consistently increased herbage N content, there was no consistent effect on herbage DM production. Lysimeter studies have shown that DCD increased herbage DM by up to 35% on a free-draining soil under low fertiliser N inputs, but there was little response at high fertiliser N rates (Dennis *et al.*, 2011). Incorporation of DCD with bandspread slurry significantly increased herbage DM production by 5.5% in one of the two-year studies (Cahalan *et al.*, 2011a). Low herbage DM response to DCD has also been reported in Moorepark (Hennessey *et al.*, 2011). Variable responses to DCD on herbage DM production have been reported in New Zealand, from 1 to 21%. The effect of DCD on herbage production appears to be more pronounced at low N fertiliser inputs, due to lower soil N availability and thus a greater impact of N saved from loss. Nevertheless, it is under high N input situations that DCD can reduce the environmental impact of Irish agriculture.

Conclusion

Our studies found that the use of inhibitors is a useful technology to reduce environmental N losses occurring within Irish agricultural systems. Reductions of NO_3^- leaching and N_2O emissions of up to 70% are sizable. Currently in Ireland there is no financial benefit associated with the reduction in environmental emissions. The agronomic benefits are less clear, but there appear to be increased agronomic responses at low N fertiliser rates. Reducing fertiliser inputs to account for N saved when using DCD could offset some of the costs of DCD. Economic evaluation of the use of inhibitors in Irish agricultural systems should not be based solely on herbage DM production. It should include potential financial benefits that result from the environmental benefits, such as reductions in greenhouse gas emissions, and increased milk production per land area at higher animal stocking rates.

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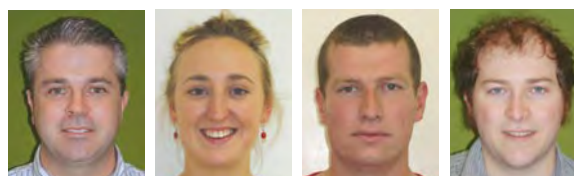
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Authors

The research team is being led by Dr Karl Richards, who is a research officer in Johnstown Castle. Walsh Fellows: Diana Selbie, Enda Cahalan and Samuel Dennis (see photos).

Johnstown Castle Research: Maria Ernfors, Eddy Minet, Gary Lanigan, Stan Lalor, John Murphy.

Collaborators: Agri-food and Biosciences Institute, Northern Ireland: Catherine Watson, Ronnie Laughlin, Karen McGeough; University College Dublin: Christoph Mueller; NUI Maynooth: Denise Rooney; Lincoln University, New Zealand: Keith Cameron, Hong Di; Environmental Protection Agency: Ibrahim Khalil; Teagasc, Moorepark: Deirdre Hennessey.



Understanding the slurry–soil interface – the ‘Cranfield cluster’

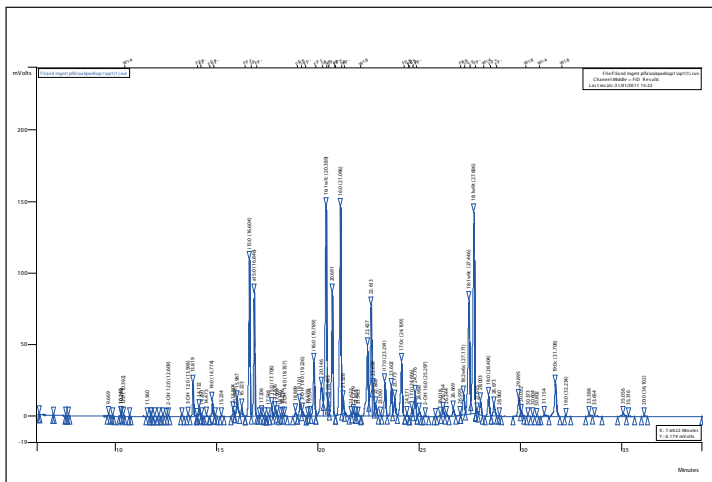
In the first cluster of linked Walsh Fellowships funded by Teagasc, researchers at Johnstown Castle and Cranfield University in the UK are expanding our understanding of processes happening when slurry is applied to soil.

Livestock production based on grass is the mainstay of Irish agriculture and is widespread globally where humid climates are suited to grass production. In temperate climates, animals typically graze outdoors in the summer and are housed in the winter to protect the soil from being damaged by stock trampling. Winter housing leads to the accumulation of slurry and manure, the recycling of which is important for the sustainability of agricultural systems: globally 130 million tonnes of nitrogen (N) and 25 million tonnes of phosphorus (P) are applied as slurry to land each year. Considerable attention has rightly been paid to maximising the nutrient efficiency of slurry applied to soil and, in so doing, reducing the emission of greenhouse gases, nitrate leaching, transport of pathogens and phosphorus movement to surface waters. Many of these processes are biologically mediated, hence the aim of the ‘Cranfield cluster’ to focus on soil biology in slurry management. This is the first Teagasc funding cluster awarded and consists of four linked Walsh Fellows associated with Cranfield University in the UK, which is renowned for its strong soil science research programme. These researchers set out in 2008 to open the ‘black box’ that is the biology and ecology of the soil–slurry interface, combining knowledge of soil ecology with

biogeochemical pools and flux models to secure effective, efficient and sustainable use of farmland resources. Their initial results provide a fascinating insight into the biology of our agricultural pastures and offer scope for novel approaches to their management.

Slurry – food for soil as well as plants

As well as providing nutrients directly available for plant growth, nitrate and phosphate, slurry also provides a readily available source of carbon, nitrogen and other nutrients, which fuels an increase in the size of the native soil microbial community after spreading. But, even in storage, slurry supports a microbially active organic ‘soup’ with its own microbial community, and there is precious little known about how the microbial community in slurry interacts with the soil microbial biomass. Does the slurry microbial community play a functional role in slurry-derived nutrient cycling in the soil, or is the recycling due to the native soil microbial community? Experiments using combinations of live soil and sterilised soils and slurries are answering these fundamental questions. These involve the use of novel approaches to characterise the soil and slurry microbial community structure (Figure 1). We have



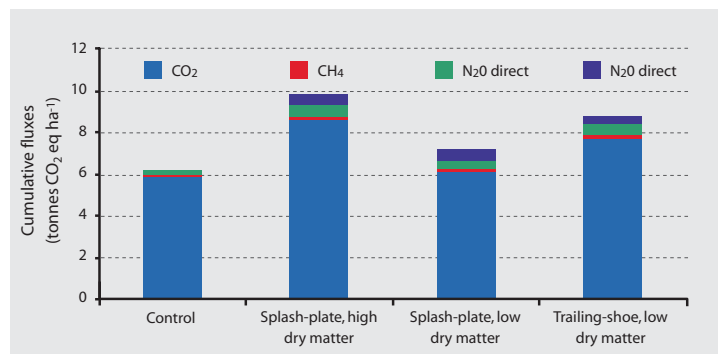


FIGURE 2: Cumulative fluxes of greenhouse gases measured on the field over the period April 2009 to June 2010. Cattle slurry with a high (8%) or low (4%) dry matter content was spread using either the splash-plate or trailing-shoe application technique. Indirect nitrous oxide (N₂O) is estimated from ammonia deposition.

shown that the effect of slurry addition on the microbial biomass carbon/nitrogen and soil nitrogen cycling was similar for sterilised and live slurry.

This suggests that the slurry microbial community does not play an important functional role in nutrient cycling in soil and that the important work is done by the native microorganisms in the soil.

Better land application for greater efficiency

Application strategies can increase nutrient use efficiency and significantly reduce gaseous emissions. Data collected is being used to parameterise a biogeochemical model, known as 'DayCent', to allow simulations to be run that are specifically targeted towards Irish conditions. Low ammonia volatilisation application techniques – such as trailing-shoe – increased soil respiration rates but did not significantly affect nitrous oxide release from soils. Other strategies such as reducing slurry dry matter content, as can also be seen in Figure 2, and switching from midday to evening application, can significantly reduce gaseous emissions. State-of-the-art stable isotope techniques, using ¹³C and ¹⁵N to distinguish slurry-derived C and N from soil or fertiliser-derived C and N, have shown that interactions between nitrogen and other nutrients, particularly carbon and phosphorus, are crucial in determining the fate of slurry nitrogen.

Biological interactions regulating phosphorus behaviour in soil

In grasslands, the application of slurries and fertilisers leads to the sorption of P at the soil surface. It is important to understand how the soil microbes and fauna incorporate and cycle P, in order to increase the availability of P to the plant community. Using experimental plots at Johnstown Castle, we have been studying the application of P fertilisation on the soil microbial community, nematodes and earthworms for the last two years. From the field plots, we see that the application of inorganic P fertiliser induces a seasonal effect on microbial uptake of P. Furthermore, data from this experiment suggests that the frequent cutting regime adopted for these field plots has induced other nutrient limitations on the soil microbial community, namely, a carbon and nitrogen limitation. To study this issue further we have set up an experiment in pots to investigate the cycling of P applied from both fertiliser and slurry (i.e., inorganic and organic) sources. This study will complement the work already undertaken at field scale by investigating the relationships between the source of P application and the vertical distribution of P through the soil under a range of soil biota-plant community scenarios.



Mesocosms (pots supporting the growth of plants and soil organisms) in the glasshouse at Teagasc Crops, Environment and Land Use Research Centre, Johnstown Castle for investigating the cycling of inorganic and organic P.

Soil protects us against slurry pathogens

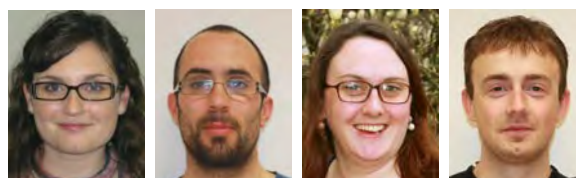
Some slurry microorganisms survive landspreading and some of these, such as *E. coli*, *Salmonella* and *Cryptosporidium*, can cause disease in humans and animals. Therefore, it is crucial to identify the factors that affect pathogen survival in soil, in order to gain maximum agronomic benefits while minimising the threats to human and animal health. An important, but relatively un-researched factor is the interaction between such pathogens and the native soil microorganisms. In one experiment, *E. coli* was found to grow profusely when added to sterile soil, yet declined rapidly in fresh soil. This demonstrates that pathogens are negatively affected by the presence of native microbes, due to antagonistic interactions such as competition for nutrients and space, and their consumption by predators. Subsequently, we have shown that subtle differences in community composition can also influence how long pathogens will survive in soil. However, the effect of the community on survival time differs between pathogen types. We are extending these studies to explore the impact of land management on the soil community, and any consequent effects on pathogen survival. This may lead to the ability to identify specific microbial configurations that promote pathogen decline, and agricultural practices that favour such configurations, the ultimate objective being an improved risk assessment model to ensure continued safe practice.

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Walsh Fellows (pictured): Emma Moynihan, Frederic Bourdin, Niamh Rogers and Paul Massey.

Cranfield University supervisors: Professors Karl Ritz and Jim Harris; Drs Mark Pawlett, Ruben Sakrabani and Sean Tyrrel. Teagasc Johnstown Castle supervisors: Professor Bryan Griffiths; Drs Fiona Brennan, Gary Lanigan, Karl Richards, Nyncke Hoekstra, Rachel Creamer and Rogier Schulte. E-mail: bryan.griffiths@teagasc.ie.



Molecular gastronomy

DR JUAN VALVERDE explores the science of cooking and flavour.

Can you imagine the effect of a sparkling jelly melting in your mouth? Have you ever tasted the amazing texture of an egg yolk cooked at exactly 68 °C? Or have you ever felt the superb velvety texture of a sorbet made with liquid nitrogen? Have you ever imagined a drink that has a different flavour on every sip? In recent years a number of chefs, including Ferran Adria (Spain), Heston Blumenthal (UK), Pierre Gagniere (France) and Rene Redzepi (Denmark) have received a lot of media attention and sparked the interest of the general public. Suddenly, people who had little or no interest in gastronomy are fascinated by this discipline and have heard, read or seen on TV some of the fantastic culinary creations. These chefs have managed to draw attention to their work because they have been able to do things that before were only imagined or described in works of fiction, making them real champions of innovation.

Real food innovation is linked to good knowledge transfer; some of the most amazing technological advances in humankind have been carried out by simply applying existing scientific knowledge in a specific situation. These chefs have taken advantage of knowledge generated from food chemistry, or molecular gastronomy in particular, and applied it in their kitchens to create some of the most amazing dishes ever accomplished.

Molecular gastronomy

Briefly, molecular gastronomy is a scientific discipline that studies what happens when we cook. It seeks to examine and explain the chemical reasons behind the transformation of ingredients: to examine in a scientific way what happens to potatoes when they roast or, from a chemical point of view, how exactly to achieve rich and silky gravies. Once we know what happens and how it happens during our Sunday roast, it is easier to eliminate worthless steps, or to add or modify new ones in order to obtain culinary perfection. For example, roasting a leg of lamb at a very low



temperature (slightly above 70 °C) for several hours (even leaving the oven on overnight so it is ready to eat the following day) gives a completely cooked, moist roast filled with flavours that you would never achieve with a more traditional way of cooking using higher temperatures, where many of the natural aromas are lost from the ingredients. The application of molecular gastronomy has made some of these chefs world leaders in food and gastronomy. Innovation, according to Steve Jobs (CEO of Apple), "distinguishes between a leader and a follower". Indeed, nine out of 10 of the St. Pellegrino top 10 restaurants use applications of molecular gastronomy. Moreover, many of these restaurants proudly market themselves as restaurants where laboratory techniques or ingredients are used. In fact, customers around the world wait patiently for months for a table at these famous restaurants.

