TEAGASC

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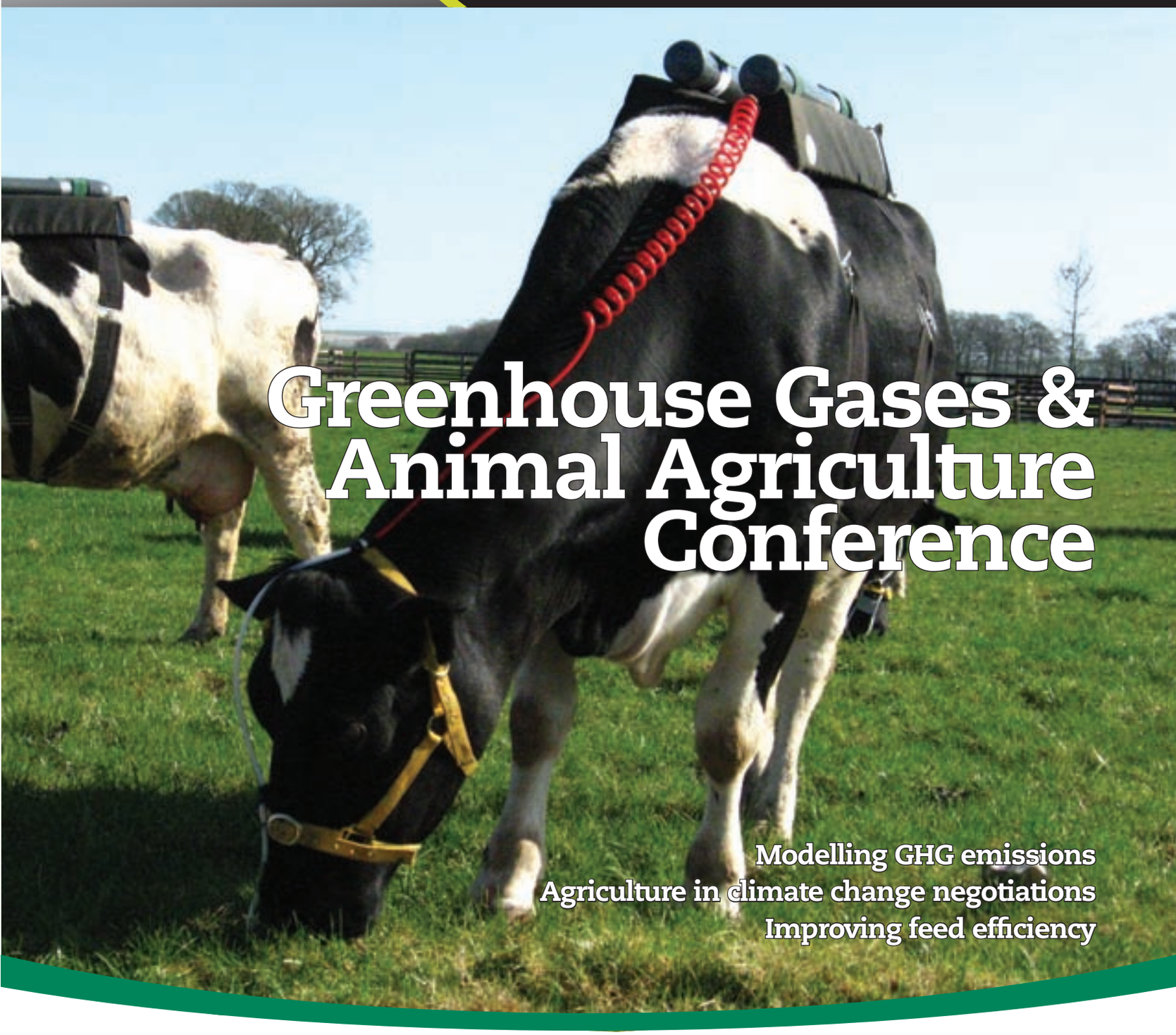

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TResearch is an official science publication of Teagasc. It aims to disseminate the results of the organisation's research to a broad audience. The opinions expressed in the magazine are, however, those of the authors and cannot be construed as reflecting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

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Greenhouse Gases and Animal Agriculture conference

Climate change is one of the biggest challenges of our time and is hugely significant for global agriculture which must both adapt to changes in climate and find ways to reduce greenhouse gas (GHG) emissions from agricultural activity. In Ireland, agricultural emissions account for approximately 30% of national emissions, and most are associated with our livestock industries. This is due to the importance of beef and dairy production in Ireland. While our highly managed grass-based systems of production are very efficient in terms of emissions per kg of milk or meat produced, research and knowledge transfer is necessary to reduce them further. Given the importance to Ireland of finding ways to reduce animal-related GHG emissions, Teagasc is delighted to co-host the 2013 'Greenhouse Gases and Animal Agriculture' conference with University College Dublin (UCD). This major international conference brings together over 400 scientists from across the globe to present the most up-to-date research on emissions from animal agriculture and will take place on the UCD campus. In this issue of *TResearch*, we include a number of papers based on research papers presented by Teagasc researchers and their collaborators at the GGAA conference. The challenge for research is to find win-win solutions, where measures adopted improve farm profitability (and thus will be readily adopted by farmers), as well as reducing GHG emissions or emissions intensity. Some measures are currently available that meet these criteria and these measures are mostly based on improved genetics, management and more efficient use of resources. Teagasc recently produced a 'Marginal Abatement Cost Curve' for GHG emissions in Ireland, which demonstrates the potential impact of such measures. Teagasc has also developed a knowledge transfer tool called the 'Carbon Navigator' which can be used to give guidance to farmers on measures they can adopt to reduce their GHG emissions and improve profitability. While much progress has been made, there is still an urgent need to develop new technologies to reduce animal GHG emissions. Scientific conferences like the GGAA, which allow scientists to meet and exchange up-to-date scientific information, are an important mechanism to assist this.

Dr Frank O'Mara
Director of Research, Teagasc
Teagasc Head Office, Oak Park, Carlow

Comhdháil ar Gháis Cheaptha Teasa agus Talmhaíocht Ainmhithe

Tá an t-athrú aeráide ar cheann de na dúshláin is mó atá fúinn sna blianta seo, go háirithe i gcás na talmhaíochta, a chaithfidh oiriúnú do na hathruithe sin agus a astaíochtaí de gháis cheaptha teasa (GCT) a laghdú. In Éirinn is í an talamhaíocht is cúis le 30% nó mar sin de na hastaíochtaí ar fad, agus ó na tionscail bheostoic a thagann a bhformhór, toisc an oiread mairteola agus earraí bainne a tháirgtear in Éirinn. An chuid sin den chóras talmhaíochta atá bunaithe ar fhéar, bainistítear é go cúramach agus go héifeachtach ó thaobh méid na n-astaíochtaí de réir an chileagraim bainne nó feola ach teastaíonn taighde agus aistriú eolais chun na hastaíochtaí sin a laghdú tuilleadh. Toisc a thábhachtaí atá sé d'Éirinn slite a aimsiú le hastaíochtaí GCT a bhaineann le hainmhithe a laghdú, is áthas le Teagasc bheith ina chomh-ósr ar an gcomhdháil 'Greenhouse Gas and Animal Agriculture' (Gás Ceaptha Teasa agus Talmhaíocht Ainmhithe) 2013 leis an gColáiste Ollscoile, Baile Átha Cliath. Tabharfaidh an chomhdháil mhór idirnáisiúnta seo breis is 400 eolaí ó gach cearn den domhan le chéile chun an taighde is déanaí ar astaíochtaí ó thalmhaíocht ainmhithe a chur i láthair agus is ar champas na hollscoile a bheidh sé. San eagrán seo de TResearch gheofar páipéir éagsúla bunaithe ar pháipéir thaighde a chuirfidh taighdeoirí Teagasc agus a gcomhoibreoirí i láthair na comhdhála sin. An dúshlán atá faoi thaighdeoirí ná réitigh ina mbíonn bua ag gach taobh a aimsiú, réitigh a chuirfidh le brabúsacht feirmeacha (ionas go nglacfaidh feirmeoirí leo go fonnmhar) chomh maith le hastaíochtaí nó déine astaíochtaí GCT a laghdú. Tá réitigh áirithe ar fáil cheana féin a chomhlíonann na critéir sin, réitigh atá bunaithe ar ghéineolaíocht fheabhsaithe, ar bhainistíocht fheabhsaithe agus ar úsáid níos éifeachtaí a bhaint as acmhainní. Le deireanas d'fhoilsigh Teagasc 'Marginal Abatement Cost Curve' (Cuar an Chostais ar Laghdú Imeallach) i dtaca le hastaíochtaí GCT in Éirinn, ina léirítear an difríocht a d'fhéadfadh bearta dá shórt a dhéanamh. Tá uirlis aistrithe eolais ceaptha ag Teagasc, leis, ar a dtugtar an 'Carbon Navigator' (an Seoltóir Carbóin), uirlis a thaispeánfaidh d'fheirmeoirí na bearta a d'fhéadfaidís a dhéanamh chun a n-astaíochtaí GCT a laghdú agus brabúsacht a mhéadú. Tá a lán dul chun cinn déanta cheana féin ach tá géarghá le teicneolaíochtaí nua chun astaíochtaí GCT a laghdú tuilleadh. Slí thábhachtach chun an t-eolas eolaíochta is déanaí a mhalartú is ea comhdhálacha den sórt seo.

An Dr. Frank O'Mara
Stiúrthóir Taighde, Teagasc
Príomhoifig Taighde, Páirc na Darach, Ceatharlach

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Dr Denis Griffin

Denis Griffin is currently the Programme Leader of the Potato Breeding programme in Teagasc Crops, Environment and Land Use Programme, Oak Park. Denis has a first class Honours Degree from UCD in Industrial Microbiology. He also holds a PhD from the Department of Botany, UCD, based on the epidemiology of Irish populations of late blight (*Phytophthora infestans*) on potatoes. Subsequently, he has worked as a plant pathologist at Syngenta, Jealotts Hill, UK, leading a team on development of new fungicide products for cereals, grape and potato.

Denis joined Teagasc as potato breeder in 2002 and has released 15 new potato varieties including Infinity - a promising new crisping variety. His research interests include breeding adapted potato varieties for a range of climatic conditions and the application of molecular markers to conventional breeding for disease resistance to late blight and potato cyst nematodes.

He also has research interests in seed production systems for potato in Africa.

He has presented papers on potato breeding and blight epidemiology at a national and international level. He has been an active member of EuroBlight, a consortium of European researchers sharing information on late blight. He is also a member of the European Association for Potato Research (EAPR) and the European Association for Plant Breeding (EUCARPIA). He was co-organiser of the international conference 'The Science of Selection: Potato Breeding Methodology for the 21st Century' – 2006 Joint Triennial Meeting of the EUCARPIA Potato Section and the EAPR Section of Breeding and Varietal Assessment. He was also co-organiser of the international conference 'Potato pests and diseases: old enemies and new threats', Triennial Meeting of the EAPR Pathology section in 2010. He is currently co-supervising six PhD students and one MSc Student.

Irish dairy geneticist honoured

Dr Donagh Berry, principal investigator in statistical genetics at Teagasc, received the Sir John Hammond Award by the British Society of Animal Science for his work in animal genetics.

Dr Berry has helped develop a system through which every young dairy bull undergoing progeny testing will be assessed for genotype, helping farmers select only elite bulls for use in their herds. His research has also moved into sheep and beef.

Internationally renowned, Dr Berry's work helped Ireland become the second country in the world to publish genomically-enhanced genetic evaluations for dairy cattle.

Dr Berry was also commended for helping develop the next generation of scientists through his teaching work, and for his communication skills in talking about science to the media and to non-scientific audiences.

Animal behaviour expert

Animal behaviour expert Dr Temple Grandin PhD recently spoke at the All-Ireland State Veterinarian's Scientific Conference.

Dr Grandin is considered the world's most famous adult with autism and has used her unusual cognitive abilities to design innovative slaughter equipment for the humane handling of livestock. Dr Grandin's low-stress handling systems are used by over half of the cattle-processing facilities in the US and Canada.

Research based on Dr Grandin's work has been carried out at Teagasc and a series of videos can be seen on the TeagascMedia YouTube channel under the 'Safe handling of cattle on farms' playlist. For further information contact: John.G.McNamara@teagasc.ie

Environmental footprint of livestock supply chains

Measuring sustainability across complex animal supply chains is not easy. In the absence of internationally agreed rules to guide robust and fair measurement there is the risk that the debates about how sustainability is measured start to detract from the task of driving real improvement of environmental performance. The urgent need for a coordinated approach based on international best practice led the FAO to initiate the Partnership on Livestock Environmental Assessment and Performance (LEAP). LEAP brings together industry, governments, civil society representatives and leading experts from around the world to develop science based, transparent and pragmatic guidance to measure and improve environmental performance of livestock products, for example, beef and lamb meat or poultry (chicken and eggs). Teagasc and the Department of Agriculture, Food and the Marine are key participants in the LEAP Partnership providing leadership on the Steering Committee, input into technical guidance being developed and through the direct support for a doctoral student to work on developing indicators for nutrient use efficiency in animal production systems. A Walsh Fellow PhD student has been appointed, under the joint supervision of Teagasc, the FAO and Wageningen University and Research.

At the Launch of the Alder and Birch Seed Orchard at the Forestry Woodlands and Bionergy Show in Stradbally were: Dr Elaine O'Connor, Forestry Development Department, Teagasc; Dr Frank O'Mara, Director of Research, Teagasc; Deputy Charles Flanagan, TD; Oliver Sheridan, Forestry Technician, Teagasc; and Nuala Ni Fhlatharta, Head, Forestry Development Department, Teagasc.

'Qualified' status for national downy birch and alder seed orchards

The national downy birch seed orchard and the national alder seed orchard have achieved 'Qualified' status following a major research effort by Teagasc to genetically improve tree quality. In the coming years, seed and planting material will be available from the seed orchards at the much-improved Qualified level. The overall objective of the tree-breeding programme is the development of a sustainable supply of improved, adapted and healthy seed within the framework of the EU Forest Reproductive Material (FRM) regulations. Within these regulations there are four Quality categories. Up to now, nearly all broadleaf trees planted have been at the lowest category i.e. Source Identified. The programme has been working towards achieving the third and fourth categories, Qualified and Tested, respectively, for birch and alder. The research team are happy to announce that the programme now has indoor seed orchards of downy birch and alder at the 'Qualified' level of improvement registered with the Forest Service in 2012. A silver birch Qualified seed orchard is scheduled for two years' time.

Ireland top in EU table for the economic impact of innovation

Two recent publications by the European Union have highlighted Ireland's success in research and innovation.
The Innovation Union Scoreboard is an annual comparative assessment of the research and innovation performance of the EU27 and the relative strengths and weaknesses of their research and innovation systems. It helps Member States assess areas in which they need to concentrate their efforts in order to boost their innovation performance. The scoreboard looks at eight innovation dimensions including: human resources; open, excellent, attractive research systems; finance and support; firm investments; linkages and entrepreneurship; intellectual assets; innovators; and economic effects. Ireland scores the highest of all Member States in terms of the economic impact of innovation. This measure takes into account employment in knowledge-intensive activities, knowledge-intensive services, exports and licence and patent revenues from abroad.
The European Commission also published the State of the Innovation Union 2012, which summarises progress at Member State and European levels towards achieving an Innovation Union. One of the tasks of this report is to highlight regional strengths in terms of scientific output. The report finds that "in absolute numbers, in terms of scientific capacity, Ireland has strong regional clusters in the fields of food, agriculture and fisheries, ICT and nanotechnology".

University of Limerick award IBR project

Dr Riona Sayers received the University of Limerick Department of Life Sciences Young Researcher 2013 Gold Medal Award for her project on 'Epidemiological investigation of Bovine Viral Diarrhoea (BVD) and Infectious Bovine Rhinotracheitis (IBR) in Irish Dairy Herds'.

Walsh Fellowships overseas training

The winners of the Walsh Fellowships (Teagasc PhD students) overseas training bursaries have been announced. They are: Sophie Sherriff, Teagasc Environment and Land Use Centre, Johnstown Castle, who will visit University of St Andrews, Scotland; Patrick Tuohy, Teagasc Animal and Grassland Research & Innovation Programme, Moorepark, who will visit Iowa State University; Stephen Moore, Teagasc Animal and Grassland Research & Innovation Programme, Moorepark who will visit La Trobe University, Australia; Pearl Nolan, Teagasc Animal & Grassland Research and Innovation Centre, Grange, who will visit MTT, Finland; Justin McDonagh, Teagasc Animal and Grassland Research & Innovation Programme, Moorepark, who will visit Lincoln University, New Zealand; and, Rachael Doherty, Animal & Grassland Research and Innovation Centre, Grange, who will visit Ruakura Research Centre, Hamilton, New Zealand.

Teagasc paper in top 10

A Teagasc research paper features at number nine in the Editor's pick of Top 10 papers of the *Foodborne Pathogens and Disease Journal's* 10-year anniversary issue.
The paper 'Characterization of Farm, Food, and Clinical Shiga Toxin–Producing *Escherichia coli* (STEC) O113' by A.M. Monaghan, B. Byrne, D. McDowell, A.M. Carroll, E.B. McNamara, and D.J. Bolton is available online: http://online.liebertpub.com/doi/full/10.1089/fpd.2012.1257

Moorepark Milk Quality Tool to assist standards on farms

A new tool to improve milk quality standards has recently been developed at Teagasc, Moorepark. It comprises a series of video clips showing critical stages of the milking process and provides guidelines and recommendations for the production of high quality milk. The user-friendly tool will provide valuable information on all aspects of quality milk production (e.g., TBC, SCC and residues). Specific topics addressed include: milking management on smaller (12 unit parlour) and larger (24 unit parlour) farms; and milking management on farms with adequate labour (two people milking) and those with some automation (automatic cluster removers and cluster flushing). The tool will also be of benefit to milk quality advisors, veterinarians and milking machine manufacturers. The video series and additional information on the chemical composition of cleaning products and procedures for cleaning equipment can be accessed at www.agresearch.teagasc.ie/moorepark/milkquality/index.asp

Understanding consumers from an industry, policy and practice perspective

An interesting consumer behaviour conference titled ' Influences on Healthy Food Choices: Insights for Industry, Policy Makers and Practitioners' was hosted in Teagasc Food Research, Ashtown, in conjunction with UCC and *safe*food in May. Findings from this conference will be published in the Autumn edition of *TResearch*.

Sexed semen trial for dairy and beef cattle

During spring 2013, a laboratory was set up at Moorepark to facilitate sorting of semen. A field trial was planned and implemented by Teagasc and ICBF with cooperation from AI studs, meat processors and the Agricultural Trust. Sexing Technologies is an American company that hold the global licence to sort semen in a range of mammalian species. They moved equipment and staff to Moorepark in March and April, and commenced sorting semen just before the spring breeding season began.

A large trial was conducted during April and May to compare the fertility performance of conventional (i.e., not sexed) and sexed semen (X-sorted, 90%). Semen generally contains roughly equal amounts of sperm bearing X (female offspring) and Y chromosomes (male offspring). As a result, the likelihood of male and female offspring are both roughly 50%. Sexed semen is enriched in sperm containing either X (female offspring) or Y chromosomes (male offspring), resulting in 90% likelihood of the desired offspring.

In total, 394 dairy farms participated. Each ejaculate that arrived at the lab was divided and processed one of four ways:

- Conventional fresh
- Sexed fresh (2 million sperm per straw)
- Sexed fresh (1 million sperm per straw)
- Sexed frozen (2 million sperm per straw).

There were 15,200 inseminations carried out on cows and heifers. Conventional frozen and sexed frozen semen is currently being prepared for a trial with suckler cows. Terminal beef sires are being Y-sorted and maternal sires are being X-sorted. The results of both trials will be reported in a future issue of *TResearch*.

MOU with ICHEC

Professor Jean-Christophe Desplat, Director ICHEC with Teagasc Director, Professor Gerry Boyle.

A Memorandum of Understanding has been agreed between Teagasc and the Irish Centre for High End Computing (ICHEC). The ICHEC's mission is to provide high-performance computing (HPC) resources, support, education and training for researchers in Ireland. Teagasc already has a number of ongoing collaborations with ICHEC and looks forward to exploring further opportunities to enhance our cooperation in the future.

First ever UK-Ireland Food Business Innovation Summit

The first ever UK-Ireland Food Business Innovation Summit and Exhibition took place in the Aviva Stadium on May 29, 2013. Over 300 leading UK and Irish food company executives and retailers, along with policy makers and research managers, attended the one-day summit themed 'Exploiting synergies for growth through innovation, research, skills and knowledge'.

Both countries share a common objective of making the sector more productive and competitive. Food and drink exports underpin the relationship between the UK and Ireland. In 2012, 42% of Irish food and drink exports, worth €3.8 billion were consumed in the UK, while the value of food exports from the UK to Ireland is in the region of GBP£3 billion per annum.

A series of presentations by leading UK and Irish food company chief executives and senior managers focussed on issues such as food security, reducing waste, the growing world population, emerging markets and shortening the food chain.

The summit was jointly organised by Teagasc and the Institute of Food Research (IFR), UK, and supported by Food Innovation Gateways, British Irish Chamber of Commerce, UK Trade & Investment (UKTI), Bord Bia and Enterprise Ireland.

Minister for Agriculture, Food and the Marine, Simon Coveney, TD, at the summit.

Higher production costs reduced 2012 farm incomes

Dr Noel Cawley, Chairman Teagasc, is pictured with the Teagasc National Farm Survey authors Anne Kinsella, and Brian Moran, Dr Thia Hennessy, at the launch of the survey. A Preliminary estimate of the survey shows that family farm income decreased by 15% in 2012, bringing the average income figure for the farming sector to €25,483. An article on forty years of the National Farm Survey will appear in the next isue of *TResearch*.

FoodWorks

Jennifer Melia, Enterprise Ireland; Pat Daly, Teagasc; Minister for Agriculture, Food and the Marine, Simon Coveney; Minister for Small Business John Perry; and, Tara McCarthy, Bord Bia, at the launch of FoodWorks 2013, a training and development programme aimed at finding and supporting Ireland's next generation food entrepreneurs. The programme, jointly run by Bord Bia, Enterprise Ireland and Teagasc, has just recruited businesses for its second year.
For more see: www.foodworksireland.ie

Teagasc partners Aquavalens in EU €9 million water project

The University of East Anglia will launch a €9 million EU-funded research project to improve the safety of European drinking water. Teagasc is one of the partners in this project.

Around 330,000 cases of water-related disease such as *E.coli* and the norovirus are reported yearly in Europe according to the World Health Organisation (WHO). Between 2000 and 2007 there were 354 outbreaks of waterborne diseases across 14 countries.

The five-year Aquavalens project will develop and apply more rapid methods of detecting viruses, bacteria and parasites in water before they can make people sick. Scientists, engineers, policy makers and public health practitioners from 39 organisations in 13 countries will come together to launch the project in Italy.

Professor Paul Hunter from UEA's Norwich Medical School will lead the research. Consortium partners include small businesses, industries, universities and research institutes. The European Union's Framework Programme 7 is funding the project.

Teagasc will work in tandem with an Irish Based SME, City Analysts Ltd, as well as a number of partners across Europe as part of the project. Dr Kaye Burgess, Teagasc Food Research Centre, Ashtown will lead the work package on behalf of Teagasc along with her colleague Dr Karl Richards, Teagasc, Johnstown Castle.

WorldWideScience

T-Stór, Teagasc's Open Access Repository is now included in searches on www.worldwidescience.org, a global science gateway comprised of national and international scientific databases and portals.

Teagasc agrees scientific collaboration with Chinese academy

Minister for Agriculture Food and the Marine, Simon Coveney welcomed the formal signing of a Memorandum of Understanding (MOU) between Teagasc and the Chinese Academy of Agricultural Sciences (CAAS) that allows the facilitation of scientific collaboration and scientific exchange between the two agencies.

The MOU follows Minister Coveney's successful trade mission to China in 2012, when Teagasc participated in the Irish Sino Forum on sustainable agriculture production, which was hosted by CAAS. The Minister pointed to the mutual benefits that can arise from a collaboration based on scientific and technological progress and he noted that these scientific exchanges had already commenced in 2013 in anticipation of the signing of the MOU. Dr Fuping Zhao undertook a six-week placement in Teagasc, working on animal genetics and breeding with one of Teagasc's leading scientist, Dr Donagh Berry, under the direction of Dr Frank O'Mara, Head of Research in Teagasc.

Awards for bioscience and ICT inventions

A new cardio-protective bacterial probiotic and a new software platform for air handling units have been recognised recently in University College Cork's (UCC) Invention of the Year awards.

Dr Catherine Stanton, an investigator at the Alimentary Pharmabiotic Centre at UCC, won a bioscience award based on her discovery of a new probiotic bacterial strain that has cardio-protective properties.Stanton and her team's research is the result of a collaboration between Teagasc, UCC microbiology and the Centre for Research in Vascular Biology.

The researchers believe this new probiotic has the scope to reduce cholesterol by 53% within 12 weeks of consumption.

Graham and Saoirse Roberts, The Burren Smokehouse, are pictured with Dr Kevin Heanue, Teagasc.

Ireland's first food Économusée

The Connemara Smokehouse, one of the few remaining specialists in Ireland making smoked wild salmon and smoked tuna, has opened Ireland's first food Économusée. An Économusée is an artisan business that opens its doors to the public to provide a learning and interpretive experience for visitors.

The Économusée concept originated 20 years ago in Quebec, Canada; where there are now over 50 Économusée. It is an initiative to support cultural tourism and contribute to the sustainability of rural areas through the creation of direct employment and by providing an attraction that disperses tourists to rural regions.

Ireland's involvement arose from an invitation to Teagasc to become a partner in an EU Northern Periphery Programme funded-project to bring the concept and business model to selected rural areas in Europe.

Dr Kevin Heanue, who is leading the project for Teagasc, said: "The Économusée concept is an innovative model of rural enterprise support which helps artisan producers diversify their businesses into the cultural tourism market by providing them with a six-step template to help them structure the visitor experience."