Culinary science in Ireland

Slowly, applications of molecular gastronomy are being introduced into restaurants in Ireland. There are already chefs using low temperatures for cooking meats, or using liquid nitrogen. I believe that there is the potential, and the market, to rapidly develop molecular gastronomy here in Ireland. In Teagasc, for example, several projects funded by the Department of Agriculture, Fisheries and Food and the European Union have developed results that could be readily applied to small-scale food industries such as restaurants, catering companies and hotels before being up-scaled for bigger food industries. This could have a great impact on the way chefs cook now and in the future and, therefore, how the food industry in general approaches innovation. Under the auspices of a European Union-funded project (ISAFRUIT) being carried out in Teagasc Food Research Centre, Ashtown, edible coatings for fresh-cut fruit products have been used to develop fresh-cut probiotic products. The knowledge generated in this project can be used to develop hundreds of innovative products. Imagine the amount of different combinations that could be generated by the simple combination



of different fruits covered in a layer of a tasty gel; it is the ultimate 21st century fruit salad, combining taste and texture. In the same project, the use of high pressure processing (an alternative to heat for cooking) on fruit juices and purées could provide caterers with exciting new products that would better retain the flavours of fresh products. This is very useful for caterers that need to re-invent dishes constantly, with almost the same products and, at the same time, pay attention to food safety. High-pressure products better retain the freshness and raw attributes of fruits and vegetables, keeping them safe for consumers. This is because microorganisms burst at high pressures while very little happens to the fruit or vegetable. This represents an interesting alternative to the rather dull sterilised and canned vegetable products that are commonly used. Heston Blumenthal, the well-known chef of the Fat Duck Restaurant in Bray, UK, uses this technique to completely extract the flesh from lobsters. Can you imagine the amount of time and money that a chef/caterer could save? Apart from the direct consequences for our taste buds! Many other ongoing or finished projects carried out in Teagasc Food Research Centre, Ashtown, and funded by the Department of Agriculture, Fisheries and Food, have gathered and generated knowledge that can be applied for the same purposes. For example, one project is looking for alternatives to the use of salt in prepared foods (Irish daily intake of salt is among the highest in Europe). Salt has an extremely negative impact on cardiovascular health; therefore, alternative taste enhancers are necessary to provide tasty but healthier food. Alternatives are being explored through the use of natural extracts. It is estimated that only 20% of a tasting experience comes from taste, which is perceived in the tongue, and detects only sweet, salt, sour or bitter (not considering umami as a taste). However, 80% comes from smell. We have around 5-10 million receptors capable of detecting smell, while we only have 9,000 to detect taste. This means that we have a lot of space to stretch our culinary ideas! Some odd food-flavour combinations have been shown to give surprising results. There is a whole branch of

science studying the reasons for these strange but perfect marriages (e.g., strawberry and coriander, pineapple, blue cheese and white wine, or oysters and kiwi fruit). In a country where the quality of ingredients is superb, and where people are so passionate about and proud of their food, a stronger effort from all players – researchers, industry, government bodies and professional associations – should be made in 2011 to put Ireland's gastronomy on the international map. This could, similarly to Spain or Denmark, help to develop Ireland's gastronomic tourism, targeting high-income tourists willing to spend money on Irish-grown and processed products. According to Ireland's Restaurant Association, 63,000 people work in the restaurant sector and it is worth €2bn. Meanwhile, there are only five restaurants with Michelin stars in the Republic of Ireland and, to date, none of them is in the top 50 restaurants list compiled by St. Pellegrino every year. The future looks promising; let's not waste the opportunity.

Bon appetit, or should I say Bain taitneamh as do bhéil!

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Dr Juan Valverde is Network Scientific Officer of the Irish Phytochemical Food Network (www.ipfn.ie) at Teagasc Food Research Centre, Ashtown.
E-mail: juan.valverde@teagasc.ie.



Streptococcus thermophilus – a new starter culture

Teagasc researchers are looking at *Streptococcus thermophilus* as a new starter culture for Cheddar cheese.

Importance of cheese

The impending abolition of milk quotas in 2015 is projected to result in a major expansion in milk production in Ireland (Department of Agriculture, Fisheries and Food's *Food Harvest 2020* report). Cheese, the export value of which was in the region of €650m in 2009, is targeted as a strategic end product to utilise a significant proportion of this extra milk, with projections of growth from 157,000 tonnes in 2009 to up to 300,000 tonnes by 2020. Expansion is expected both in terms of volume, and also in increased cheese diversification. Such expansion will require the development of starter cultures capable of delivering specific flavours under demanding industrial conditions.

Cheese ripening and starter cultures

Cheese ripening consists of a complex series of chemical and biochemical reactions that contribute to texture and flavour development. Many of these reactions are a result of bacterial activity during ripening. The bacterial flora of most varieties is complex, consisting of added starter strains, as well as an endogenous secondary flora, referred to as the non-starter lactic acid bacteria (NSLAB).

Currently, Cheddar cheese starters are composed of several defined, well-characterised *Lactococcus lactis* strains chosen for their acid-producing ability and high bacteriophage insensitivity (a bacteriophage is a virus that attacks bacteria). This has resulted in the use of an increasingly small number of lactococcal strains, which are expected to perform reliably within strict manufacturing schedules to produce consistent quality product.

However, the destructive potential of lactococcal phage, which reduces the rate of acid production, is detrimental in modern processing plants. Phage susceptibility can frequently emerge after extended use of cultures, leading to disruption of manufacturing schedules and reduction in product quality.

The capacity of strains to impact on cheese flavour/aroma is derived from their ability to degrade proteins (proteolysis), carbohydrates (glycolysis) and lipids (lipolysis). However, differences in the presence and expression of genes involved in these biochemical pathways exist between bacterial strains and should be key criteria for consideration in strain selection.



Image courtesy of Bord Bia.

Streptococcus thermophilus in Cheddar cheese

The inclusion of *Streptococcus thermophilus* (*S. thermophilus*) strains as phage-unrelated starter components with lactococci is increasingly being promoted by starter companies for use in the manufacture of Cheddar cheese. The rationale is that in the event of lactococcal phage attack, *S. thermophilus* will ensure acid production. However, the lack of knowledge of the impact of *S. thermophilus* on Cheddar cheese quality and flavour, combined with the increasing use of these organisms by industry, prompted a research programme at the Teagasc Food Research Centre, Moorepark, to address these issues.

S. thermophilus research at Moorepark

Studies at Teagasc Food Research Centre, Moorepark, followed three main strands to assess:

- the biodiversity of strains of *S. thermophilus* in the Moorepark culture collection, and to compare it to that of commercial strains;
- the potential of a test strain of *S. thermophilus* to impact on flavour development in Cheddar cheese; and,
- the impact of inclusion of biodiverse strains of *S. thermophilus* to diversify Cheddar cheese flavour.

Biodiversity of *S. thermophilus* strains

Screening of the Moorepark culture collection was undertaken using a combination of both phenotypic and genotypic analyses. The biodiversity of strains of *S. thermophilus* was established using pulse field gel electrophoresis (PFGE) to create a unique DNA profile for each strain. A database of 200 *S. thermophilus* strains, including commercial strains, was established. The profiles were subsequently clustered using BioNumerics software (Figure 1) and a subset of strains was characterised for phenotypic traits, i.e., rate of acidification, proteolytic abilities, autolytic abilities and ability to metabolise galactose. The galactose moiety of lactose is generally not fermented by *S. thermophilus*; hence, its release in the cheese is of industrial significance as it could promote the growth of certain NSLAB, which in turn could adversely impact on product quality. This study highlighted the larger biodiversity of *S. thermophilus* strains in the Moorepark culture collection compared to that which is currently available to industry.

Flavour development in Cheddar cheese

To fully assess the role of *S. thermophilus* in Cheddar cheese ripening and flavour development, biochemical and microbiological aspects need to be studied in an integrated manner. Flavour development in Cheddar cheese was assessed in an initial study using bulk starters of a test strain of *S. thermophilus* alone or in combination with *L. lactis*. The evolution of starters and NSLAB, glycolysis (evolution of lactose and galactose), lipolysis (evolution of free fatty acids), indices of proteolysis (free amino acid development), volatile compounds (using gas chromatography-mass spectrometry) and sensory analysis was monitored over a 12-month ripening period. Applying multivariate statistical analysis (principal component analysis) on these data, the research team found that inclusion of even small levels of *S. thermophilus* in the starter mix has the potential to alter the flavour, especially in longer ripened cheeses. Microbiological analysis showed that the presence of *S. thermophilus* increased the level of NSLAB present in the cheese early during the ripening. Randomly amplified polymorphic DNA (RAPD) was used to trace the development of the NSLAB flora throughout ripening in each cheese. The analysis showed that the

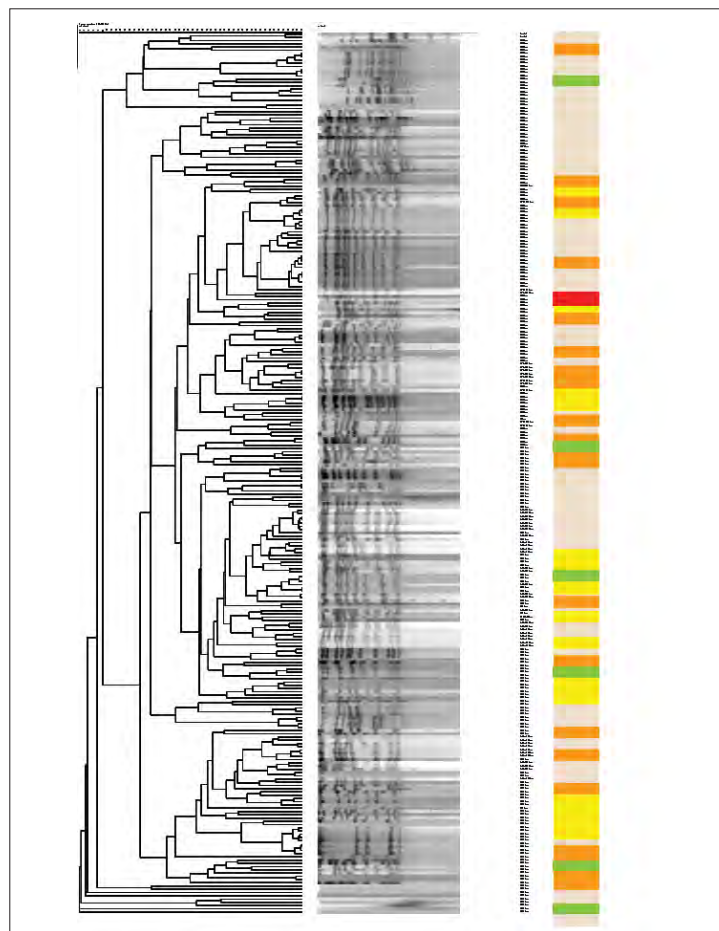


FIGURE 1: Dendrogram of pulse field gel electrophoresis DNA profiles showing the biodiversity of strains of *Streptococcus thermophilus*. In grey: strains from the Moorepark culture collection; yellow and orange: commercial/industrial strains; red: type of strain used in first study; green: biodiverse strains used in second study.

dominant strain was altered in cheeses containing *S. thermophilus* in comparison to cheeses made using only *L. lactis*. The early development of the NSLAB flora, as well as alteration of the dominant strain, is likely to influence flavour development. The degree of alteration in the flavour was found to be dependent on the level of *S. thermophilus* present.

Diversification of Cheddar cheese flavour

The potential of a range of biodiverse strains of *S. thermophilus* to diversify Cheddar cheese flavour was assessed by selecting six strains from different regions of the dendrogram (Figure 1) and possessing different phenotypic traits. Concentrated formats of these strains were made which contained 10^{10} cfu/mL of viable cells, a similar level to commercial concentrated cultures. A control cheese was made using a 0.1% inoculum of a commercial lactococcal mix. For the experimental cheeses, the same lactococcal mix was used, to which one of the six strains was added (0.042%).

As before, the cheeses were subject to rigorous analysis during manufacture and ripening. In comparison to cheeses made with only lactococci, inclusion of individual strains of *S. thermophilus* reduced the cheese make time by 20 to 40 minutes, depending on the strain, without adversely affecting the composition of the cheeses.

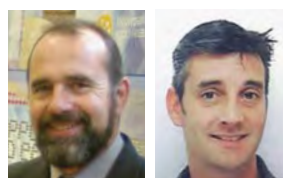
Inclusion of strains of *S. thermophilus* reduced the level of residual lactose but increased the levels of galactose in a strain-dependent manner. As observed in the previous study, higher levels of NSLAB were observed in the cheese made using *S. thermophilus*. Results of volatile and sensory data showed the potential of some strains to diversify Cheddar cheese flavour, while other strains did not alter the flavour profile significantly.

Benefits to industry

The key observation that *S. thermophilus* has the potential to impact on cheese flavour and quality is of very significant importance to commercial cheese manufacturers and culture supply companies. *S. thermophilus*, while not a traditional component of the starter system for Cheddar cheese manufacture, has achieved widespread application due to a number of favourable technological properties. The data generated in this project clearly demonstrates the potential of these strains to impact on cheese quality. The fact that a wide biodiversity of strains was demonstrated indicates that with correct strain selection it should be possible to identify strains that will suit the commercial objectives of different companies.

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Dr Tom Beresford is Head of the Food Biosciences Department and Dr John Hannon is a researcher in the Food Biosciences Department at the Teagasc Food Research Centre, Moorepark. E-mail: john.hannon@teagasc.ie.



Food industry development

PAT DALY describes how Teagasc's food programme supports the Irish food processing industry.

2010 was a very productive year for Teagasc activity in providing technology development supports for the food-processing sector, with a high level of demand, which has continued into 2011. In 2010, contract research and technology support services were provided on a fee-paying basis to about 300 clients, primarily food-processing companies. Additionally, several hundred companies were assisted through the provision of technical advice, usually by telephone or direct contact through our technical information service. Industry contract research and technology development services are a key conduit for knowledge transfer between Teagasc and the food industry. The extensive Food Research Programme at Teagasc generates the knowledge for this interaction with industry. All industry contract research projects are carried out on a confidential contract basis and, where necessary, are undertaken under intellectual property (IP) agreements. Teagasc's clients for 2010 reflected the full spectrum of the food-processing sector and included international companies, small and medium-sized companies (SMEs), artisan/specialty businesses, start-up businesses, large retail groups, service companies to the sector, Government departments and food development agencies.