For more on the project see *TResearch* Autumn 2012 (p34-35).

Maitre seminar

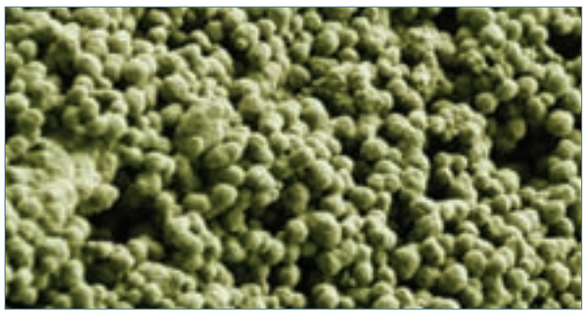
Teagasc and UCC researchers watch their television interviews at the Maitre training seminar (FP7-funded media training for food researchers) that took place at Teagasc Moorepark on April 15 and 16, 2013.

Next generation sequencing

Teagasc, and the Alimentary Pharmabiotic Centre (APC) recently secured funding to greatly expand the DNA sequencing facilities at Teagasc Food Research Centre, Moorepark. Three additional state-of-the-art sequencing platforms, an Illumina MiSeq, an Ion PGM and an Ion Proton, will greatly expand the number of options open to researchers. A combination of a Teagasc equipment grant and Science Foundation Ireland infrastructure funding has made it possible for this centre to be one of the few around the world to have access to such a full range of sequencing resources. APC researchers, collaborators and other researchers are encouraged to contact Paul Cotter (paul.cotter@teagasc.ie) or Fiona Crispie (fiona.crispie@teagasc.ie) to discuss their sequencing needs.

Novel enriched fat replacers

Teagasc is seeking partners within the food ingredient industry to optimise and validate a novel energy-efficient process to produce quality protein-based fat replacers for a range of low fat foods for commercialisation purposes.



Dried calcium-enriched fat replacer particles 200 nm in diameter.

Dr Mark Auty,
Teagasc Food Research Centre, Moorepark.

For further information contact:
Miriam Walsh, PhD.,
Head of Intellectual Property, Teagasc.
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Summary

Teagasc researchers have developed and protected, by filing a patent application, an energy-efficient method to produce novel, protein-based, calcium-enriched fat replacers. This process is based on the self-separation properties of proteins, careful process control and the use of basic liquid processing equipment to generate consistently sized, high quality calcium-enriched fat replacers. This energy-efficient, environmentally-sustainable method is relevant to companies wishing to produce high quality low-fat food products more cost effectively.

Value proposition

Reduction in energy costs

Most existing fat replacers are based on microparticulated whey proteins (MWPs) produced by extensive mechanical processes that require high levels of energy, e.g., heating, mixing, shearing, size reduction and homogenisation. This technology is relevant to MWP producers that wish to reduce their manufacturing costs, as the technology is based on a gentler processing approach that exploits the natural tendency of certain protein-polysaccharide mixtures to phase-separate.

Greater demand for high quality low-fat, functional foods

There is an urgent need to reduce fat in people's diets (>300m obese adults worldwide) and market studies show that consumers want foods that are nutritious and healthy, but also retain great taste and flavour. The high quality fat replacers produced with this technology have added health benefits as they are naturally enriched with absorbable calcium and soluble dietary fibre.

The technology

This novel technology produces a whey-protein based, calcium-enriched fat replacer through exploitation of the natural separation tendencies of certain proteins and polysaccharides in a process called "kinetic trapping". This produces separated spherical calcium enriched MWPs, in the size range 0.1 to 3µm, dispersed in a konjac gum-rich solution that can then be provided in either liquid or dried form. The liquid can be spray dried and added as a weight-for-weight fat replacer to yoghurt, low fat spreads, mayonnaise and ice cream products. Preliminary informal sensory analysis indicated a creamy mouthfeel to all resulting products, particularly ice cream, with comparable sensory properties to current market-leading fat replacers. Significantly, the novel enriched fat replacer can be produced using basic liquid processing equipment, e.g., steam-jacketed vessels, low-pressure pumps and gentle paddle mixers.

Intellectual property status

Teagasc recently filed a preliminary patent application.

Competitive advantage of technology

- Easily transferable to industry as it only requires basic and readily-available food processing equipment.
- An energy-efficient process that could significantly reduce manufacturing costs.
- The size of the spherical particles produced can be controlled (100nm – 5µm), adding to product consistency.
- The end product is naturally enriched with absorbable calcium and soluble dietary fibre, unlike existing MWPs.

Of interest to

This technology would be relevant to food ingredient companies wishing to manufacture high quality protein-based fat replacers, at reduced costs, for incorporation into a range of low-fat food products.

This project was supported by Enterprise Ireland (ref: POC-2009-260).

Agriculture in the climate change negotiations

John Muldowney and Jerome Mounsey
Department of Agriculture, Food and the Marine.
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John Muldowney and Jerome Mounsey from the Department of Agriculture, Food and the Marine outline how Ireland is contributing both nationally and internationally to reduce greenhouse gas emissions from agriculture.

In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was founded to cooperatively limit and to cope with climate change. "Ensuring that food production is not threatened" is explicitly mentioned in the objectives of the UNFCCC. However, the focus of negotiations has largely been on reducing greenhouse gas (GHG) emissions from energy, industrial activities and realising the potential of forestry as a carbon sink. There has been relatively little attention by the UNFCCC to address the challenges and opportunities for the agriculture sector.

In recent years, there has been an increasing focus on agriculture within the UNFCCC. At the Conference of the Parties (COP) 17 in Durban, the conference reached a decision to request: "the Subsidiary Body for Scientific and Technological Advice to consider issues related to agriculture at its thirty-sixth session, with the aim of exchanging views and the Conference of the Parties adopting a decision on this matter at its eighteenth session". The Subsidiary Body for Scientific and Technological Advice (SBSTA) is one of two permanent subsidiary bodies of the UNFCCC. The task of the SBSTA is to provide the COP with advice on scientific, technological and methodological matters.

This was the first time that the UNFCCC adopted a decision on agriculture and established a specific agenda item to discuss this sector. The most recent IPCC 4th Assessment report and. "The Emissions Gap Report" by the United Nations Environment Programme, highlighted the significant mitigation potential of agriculture, which could help contribute towards keeping global temperature rises below the 2°C limit agreed in Cancun in 2010. However, to effectively realise this potential, systematic and dedicated discussion and decisions within the UNFCCC are needed. A large number of countries have been actively involved in the UNFCCC discussions on agriculture and, although progress has been made, no clear consensus has been reached yet on how to adequately address this very important sector.

Building the proof

Agriculture is a unique sector, where mitigation and adaptation are intertwined; and, it poses challenges to the UNFCCC framework, which has traditionally addressed the two as separate issues. The relationship between agriculture and food security (a basic human need) further complicates the work focus in agriculture as some developing countries, which are expected to suffer the greatest impact of climate change, prioritise adaptation to ensure food supply in a changing climate. With the human population predicted to reach nine billion by 2050, latest projections by the FAO suggest that global food production must increase by 60% by 2050, compared to 2005; a trend which will lead to increased GHG emissions from agriculture. Therefore, mitigation in the agricultural sector may have to be looked at differently than other sectors because food supplies must increase to meet the needs of a growing global population. An increased recognition that mitigation can mean a reduction in emissions compared to business as usual, based on an assessment of circumstances, existing systems and technology availability, rather than an absolute reduction could be a useful step.

Sharing knowledge

While scientific knowledge and experiences already exist, there is a need to cooperate in sharing knowledge in order to learn from past and current experiences, further identify climate relevant technologies, practices and processes, and enhance understanding of their deployment and effects. It is also necessary to enhance research and development cooperation, and to further catalyse relevant activities of international organisations and relevant stakeholders (FAO, Global Research Alliance, etc). The wide diversity of agricultural systems worldwide, as well as specific national and regional development priorities, objectives and circumstances mean that a 'one size fits all' approach does not apply for agriculture in relation to climate change.

As discussions continue, countries are generally in agreement on the importance of agriculture in contributing to food security and employment, as well as the need to improve understanding of agriculture and how it can contribute to realising climate objectives. However, finding an acceptable approach to address the climate change-related challenges faced by agriculture worldwide, and to ensure that "food production is not threatened", has yet to be found. The ongoing discussions on agriculture at the UNFCCC are therefore crucial to ensure that the climate change challenges and possible opportunities for agriculture are acknowledged and reflected in any proposed new comprehensive global agreement on climate change post 2020.

Irish agricultural GHG status

Over recent years, Irish agricultural GHG emissions have been falling steadily (-17.6%) since a peak in 1998 of 22.35Mt CO2, due to improved efficiencies. However, the sector remains a significant proportion of total national GHG emission at approximately 32% in 2011. In a European context, this emissions profile is uniquely high and, even in the developed world, only New Zealand has a higher proportion of emissions from agriculture.

The emissions reduction potential of the agriculture sector is limited due to the dominance of ruminant livestock. However, the Department of Agriculture recognises the key roles of continued research and the need to realise greater efficiencies at farm level. In spite of these very challenging economic times, the Department has continued to support extensive research and knowledge transfer programmes at national level. In addition, Ireland is engaged with the EU Joint Programming Initiative – Agriculture, Food Security and Climate Change (FACCE-JPI) and is also a founder member of the Global Research Alliance on Agricultural Greenhouse Gases, which was established in December 2009. Adapting to the future impacts of climate change is also an important area for consideration at national level.

Ireland's participation in the UNFCCC discussions on agriculture is crucial to ensure that the importance and interaction of agriculture and climate is acknowledged and reflected in the outcomes of the UNFCCC negotiations. Ireland, in its current role as EU presidency, is working to ensure that the EU position on agriculture at the UNFCCC reflects this importance.

On behalf of the Joint Programming Initiative on Agriculture Food Security and Climate Change (FACCE-JPI) and the High Level Panel of Experts of the Committee on World Food Security (CFS-HLPE), Teagasc organised the second workshop of the international research initiatives on agriculture and climate change.

These include:

- FACCE-JPI (Joint Programming Initiative Agriculture, Food Security and Climate Change)
- CFS-HLPE (High Level Panel of Experts of the United Nations Committee on World Food Security)
- Global Research Alliance
- Climate Change, Agriculture and Food Security Programme of Consultative Group on International Agricultural Research (CGIAR)
- The Joint Research Centre of the European Commission (JRC)
- Belmont Forum
- Wheat Initiative
- Embrapa and IntensAfrica (observers)

This workshop took place in Bonn on June 4-5, coinciding with the annual series of scientific and technical meetings of the United Nations Framework Convention on Climate Change (UNFCCC). The initiatives agreed on:

- The opportunity and need for continued and stronger interaction through annual meetings.
- The added value of shared learning on common methodological research challenges.
- Potential areas of the joint activities to be of relevance to the UNFCCC and CFS processes.

Teagasc and the Department of Agriculture, Food and the Marine are Governing Board members of FACCE-JPI.

Sustainability initiatives in the Irish livestock sector

Padraig Brennan, Bord Bia, explains recent initiatives involving Bord Bia, Teagasc and private industry to develop the Irish food industry sustainably.

Environmental sustainability continues to grow in importance as a strategic business issue among leading food and drink customers globally. Research undertaken by Bord Bia in 2012 clearly showed that sustainability is now a core part of the commercial strategies for many of them. This is further evidenced by the increasing focus on the Dow Jones Sustainability Index, which ranks the world's top 2,500 companies in terms of their sustainability performance.

What is meant by the term sustainability varies depending on the market or customer in question. For some, it is about food safety, traceability and quality; for others it is about emissions or resource efficiency; while others believe the focus is on issues such as animal welfare.

Most leading multinational customers have set out long-term targets to enhance the sustainability of their supply chain. For many, the driving factor behind these targets is the security of their supply chain over the medium to longer term. Critically, many are seeking solutions to help them achieve these targets and increasingly recognise the role that their suppliers will play in their delivery.

This presents considerable opportunities - for those suppliers who proactively develop initiatives in the areas such as greenhouse gases, water, welfare and biodiversity - to develop stronger business relationships with them. These customers will be critical to the Irish food sector as it seeks to increase the value of its exports from €8bn to €12bn in line with the ambitions set out in *Food Harvest 2020**.

Building the proof

It is with this in mind that Bord Bia launched the 'Origin Green' Sustainability Development Programme (www.origingreen.ie) in June 2012. Origin Green is designed to provide a platform at both farm and manufacturing level to demonstrate our commitment to producing as sustainably as possible and deliver further improvement over time, while also helping to communicate our actions in the marketplace.

At farm level, Origin Green incorporates the work that Bord Bia and Teagasc have been doing to build sustainability measures into Bord Bia's Beef and Lamb Quality Assurance Scheme (BLQAS).

Currently, around 32,000 beef farmers participate in the BLQAS, which accounts for almost 80% of Ireland's beef production. Each farm is audited every 18 months across areas ranging from traceability, medicines, animal welfare, health and safety and environmental issues. Since May 2011 participating farmers also take part in a sustainability assessment of their enterprise.

On-farm sustainability assessment

In early 2011, Bord Bia, in partnership with Teagasc, received PAS2050 accreditation from The Carbon Trust in the United Kingdom for our methodology and model for assessing the carbon footprint of Irish beef production.

Since May 2011, Bord Bia has been gathering production-based information on participating farms to allow us to assess their emissions performance. The type of information being collected is as follows:

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- Level of beef production
- Length of time animals are outdoors
- Details on feeds consumed by animals
- Chemical fertilizer usage
- Manure management

This information is combined with a livestock profile for each farm from the Department of Agriculture's AIM (Animal Identification and Movement) database to provide an indicative performance for each farm. This allows farms to be compared to others in a similar production system and highlight areas offering potential for improvement.

This forms the initial feedback that participating farmers receive. To date, almost 40,000 farmers have taken part in this assessment.

The next stage of the beef sustainability programme has been introduced over recent months. This focuses on providing practical feedback and advice to farmers on what they can do to improve their environmental performance and, at the same time, improve the efficiency of the farm. This takes the form of the Teagasc/Bord Bia Farm Carbon Navigator tool.

The areas being assessed in the tool are as follows:

- Grazing season
- Age at first calving
- Calving interval
- Live weight performance
- Nitrogen fertilizer use
- Manure management

The information collected on-farm by Bord Bia helps us create a picture for the current farm performance. The tool then allows the farmer, in conjunction with their advisor, to set targets for each measure to see what impact it could have on greenhouse gas emissions and the economic performance of the farm.

Carbon Navigator tool

A similar approach is being adopted for the Irish dairy sector as part of a National Sustainability Scheme currently being finalised. In 2012, Bord Bia and Teagasc received PAS2050 accreditation for a methodology and model to assess the emissions associated with Irish milk production following a pilot project with a leading milk processor. A dairy Carbon Navigator tool similar to that being implemented in beef has also been developed and will be rolled out during the second half of 2013.

Other sustainability areas

The Sustainability agenda at both a policy and market level incorporates more than greenhouse gas emissions. Recognising this fact, Bord Bia is introducing measures to examine areas such as biodiversity and water on Irish farms. These measures focus initially on gathering information with regard to the following:

- Hedgerow management
- Tree planting
- Wildlife habitats
- Areas of conservation
- Rainwater collection, and
- Water conservation.

Information gathered here will enable Bord Bia to work closely with Teagasc, and other relevant organisations, to provide clear guidance and advice to farmers on how they can further enhance their performance in these areas.

Practical benefits from focusing on sustainability

The business case for measuring environmental performance on livestock farms is compelling as measures that enhance the economic performance of a farm typically also deliver economic benefits through lower costs of production.

At farm level, sustainability comes down to minimising the amount of resources (e.g., electricity, feed, water, etc.) used to produce a kg of output. Results from our work to date shows that while Irish farmers on average compare very favourably by European and International standards, there is significant variation evident across farms. This variation offers valuable learnings, as the practices adopted by the best-performing farms can provide practical guidance for other farms.

At an industry level, sustainability also offers potential benefits. Being able to demonstrate the credentials and the commitment of the Irish livestock sector to produce in a sustainable manner allows exporters highlight how Ireland offers a source of food products that will help their customers achieve their own sustainability targets. This in turn can help build stronger relationships with key customers and over time secure an improved market position.

Improving performance

Irish livestock production has strong sustainability credentials. The introduction of sustainability measures across beef and dairy allows Ireland to take a lead in the drive to produce sustainably, while also helping farmers identify ways of improving the environmental and economic performance of their enterprises. While this work will continue to evolve as science develops further, the focus will continue to be on providing practical feedback and advice to farmers to help them improve their performance from both an environmental and economic perspective.

*Food Harvest 2020 is the industry-led strategy, supported by Government, that sets out the ambition, vision and targets for growth of the Irish agri-food sector towards 2020.

AGRI-I: An Agricultural Greenhouse Gas Research Initiative for Ireland

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Food Harvest 2020 envisages ambitious expansion, with a 50% increase in dairy production. However, this expansion will occur within an EU policy context whereby greenhouse gas emissions (GHG) must be reduced across Europe. Furthermore this reduction only applies to the non-emission traded sectors (the agriculture, waste, residential and transport sectors). As agriculture comprises over 40% of this category of emissions, there will inevitably be sustained pressure into the future to at least limit any emissions rise associated with agricultural expansion.

Over the past decade, considerable research has been carried out on agricultural greenhouse gas emissions, funded primarily by the Department of Agriculture, Food and the Marine (DAFM) and the Environmental Protection Agency (EPA). However, whilst this research was of very high quality, there was fragmentation, duplication, and little co-ordination either in terms of addressing a large set of objectives or standardised experimental approaches. In response to this, the Department of Agriculture, Food and the Marine and COFORD (the Council for Forest Research and Development) have jointly funded the establishment of The Agricultural Greenhouse Gas Research Initiative for Ireland (AGRI-I). This is an organisational and collaborative framework designed to: build a critical mass of scientific expertise in GHG research, co-ordinate uniform measurement protocols, and address a specific set of research issues.

The AGRI-I network has a specific set of research aims, primarily focussed on the inclusion of validated GHG emissions mitigation strategies into the national inventory. Currently, the EPA calculates the national Greenhouse Gas budget and submits the National Inventory Report to the United Nations Framework Convention on Climate Change (UNFCCC). However, there are currently very few mitigation strategies that can be 'counted' in this National Inventory, primarily due to the lack of compliant datasets, particularly in terms of the amount of emissions associated with different nitrogen (N) inputs or land-uses. In order to allow for a greater flexibility in the Inventory to account for mitigation, the initial workplan consists of four core projects.

- Develop higher tier disaggregated nitrous oxide emission factors
- Quantify carbon (C) sequestration potential of managed grasslands across a range of soil types.
- Develop biogeochemical models that will allow for a move to Tier 3 emission factors.
- Further develop mitigation strategies for enteric methane emissions from livestock.

Developing disaggregated nitrous oxide emission factors

The objective of this project is to quantify the amount of nitrous oxide (N_2O) associated with different fertiliser inputs. Currently, the default emission factor (the amount of N_2O released per amount of N applied) is set at 1%, regardless of N type. Here, emission factors will be disaggregated between N source (CAN, urea, urine, dung), soil type and temporally for different times of the year. This will allow for the inclusion of mitigation strategies in the inventories such as switching from CAN to urea fertiliser (see Figure 1), incorporation of nitrification and urease inhibitors, altered fertiliser timing and low N dietary strategies. Ammonia N and leached N associated with the experimental treatments will also

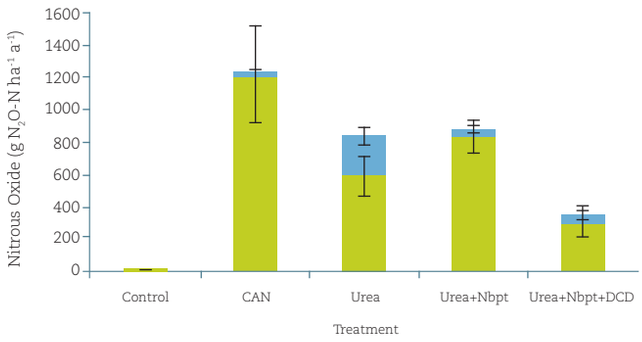

Figure 1: Annual total direct and indirect N_2O emissions associated with CAN, urea, urea with a urease inhibitor (NBPT) and urea with both a nitrification inhibitor (DCD) and a urease inhibitor (NBPT). Indirect emissions were calculated from measured ammonia emissions.

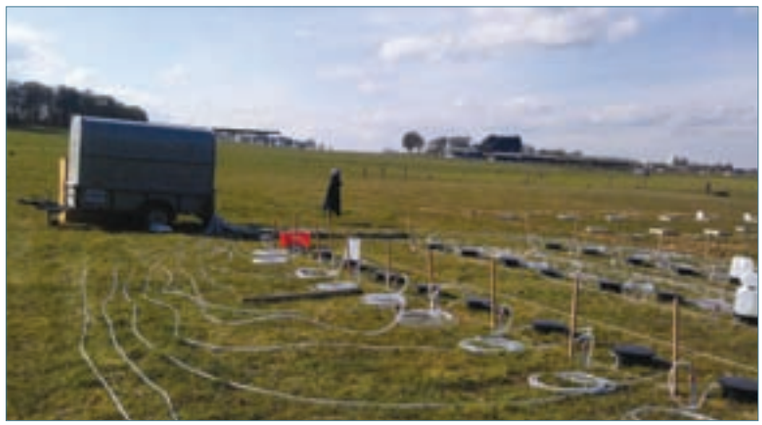

Figure 2: Dynamic chambers deployed for ammonia measurements.

be measured as part of a linked Stimulus (DAFM) project Sustainable Use and Dissaggregated Emissions of Nitrogen (SUDEN).

Quantification of grassland C sequestration

Research has shown that European grasslands effectively remove carbon dioxide (CO_2) from the atmosphere during photosynthesis. Whilst some of this CO_2 is re-emitted during plant and soil microbial respiration, there is a net 'sink' of approximately 1-3 tonnes of CO_2 per hectare per year. This project is tasked with quantifying the carbon budget associated with Irish grassland and cropland systems across a range of soil types. This will be the first step to pasture management inclusion in national inventories. In addition, it will robustly quantify sequestration for managed pasture for use in the life cycle analysis. Indeed, it has been previously noted that the 'C offset' when sequestration is taken into consideration could be as high as 40–70% of total GHG emissions from grassland-based systems. The project also quantifies the effect of pasture management on C sequestration and is tasked with ranking strategies based on their enhancement potential of pasture C sinks. The management options being explored include the effects of stocking rate, drainage, biochar application and organic manure application.

Biogeochemical modelling of GHG emissions.

Process models need to be developed in order to spatially scale up the experimental results generated in other projects and extrapolate them for the whole country. These models allow for country-specific climatic conditions to be accounted for, as well as site/region-specific management and can be used as a tool for scenario-testing and policy development. In particular, predictive models will facilitate the effects of climate change on our mitigation strategies and essentially 'future proof' any particular measure to be assessed. This project will develop process models that simulate GHG emissions at both the local/farm and regional scales. The model outputs will aid the interpretation of experimental results and identify the consequences of the experimental set-up chosen and the key factors underlying the observations. Also these models will aid pinpointing of the difficulties and uncertainties with inventories of greenhouse gas emissions on a regional to national scale. The models being used include RothC/Ecosse as well as more complex models such as DNDC and DailyDAYCENT. A data archive will also be developed in order to store results from these and other DAFM-funded projects. It is envisaged that the database this will be a resource that can be added to and used in perpetuity.

Interactions with European and global networks

AGRI-I also plans on sharing data and resources with both individual country Networks and European/global research initiatives. In particular, a formal link has been made with the UK's Greenhouse Gas Platform (www.ghgplatform.org.uk/), which is also seeking to refine emissions associated with methane and N_2O. As a result, both networks are adhering to similar experimental protocols and co-operating in data archiving with the aim of pooling experiments and datasets. AGRI-I has also engaged with the EU Joint Programming Initiative on Food Security, Agriculture and Climate Change (www.faccejpi.com/). The objective of this Joint Programming is to increase the value of relevant national and EU R&D funding by concerted and joint planning, implementation and evaluation of national research programmes. In this Joint Programming, Member States are expected to coordinate national research activities, group resources, benefit from complementarities and develop common research agendas. As a result, AGRI-I has provided funding for members to engage in collaborative research with the FACCE-JPI on methane reduction strategies, as part of an EU-wide JPI call on agricultural greenhouse gases. This will allow for Irish researchers to pool resources and engage in an ambitious programme of research on enteric methane reduction that would not be financially possible for the network alone. Collaboration is also occurring at a global scale via the Global Research Alliance (GRA, www.globalresearchalliance.org/). The GRA consists of Livestock, Cropland and Rice Groups, which align research between countries. In addition, Inventories and Carbon/Nitrogen cross-cutting groups help in establishing measurement and experimental protocols.

Acknowledgements

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Reducing GHG emissions for beef cattle systems

Teagasc and Bord Bia have been working on strategies to reduce greenhouse gas emissions from Irish beef cattle systems.

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The agricultural sector is faced with the dual challenge of meeting increasing global food demand and addressing concerns in relation to global greenhouse gas (GHG) emissions. In the case of Ireland, agriculturally-derived emissions have shown steady reductions in recent years; in 2010 agricultural GHG emissions were 8.3% lower than 1990 levels but still represented 30.4% of total national GHG emissions (EPA, 2011). It is estimated that Irish agricultural GHG emissions will increase by 7% by 2020 due to increased production (Donnellan *et al.*, 2012); however, there is scope to mitigate GHG emissions if production efficiency at farm level is improved. Teagasc and Bord Bia have been working collaboratively to develop systems to "measure and reduce" GHG emissions from Irish beef farms. The objective was to develop an internationally-accredited approach to audit GHG emissions from beef farms and, consequently, to put in place tools to enable farmers to identify management strategies to reduce emissions.