The competitive position of food businesses is very dependent on their capacity to absorb new knowledge and skills, and convert them into innovative solutions. The sector could be described as containing a relatively small number of companies with well developed R&D capabilities, a large number of SMEs and a growing number of artisan/specialty and start-up food businesses. Approximately 90% of all food companies in Ireland are categorised as SMEs. Thus, Teagasc gives a special focus to supporting the SME sector due to the importance of this group in terms of numbers employed, geographical spread, and their recognised potential to grow and operate in export markets. The technology services programme at Teagasc uses a combination of mechanisms and a customer-focused approach to support this very diverse food-processing sector. Teagasc resources and expertise extend from farm level food production through to food retailing and the consumer. The food programme is based around three core research or knowledge generation areas (food biosciences, food chemistry and technology, and food safety), and an industry development programme that has a major focus on knowledge transfer to industry. Over 200 scientists, technologists and support staff are involved in delivery of the programme. The R&D facilities at the Teagasc Food Research Centres in Ashtown in Dublin and Moorepark in Fermoy, Co. Cork contain a wide range of food-processing facilities and equipment, which includes pilot- and production-scale facilities for dairy, beverage, meat, bakery and prepared foods. Moorepark Technology Ltd., located on the Teagasc Cork site, is a joint venture between Teagasc and several major food companies. The facilities are regulatory-approved food-processing plants and operate to the best quality assurance standards. Specially designed incubation units are available for sole use by client



(Image courtesy of Bord Bia.)

The majority of clients are from the meat processing, dairy processing, and cereals/bakery/confectionery sectors, reflecting Teagasc's major work programme and level of expertise in these areas.

companies. Additionally, modern food preparation, food display and sensory testing facilities are available for preparation and display of product to clients. Well-equipped and modern laboratories are available for microbiological, chemical and physical testing of product. Our scientists and technologists are very experienced in providing customised solutions to a sector with very diverse R&D needs and capabilities. The Teagasc industry support programme is closely aligned with other food development agencies such as Enterprise Ireland and Bord Bia, and many joint programmes are provided for industry. In addition, Teagasc has extensive linkages to food research institutes across Ireland and worldwide. The technology support programme can be described under a number of headings as follows:

Industry contract research

A large volume of contract research was carried out for industry during 2010. This work is carried out on a confidential and client-customised basis. Contract research for industry can be described in two broad categories. The first is collaborative research involving active participation of researchers from more than one party. This can include industry-sponsored research (company funding the research and/or staff), or publicly funded collaborations (e.g., innovation partnerships). IP ownership depends on the levels of input from each party and is negotiated on a case-by-case basis. The second category is where the contract research is performed by Teagasc to a work programme designed by the contractor, and where all results and IP generated are owned primarily by the contractor. During 2010 contract research was carried out for approximately 25 companies, most of which are major food-processing companies in Ireland. Another major component of the industry development support programme is the provision of technology services for industry. These services can be described under three broad headings.

1. Product and process development and associated product testing

This support operates by providing access for businesses to regulatory-approved pilot- and production-scale processing plants, as well as the expertise of product development technologists. This activity also provides opportunities for industry to interact with a research scientist working across a range of food products and processing technologies. Product development supports are provided on a confidential one-to-one basis either at the Teagasc Food Research Centre or in the food business premises. Product testing is carried out for the purpose of providing product reference standards for companies, to solve a product or processing issue, to monitor



Meat training workshop at Teagasc Food Research Centre, Ashtown. Training courses and seminars are a very effective means of supporting food businesses in both knowledge transfer and skills development.

product/process development work, or as an independent specialist testing resource for industry. For this work a wide range of analytical equipment and expertise is used and draws on a substantial depth of analytical expertise built up over many years in our food research programme. Product testing can involve a combination of microbiological, chemical, physical and sensory testing, and is carried out at well-equipped laboratories at Ashtown and Moorepark. Product development activity during the year extended across all mainstream food products: dairy, meat, cereals, fruit and vegetables, and prepared foods. During 2010 approximately 200 product development and testing projects were carried out on behalf of a very wide range of food-processing companies.

2. Specialist technical training courses and seminars

Training courses and seminars are a very effective means of supporting food business in both knowledge transfer and skills development. Courses and seminars are provided principally on specialist topics such as: emerging food legislation; processing technologies such as meat, dairy and cereal products; food assurance standards; and, as a means of disseminating outputs from research projects. Courses and seminars are provided at a number of locations and in company, and are generally aimed at technical and production managers in food businesses and food regulatory personnel, and these events provide excellent opportunities for interactions between industry stakeholders. During 2010 five major research dissemination workshops and 39 training

- During 2010, contract research and technology support services were provided on a fee-paying basis to almost 300 clients.
- Development supports available from Teagasc are:
 - collaborative and contract research (industry/public funded); and,
 - technology services (training courses/seminars, consultancy, product development, technical information).
- A joint development support initiative from Enterprise Ireland and Teagasc is in place supporting food SMEs with a high innovation potential, particularly those with the potential to develop as food export companies.
- Teagasc food industry technology development supports are underpinned by an extensive food research programme with international linkages, and our interactions with the food industry are a key vehicle for research knowledge and technology transfer to the Irish food industry.



Food product development expertise and facilities are available to clients at Teagasc Food Research Centres in both Ashtown and Moorepark.

courses and technical seminars were delivered to industry, with an attendance of almost 800 personnel.

3. Consultancy

A technical consultancy service is available to industry where researchers and technologists provide individual advice on technical issues. Consultancy activity is usually carried out in the client company premises. Key activities in this area are providing solutions on processing technologies and in the implementation of food retailer assurance standards, company safety and quality management systems, and national standards such as the Bord Bia Quality Assurance Standards. During 2010 approximately 50 consultancy projects were carried out. The food industry client base extends across all food sub-sectors, processing technologies, service providers and education institutes. The majority of clients are from the meat processing sector (20%), dairy processing sector (20%), and cereals/bakery/confectionery (12%), reflecting the size of these sectors in terms of numbers of companies, employment levels and also that Teagasc has a major work programme and level of expertise in these areas. Service businesses to the food sector and statutory organisations are also a significant client base. Services typically include consultants, trainers and test laboratories attending training courses and scientific seminars. These services are an important conduit of knowledge transfer for Teagasc to a wider and often local agri-food sector. Statutory organisations such as government departments, local authorities, and national and regional food/business development agencies are also important clients, and Teagasc provides technology development supports for many small and artisan businesses through these development agencies.

For more information on the above please see www.teagasc.ie/research/food.asp (Ashtown and Moorepark), or www.relayresearch.ie.

Pat Daly is Head of the Food Industry Development Department, Teagasc Food Research Centre, Ashtown, Dublin 15. E-mail: pat.daly@teagasc.ie.



Microbial tolerance to biocides

Researchers at Teagasc Food Research Centre, Ashtown, in collaboration with University College Dublin and industry partners, investigate the potential emergence of biocide-tolerant food-borne pathogens in the food industry.

Biocides are chemical or biological agents such as disinfectants, antiseptics and sterilants used to control microbial contamination and achieve a high standard of hygiene in food-processing plants. They are also used as preservatives in food and drink to control the growth of spoilage bacteria, and in animal husbandry to protect food animals from zoonotic agents (diseases of animal origin). Several reports describe the emergence of tolerance to biocides in food-borne pathogens such as *E. coli* and *Salmonella*. The occurrence of biocide-tolerant bacteria would potentially add to the food safety challenges already posed by microorganisms in the food industry. Ongoing work at Teagasc Food Research Centre in Ashtown is investigating bacterial tolerance to biocide formulations currently used in the Irish food industry and is examining how it may impact on the ability of bacteria to survive food-processing stresses, such as heat and low pH.

Development of antimicrobial resistance

The widespread use of antimicrobial compounds in food animal production has come under scrutiny following reports that it contributes to the emergence of resistance in bacteria of food animal origin. Over-reliance on antimicrobial agents for disease control in food-producing animals has become a public health concern as it could lead to an increase in the transmission of resistant bacteria to humans via the food chain. Ultimately, this could compromise the use of clinically important antimicrobial compounds to treat human illness. In a similar way, bacteria have been isolated that demonstrate an increased tolerance to biocides, with a related increased resistance to antimicrobials.

While the use of antimicrobial compounds for the treatment of humans and animals is carefully regulated, this is not the case for biocides. In Europe, the active ingredients in biocide-containing products need to be approved and considered safe before they are sold commercially. Although classed as safe, bacterial tolerance could potentially develop to the active agents in biocide-containing products, especially when the widespread use of biocides in the environment is considered. While application of biocides in the food chain should eliminate microorganisms, some biocide-tolerant strains of bacteria may remain in the chain – posing an increased risk to consumer health.



Bacterial tolerance to biocides

In order to establish baseline tolerance to biocide formulations currently in use in the Irish food industry, this study investigated a large panel of food-borne bacteria ($n=400$) of well-defined epidemiology. The biocides selected ($n=8$) were chosen in consultation with the food industry. A minimum inhibitory concentration (MIC – lowest concentration of an antimicrobial that will inhibit the visible growth of a microorganism after incubation) was determined for each formulation by exposing the bacteria to concentrations ranging from 0–200% of the working concentration, as recommended by the manufacturer. The antibiotic resistance profile of these bacteria was also determined using a panel of 15 different antimicrobial compounds. The biocide MICs ranged from 0.2 to 50% of the manufacturer's recommended working concentration, and bacterial tolerance to biocide formulations at the recommended concentration was not evident.

A selected number of isolates were cultured in the presence of increasing concentrations of the biocide formulations. Using this *in vitro* selection method, a number of biocide-adapted strains were recovered, which demonstrated an increased tolerance to the formulation compared to their isogenic parent (i.e., parents with identical genes). However, the biocide-tolerant phenotype was unstable and was not maintained in the absence of the biocide. Industrial biocide formulations contain multiple active agents and this is thought to be one of the reasons why this study was unable to recover bacteria with stable biocide tolerance. To test this hypothesis, a selected number of bacteria were screened for their tolerance to three individual biocidal active agents (benzalkonium chloride, chlorhexidine and triclosan), all commonly used in the formulation of industrial biocides.

High-level tolerance to the individual biocidal active agents was found in four *E. coli* and eight *Salmonella* isolates and was stably maintained over several generations. Large increases in the MIC for the active agent triclosan in particular were noted, with triclosan-tolerant bacteria growing at concentrations 160-fold higher than the MIC for isogenic parent strains. These data show that while bacteria with stable tolerance to industrially formulated biocides were not isolated, it was possible to isolate bacteria with stable high-level tolerance to the individual active agents commonly found in these formulations. Bacteria tolerant to the individual biocidal active agents were re-



*Far left: High-level tolerance to the individual biocidal active agents was found in four *E. coli* and eight *Salmonella* isolates and was stably maintained over several generations.*

Left: Triclosan is found in a number of domestic cleaning products, antibacterial handwashes and cosmetic products, and is increasingly used in the cleaning regimes of the food industry.

screened against the same panel of 15 antibiotics used to test the parent strains in order to determine whether changes in the antibiotic resistance profile also occurred. No differences in the antibiotic susceptibility of the *E. coli* isolates were detected; however, all *Salmonella* isolates exhibited an alteration in their antibiotic resistance profiles for at least one clinically important antimicrobial compound.

Food processing stresses

Studies have shown that food-borne pathogens can persist in processing environments and may subsequently contaminate foods. In an attempt to overcome this risk, food-processing strategies such as the use of heat and low pH are applied to reduce or eliminate these microorganisms. Tolerance to industrially formulated biocides could potentially facilitate survival of pathogens in heat and acid challenges during food production. Part of this study compared the survival of biocide-tolerant and susceptible *E. coli* isolates to acid and heat, and noted that biocide tolerance did not confer a selective advantage. It is expected that data from this study might be useful for inclusion in risk assessment models to allow the food industry to build realistic food safety margins into their processes.

Benefits to food industry

The findings of this study are relevant to the modern food industry as they provide novel information on baseline tolerance of food-borne pathogens to a number of biocide formulations used in food production plants. The bacteria studied were found to be tolerant to low levels of these biocide formulations (0.2-50% of the manufacturer's recommended working concentration). None of the isolates survived at concentrations above the recommended working concentrations. Although this study could generate bacteria displaying an increased tolerance to industrial biocide formulations, this biocide-tolerant phenotype was unstable in the absence of selection. Interestingly, *E. coli* and *Salmonella* were isolated with stable high-level tolerance to the active agents contained in biocide formulations, such as triclosan. Misuse of products containing this agent could possibly contribute to the emergence of biocide-tolerant food-borne bacteria. Triclosan is found in a number of domestic cleaning products, antibacterial handwashes and cosmetic products, and is

increasingly used in the cleaning regimes of the food industry. Genomic and proteomic studies are currently underway in Teagasc Food Research Centre, Ashtown and University College Dublin to determine how bacteria respond to biocides. The data generated by this study will contribute towards a greater understanding of the biocide-tolerant phenotype at a fundamental level so that guidance can be provided to the food industry regarding appropriate biocide usage.

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Dr Mary Lenahan, Áine Sheridan, Dr Geraldine Duffy and Dr Kaye Burgess, Food Safety Department, Teagasc Food Research Centre, Ashtown, Dublin 15. Professor Séamus Fanning and Órla Condell, UCD Centre for Food Safety, School of Agriculture, Food Science and Veterinary Medicine, Veterinary Sciences Centre, University College Dublin, Belfield, Dublin 4. E-mail: kaye.burgess@teagasc.ie.



Meat quality control

Teagasc researchers are looking at integration of food quality assurance and legislative food safety process controls in meat processing.



Liberalisation of global food trade and increasingly discerning consumers have driven the demands both for cheaper meat products and for meat that is healthy and safe to eat, and that has been produced to the highest animal welfare standards. Highly technical quality assurance standards (QAS) have developed in recent years to allay consumers' fears on the quality, safety and provenance of the meat they purchase. Standards such as the Bord Bia meat schemes, the Red Tractor scheme in the UK, the QS scheme in Germany, and the IKB in Holland, have served to alleviate consumer fears. Meat products produced, for example, in the Bord Bia schemes are now clearly identified with a quality assurance logo highlighting the fact that the meat is produced under the highest possible standards and is fully traceable (in this case to farms of Irish origin). Quality assurance schemes may be regarded as complex codes of practice in which prescribed standards based on best practice and up-to-date science are adopted by all stakeholders involved. The validity of the code is based on independent verification through international certification standards such as EN45011.