Carbon auditing Irish beef farms

A methodology has been developed for "auditing" GHG emissions from Irish beef farms. The methodology employs the GHG model developed by Foley *et al.* (2011) and integrates the beef enterprise production profile with various GHG emission factors. A key requirement was to use an internationally-accepted accreditation process and, therefore, the model is compatible with the requirements of the British Standards Institute (BSI) Publically Available Specification (PAS) 2050 which builds on the life cycle methods of ISO 14040 and ISO 14044. A pilot phase involving 200 participants in the Beef Quality Assurance Scheme (BQAS), an independently accredited national scheme for beef production in Ireland operated by Bord Bia, was conducted prior to the wider roll out to all 32,000 participants in the BQAS. Results of the pilot phase (Figure 1) showed that suckler beef systems had higher emissions than dairy beef systems. There were no significant differences between systems within the suckler beef or dairy beef categories.

Mitigation of GHG emissions

The optimisation of production efficiency is a key strategy in mitigating GHG emissions from beef production systems. A number of strategies have been identified that offer the potential to reduce GHG emissions per kg beef produced from beef cattle production systems while also improving farm productivity and, thus, profitability.

Extended grazing

Extending the grazing season provides opportunities to reduce GHG emissions in two ways. Firstly, the shorter indoor period results in lower quantities of slurry stored leading to a direct reduction in slurry-origin methane and nitrous oxide emissions. Grass-based diets are also associated with lower enteric fermentation emissions relative to grass silage-based diets.

Improved sward quality

Improving grass quality can reduce emissions by: increasing the efficiency of sward utilisation thus improving the efficiency of fertilizer usage; reducing methane emissions per kg of beef produced as a result of lower sward fibre content; and improving livestock productivity thus, increasing live-weight gain per day.

Increased use of clover

White clover can reduce nitrogen fertilizer use and, therefore, nitrous oxide emissions, significantly. The reduction in fertilizer also reduces indirect emissions for the farming system by reducing the GHG emissions associated with the production, marketing and distribution of the fertilizer.

Improved manure management

Increasing the quantity of slurry spread in spring rather than summer and adopting low emission application methods reduces ammonia emissions as spring weather conditions are normally associated with lower NH_3 losses and, thus, lower N_2O emissions associated with redeposition. Lower ammonia losses also increases the fertilizer replacement value of slurry, and, therefore, reduces the total fertilizer N inputs and reduces associated N_2O emissions from soil and CO_2 emissions from fertilizer manufacture.

Improved animal productivity

Improving the productivity of beef cattle, either through improving genetic merit or through improved management, can reduce GHG emissions per unit of beef output in a number of ways:

- **Reducing age at first calving:** Reducing age at first calving is associated with lower feed, enteric fermentation and manure management emissions for first calving heifers.
- **Increasing the longevity/survival of suckler beef cows:** Lower values for survival mean that the replacement rate of a suckler herd is higher, increasing the number of replacements required to be reared and increasing the GHG emissions produced per cow calving.
- **Improving the calving rate of suckler beef cows:** Higher calving rates reduce carbon footprint by increasing output per cow unit, thus "diluting" the GHG footprint over a greater quantity of beef.
- **Improving the feed efficiency of beef cattle:** This would reduce the feed inputs, and associated emissions, per unit of output.

Increased animal performance. The impact of improved average lifetime daily gain for beef production systems is to 'dilute' the GHG emission association with production. No changes in feed efficiency are assumed.

Carbon Navigator

In addition to estimating GHG emissions on beef farms, it is necessary to provide recommendations for the reduction of these emissions. An online software program has been developed to assist farmers to identify measures to reduce GHG emissions and to achieve these reductions by setting targets for key aspects of their production system. This software program is called the Carbon Navigator and focuses on "distance to target" – in other words the focus of the program will be to provide farmers with an indication of how current and target levels of GHG emissions relate to poor, average and high performing farms operating comparable farming systems. It will not be necessary to estimate total beef farm system GHG emissions to use this program; it aims to "cut" rather than "count" emissions. The program focuses on mitigation options that are cost effective and, in most cases, improve farm profitability.

The mitigation options available in the Carbon Navigator are primarily those described above and represent options that both reduce GHG emissions while also increasing farm profitability (see Figure 2). The Carbon Navigator assesses each option using a common approach and presents the user with an output sheet outlining; current and target levels of production, impact on GHG emissions versus comparable production systems, a "score" (from 1 to 10) for each measure, an indication of financial impacts and, an outline of how the measure impacts on GHG emissions. The scores achieved for each measure is also presented graphically to provide a simple comparison of current and target levels of performance for each mitigation measure.

Summary

Globally agriculture faces the dual challenges of increasing production and reducing GHG emissions. This will require innovation and productivity gains to improve GHG emissions efficiency in terms of CO_2-eq/kg beef carcass. A range of mitigation options have been identified to reduce GHG emissions per kg beef for pasture based beef cattle systems. The key area for attention is to increase animal live weight and reproductive performance levels. Other potential mitigation strategies include extending the grazing season, increasing the use of clover and improving slurry management. GHG measurement and mitigation programmes have been developed, which will improve the capacity of Irish beef farms to adopt these strategies.

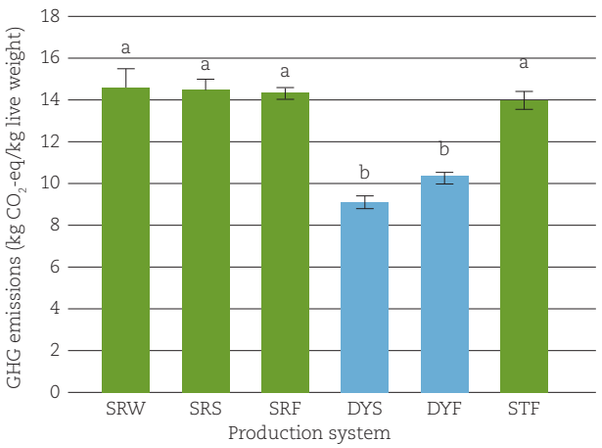

Figure 1. Greenhouse gas emissions from Irish beef production systems, SRW = Sucker to weanling; SRS = Suckler to store/finish; SRF = Suckler to finish; DYS = dairy calf to store/finish; DYF = dairy calf to finish; STF = Store to finish.

Figure 2. Screenshot of the Carbon Navigator on the Bord Bia Quality Assurance web portal

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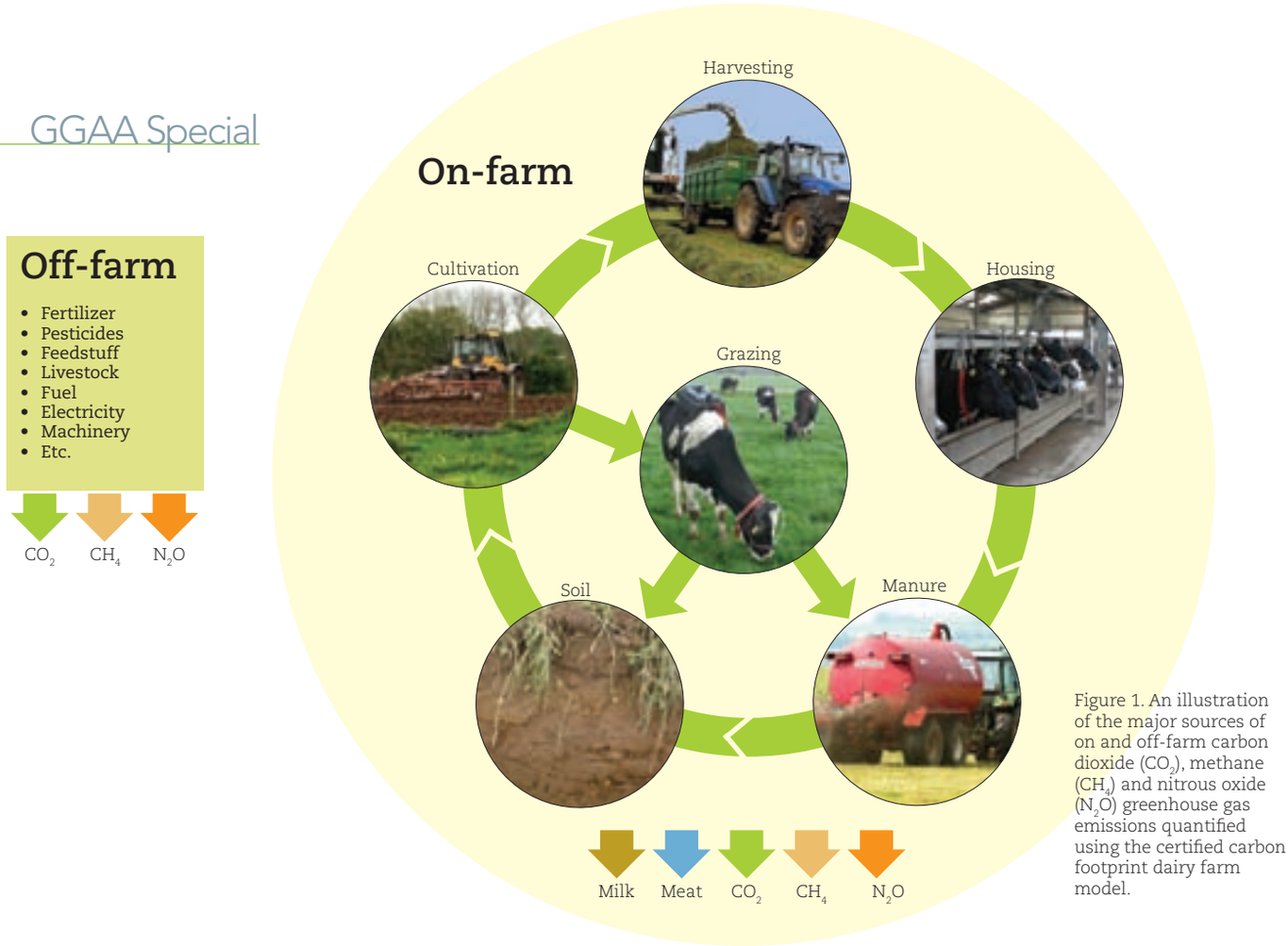

Figure 1. An illustration of the major sources of on and off-farm carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) greenhouse gas emissions quantified using the certified carbon footprint dairy farm model.

Modelling a Certified Carbon Footprint of Irish dairy farms

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In contrast to most developed countries, with the exception of New Zealand, dairy farming is a key source of Ireland's national greenhouse gas (GHG) emissions (≈ 10%). This large contribution can predominately be explained by two factors: firstly, the absence of a significant heavy industry sector in Ireland; and secondly, the high population ratio of cattle to humans. It is anticipated post the abolition of the EU milk quota system in 2015, Irish dairy production will grow substantially. However, primary Irish agriculture is part of the European non emission trading sector, which has been set a target to reduce GHG emissions by 20% by 2020 relative to 2005 levels. Thus, there is an increasing need to measure and reduce the GHG emission generated per unit of milk (carbon footprint) of commercial dairy farms.

Direct measuring of GHG emissions from dairy farms is physically and logistically difficult, if not impossible. There are simply too many diffuse sources of GHG to measure. A more practical approach that is relatively inexpensive while still being highly accurate is through computer modelling. The accepted methodology to model the carbon footprint of milk is life cycle assessment (LCA). Although, many have quantified the carbon footprint of milk production using LCA, few have used a certified approach. Thus, a study was undertaken by Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, in conjunction with Bord Bia to develop a certified model capable of delivering a representative carbon footprint for Irish milk production.

Model description

A model was developed to quantify the carbon footprint of milk according to the PAS 2050 LCA methodology. PAS 2050 (2011) is an independent publicly available specification, developed by the British Standards Institute and Department for Environment, Food and Rural Affairs (UK) to provide a consistent method for assessing the life cycle GHG emissions of goods and services. The approach requires the estimation of on- and off-farm GHG emissions associated with dairy farming (Figure 1) with the unit of measurement being carbon dioxide equivalent (CO_2-eq) emission expressed in kilogram of fat and protein corrected milk (FPCM).

To calculate GHG emissions from on-farm sources the Intergovernmental Panel on Climate Change (IPCC) guidelines were followed. The major GHG emissions calculated using the IPCC guidelines included:

- Methane belched and respired by cattle and methane from manure storage.
- Nitrous oxide from soil following spreading manure and artificial N fertilizer.
- Carbon dioxide from fossil fuel, lime and fertilizer.

Off-farm GHG emissions associated with the production of purchased inputs - such as concentrate feeds, fertilizers, detergents, energy, etc. - were calculated using the Carbon Trust database and scientific literature. The total annual GHG emission's quantified by the model and associated with milk production was calculated by economically allocating CO_2-eq emission between milk and meat. Using the PAS 2050 LCA methodology, the economic allocation was based on culled cows, surplus calf and milk sales.

The carbon footprint model developed was embedded within the Bord Bia Quality Assurance database. The required information was sourced from a combination of on-farm data collection through the completion of an on-farm survey by Bord Bia-certified recorders and national livestock population databases.

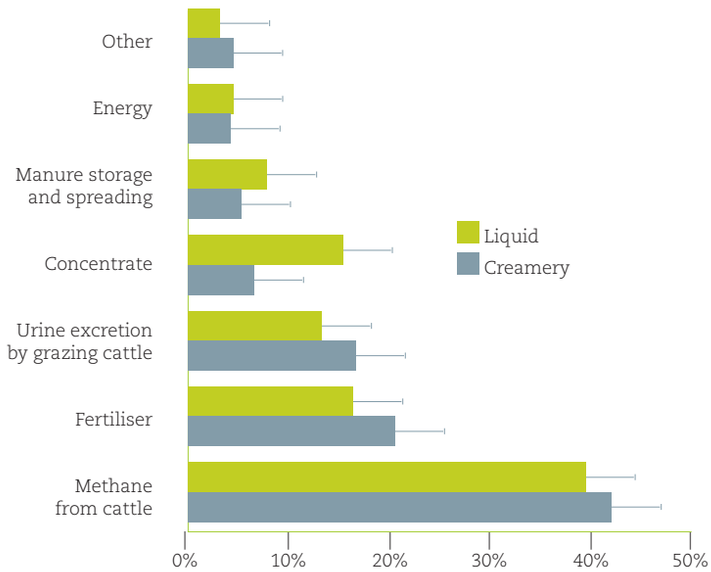

Figure 2. The percentage contribution of various sources to the carbon footprint of creamery and liquid milk producers. The sources that comprised the other category included lime, refrigerants, chemicals and detergents.

Certification

To certify the carbon footprint model, a group of farms were evaluated. The sample comprised of two distinct categories, namely liquid milk producers and creamery or manufacturing milk producers. To ensure the sample was representative of the producers in each category, 40 liquid suppliers and 75 creamery producers were randomly selected.

The Carbon Trust Certification Company reviewed all the carbon footprint model procedures. To certify the model the Trust selected a random group of farms representative of each category. Each of the randomly chosen farms were then assessed to check key variables. Some outliers in the dataset were investigated further to confirm whether the information collected was accurate and whether the model was operating correctly. Once this process was completed, the Carbon Trust certified the model was consistent with the PAS 2050 LCA methodology and suitable for evaluating Irish milk production systems.

Model application

The application of the certified carbon footprint model (Figure 2) showed that the largest contributor to the carbon footprint of liquid and creamery suppliers was methane belched and respired by cows (enteric fermentation). The remaining sources of the carbon footprint of the creamery suppliers were predominately artificial fertilizers and urine excretion by grazing cattle. However, for liquid suppliers, purchased concentrate feed was also a key source of the carbon footprint given the greater reliance on imported feedstuffs on these farms.

The analysis showed that there was a large range in emission estimates. The results showed that the carbon footprint of creamery producers differed by 50% between the top and bottom 10% when ranked by emissions per kg of FPCM. For liquid producers, the range between the upper and lower 10% of suppliers' carbon footprints was even greater at 75% when ranked by emissions per kg of FPCM. The comparison between the mean carbon footprint of creamery and liquid producers showed that liquid suppliers emitted a 7% higher carbon footprint per kilogram of FPCM. Thus, the variation in CO_2-eq emission per kilogram FPCM between production systems was substantially lower than the difference between farms. This finding is consistent with previous research and suggests that there is significant potential for both liquid and creamery suppliers to reduce their carbon footprint.

The next step of this research is to use the certified model to quantify the average carbon footprint of Irish milk production. This will provide a verifiable carbon footprint for Irish milk production, which can be benchmarked over time to evaluate the change in the carbon footprint of Irish milk. It will also allow for international comparisons with nations who also use a certified PAS 2050 LCA methodology. This will occur through the integration of this model with the Teagasc National Farm Survey data recording system.

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Enteric methanogenesis in beef cattle

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Methane produced in the digestive system of ruminants accounts for almost half of greenhouse gas (GHG) emissions from Irish agriculture. It also represents a loss of energy for cattle and sheep, representing 2-12% of their gross energy intake. Improved animal productivity and dietary manipulation are two strategies for reducing emissions indices. Experiments were undertaken to quantify firstly methane emissions by finishing beef cattle consuming a range of alternative diets, and secondly the emissions of these systems when account was taken of land use and land use change. In addition, *in vitro* rumen batch digestion tests were undertaken as a relatively cost-effective method of rapidly screening methanogenesis with a wide range of dietary ingredients and additives under standard conditions.

Finishing beef cattle

Although grass silage is the main winter-feed for cattle in Ireland, there are circumstances where forage maize or whole-crop small-grain cereal silages can be attractive. From a GHG perspective this holds the additional attraction that increasing starch content in the diet has the potential to reduce enteric methane emissions intensity (g CO_2-eq/kg beef carcass). Therefore, studies were undertaken where finishing beef cattle were offered maize or whole-crop wheat silages that differed in starch content, and their methane output was compared with cattle consuming diets based on grass silage (no starch) or cereal grains (very high starch) offered to appetite. Methane output was measured using sulphur hexafluoride as a marker.

Increasing the starch content of maize or whole-crop cereal silages significantly reduced methane emission intensity, with about half of this effect coming from an increase in the daily rate of carcass gain and the remainder coming from a reduction in the absolute quantity of enteric methane emitted daily. This effect of dietary starch content was maximised where cereal grains were fed to appetite, with the methane emission intensity being reduced by 24-65% compared to the forage-based diets. This effect is not simply one of starch content *per se*, but also reflects the net energy content of these diets. Hence, for example, the grass silage was associated with an energy content and corresponding methane emission intensity that was in the middle of the values obtained with the whole-crop wheat silages assessed.

Beef systems assessment

The reduction in the intensity of enteric methane emission summarised above needs to be considered within the overall context of the total beef production system. Therefore, a lifecycle assessment (LCA) was undertaken to account for GHG emissions from enteric fermentation, manure, soils, indirect nitrous oxide emissions and the production of inputs. The methodology used estimated both financial performance and emission efficiency for seven beef finishing strategies.

Methane, nitrous oxide and carbon dioxide contributed 42-59, 23-29 and 17-29% of total GHG emissions across the beef systems modelled. The calculated GHG emissions were lowest with the diets based on high-starch maize silage and cereal grains fed to appetite (18.3 and 19.2 g CO_2-eq/kg beef carcass, respectively), intermediate for the grass silage diet (21.7 g/kg) and highest for the low-starch whole-crop wheat silage diet (24.0 g/kg). However, when account was taken of potential or estimated carbon sequestration by permanent pastures and carbon loss due to land use change from permanent pasture to arable crops, the rankings changed. In this case, the corresponding whole-farm system GHG emissions for the four diets previously mentioned was 16.8, 18.4, 15.6 and 19.3 kg CO_2-eq/kg beef carcass. These findings showed the attractiveness of the system based on permanent grassland, and highlighted the necessity to undertake a fully holistic assessment of how GHG mitigation strategies impact on whole-farm system emissions. An incomplete assessment can lead to erroneous conclusions being made.

In vitro studies

In vitro rumen techniques attempt to simulate conditions in the rumen, and the batch digestion version does this under conditions where simulated intake, passage rate, absorption and rumination are considered similar for each treatment. It therefore helps produce a methane output value for a feed ingredient, derived under standardised conditions.

In the series of studies undertaken it was shown that neither the grass species (n = 5) nor perennial ryegrass variety (n = 7) evaluated influenced methanogensis when each was managed under a similar simulated intensive grazing regime throughout the season. However, doubling the water-soluble carbohydrate content in grass reduced methane output (mmol CH_4/g of apparent DM digested) by 14%, and this effect was more marked with fructan than sucrose.

Managing grassland so that grazing cows were offered a sward allowance of 15 or 20 kg dry matter (DM)/day throughout the grazing season did not alter the methanogenic characteristic of the herbage. In contrast, managing the grass so that herbage mass at the commencement of each grazing was 2,400 rather than 1,600 kg DM/ha resulted in a 6% increase in methane output.

In each of the above cases where assessments were made throughout the grazing season there were seasonal effects on the methanogenic character of grass, although this could not reliably be attributed to any single measured chemical composition trait.

White clover has been associated with less enteric methane production than grasses grown with inorganic nitrogen (N) fertiliser. This was confirmed in the present series of experiments where three different white clovers averaged 25% lower methane output than four grass species (perennial ryegrass, cocksfoot, meadow fescue and timothy). A surprising outcome when a range of mixtures of each white clover with each grass were assessed was that the methane output was higher than predicted based on the methane outputs measured with the monocultures. In the case of the 50:50 mixture of clover and grass this averaged at a 5% overyield of methane. This finding needs to be assessed under *in vivo* conditions.

Both reseeded and old permanent grassland swards in Ireland contain some content of non-legume forbs. Six commonly found species were assessed on two occasions during the grazing season, but none were found to provide consistently low methane outputs.

Compounds such as nitrate in herbage can act as an alternative hydrogen sink to methanogenesis, thereby reducing methane output for herbage. This was evident when assessing the effects of applying inorganic N fertiliser to grassland (0 and 100 kg N/ha resulted in 60.0 and 57.2 ml CH_4/g DM digested, respectively) and when comparing autumn grass with primary growth grass (52.9 and 63.2-64.4 ml CH_4/g DM digested, respectively).

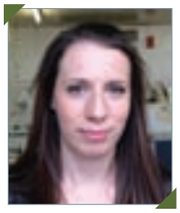
Grass can be utilised at a range of growth stages, and advancing growth stage increased methanogenesis. Thus, grass sampled from the primary growth on 12 May and 7 July had digestibilities of 789 and 551 g/kg, respectively, with corresponding methane outputs of 49 and 55 ml CH_4/g DM digested. Approximately 28% of grassland in Ireland has at least one harvest of silage taken each year, and in the *in vitro* studies ensilage reduced the methane output associated with herbage by 9%.

Finally, a series of chemical and biological agents were co-incubated with different dietary ingredients. Lauric and linolenic acids, and two halogenated methane analogues, generated the more marked reductions in *in vitro* rumen methane production.

Acknowledgements

Funding for these studies was provided under the National Development Plan through the Research Stimulus Fund administered by the Department of Agriculture, Food & the Marine (DAFM; 05-224, 06-361 and 07-517). The research was undertaken in collaboration with the School of Agriculture, University College Dublin; AGRIC, Teagasc, Moorepark, Co. Cork; DAFM, Backweston Farm, Co Kildare; Instituto de Ganadería de Montana (CSIC-ULE), Universidad de León, Spain.

Chemical markers for rumen methanogens and methane production



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Researchers report on their investigations into a novel chemical analysis-based technique to estimate methane levels from ruminant animal production.

Methane production by ruminants is a significant contributor to greenhouse gas emissions in animal production in Ireland, and a source of inefficiency in the conversion of feed energy into milk or meat. It is a particular problem for Ireland because of our large numbers of cattle and sheep. The high-forage diets that are typical for most production systems also lead to high methane emissions. The current methods for estimating methanogen populations (methane-producing microorganisms in the ruminant digestive system) or measuring methane production are costly and can have large experimental errors. For example, measurements with respiration chambers are costly and can only be obtained with small numbers of animals. Measurements using the sulphur hexafluoride (SF_6) tracer technique are quite laborious and also subject to larger experimental error. We have investigated a new chemical marker approach to study the population of methanogens, in this case from the *Archaea* domain, in the rumen, as well as their production of methane.

Estimating methanogen populations in the rumen

Quantitative real-time PCR (qPCR) has become the method of choice for quantification of methanogens in the rumen. Methanogen abundance studies normally measure levels of the specific methanogenic 16S rRNA (rrs) gene, the methyl-coenzyme M reductase (mcrA) gene that is involved in methane production, or both. There are a number of underlying problems with the qPCR technique, including differences in the rrs gene copy number within a genome, differences in genome copy number within a cell, and lack of specificity of the primers used in the PCR reaction.

We have investigated alternative chemical markers for methanogens, based on the distinctive ether lipids of archaeal cell membranes, measured using gas chromatography-mass spectrometry. The membranes of *Archaea* contain dialkyl glycerol ethers, such as 2,3-diphytanayl-O-*sn*-glycerol (archaeol), and glycerol dialkyl glycerol tetraethers (GDGTs), such as caldarchaeol (GDGT-0) in different proportions (Figure 1). These compounds have been used as proxies for determining levels of methanogens in other ecosystems. For example peat bogs; and palaeoclimatologists also base estimates of ancient sea temperatures on profiles of these lipids in marine sediments. We found significant relationships between concentrations of archaeol in rumen fluid and estimates of methanogens based on qPCR, though the inconsistency of estimates using different primer sets confirms the problems with qPCR.

Very recent work, also presented at the Greenhouse Gases and Animal Agriculture 2013 meeting (McCartney *et al*., 2013a), suggests that the methanogen membrane adapts to contain more GDGT in challenging rumen conditions such as low rumen pH, low structural carbohydrate availability and/or high passage rates. This change will reduce membrane permeability and so increase the energetic efficiency of the methanogen cell under these conditions.