Quality assurance schemes have also always had a strong retailer influence and increasingly form the basis of strong commercial agreements between meat companies prior to supply of product. All Irish-based retailers now require that a recognised quality assurance scheme certified to an international standard is in place both at producer and factory levels. This has created opportunities for all stakeholders in the quality-driven supply chain process, i.e., producers, processors, advisers, state agencies and regulators. Irish meat products now compete on an international stage, certified under standards such as those operated by Bord Bia. Teagasc, through its food research and industry development programme, has for many years assisted state agencies and food companies (in particular SMEs) in the development and implementation of world-class quality assurance standards. This

has been achieved through technical consultancy and specialist training, backed up with cutting-edge research and technology, and has helped to position Ireland in the elite of food production and processing countries in Europe.

Scope and significance of quality assurance standards

Quality assurance standards nowadays not only cover food safety checks within the framework of a hazard analysis critical control point (HACCP) framework, but also animal welfare, processing and slaughtering interventions, product compositional parameters, producer and supplier controls, and traceability. Good manufacturing practice (GMP) is required at processor level, while at producer level, practices based on good agricultural practice (GAP) are advocated. All the above is encompassed within a framework of total quality management (TQM). Taking the Bord Bia schemes operated in Ireland as an example of a world-class integrated quality assurance process, quality assurance is operated at key stages in the supply chain. Quality assurance in this context involves the implementation of checks and measures, with associated procedures and record-keeping that are designed to eliminate deficiencies or weaknesses in quality and safety at all stages. Quality assurance, in conjunction with quality control, assures the highest possible standard of product.

Benchmarking

The fact that Ireland now competes in a globalised marketplace emphasises the continued importance of benchmarking against international equivalents. Ireland, however, is now in a unique position where our standards are seen as best international practice and subsequently benchmarked by other counterparts. Benchmarking should ultimately be conducted with commercial profit or gain at the forefront. Without this approach a benchmarking exercise could be a time-consuming and costly exercise for all stakeholders.

Quality assurance and commission regulation EC 2073/2005

Quality assurance based on a planned series of measures and checks as outlined in this article has been facilitated in recent years through the introduction of regulation EC 2073/2005 on the microbiological criteria of foods. This regulation, and its subsequent amendments, has been particularly important in the context of the meat sector, and indeed many of its integral microbiological criterion checks have now been adopted by quality assurance standards.

A microbiological criterion is defined in the regulation as "a criterion defining the acceptability of a product, a batch of foodstuffs or a process, based on the absence, presence, or number of microorganisms, and/or on the quantity of their toxins/metabolites, per units of mass, volume, area or batch".

In this regulation two types of microbiological criteria are defined:

1. **Process hygiene criteria:** Process hygiene criteria indicate the acceptable functioning of the production process. They apply at specific stages during the production process. In the event of unsatisfactory results, the food business operator must review the process and improve hygiene to ensure future production will meet the criteria. Corrective actions should include those specified in the Regulation.
2. **Food safety criteria:** These criteria are used to assess the safety of a product or batch of foodstuffs. They apply to products throughout their shelf life and, if exceeded, should result in the withdrawal or recall of the product(s) from the market.

Microbiological criteria and HACCP integration

All food business operators (with the exception of primary producers) are legally obliged to put in place, implement and maintain a permanent procedure or procedures based on HACCP principles (Article 5 of Regulation (EC) No 853/2004). HACCP is a preventive approach to food safety, i.e., it identifies what can go wrong and plans to prevent it.

The approach advocated by QAS and legislation is to utilise microbiological criteria within the framework of a comprehensive food safety management system based on the principles of HACCP. Microbiological criteria should be used when validating or verifying the correct functioning of HACCP-based procedures and good hygiene practices. This approach gives a greater degree of food safety control to the business operator. Food business operators who sample and test a specified point in the production process, or at a defined end point, can demonstrate that the system in place is working effectively. This, together with other verification practices (for example review of HACCP system, review of customer complaints/system failures), helps to demonstrate compliance with the sixth principle of the Codex HACCP requirements (i.e., verification). This aspect can also be used by regulatory authorities as part of their ongoing compliance verification.

Food business operators can further use process and end-product data, trended over a period of time, to further improve on the process controls or to examine end products as part of the measures to verify and/or validate the efficacy of the HACCP plan.

Sampling plans and quality assurance

Bacteria are rarely distributed evenly throughout a food product but are more likely to be distributed randomly. Some bacteria present on a food surface may be unable to grow, some may die and some may find themselves in conditions where they can easily multiply. The resulting growth distribution containing pockets of bacterial cells is described as a contagious distribution. As the number of samples tested increases so



(Image courtesy of Bord Bia.)

Bord Bia schemes are now clearly identified with a quality assurance logo highlighting the fact that the meat is produced under the highest possible standards and is fully traceable.

does the confidence in the test result, but so also do the testing costs. To be fully confident, every product would need to be tested, but this would be impractical, as microbiological testing to standard methods is destructive in nature. Microorganisms in food are also unevenly distributed and microbiological testing alone can never guarantee food safety. A more practical approach, which is adopted in modern quality assurance schemes, is to use microbiological testing to verify the correct functioning of the HACCP-based procedures and other good hygiene practices.

Industry benefits

Retailers and international meat buyers who purchase Irish meat products in huge quantities now demand that a world-class quality assurance standard is in place, at both producer and factory level, with independent verification. In many instances, e.g., beef production, a premium is given to producers of top quality animals produced under a recognised quality scheme.

Irish quality-assured meat products are highly regarded both in Ireland and internationally as top quality and fully traceable. Consumers are becoming more and more vigilant and, while price is an increasing issue, evidence of traceability, quality and provenance is also sought.

Irish food SMEs are currently in an excellent position to benefit from the increasing demand for top quality meat. This sector is strongly poised to ensure success despite the difficult economic climate.

Kevin Brennan is a food safety and quality specialist based in the Teagasc, Ashtown, Food Industry Development Department.
E-mail: kevin.brennan@teagasc.ie.



The grass is greener

Grass, one of our greatest natural resources, has potential far beyond its current use. Teagasc researchers are involved in a number of projects to investigate alternative applications for Irish grass.

The need to develop alternatives to non-renewable fossil fuel-derived products has stimulated an interest in plant biomass as a 'natural chemical factory' to provide renewable energy, chemicals and materials. Grassland biomass represents the most significant biomass resource in Ireland, accounting for approximately 90% of the 4.3 million hectares of agricultural land. High yields can be achieved and, in contrast with many other energy crops, the use of grassland removes the need for adoption of new farming practices and annual tilling, and promotes the preservation of habitat biodiversity. This article outlines some of the potential applications for grass.

Primary processing steps

While fresh grass can be used as an industrial biomass feedstock, in most cases it may be necessary to preserve it as silage to ensure year round availability and a predictable quality. Grass silage can be used directly or separated into solid and liquid fractions that can be further refined into a range of marketable products. The separated solid fraction is rich in cellulose, hemicellulose and lignin, while the liquid fraction contains a mixture of protein components, organic acids, water soluble carbohydrates, minerals and other substances, which can be subjected to a series of downstream processes to recover valuable products.

Solid fraction

Thermal insulation

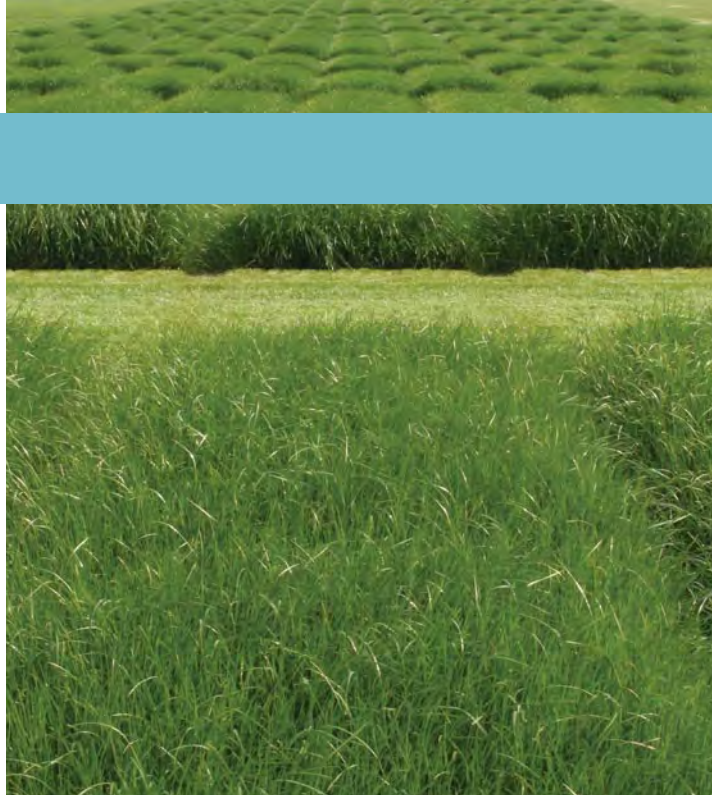
Thermal and acoustic insulation boards from grass fibre are being successfully manufactured and marketed in Switzerland (www.gramitech.ch). It is claimed that these boards combine winter cold, summer heat and sound insulation protection on a par with petrochemical-derived insulation products (Figure 1).

Particleboard

Particleboard is conventionally made from wood fragments, such as chips or shavings, which are mechanically pressed into sheet form and bonded together with resin. Researchers in Turkey have investigated the use of grass fibre for particleboard production, stating that up to 13% substitution of wood fragments with grass fibre yielded boards of acceptable mechanical properties.

Biocomposites

Biocomposites are hybrid materials made of a polymer resin reinforced by natural fibres, combining the high mechanical and physical performance of the fibres with the appearance, bonding and physical properties of polymers. A major application of biocomposites is in the motor industry, where biocomposites from hemp and other bast fibres are used for interior panelling. A number of researchers are investigating the application of grass fibre-based polymer composites.



Horticulture

Peat is the main soil-less growth media available for horticulture. However, interest in alternatives to peat is increasing due to environmental issues related to the destruction of peatland habitats and the growing awareness of the benefits of using renewable materials. At present, organic non-peat growing media include coir, wood fibres, composted bark and composted green waste. Researchers in Austria have investigated the use of the solid fraction of grass silage in hydroseeding (a process for rapid turf establishment based on a single spray application of a seed, fertiliser and growth media mix).

Paper-making

Wood and recycled fibre are the main fibre sources available for paper-making. However, continuous recycling of fibre reduces the strength of the paper produced. Large fluctuations in the price of raw materials have stimulated the search for alternative fibre sources with Smurfit Kappa, for example, investigating the use of sugar beet and grass fibre.

Combustion

Local resources of solid biomass fuel consist of wood and straw, and in recent years this has been supplemented with willow and miscanthus. Although the high ash content of dry grass makes it unsuitable for combustion, the higher fibre and lower mineral content (N, Cl and K removed in liquid fraction) of the separated solid fraction may make it suitable for combustion after drying.



FIGURE 1: Installation of insulation boards made from grass fibre (Source: Stefan Grass; www.gramitech.ch).

Liquid fraction

Lactic acid

Lactic acid is the major fermentation product produced during ensilage, with values ranging from 20–40g/kg in well preserved extensively fermented grass silage. Lactic acid represents a major renewable platform chemical and is used widely in the pharmaceutical industry as a precursor chemical, in the cosmetic industry as a moisturiser and as a building block for biodegradable plastic (polylactic acid).

Amino acids

Amino acids are used for a wide variety of applications in industry including the synthesis of drugs, cosmetics and food additives. Free amino acid values can range from 2–24g/kg in well preserved grass silage.

Anaerobic digestion

Anaerobic digestion (AD) is a biochemical process in which bacteria convert organic material into renewable energy in the form of biogas. Over 6,000 on-farm biogas plants in Germany use feedstocks such as maize and grass silages and animal manure for biogas production. Fresh grass, grass silage and/or any waste stream from the above refining processes could potentially be used for biogas production.

Heat and energy

The biogas produced from AD (about 55% CH₄) is generally used on site in combined heat and power engines. In most instances the electricity generated is sold to the national grid, while the heat is ideally used on the farm or sold as a local heat supply. Alternatively, the biogas can be upgraded (i.e., removing CO₂, H₂S and water vapour) to natural gas quality (>97% methane) and injected into the natural gas grid as biomethane. Bord Gáis recently acknowledged the huge potential of grass biomethane for the renewable gas industry in Ireland.

Transport fuel

Biomethane can also be compressed and used as a transport fuel (Figure 2). Most of the major car manufacturers now supply compressed natural gas (CNG) vehicles. Almost 1.5 million CNG vehicles are currently used in Europe, and the substitution of natural gas with compressed biomethane offers reduced greenhouse gas emissions and lower fueling costs compared with ignition diesel engines.



FIGURE 2: Biomethane filling station (Source: Erdgas Mobil GmbH; www.erdgas-mobil.de).

Digestate

AD also allows for nutrient recovery, and the residual material remaining after digestion can be returned to the land as a biofertiliser, thus helping to maintain the nutrient balance and to reduce inorganic fertiliser requirements.

Technology in action

Two examples of the integrated industrial use of grass include:

Green biorefinery pilot plant, Utzenaich, Austria

This plant is located on the site of an existing biogas plant, which utilises slurry together with maize, sunflower, triticale and grass silages. After separation of the grass silage in the green biorefinery, the solid fraction is used as a feedstock for AD, while the liquid fraction is further refined to extract lactic and amino acids. Electricity produced from the biogas is sold to the national grid, while the heat is used on site to dry the solid fraction of the digestate prior to packaging for use as garden compost. The aim of this plant is to demonstrate the technical and economic feasibility of a green biorefinery.

Maihingen biogas plant, Germany

The Maihingen plant is operated by a number of farmers and private investors and utilises maize, grass and wholecrop cereal silages for biogas production. Some of the biogas is used on site for the co-generation of heat and electricity, with the latter being sold to the grid. Erdgas Schwaben GmbH (a German energy supply company) takes the remaining biogas and upgrades it to biomethane before injecting it into the natural gas grid.

Ongoing Teagasc research

A Department of Agriculture, Fisheries and Food-funded project (GreenGrass) is currently ongoing at Teagasc, Animal & Grassland Research and Innovation Centre, in collaboration with University College Cork (Dr Jerry Murphy) and the Questor Centre, Queen's University Belfast (Dr Elaine Groom). The focus of this work is to investigate: (a) the potential of different grass species and red clover for use as a biomass feedstock; (b) the potential of these species to provide fibre for industrial applications; and, (c) the optimisation of AD technology for grass silage feedstocks.

A second project, Bio-GrAss, which includes Teagasc's Crops, Environment and Land Use Research Centre, Oak Park and University College Dublin, is investigating the greenhouse gas balance of grass-to-energy conversion.

Dr Joseph McEniry is a Contract Research Officer, Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co Meath. **Colman King** is a Teagasc Walsh Fellow with the School of Architecture, Landscape and Civil Engineering, University College Dublin. **Dr Padraig O'Kiely** is a Senior Principal Research Officer, Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co Meath. E-mail: padraig.okiely@teagasc.ie.



Shedding light on the milking routine

Researchers at Teagasc Animal & Grassland Research and Innovation Centre have been looking at the most efficient lighting options for the dairy industry.

The application of electric lighting is a substantial energy input in the operation of a modern dairy farm. Energy audits carried out by Teagasc Animal & Grassland Research and Innovation Centre in 2009 identified lighting as one of the major consumers of electricity, accounting for 7% of total electrical energy used on Irish dairy farms. The cumulative magnitude of energy used by lighting equipment in all areas of the milking operation is somehow perceived not to be as significant as it really is. In fact, electricity used by lighting can add up to 1kWh per cow per week.

Moisture-resistant double fluorescents and high-bay metal halide lamps are the two most common types of lighting systems used on Irish dairy farms. Teagasc energy audits have shown that similar size dairies using metal halide lights can use over three times more electricity on lighting than a farm using fluorescent lights. This is because of the high wattage of the metal halide fittings. Metal halide fittings are typically suspended from the dairy roof in a single row over the milker's pit. The nature of this lighting strategy leads to shadows being cast by the milking machine, stallwork, milk meters and automatic cluster removers. Lux measurements (measure of illumination – see panel) taken in the milker's pit tend to be well below desired levels when excessive shadows are cast.

The alternative, fluorescent lighting, generally consists of two rows of double tube luminaries mounted over the edges of the pit, as illustrated in Figure 1.

Teagasc lighting experiment

The milking operation on a dairy farm is a critical task that requires unhindered visual observations of the milking equipment and the udder. Inadequate lighting can accelerate fatigue and diminish the performance of the milker. Bearing this in mind, a series of tests were carried out on five different lighting types by engineers at Teagasc. The objective of these tests was to identify the lighting technologies with the highest efficacy and efficiency (Figure 2).

During the course of the lighting experiments it was noted that modern fluorescent tube fittings tend to interfere with milking parlours' automatic cow identification systems, reducing the effective distance from the cow's ear tag to the antenna. The underlying reason for this is the use of high frequency switching ballasts, within the light fittings themselves. These ballasts give out high-frequency nuisance signals that interfere with the automatic identification antenna. Table 1 illustrates the dramatic effect these lights have on the tag-reading abilities of the automatic identification system when suspended one

metre above the antenna. The older switch start or magnetic ballast fluorescent tubes are still commercially available and where automatic identification systems are installed these lights are the only viable option. While not the most efficient solution, they will, however, offer substantial savings over the high-bay metal halide lamp and will provide sufficient lux levels at the cow's udder. Where automatic cow identification is not installed any type of fluorescent can be used. The most commonly used type of fluorescent tube found in the dairy is the double five foot fluorescent tube. These tubes have a diameter of one inch and are referred to as T8 fittings in the lighting industry. A number of options exist to improve the efficiency of these fittings.

The T5 fitting is an increasingly popular development in fluorescent lighting. T5 lamps

Measurement of light and luminary efficiency

Lux is the most commonly used measure of light intensity. Lux takes into account the area over which the luminous flux is spread. Lux can be easily measured using commonly available lux meters. The lumen (lm) is the SI unit of luminous flux, a measure of the power of light perceived by the human eye. A flux of 1,000 lumens, concentrated into an area of one square metre, lights up that square metre with an illuminance of 1,000 lux.

To determine the performance of one luminary relative to another two properties are compared:

- efficacy – artificial light sources are usually evaluated in terms of luminous efficacy of a source (LES), which is a figure of merit for light sources. It is the ratio of luminous flux (in lumens) to power (in watts). The efficacy of one light source can be directly compared to another; and,
- efficiency – an efficacy figure of 683lm/W corresponds to an efficiency of 100%. The efficiency of a luminary is the ratio of its efficacy to the maximum 683lm/w.

The IES (Illuminating Engineering Society) recommends 500 lux on the operating plane (at the cow's udder) for the milking routine, 200 lux for walkways and 100 lux for holding areas.



FIGURE 1: A well-lit parlour with two rows of double fluorescent fittings.



FIGURE 2: Types of lighting available for milking parlours (from top): T5 tube; T8 to T5 converter; LED tube; and, conventional T8 tube.

Table 1: Table showing luminous efficiency, power consumption, luminous efficacy, lux values and effective tag reading distance for three high frequency ballast fittings (columns 1, 2 and 3), one magnetic ballast light fitting (column 4), and a metal halide light fitting (column 5).

	Double 19W 5Ft LED	Double 49W 5Ft T5	Double 5Ft T8 to T5 converter	Double 58W 5Ft T8 (magnetic)	400W high bay metal halide
Luminous efficiency	20.99%	15.53%	10.13%	12.17%	6.54%
Power consumption (W)	36.8	92.3	51.8	103.5	450.0
Luminous efficacy (Lm/W)	111.4	103.5	81.3	72.8	44.7
Lux at one metre	653.0	1516.0	685.0	1402.0	3200.0
Tag read distance	31.0	25.0	37.0	102.0	102.0

have a diameter equal to 5/8 inch. These lamps are approximately 40% smaller than T8 lamps. Traditionally, upgrading to T5 lamps required the purchase of a new light fixture. T8 to T5 converters are now commercially available to convert existing T8 fittings to T5 fittings without the requirement to change the fixture itself. These converters do reduce the power consumed by the light fitting but at the expense of light output, resulting in poor efficiencies; therefore, they are not as attractive an option as they would initially appear to be.

T8 LED (light emitting diode) tubes are also available, although these are quite new to the market. Luminous efficiency, power consumption and a lux value recorded one metre from the light fittings are displayed in Table 1.

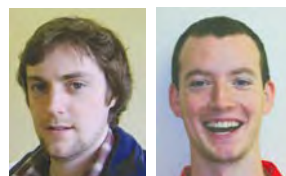
Using the double 58 watt five foot T8 as the benchmark and current industry standard, it is clear that efficiency gains can be made by upgrading existing lighting. One point to note is that the lux values for the T5 fitting are far higher than required; in fact, the number of light fittings in the dairy could be halved while still meeting the required 500 lux on the working plane (at the cow's udder). Moving from double T8 fittings to half the number of T5 fittings would reduce power consumption on lighting by 40% while still providing the 500 lux recommended by the IES (Illuminating Engineering Society). LED tubes are very efficient and would save 48% on power usage. However, one LED tube currently costs approximately €85 compared to €10 per T5 tube, making them an unattractive option even when their longer life is taken into account.

Benefits to the industry and further work

Performances of these light types will be monitored over time for any changes in light output or power consumption. New technologies to reduce dairy farm electricity consumption are being identified and evaluated on an ongoing basis as part of the larger energy research programme in Moorepark. This programme aims to promote a more energy-efficient approach to dairy farming, which in the long term will result in lower energy input costs.

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John Upton is a Research Officer at Teagasc, Livestock Systems Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork. Michael Murphy is a Teagasc Walsh Fellow registered with Cork Institute of Technology. E-mail: john.upton@teagasc.ie.



Cereal quality for pig diets

PEADAR LAWLOR investigates grain quality for pigs and offers advice to producers regarding predicting its nutritive value.

Wheat and barley are the predominant cereals used in Irish pig diets. The quality of these home grown cereals (i.e., their nutritive value) will have a huge influence on pig growth and feed efficiency. This is more important now than ever, with feed ingredient prices at an unprecedented high.

Cereal quality

Hectolitre weight is the standard measure of cereal quality in Ireland. It is the standard European Community mass per storage volume (density) measurement and is expressed in kg per hectolitre (100 litres). Low hectolitre weight cereal is associated with reduced feeding value because it contains less starch, more fibre, and more foreign material may be present. However, many studies show that hectolitre weight is a poor predictor of the digestible energy (DE) value of cereals (Zijlstra *et al.*, 1999; O'Doherty and Dore, 2001), or pig performance (HGCA, 2001).

Prediction of the nutritive value of cereals is more accurately based on chemical characteristics than on hectolitre weight. Zijlstra *et al.* (1999) found that the single best predictor of DE in wheat was xylose, followed by total non-starch polysaccharides. Using two chemical characteristics (crude protein and neutral detergent fibre) together resulted in the best prediction of DE content.

According to work by Fairbairn *et al.* (1999), acid detergent fibre can be used to predict the DE content of barley with an accuracy of 85%. These chemical characteristics can be rapidly obtained using near-infrared spectroscopy (NIRS). Currently, NIRS calibrations that directly predict the energy value as well as other chemical and physical characteristics of whole cereal grains for different types of livestock, including pigs, are being commercialised. Such a rapid test could result in huge feed cost savings for producers, by enabling them to discriminate between batches of grain differing in DE content and more accurately formulate diets.

An experiment conducted in Moorepark looked at batches of wheat differing in hectolitre weight. In brief, three diets were formulated with: (1) high quality



wheat (HQ); (2) good quality wheat (GQ); and, (3) poor quality wheat (PQ) (Table 1). Diets were formulated to 11.2g/kg lysine and 13.6MJ/kg DE, and contained 744g/kg wheat and 222g/kg soya-bean meal. As expected, the HQ wheat resulted in the best animal performance. However, unexpectedly, the GQ wheat resulted in poorer growth rate than the PQ (Table 2). On examination of the data, the yeast and mould counts for GQ and PQ wheats were 10-fold higher than for HQ. This might indicate a presence of mycotoxins in the GQ and PQ wheat. However, presence or absence of moulds does not confirm that a mycotoxin is present and, unfortunately, mycotoxin analysis was not performed on the wheat used in this experiment. Another plausible explanation for the difference in animal performance might be a difference in the DE content of the test wheats. This was calculated using a prediction equation from Zijlstra *et al.* (1999) and does, to a large degree, explain the animal performance differences observed. Interestingly, using August 2010 finisher feed price (€222/tonne) and pig price (150c/kg DW), and using a fixed duration of feeding, the differential in the margin over feed was €6.93 per pig between diets formulated with HQ as opposed to GQ wheat. This differential is huge, especially considering that the hectolitre weights of both wheat types were similar.

It is evident from this work that producers need to be more scrupulous when purchasing feed ingredients. Better predictors of grain quality should be used. NIRS allows rapid determination of chemical composition compared to wet chemistry and the analysis cost involved will be money well spent. Cereals could then be priced according to their true nutritive/feeding value.

Mycotoxin contamination

Mycotoxins are defined as secondary metabolites of mould growth and are thought to be produced in response to stress factors experienced by the mould. A brief overview is given below and for a more extensive review please see Lawlor and Lynch (2001a,b).

Weather-damaged grain often leaves the kernel more susceptible to mould and fungal growth in the field and during storage if moisture content is not adequately

reduced. This may result in the presence of mycotoxins (i.e., toxins produced by the moulds). Mycotoxin-contaminated grain, when fed to pigs, is likely to depress average daily gain (ADG) as well as adversely affecting feed conversion efficiency (FCE). Farmers that are home compounding and buying large consignments of barley and/or wheat should have a sample tested for mycotoxins prior to their incorporation into diets. Specific testing for the presence and quantities of mycotoxins is essential to determine toxicity, since fungal/mould presence only determines the potential for toxins to be produced. Mould contamination can often occur in pockets in grain and incorrect sampling procedures may actually miss these 'hot spots'. Mycotoxins may also be present after fungi have lost their viability. Table 3 shows the maximum concentrations of three different mycotoxins that should be allowed in pig diets (Diekman *et al.*, 2008).

Other factors to consider

Plant breeders do not necessarily have the animal feeding value of a grain in mind when developing new varieties. For instance, most feed barley originates from varieties that were bred for malting purposes but failed for this purpose. The protein content of malting and feeding barley in Ireland was low in 2009 and again in 2010. Many factors such as yield, weather, levels of nitrogen applied, etc., influence the protein content of a cereal. It is too early to say whether the drop in protein observed in the past two years is a real trend or just a blip.

Summary

Hectolitre weight is a poor predictor of animal performance. When purchasing grain, producers should use better predictors of its nutritive value. NIRS is advanced enough now that some of these predictors can be cost effectively obtained in a timely manner. It is recommended to avoid grain with mycotoxin contamination, as not only does it reduce feed intake and ADG, it can also cause fertility problems in sows.

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Table 1: Analysis of wheats fed to finishing pigs (Lawlor and Lynch, 1999).

	HQ	GQ	PQ
Origin ¹	Britain	Ireland	Ireland
Hectolitre weights (KPH)	74.2	73.3	67.0
Yeast and mould count (10 ⁴ /g)	4.5	38	65
Crude protein (%)	11.6	10.3	10.6
Fibre (%)	2.15	2.52	3.09
Fat (%)	1.70	1.85	1.85
Ash (%)	1.53	1.54	1.51
Digestible energy (MJ/kg) ²	14.2	13.7	13.5

¹Wheats were harvested in 1997 when harvesting conditions were difficult in Ireland.

²Calculated using prediction equation (Zijlstra, et al., 1999).

Table 2: Effect of wheat quality on finisher pig performance (Lawlor and Lynch, 1999).