Estimating methane production

Respiration chambers (Figure 2) are airtight facilities, allowing the capture and analysis of all gases produced by the animals. The SF_6 canisters collect a sample of breath over the day and daily output is calculated relative to amount of a known tracer (SF_6) released from a permeation tube located in the

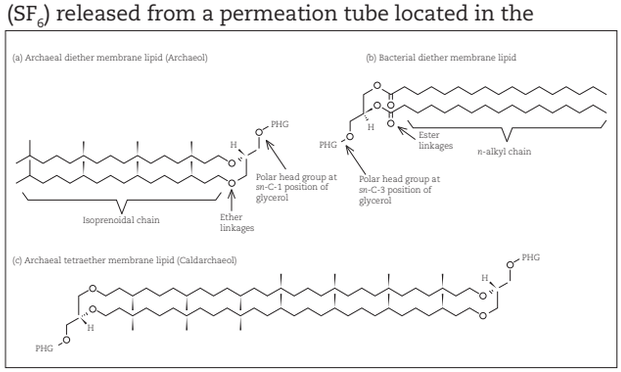

Figure 1. Comparison of the structures of membrane lipids of archaea (a) and bacteria (b). Examples of the core membrane lipids found in the archaea, including archaeol (a) and caldarchaeol (c). Reprinted with permission from McCartney *et al*. (2013b) © The Animal Consortium 2013.

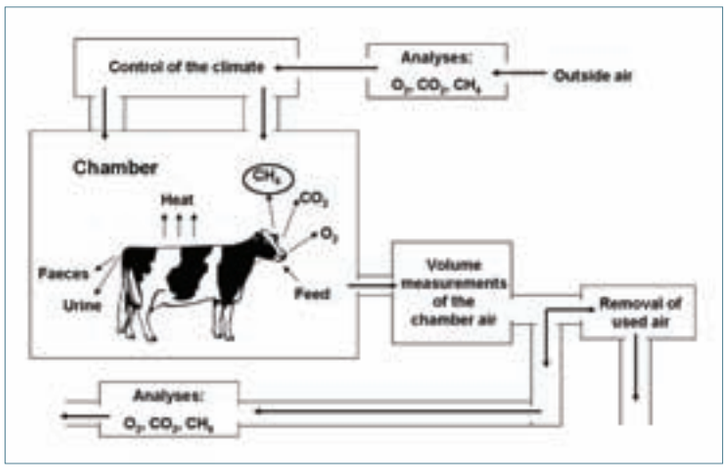

Figure 2. Schematic diagram of an open-circuit respiration calorimetric chamber. Redrawn, based on Soliva and Hess (2007).

rumen. The problems and limitations of these techniques in terms of cost, labour requirement, confinement of animals, and experimental error were mentioned briefly above. Archaeol can be measured in faeces of ruminants, so we investigated whether faecal archaeol could be used as a proxy for measuring methane production. The advantages of using the faecal archaeol method for estimating methane emissions in comparison to traditional techniques include limited/no contact with the animal, relatively simple sampling/processing methods, relatively low cost, and the opportunity to pool samples together, or to take individual measurements prior to analysis.

Initial studies showed that archaeol is a distinctive component of ruminant faeces, not being detected in faeces from a range of non-ruminant species (Gill *et al*., 2010). Several studies have now investigated the relationship between faecal archaeol and methane production (Gill *et al*., 2011; McCartney *et al*., 2013b) and treatment means are summarised in Figure 3. When comparing techniques, there was a good relationship between faecal archaeol concentration and methane production expressed per unit dry matter. In addition, changes in methanogen abundance were detected when animals were fed different dietary treatments, including high starch and leguminous feeds (reduced methanogen abundance), and high fibre feeds (increased methanogen abundance). However, there was considerable variability for individual values within treatment means. A further problem is that the positive intercept for the relationship shown in Figure 3 suggests some selectivity in what flows out from the rumen. Selective retention of methanogens in the rumen means that whilst methane is still being produced in the rumen by methanogens, their retention in the rumen means that they cannot be detected (as archaeol) in the faeces. In addition, there is a poor relationship between archaeol concentration in the rumen contents and faeces.

Studies by other groups are investigating milk fatty acid profiles as proxies for methane production and the same problem of variation in the relationship between the production of methane and the outflow/absorption of the precursors of milk fatty acids may apply.

Although these problems limit the application of marker approaches based on analysis of milk or faeces, the use of archaeol as a general marker for methanogen abundance in the digestive tract shows promise. We will use archaeol alongside qPCR to study the location and kinetics of methanogens within the rumen. We continue to look for a methanogen marker that is not affected by selective retention in the rumen.

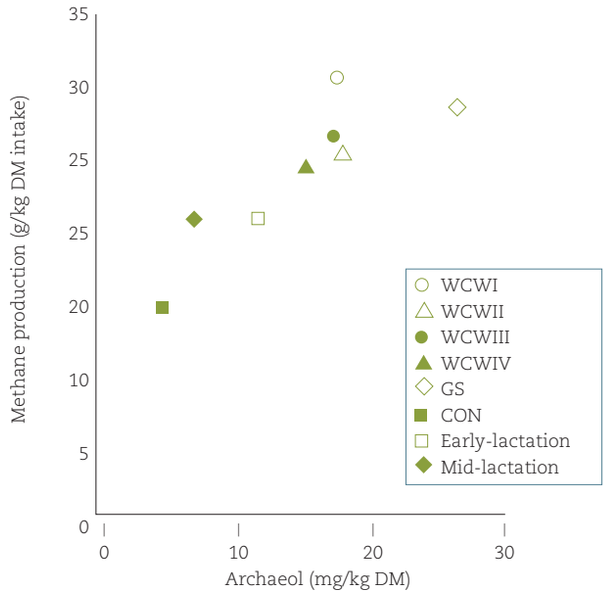

Figure 3. Relationship between faecal archaeol concentration (mg/kg DM) and methane production (g/kg DM intake) based on treatment means from three studies. Reprinted with permission from McCartney *et al*. (2013b) © The Animal Consortium 2013. Treatment means are presented for a series of diets based on whole-crop wheat (WCW) with varying straw/grain ratio, high concentrate (CON) and high grass silage (GS). Other treatment groups are for cows fed grass silage and concentrates in either early- or mid-lactation.

Acknowledgement

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Improving feed efficiency

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Researchers have been investigating strategies to reduce methane emissions and improve feed efficiency in cattle by understanding the rumen microbiota using molecular approaches.

Challenges facing the agri-food industry

The agri-food industry - with an export value of over €9bn, contributing 25% of net foreign earnings annually and employing 8% of the national workforce - is Ireland's largest indigenous sector and is critical to national economic growth. Within this, beef and dairy production cumulatively account for over 70% of gross agricultural output and 50% of export value. Globally, agriculture is faced with the major challenge of catering for a projected 70% increase in food requirements for a rapidly increasing human population, while concomitantly adhering to strict environmental legislation under the European Climate Change Programme which implements the Kyoto Protocol. The *Food Harvest 2020* report has set ambitious growth targets for the Irish beef and dairy industries with increases in output value of 20% (now revised to 40%) and 50%, respectively, by 2020. However, currently in Ireland, agriculture accounts for a higher proportion of national greenhouse gas (GHG) emissions than any other EU country, with enteric methane (CH_4) from ruminants responsible for approximately 50% of this. Consequently, if projected increases in beef and milk output are to be met in an economically and environmentally sustainable manner, major improvements in the efficiency of these production systems at farm level is necessary.

Feed efficiency, methanogenesis and the rumen microbiome

The rumen 'microbiome', an amalgam of microbes, their genetic elements (genomes), and environmental interactions, is fundamental to a ruminant animal's ability to digest and convert plant material into high quality, healthy human food products (meat and milk). Recent published data, including our own, shows a clear influence of the rumen microbiome on the efficiency in which feed is utilised by the host as well as on the quality of ruminant products. For example, volatile fatty acids generated through microbial-mediated ruminal anaerobic fermentation can contribute up to 70% of the energy requirements of the host animal. This fermentative process is, however, accompanied by methanogenesis, an essential, though energetically wasteful process, accounting for up to 15% of dietary gross energy. A fundamental knowledge of the rumen eco-system is thus critical to understanding, and positively manipulating, rumen fermentation and improving nutrient utilisation. Methane is produced by methanogenic archaea. Despite their relatively low abundance (0.5 to 3% of total rumen microbes), methanogens play an important role in hydrogen metabolism within the rumen, and thus help maintain rumen function, though producing the potent GHG CH_4 as a by-product. Feed is the single greatest cost in ruminant livestock systems, accounting for up to 80% of the direct costs in beef cattle production. Accordingly, improving the efficiency with which ingested feed is utilised by the animal is central to economic sustainability. The objective of Irish beef production systems is to maximise the utilisation of forage-based diets; thus reducing reliance on more costly purchased feedstuffs. Recently, residual feed intake (RFI) has become the measure of choice for feed efficiency in beef cattle, with efficient animals denoted as those that consume less feed than their contemporaries of similar body weight and growth performance. There is some emerging evidence to suggest that feed efficient cattle may emit less methane, though the biological mechanisms involved are not fully understood.

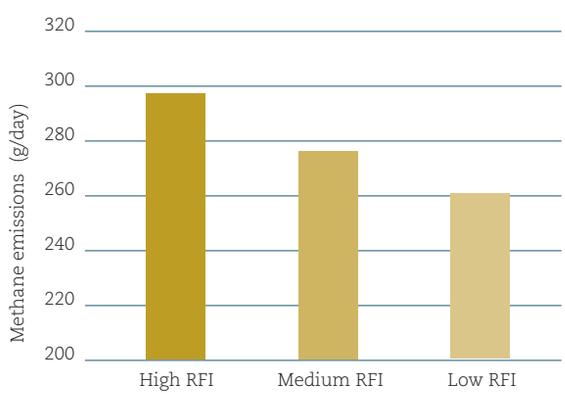

Figure 1: Methane emissions (g/d) of heifers differing in Residual Feed Intake (RFI) offered grass silage.

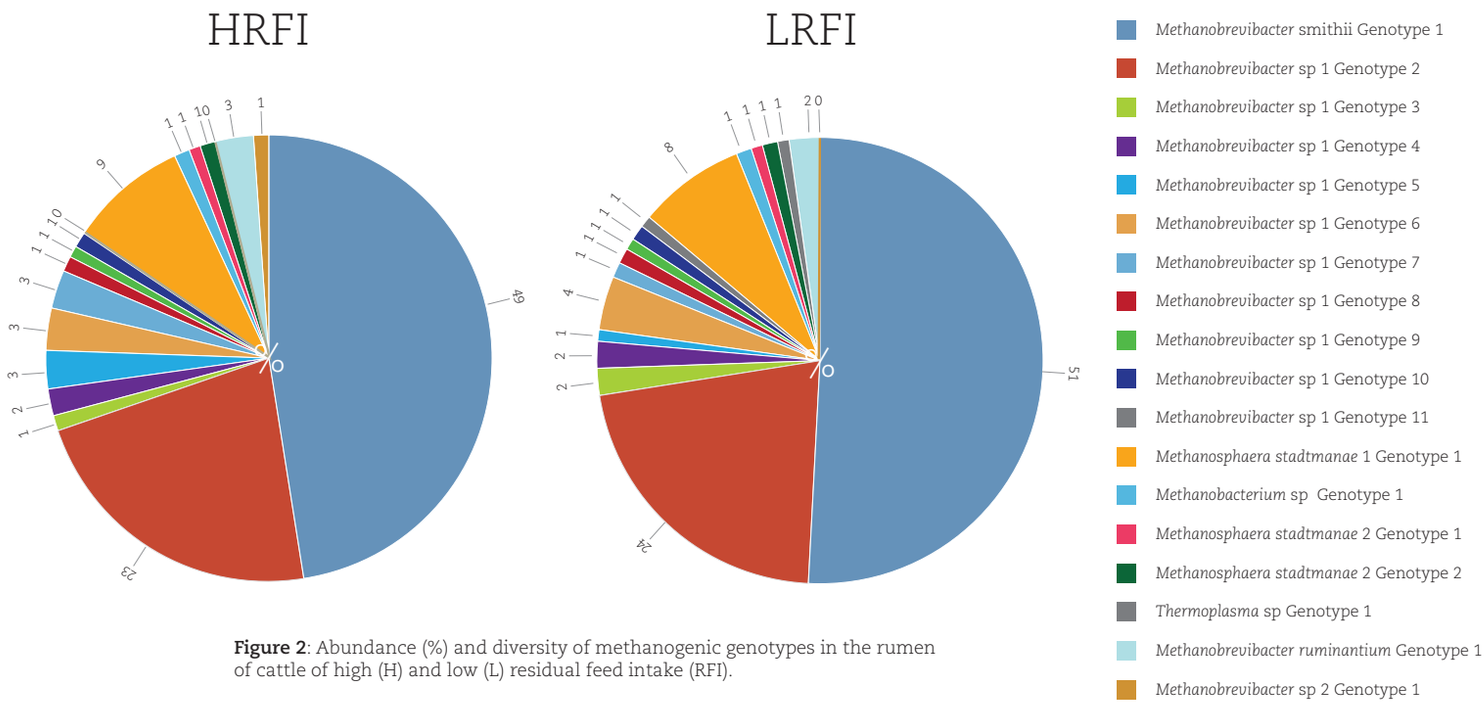

Figure 2: Abundance (%) and diversity of methanogenic genotypes in the rumen of cattle of high (H) and low (L) residual feed intake (RFI).