	HQ	GQ	PQ	s.e.	P%
Initial weight (kg)	38.1	38.5	38.8	0.7	NS
Slaughter weight (kg)	91.9	89.3	91.4	1.1	NS
Carcass weight (kg)	69.9	67.1	69.8	1.0	9+
Feed intake (g/day)	2055 ^a	2086 ^a	2276 ^b	57	**
Daily gain (g/day)	727 ^a	667 ^b	703 ^{ab}	18	7+
Feed conversion efficiency	2.94 ^a	3.22 ^b	3.28 ^b	0.07	**
Lean (%)	57.0	58.4	57.3	0.6	NS
Kill out (%)	76.1 ^{ab}	75.2 ^a	76.4 ^b	0.4	7+

^{ab} Values in rows not sharing a common superscript are significantly different (P<0.05).

Table 3. Recommended maximum concentrations of mycotoxins in pig diets.

Pig	Dietary concentration		
	Deoxynivalenol (ppm)	Zearalenone (ppm)	Aflatoxin (ppb)
Breeding herd	1.0	2.0	100
Piglets	1.0	1.0	20
Weaners	1.0	1.0	*
Finishers	1.0	3.0	200
Boars	1.0	3.0	*

*Concentrations not determined.

Dr Peadar Lawlor is a Principal Research Officer in Teagasc's Pig Development Department, Animal Et Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork. E-mail: peadar.lawlor@teagasc.ie.



Variety contribution to perennial ryegrass swards

In Ireland milk and beef are produced predominantly under grazing systems where perennial ryegrass (*Lolium perenne* L.) is the most important grass species. Dry matter (DM) yield is an important variety trait in grazing-based systems. Ongoing work at Moorepark is evaluating the effect of variety proportion in a mixture, and the resulting effect on DM yield and plant establishment.

Variety inclusion in mixtures

To date, there has been little information available as to what are the optimum inclusion rates of cultivars in a grass mixture. General guidelines recommend 12–14kg of seed/acre, with recommendations for three to four cultivars in a mixture and a minimum of 3kg per variety in order for it to contribute to the overall sward. Work is currently ongoing in Moorepark to assess the effects of sowing proportions on variety performance in mixtures compared to monocultures. Starch gel electrophoresis is being used to identify changes in the sward composition. The active phosphoglucoisomerase (PGI) enzyme is of interest in this technique. Perennial ryegrasses possess two loci, commonly called PGI-1 and PGI-2, which produce this enzyme. The PGI-2 locus normally codes for three common alleles, usually known as A, B, and C, and a much rarer allele D, and is of interest in this technique. The enzyme is dimeric and so can be interpreted for genotype. Based on the band patterns the genotype of a plant can be identified. The technique is used to identify the genotype frequencies of the sward and changes can be attributed to changes in the composition of the sward. A plot experiment was sown in autumn 2009 using three varieties (two diploids [Abermagic and Twystar] and one tetraploid [Greengold]). Treatments were as follows: three monocultures, 11 two-way mixtures of different sowing rates and one three-way mixture, resulting in 15 treatments in total. The plots were managed under a simulated grazing regime throughout 2010. There were three replicates of each treatment, resulting in 45 plots in total. Using electrophoresis, the genotype frequencies of each treatment were compared with the genotype frequency of the individual cultivars in monoculture to determine the composition of the binary mixtures. A simulated grazing management was imposed, with eight cuts taken across the year to mimic a typical grazing rotational system at farm level.



Plots at Moorepark.

Results

Provisional results are presented. Dry matter yield results from 2010 (year one of the experiment) for the simulated grazing management are presented in Figure 1. Total DM yield ranged from 11.3t DM/ha to 10.2t DM/ha. The results clearly indicate that Abermagic was the highest yielding monoculture and Twystar the lowest. It is clear from the graph that the mixtures that contained a high proportion of Abermagic at sowing had the highest DM yield, and as the sown proportion of Abermagic declined in a mixture, the DM yield of the mixtures also declined.

In spring 2010 the proportion of Abermagic had decreased in all the swards, with a greater decrease observed when Abermagic was sown with the tetraploid Greengold than with the diploid Twystar.

This suggests that the performance of a cultivar as a monoculture is a good indicator of the potential performance of a mixture when the monoculture is included at a high proportion in that mixture. The three-way mixture, which contained equal proportions of each of the three cultivars, out yielded the two lower-producing monocultures. This may be due to competition occurring among the cultivars in the mixture and Abermagic dominating the other two cultivars. Further research on this is necessary before final conclusions can be drawn. The experiment will continue into 2011 and 2012 to identify sward compositional changes that may occur. The electrophoresis technique was used at various stages across the year to determine the

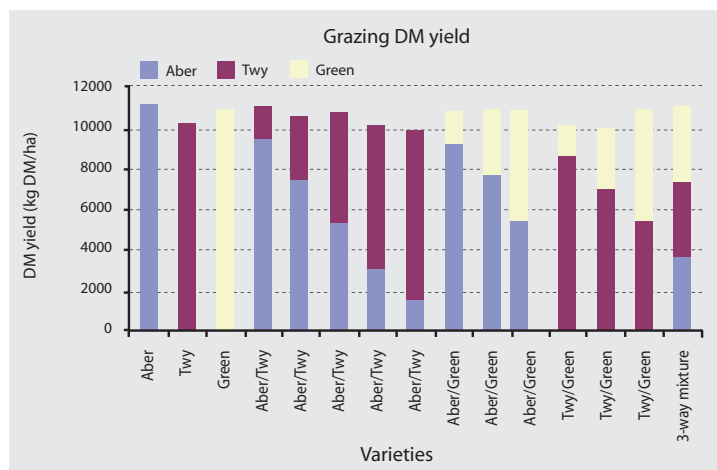


FIGURE 1: DM yield performance of monocultures and mixtures of three perennial ryegrass cultivars under a simulated grazing management. Results are preliminary and based on one measurement year. Different colouring indicates sowing proportions of each cultivar.

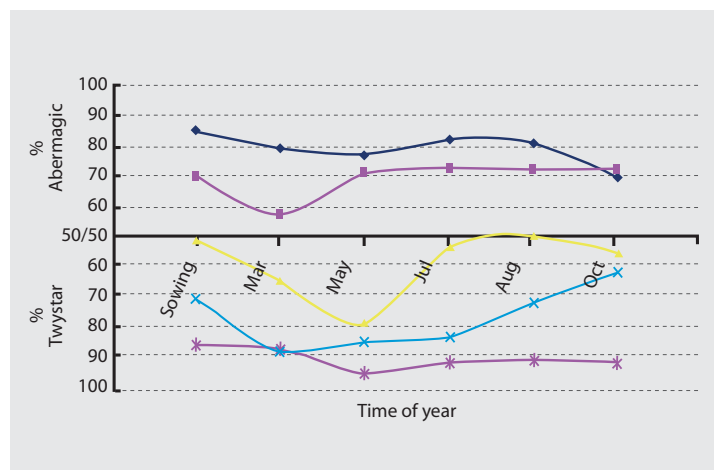


FIGURE 2: Changes in proportion of Abermagic and Twystar in a sward when sown in a binary mixture from sowing through to end of first harvest year.

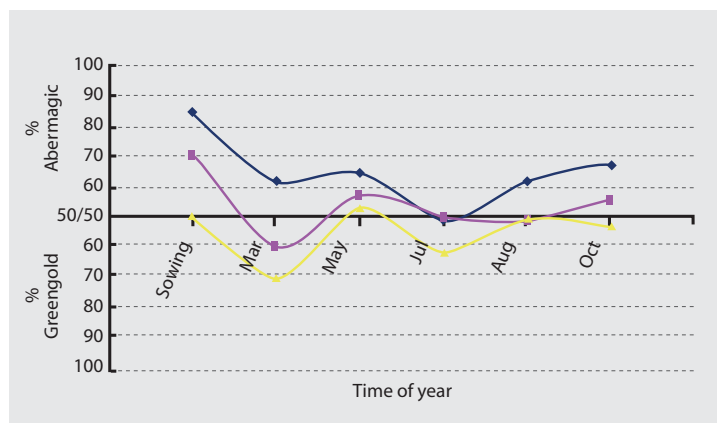


FIGURE 3: Changes in proportion of Abermagic and Greengold in a sward when sown in a binary mixture from sowing through to end of first harvest year.

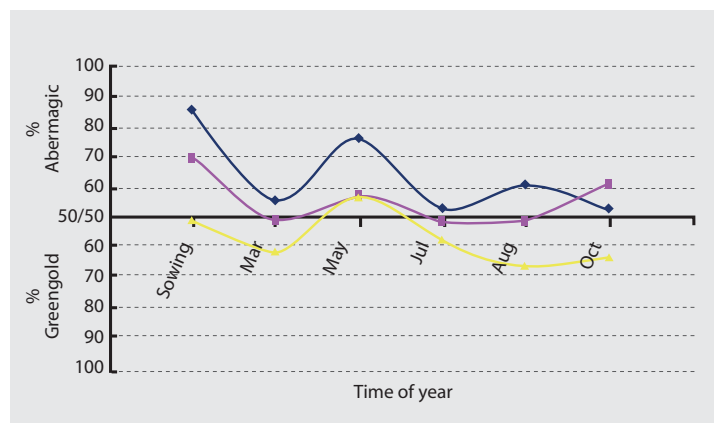


FIGURE 4: Changes in proportion of Twystar and Greengold in a sward when sown in a binary mixture from sowing through to end of first harvest year.

change in the composition of the varieties in the sward from sowing through the first full cutting year. Figures 2, 3 and 4 show the sward changes from sowing until the end of the first full harvest year for the Abermagic/Twystar (Figure 2), Abermagic/Greengold (Figure 3) and Twystar/Greengold (Figure 4) binary mixtures. In spring 2010 the proportion of Abermagic had decreased in all the swards, with a greater decrease observed when Abermagic was sown with the tetraploid Greengold than with the diploid Twystar. The proportion of Twystar had increased in all the binary mixtures with Abermagic; however, Twystar had decreased when sown with the tetraploid. At low sowing proportions, the tetraploid variety Greengold increased substantially in the sward; however, when it was included at 50% of the sward, its composition in the sward remained relatively constant.

This work provides a useful method to identify changes in the composition of swards from sowing through the establishment phase. It is clear that the proportion at which a variety is sown is not necessarily the proportion of that variety that will actually establish and remain in the sward. This work

will continue through 2011 and 2012 to gain a better understanding of the sward compositional changes that occur, and to determine optimum variety inclusion rates in mixtures. Ultimately, it will allow the grassland industry to formulate mixtures with a greater understanding of the potential competition and survival among plants in mixtures.

This work was funded by the Teagasc Core Programme.

Dr Mary McEvoy is a Research Officer and Vincent Griffith is a Teagasc Walsh Fellow at the Grassland Science Research Department, Animal & Grassland Research and Innovation Centre. E-mail: mary.mcevoy@teagasc.ie.



Food Harvest and greenhouse gas emissions

An economic model of Irish agriculture (the FAPRI-Ireland model) has been used by Teagasc economists to project the change in Irish agricultural GHG emissions that would result from the achievement of the targets set out in the *Food Harvest 2020* report.

The Food Harvest (FH) 2020 Committee's Report (Department of Agriculture, Fisheries and Food, 2010) was published in July 2010. The FH report includes a range of specific volume and value growth targets for the different elements of the Irish agri-food sector.

The projected greenhouse gas (GHG) emissions associated with the achievement of the FH targets (referred to as Scenario 2) are contrasted with the current level of GHG emissions from the agriculture sector and the projected level of agricultural production and associated GHG emissions that might prevail in 2020 in the absence of an FH implementation plan (referred to as Scenario 1).

An important assumption associated with these projections is that GHG abatement technologies that are currently under development (such as livestock dietary management, grassland management and grassland/cropland nutrient management) are not adopted by 2020. That is not to say that these technologies will fail to deliver a reduction in emissions, but rather that the level of reduction that the technologies could achieve is an unknown. By excluding them from our projections, we can measure the scale of the reduction that such abatement technologies would need to deliver. Given that Irish agriculture is largely based on dairy and beef production, these two sectors together generate the bulk of GHG emissions from Irish agriculture. Emissions from agriculture amounted to 26.1% of Ireland's total GHG emissions in 2008 (McGettigan *et al.*, 2010). Ireland faces a 20% GHG reduction target by 2020 under the EU Effort Sharing Agreement (European Parliament and Council of the EU, 2009). Achievement of the FH targets for the dairy and beef sectors is likely to result in some change in the intensity of production, as well as in the composition and size of the Irish cattle herd. However, accurately assessing how the changing intensity of production or how the relative shares of dairy and beef animals in the cattle herd will affect GHG emissions is not a simple task, since many factors have to be taken into consideration. Hence it is necessary to model economic and biological relationships and project how they are likely to evolve in the future. Based on the projected level of agricultural production and input usage, the modelling approach also provides projections of GHG emissions from Irish agriculture.

The level of GHG emissions produced, under the assumption that the FH targets are achieved (Scenario 2), can be determined and can be contrasted with the level of GHG emissions projected under the no policy change scenario (Scenario 1). The likely change in GHG emissions from Irish agriculture that would arise with the achievement of the FH agricultural output targets can then be determined.



Agricultural GHG emissions: Scenario 1

For Scenario 1 the projected changes in the levels of output in the beef, sheep, pig and dairy sectors between the 2007 to 2009 reference period and 2020 are shown in Figure 1. These are contrasted with the targets that are presented in the FH Report. Under Scenario 1, the FH targets would not be achieved by 2020. The value of output from the beef, sheep and pig sectors is projected to increase, but the magnitude of improvement in the value of output projected is significantly lower than the target set for 2020 in the FH Report. Under Scenario 1 Irish milk production is projected to expand by approximately 26% in volume terms by 2020, which is also less than the FH target. Even though suckler cow numbers decline, the increased milk production requires more dairy cows and the dairy cow progeny contribute to an overall increase in beef production. The Scenario 1 agricultural activity projections are used to project GHG emissions. These are shown in Figure 2. Agricultural GHG emissions decline by 10% relative to the 2005 level by 2020. Rising emissions from the dairy herd are offset by a decline in emissions from the suckler herd.

Agricultural GHG emissions: Scenario 2 (Food Harvest)

Using the FAPRI-Ireland model, the value and volume of output associated with the targets set for 2020 in the FH Report can be identified, allowing the calculation of associated GHG emissions. In Figure 3 the intensity of nitrogen fertiliser usage per hectare of grassland is shown under Scenario 1 and Scenario 2. The increased intensity of dairy production under Scenario 2 causes some increase in the usage of nitrogen but this is partially offset by the reduction in the suckler herd. The net result is an 11% increase in fertiliser usage per hectare of grassland under Scenario 2 relative to Scenario 1 by 2020. Other things being equal, this increase in nitrogen usage has adverse consequences for GHG emissions. Figure 4 shows how the ratio of dairy cows to beef cows would evolve under Scenario 1 and Scenario 2. The increase in the number of dairy cows and the fall in the number of suckler cows under Scenario 2 are projected to return the ratio to levels last seen in the early 1990s. Herd composition has consequences for the level of GHG emissions, given that dairy cows produce more emissions per head than beef cows. The projected level of GHG emissions under Scenario 2 can be compared with both the historical level of GHG emissions and the GHG emissions projected under Scenario 1. Returning to Figure 1, historical GHG emissions are presented along with the projected level of GHG emissions under both scenarios. Under Scenario 2, where the FH targets are achieved by 2020, GHG emissions

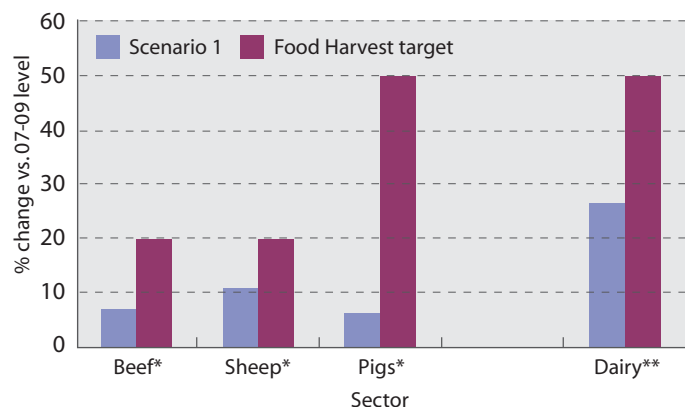


FIGURE 1: Scenario 1 increase in activity by 2020 and Food Harvest 2020 targets. *The output targets for beef, sheep and pigs are value targets. **The output target for dairy is a volume target. Source: FAPRI-Ireland (2010).

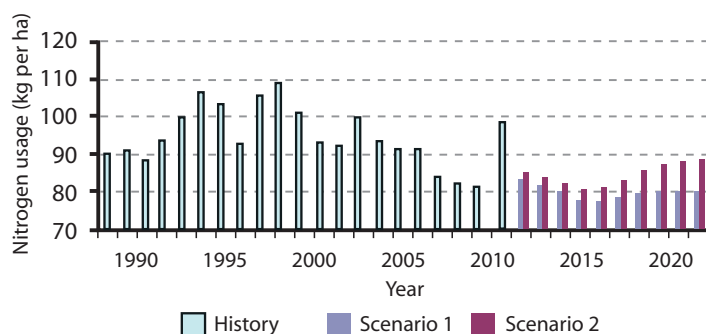


FIGURE 3: Intensity of nitrogen usage on grassland in Ireland: historical data and projections under Scenario 1 and Scenario 2. Source: FAPRI-Ireland (2010).

increase relative to Scenario 1, principally due to the increase in dairy cow numbers and associated dairy emissions, which more than offset the contraction in emissions arising as a result of the fall in the size of the suckler herd over the projection period. By 2020 the level of GHG emissions under Scenario 2 represents an increase over the Scenario 1 level in 2020 of approximately 1.2 million tonnes CO₂-equivalents.

Conclusions

The overall uncertainty regarding future levels of GHG emissions from agriculture remains high, even when we abstract from the uncertainty related to agricultural and trade policy and the general macroeconomic environment. While technologies exist to reduce emissions at farm level, the level of adoption of these technologies in the coming years and the reduction in emissions they might deliver remains unknown. What is clear from the research reported in this paper, however, is that in the absence of the widespread adoption by Irish farmers of practical GHG abatement technologies over the next 10 years, the achievement of the agricultural output growth targets as set out in the Food Harvest Committee's Report would lead to increased GHG emissions from the Irish agriculture sector.

References and further reading

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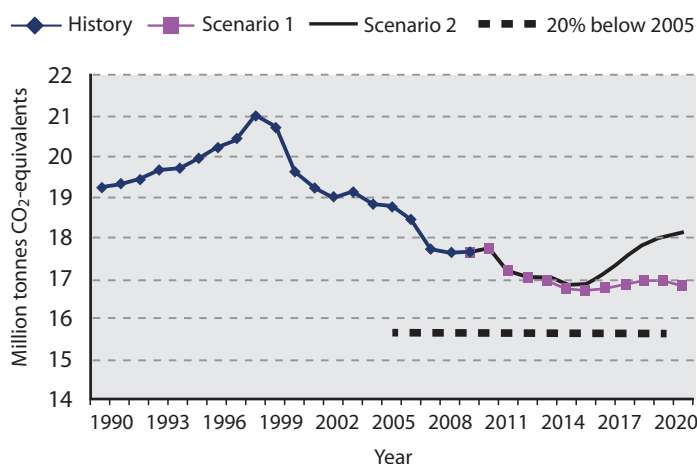


FIGURE 2: Historical and projected Scenario 1 and projected Scenario 2 GHG emissions from Irish agriculture. Excludes agricultural emissions from fuel combustion. Source: FAPRI-Ireland (2010).

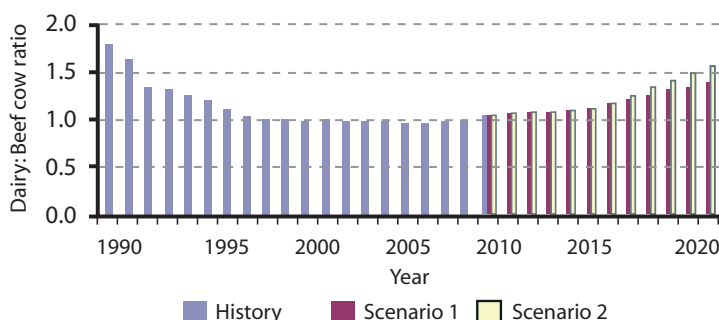


FIGURE 4: Ratio of dairy cows to beef cows in the Irish cattle herd: historical data and projections under Scenario 1 and Scenario 2. Source: FAPRI-Ireland (2010).

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Trevor Donnellan and Dr Kevin Hanrahan are Principal Research Officers at the Agricultural Economics and Farm Surveys Department, Teagasc. E-mail: trevor.donnellan@teagasc.ie.



Reviewing recent developments in farm investment

The ongoing banking crisis is having serious repercussions for economic activity across all sectors of the economy. In this article economists based in the Rural Economy Development Programme and Trinity College Dublin explore the implications for farm investment and the potential expansion of the agricultural sector.

The Teagasc National Farm Survey has collected data on new farm investment for many years. This article summarises the results of recent research into the factors that drive, and indeed inhibit, new farm investment. Specifically, the impact of the ongoing financial crisis and the implications for farm investment are addressed.

The development of farm investment 1996 to 2010

Total net new investment at farm level recorded by the National Farm Survey from 1996 to 2010 is presented in Figure 1. Net new investment is defined as all capital expenditure, less sales of capital and grants received. It includes investment in machinery, buildings, quotas and land improvements but does not include land purchase. As can be seen, there was very little change in the level of investment between 1996 and 2005, with the annual aggregate figure averaging about €550 million. Generally over this period investment in machinery was almost double the level of investment in buildings.

Investment activity accelerated in the 2006 to 2008 period and investment in buildings outstripped machinery. This increased investment activity was largely policy driven. Cross compliance obligations introduced under the Nitrates Directive meant that many farmers were obliged to invest in farm waste management facilities and the Irish Department of Agriculture, Fisheries and Food (DAFF) operated the Farm Waste Management Scheme over this period where grant aid of up to 70%, in certain cases, was available.



Research indicates that for the first time since the beginning of the Celtic Tiger era, Irish farmers are credit constrained and may have to use their own funds to undertake capital improvements to buildings, purchase new machinery and make land improvements.

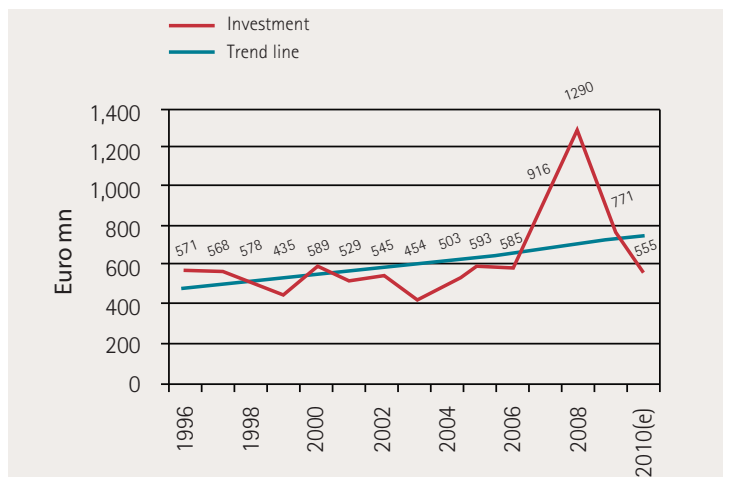
Investment fell significantly in 2008 and 2009. This fall off in investment coincided with the overall downturn in the economy, a collapse in farm incomes and the closure of the grant schemes available for farm buildings.

To put the level of on-farm investment in context, Figure 2 compares investment levels to aggregated family farm income as recorded by the National Farm Survey. The data shows that between 1996 and 2008, investment has continued to increase despite the general downward trend in farm incomes. In this context, it is interesting to consider why investment would have continued to be sustained while returns were falling.

Factors driving farm investment

An econometric model of farm investment was developed to identify the factors that had a significant effect on investment levels in the 1996 to 2010 period. This model uses a structural investment approach to consider the impact of profitability on farmers' decisions to undertake additions to the capital stock.

The results of the model reveal government grants as the single most important determinant of farm investment. The role of government grants in stimulating investment highlights the importance of the policy environment to farmers' investment decisions. This indicates that cost-effective and targeted investment policy is vital to the sector going forward. Contrary to *a priori* expectations, the results of the model reveal a negative relationship between farm-level profitability indicators (fundamentals) and investment. The results are statistically robust to ensure that our



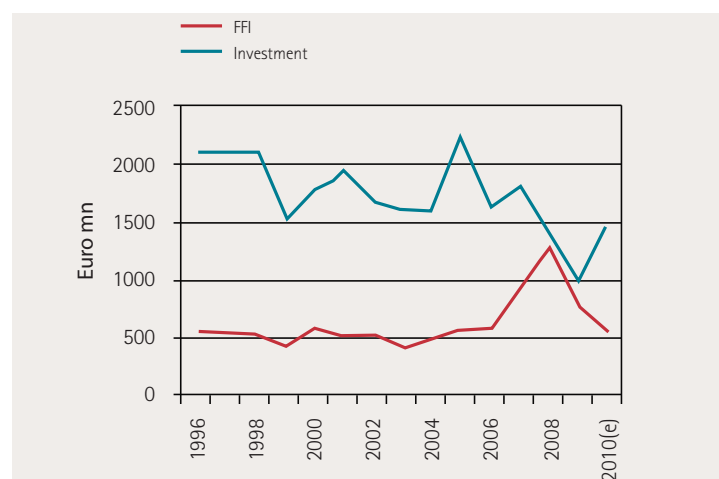
Source: National Farm Survey, Teagasc.

FIGURE 1: Total on-farm net new investment.

model includes the role of farm income, investment grants received, age of the farmer, size of the farm and the general operating environment in determining investment levels. There are a number of potential explanations why farm investment may not be driven by farm fundamental profitability indicators. The first relates to government grants and obligatory investment. Compliance with environmental, waste and safety standards would have required the vast majority of farmers, even loss-making farmers, to undertake investment if they wanted to continue in farming. This might explain why investment increased even as farm incomes declined. Furthermore, for a wide array of personal and cultural reasons, farmers may be reluctant to exit the sector even if fundamentals are falling. In this context, they may view additional investment as a method to potentially drive returns in the future and thus arrest the declining current profitability. The incidence of off-farm employment is quite high throughout the period examined and has often been cited as a driving force for farm investment. The presence of off-farm income is tested empirically in the model and the results show that there is no statistically significant relationship between investment and off-farm income. Some of the most interesting results coming from the model relate to the impact of the recent financial crisis.

Exploring the consequences of the banking crisis for farm investment

Over the period examined, there have been substantial changes to the financial operating environment for farmers. The current financial crisis was preceded by a prolonged credit boom. The econometric model is used to test whether financing frictions had a different impact on farmer investment before and during the current crisis. Specifically, the significance of debt overhang (outstanding borrowings) in the investment decision is tested. The results show that there is no significant relationship between investment and debt overhang during the pre-crisis period but that there is a significant negative relationship between these two variables in the years 2008 and 2009. This suggests that prior to 2008, farmers' initial leverage levels had no impact on their investment activity. However, since 2008, farmers with higher outstanding debts are less likely to invest, most probably because of access to credit issues. This finding holds when consideration is given to controls for farm level profitability, and the level of investment grants received, as well as the farmers' age, size of the farm and the general operating climate. Controlling for these issues allows us to isolate the impact



Source: National Farm Survey, Teagasc.

FIGURE 2: Total real farm income (FFI) and investment (€ million)

of financing constraints from farm level fundamentals and the general market environment. This finding is significant, as it suggests that the ongoing difficulties in the Irish financial system inhibit the ability of farmers to access credit for investment and expansion purposes. The results suggest that farmers may be constrained to using their own internal sources of capital to fund investment expenditure. This was not the case in the pre-2008 period when farmers had significant access to investment credit.

Concluding remarks

Irish agriculture faces significant investment challenges in the coming years. The recent Department of Agriculture, Fisheries and Food's *Food Harvest 2020* report has set ambitious targets to grow the agricultural sector. It is most likely that significant farm investment will be required to meet many of the targets set out in the *Food Harvest* report. The results of this research suggest that the ongoing financial and banking sector crisis will act as a major obstacle to securing external capital for investment and providing farmers with the credit and support lines needed to grow and develop their businesses. Our research indicates that for the first time since the beginning of the Celtic Tiger era, circa 1995, Irish farmers are credit constrained and may have to use their own funds to undertake capital improvements to buildings, purchase new machinery and make land improvements. This will inhibit the ability of the sector to make profitable investments in the future.

The results of the analysis show that government grants have proved hugely successful in encouraging farm investment in the past. However, it remains to be seen whether there is sufficient political will and/or resources available to institute another funding scheme for farm investment in the near future. These challenges will be set in the context of the severe ongoing financial constraints on government finances and are evidenced by the recently announced suspension of targeted agricultural modernisation schemes (TAMs) by the Department of Agriculture, Fisheries and Food. In conclusion, our research points to a very challenging investment climate for farms going forward.

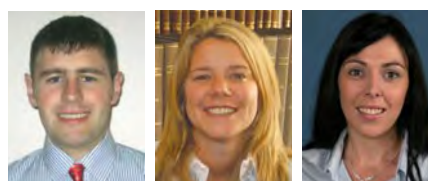
The research paper that this article is based on can be found at: <http://ideas.repec.org/p/tcd/tcduee/tep0311.html>.

This research is funded by the Teagasc Walsh Fellowships Scheme.

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Conor M. O'Toole is a Teagasc Walsh Fellow and PhD candidate at the Department of Economics, Trinity College Dublin. Dr Thia Hennessy is Head of the Agricultural Economics and Farm Survey Departments in the Rural Economy Development Programme, Teagasc. Dr Carol Newman is a Lecturer in Economics at Trinity College Dublin. E-mail: otoolecm@tcd.ie.



The general public's preferences towards rural landscapes

PETER HOWLEY, Rural Economy Development Programme, Athenry, has been examining the general public's preferences in relation to rural landscapes. Results suggest that the general public have a strong preference for agricultural landscapes, particularly those representative of extensive as opposed to intensive farming practices.

Attitudes towards the landscape

Society increasingly values agricultural landscapes and their potential to provide a range of public goods and services. In addition to providing us with food and other raw materials, farming activity has environmental, aesthetic and social functions. While food security was the dominant concern for the general public at the onset of the Common Agricultural Policy, concerns surrounding the environmental impacts of agricultural activity are now just as important to citizens of the EU. Through the implementation of, among other things, a variety of agri-environmental schemes and the Habitats and Birds Directives, the European Union has sought to implement policy measures aimed at protecting the countryside landscape (see panel). Despite this increasing policy concern, there is considerable uncertainty regarding what the general public wants in relation to the landscape. Situated within this overall context, the aim of this study was to provide a more detailed understanding of the general public's rural landscape preferences. In particular, this study explored what particular landscape attributes the general public prefers the most and also if these landscape preferences differed across individuals, i.e., whether personal characteristics, residential location and, indeed, general attitudes towards the environment impacted on respondents' visual assessment of particular rural landscapes. Land use policy can be improved if decision makers in both the environmental and agricultural sectors are better informed about the landscape preferences and attitudes toward the environment among various user groups.

Survey design

A survey of 430 individuals living in Ireland was conducted in the summer of 2010. Respondents were asked to indicate their preferences for rural landscapes by rating 47 landscape images on a scale from 1 (not very highly) to 6 (highly). The photographs themselves were selected with the aim of representing a broad geographic and thematic representation of rural landscapes in Ireland. Specifically, the photographs selected for examination in the survey were grouped into five main categories: intensive farming landscapes; extensive farming landscapes; cultural landscapes; wild nature scenes; and, water-related landscapes. Environmental value orientations were measured by including a series of attitudinal statements in the survey. Based on these attitudinal statements, individuals were classified as having what we termed as firstly a 'multifunctional value' orientation; that is, having a strong support for the intrinsic value of nature and the amenity, as well as the visual value of the landscape. Secondly, there are individuals with what can be called an 'agricultural productionist' value, that

is, viewing the landscape as being useful principally in producing food and fibre. And, finally, individuals who were relatively indifferent to environmental issues, which we termed as 'environmental apathy', were identified.

Survey findings

Of the variety of landscapes under examination, landscapes with water-related attributes as its dominant feature (e.g., rivers, lakes, the coast, etc.) were the most preferred by respondents. In relation to agricultural landscapes, respondents rated all of these quite highly as all the mean scores were at the upper end of the six-point scale. The agricultural landscapes that respondents appeared to like most, however, were the more extensive farming landscapes. This supports findings in a variety of other studies, which suggest that modern intensive farming landscapes are less attractive to the general public due mainly to the homogeneity of this type of landscape. Bogland and wild unmanaged vegetation were the landscape types that the general public liked the least.

Demographic effects

This study examined if preferences towards each of the five derived categories of landscape varied between individuals with different background characteristics (e.g., age, social class and residential location) as well as environmental value orientations. The results revealed some interesting differences in that personal characteristics, location and overall environmental attitudes were found to significantly affect preferences towards each of the landscape types examined. In relation to the agricultural landscapes, while the general public generally had a positive attitude towards these landscapes, there were some interesting differences between different cohorts of the population. For instance, relatively older respondents were more likely to have a stronger preference for both types of agricultural landscapes (intensive and extensive) than younger individuals. This could be reflective of generational differences in culture and upbringing with relatively elderly respondents more likely to be familiar with agricultural landscapes. On the other hand, relatively older individuals were less likely to rate water-related landscapes as highly and this could be attributable to older people's greater vulnerability to the dangers of this type of landscape. Individuals with a farming background were more likely to rate traditional more extensive farming landscapes highly than respondents with no farming background. Furthermore, individuals living in rural, as opposed to urban, areas were also found to be much more likely to rate farming landscapes highly in terms of overall visual attractiveness.



From left: Intensive farming landscapes are less attractive to the general public.

Landscapes with water-related attributes as their dominant feature were the most preferred by respondents. Looscaunagh Lough, Killarney.

Well-maintained traditional extensive farming landscape.

Attitudes to the environment

Environmental attitudes were perhaps the most significant determinant of landscape preferences, as these were found to strongly affect preferences for each of the landscape types examined. Individuals with what was termed as a strong 'multifunctional value' orientation were found to be more likely to rate all the landscape types highly (extensive farming landscapes, cultural landscapes, wild nature scenes and water-related landscapes), with the exception of intensive farm landscapes. These landscape types may be preferred over intensive farming landscapes by respondents with a strong multifunctional value because of their strong amenity, ecosystem or wildlife aspects. Respondents with a strong agricultural productionist value orientation, or those who were relatively indifferent to environmental issues (environmental apathy), were found to be less likely to rate wild nature scenes as highly. It could be that the relatively unproductive nature of this type of landscape makes it unattractive for these respondents. Finally, respondents who could be classified as being indifferent to environmental issues (environmental apathy) were more likely to rate intensive farming landscapes highly in terms of beauty.

Importance for policy-making

Agriculture, in addition to supplying market goods, jointly produces a number of public goods such as landscape elements and services. Many of the distinctive characteristics of particular landscapes are in danger of being lost, even though they are highly valued by society. This is due to external economic and environmental pressures, which can lead to radical changes in the landscape, except where appropriate policies are in place. This article reports results from a nationally representative survey designed to provide a better understanding of individuals' preferences in relation to rural landscapes. Given its amenity and recreational, as well as productive capacity, it will be important to maintain the landscape in line with the general public's needs and preferences. Results indicate that, overall, individuals strongly value the visual amenity benefits of agricultural landscapes, in particular those that are representative of more extensive as opposed to intensive farming practices. The results also suggest, however, that there are distinct differences in terms of landscape preferences between different demographic groupings and also depending on individuals' environmental attitudes. More specifically, in relation to agricultural landscapes, relatively older respondents, those living in rural areas and/or respondents with a farming

The Habitats Directive (more formally known as Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) is a European Union directive adopted in 1992 and is one of the EU's two directives in relation to wildlife and nature conservation, the other being the Birds Directive. It aims to protect some 220 habitats and approximately 1,000 species listed in the Directive's annexes. The Birds Directive (more formally known as Council Directive 2009/147/EC on the conservation of wild birds) is a European Union directive adopted in 2009. It replaces Council Directive 79/409/EEC of April 2, 1979, on the conservation of wild birds, and aims to protect all European wild birds and the habitats of listed species, in particular through the designation of special protection areas.

background were more likely to rate agricultural landscapes in terms of visual amenity as highly. In addition, respondents who could be classified as having a positive view in relation to the environment (multifunctional value) were more likely to rate extensive farming landscapes as highly. In terms of land use policy, given the diversity of preferences a 'one size fits all' approach will not meet the general public's needs.

Acknowledgements

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Dr Peter Howley is a Research Officer, Rural Economy Development Programme, Teagasc, Athenry, Co. Galway. E-mail: peter.howley@teagasc.ie.



T Events

2011 JUNE

June 23

Teagasc Oak Park Crops Research Centre, Carlow

Crops and Energy Open Day

The Energy Open Day will take place from 9.00am to 2.00pm, with a theme of 'Growing Opportunities for Irish Farmers'. This free event is centred around Teagasc bioenergy research and will focus on the technical aspects of growing and utilising bioenergy resources, particularly miscanthus and SRC willow. The event will also cover the Bioenergy Scheme, which provides grants towards the cost of planting and establishment.

From 2.00pm to 7.00pm, the Crops Open Day, entitled 'Meeting Production Targets' will cover a range of topics, including: oil seed rape agronomy; cereal disease control; winter wheat and spring barley varieties; weed control in cereals; nitrogen management in cereals; and, soil and cultivation.

June 29

Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Moorepark '11 – Irish Dairying: Planning for 2015

Teagasc invites dairy farmers and all involved in the Irish dairy industry to Moorepark '11, the Teagasc National Event for 2011. Set against the backdrop of milk quota removal in 2015, volatility in milk price, and a positive market outlook for dairy products due to significant growth in world demand, this event is a necessity for all commercial dairy farmers. Moorepark '11 is an ideal opportunity to see at first hand the results of the comprehensive research programme at Moorepark, and to meet Teagasc research and advisory staff.

Margie Egan 025-42292 margie.egan@teagasc.ie
www.agresearch.teagasc.ie/moorepark

June 30

Teagasc Food Research Centre, Ashtown, Dublin 15

Food Product Traceability and Recall Seminar

Find out how other businesses approach traceability and what technology is on offer.

www.teagasc.ie/ashtown/events/2011/20110518.asp

AUGUST

August 22-24

Castleknock Court Hotel, Dublin, Ireland

Irish Meeting on Agricultural Occupational Safety and Health

Organised jointly by the Health and Safety Authority and Teagasc, this is an occasional meeting in the rota of Nordic Meetings on Agricultural Occupational Safety and Health. Improving occupational health and safety in the agriculture sector presents a worldwide challenge. This meeting will demonstrate what has been achieved in Ireland so far and consider strategies to target future progress. Everyone working in the field of occupational safety and health in agriculture is welcome. john.g.mcnamara@teagasc.ie

SEPTEMBER

September 4-8

Dublin Castle Conference Centre

International Conference: Eucarpia Forage and Amenity Grasses Section Meeting

The theme of the meeting is 'Breeding strategies for sustainable forage and turf grass improvement'. Over recent decades many developments in science and technology became available for application in breeding. Advances in tissue culture, cross species hybridisation, quantitative genetics and computational power, and biotechnology all have enormous potential, and are all being used with great success. This conference will ask the question: "What will the future of forage and turf grass breeding look like?"

susanne.barth@teagasc.ie www.eucarpia.org

September 7

Teagasc Grange

Derrypatrick Beef Open Day

www.teagasc.ie/events

September 12-15

Dublin

7th International Conference on Predictive Modelling of Food Quality and Safety (ICPMF7)

This conference will bring together leading academics, research scientists and food professionals who are currently developing and using simulation and optimisation tools to enhance the quality and safety of food. This event also aims at attracting various stakeholders throughout the food chain, including policy makers and international authorities. On September 16, a collaborative EU Framework Project Seminar will be held.

www.icpmf.org/2011

September 14-16

The Mansion House, Dublin

Catchment Science 2011

Entitled 'Catchment scale research and evaluation for agriculture and water quality', this international conference is aimed at scientists, policymakers, farmers and managers. Jointly hosted by the Irish Agricultural Catchments Programme (Teagasc/DAFF) and the UK Demonstration Test Catchments Projects (Defra/EA). catchments@teagasc.ie www.teagasc.ie/catchmentscience

September 28-29

Teagasc Food Research Centre, Moorepark

Cheese Symposium 2011

This symposium aims to cover the most recent fundamental and applied scientific research developments in the areas of: flavour development; diversification; health and nutrition; and, fat and/or salt reduction in cheese. It will provide a forum for academia and industry to share experiences on the latest developments and applications of cheese research. The programme will appeal to all involved in cheese research or production. A book of abstracts of all oral and poster presentations will be available on the day and selected oral presentations will be published in the *Journal of Dairy Science and Technology* at a later date.

Niamh O'Brien 025-42313 cheesesymposium2011@teagasc.ie

OCTOBER

October 10-12

Burlington Hotel, Dublin

4th International Symposium on Animal Functional Genomics

This symposium will provide an exciting opportunity for scientists working across a wide range of disciplines to meet and discuss the latest groundbreaking developments in the fast-moving field of animal functional genomics. Topics will include: application of new genomics technologies; computational biology and bioinformatics; and, systems biology. The symposium is targeted at academic researchers, industry scientists, policy makers and regulators who wish to learn about the latest developments in basic and applied animal functional genomics research.

http://isafg2011.org/isafg_announcement.pdf

2012

Dublin City of Science 2012

Dublin has been chosen to host Europe's largest science conference, ESOF 2012 (Euroscience Open Forum), from July 11-15, 2012. To celebrate this prestigious international event, City of Science 2012, a programme of science-related events and activities, will run throughout the year across the island of Ireland. Teagasc will be running a series of events during 2012 in support of City of Science 2012. www.dublinscience2012.ie