Research findings

We recently conducted a study at AGRIC Grange to examine the relationship of phenotypic residual feed intake with methane emissions in beef heifers (Fitzsimons *et al*., 2012). Simmental heifers were offered a grass silage diet over 120 days and CH_4 production was estimated using the sulphur hexafluoride (SF_6) tracer gas technique. Heifers were ranked on the basis of RFI and divided into low (efficient), medium or high (inefficient) groupings. Mean live weight (485 kg) and daily live-weight gain (0.6 kg) did not differ between the groupings; but high RFI heifers consumed nine and 14% more than medium and low RFI heifers, respectively. Similarly, daily CH_4 emissions were lower for low than high RFI heifers, with medium RFI animals being intermediate (Figure 1).

In a further experiment we examined the composition of the ruminal microbiome in low and high RFI heifers and how this in turn was affected by whether a forage- or a concentrate-based diet was offered. Rumen digesta samples were collected from high and low RFI animals at the end of both dietary periods to characterise the diversity of the methanogenic population, using a range of molecular technologies including clone library analysis and methanogen-specific tag encoded pyrosequencing. We found that *Methanobrevibacter* spp. was dominant amongst methanogens in the rumen, with *Methanobrevibacter smithii* the most abundant species detected. Although the abundance of either total or specific methanogenic species did not differ between animals divergent in feed efficiency, their relative abundance was affected by diet type. At the genotype level, however, we found that various genotypes of *Methanobrevibacter smithii* were more abundant in cattle of high compared to low feed efficiency across diet (Carberry *et al*., 2012; Figure 2). Our results demonstrate that a core group of methanogens exists regardless of feed efficiency potential, however, significant differences in the distribution of within-species, microbial genotypes are evident between efficient and inefficient animals. It is possible that these differences in genotype abundance may drive the observable changes in methane emissions between animals of high and low feed efficiency.

Conclusions and implications

Our research aims to comprehensively understand the composition and functional role of the bovine rumen microbiome to underpin improved feed efficiency, animal performance and methane abatement. Our studies conducted to-date suggest that variation in the ruminal fermentation process affects the animal's ability to efficiently utilise feed and that this is mediated to some extent through the composition and activity of the ruminal microbiome. Future work will focus on examining interactions between, and the functional capacity of these microbes, including identifying the most potent methanogens. Such an approach will better facilitate the development of strategies focused on methane abatement without compromising animal performance. This will ultimately give beef and dairy producers a competitive advantage by reducing the environmental footprint of Irish agriculture.

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Management of on-farm emissions from manure

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In Ireland, agriculture accounts for 32% of total greenhouse gas (GHG) emissions and 98% of total ammonia emissions. Methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3) losses associated with slurry management constitute 12% and 30% of sectoral GHG and NH_3 emissions respectively with most of these emissions associated with dairy and beef production. As *Food Harvest 2020* envisages growth in terms of both dairy and beef production, it is urgent to develop mitigation strategies, particularly as the EU 2020 Climate and Energy Package has set a 20% reduction targets for GHGs.

How do manure emissions arise?

Greenhouse gas and NH_3 emissions associated with manure management arise primarily from housing and storage and during the land-spreading of manures (Figure 1).

Housing and storage: Emissions from housing and storage are dominated by methane and ammonia. Methane is the major GHG associated with animal housing and storage as approximately 80% of cattle and pigs are housed on liquid manure/slurry in Ireland. As slurry is anaerobic, methanogens (which require an oxygen-free environment) are able to ferment carbohydrates in the slurry, releasing methane. Nitrous oxide is a minor component of housing emissions. The bulk of emissions are associated with solid straw-based housing systems, where the manure is aerobic. This retards methane losses but results in N_2O associated with nitrification of ammonium and the denitrification of nitrate. Ammonia, another reactive nitrogen (N) gas, mainly originates from the breakdown of urea in urine and occurs from two sources in an animal housing system, from the concrete slatted floor and from the slurry storage tank below the slats, with each contributing approximately equally to the loss.

Land spreading: Ammonia and N_2O are the primary gaseous emissions associated with land-spreading manure. The volatilization of ammonia takes place when soils are moist and warm. Hydrolysis of ammonium to ammonia occurs and, as the soil dries, the ammonia is volatilized to the atmosphere. The vast majority of Irish cattle slurry is spread using a splash plate application, where the slurry is spread in a thin uniform layer on the ground, and as a result ammonia loss is the major N loss pathway during land spreading. Nitrous oxide losses are associated with nitrification and denitrification of N in the soil. Accordingly, any reduction in ammonia loss can result in an increase in N_2O losses.

Abatement of housing and storage emissions

There are currently few empirical gaseous emissions studies on housing and storage systems in Ireland. Teagasc has been engaged in measuring emissions associated with housing and storage systems as part of BATFarm, an Interreg IV Project (www.batfarm.eu). Emissions from different animal types, as well as the use of mechanical aeration and slat mats and valves (which cover the slat) have been investigated, with gases measured using photo-acoustic gas analysers that allow for real-time measurements of all gases simultaneously.

Methane emissions: The mean methane emission rate across all farms and cattle type was 43.7 (SD 19.6) g CH_4-C 500 kg LW^{-1} d^{-1} with mean daily fluxes ranging from 22.4 g CH_4-C 500 kg LW^{-1} d^{-1} for steers to 75.0 g CH_4-C 500 kg LW^{-1} for dairy cows in housing with mechanical aeration (Figure 1). While aeration of slurry should, in theory, reduce methane high observed emissions were associated with a large number of agitation events resulting in ebullition of methane from the slurry tank. Despite these high levels, slat mats and valves appeared to reduce methane emissions by 35%. Methane emissions from dairy cows fed a predominantly maize diet were 41% lower compared to cows on a grass silage-based diet on Farm DFa (Figure 1). Emissions associated with a predominantly maize silage diet are likely to have resulted in reduced emissions due to changes in slurry C:N ratio.

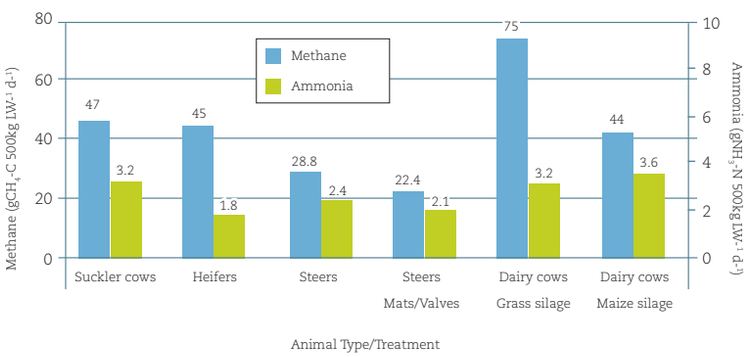


Figure 1: Methane and ammonia emissions associated with different animal types and storage treatments.

Ammonia Emissions: Ammonia emissions were observed to be highly variable across all farms, with daily mean fluxes ranging between 4.5 g NH_3-N 500 kg LW-^{1} d-^{1} and 33.1 g NH_3-N 500 kg LW-^{1} d-^{1} (Figure 1). The mean ammonia emission across all farms was 16.6 ± 8.4 g NH_3-N 500 kg LW-^{1} d-^{1}. The lowest emissions were associated with beef cattle housing that had employed slat mats with valves and this abatement technique was observed to reduce ammonia emissions by 60%. However, there were no significant differences in emissions from either grooved or curved mats. The highest ammonia emissions were associated with housing that had employed automatic aeration systems to agitate the slurry, as aeration promoted volatilisation. There was no clear effect of animal type and/or diet on ammonia emissions.

Abatement of land-spreading emissions

Diet manipulation

Altering animal diets in order to lower crude protein with high net energy feed, such as maize or supplementation with amino acids has been shown to reduce the amount of N excreted without impacting on performance. This reduction in crude protein has been shown to reduce both ammonia (12%) and N_2O (18%) emissions (Meade *et al.* 2010).

Land-spreading strategies

The vast majority of Irish cattle slurry is spread using a splash plate application, where the slurry is pressurised against a plate and is spread in a thin uniform layer on the ground, which can volatilise quickly. The land-spreading of cattle slurry in any one year can typically account for between 30-40% of total national NH_3 emissions. Therefore, a method of slurry application that reduces NH_3 emissions will impact substantially on Ireland's emission levels. The reduction of NH_3 also offers the opportunity for greater recovery of the N in manure. Therefore, abatement strategies will assist in increasing N efficiency on farms which is a requirement of the Nitrates Directive Action Plan and the National Climate Change Strategy.

The trailing shoe is used to apply slurry in narrow bands on the soil surface and beneath the crop canopy. This reduces volatilisation as: the surface area exposed is reduced; and, slurry is placed below the grass canopy. The adoption of trailing shoe delivers a 28% reduction in terms of NH_3 emissions but suprisingly does not result in significantly higher N_2O emissions (Table 1). So-called 'soft' measures, which are cost-neutral, such as altered timing of application result in comparable ammonia reductions ($p > 0.05$) compared to trailing shoe application. However, direct N_2O emissions are marginally higher when slurry is applied early in the season (February to March, Table 1).

Table 1: Emissions reduction potentials relative to baseline scenarios. Baselines include 1) splashplate application, 2) summer spreading, 3) Grass-fed diet.

Technique	Ammonia reduction (% relative to baseline)	N_20 reduction (% relative to baseline)
Trailing shoe (1)	-28%	0%
Early spreading (2)	-20%	11%
Addition of chemicals (1)	-17%	-5%
Reduced N in diet (3)	-12%	-18%

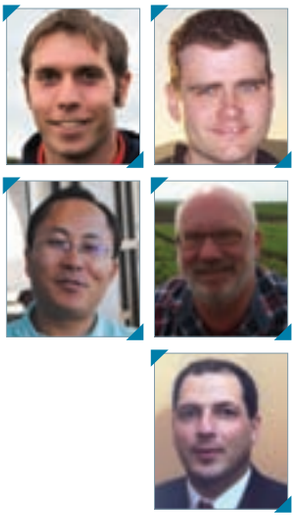
Conclusion and perspectives

Farm emissions of ammonia and methane were highly variable. In general, methane reduction strategies should be focused on housing/storage emissions while nitrous oxide reduction strategies should be directed towards land spreading. However, ammonia loss is ubiquitous and equal emphasis should be placed on retaining total ammonical nitrogen (TAN) at both the housing/storage and land-spreading stages.

Acknowledgement

This work has been co-financed by BATFARM Interreg-Atlantic Area Project (2009-1/071) entitled "Evaluation of best available techniques to decrease air and water pollution in animal farms". This project is supported by the European Union ERDF – Atlantic Area Programme – Investing in our common future.

Measurements of soil nitrous oxide emissions, using static chambers, at Teagasc Solohead Research Farm.



Nitrous Oxide production from Irish grassland

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Background

Nitrous oxide (N_2O) is a potent greenhouse gas (GHG) and contributes up to 38% of Ireland's agricultural GHG emissions, which represent one-third of national GHG emissions. Grassland accounts for up to 90% of Ireland's utilisable agricultural area and is, therefore, a large contributor to national emissions. Ireland is committed to reducing its national GHG emissions, relative to 2005 level, by 2020 under the EU Climate and Energy Package targets. If these reductions are to be achieved, proper measurement and reporting of N_2O emissions from Irish grassland is essential.

Nitrous oxide emissions, however, are subject to large temporal variation, which makes it difficult to acquire accurate estimates of annual N_2O emissions. Despite this, there have been few long-term studies on N_2O emissions in Ireland and internationally.

In 2008, a study was commenced to investigate N_2O emissions from Irish grassland at Teagasc Solohead Research Farm. The objectives of the study were: to quantify annual N_2O emissions and emission factors from Irish grassland used for dairy production; and to assess their annual variation.

Where does N_2O come from?

Nitrous oxide is produced by multiple soil processes such as nitrification and denitrification. Denitrification occurs under wet soil conditions. The degree of soil wetness determines whether partial or complete denitrification takes place. Wet, but aerobic soil conditions favours partial denitrification and N_2O production, whereas saturated anaerobic soil conditions favours complete denitrification of soil nitrate to N2 gas (environmentally benign). Partial denitrification of nitrate is considered as the main process producing N_2O in grassland soils and is controlled by a number of factors; the most important being soil N content, carbon content, temperature and water content. The greatest extent of N_2O emissions on Irish grassland arises from applications of fertiliser N and animal slurries, N deposited by grazing animals and from N released from soil organic N (mineralisation).

Field measurements of N_2O

In the present study, N_2O emissions were measured weekly using a static chamber method (see photo above) from perennial ryegrass/white-clover grassland

(WC) and perennial ryegrass control plots (GB) between 2008 and 2012. The WC represented a typical pasture-based dairy sward. It consisted of three paddocks (1.6 to 2.07 ha) used primarily for grazing by dairy cows. Annual average stocking density was 2.35 cows/ha and annual fertiliser N input was 86 kg/ha. There were three GB plots established to measure the background soil emissions of N_2O. The GB (11 × 3m area) plots received no external input of N or grazing. Daily rainfall and soil temperature at 0-10cm depth were recorded on the farm.

Annual N_2O emissions from Irish grassland

The annual emission of N_2O from grassland ranged from 4.4 to 34.4 kg N_2O-N/ha from WC and 1.7 to 6.3 kg N_2O-N/ha from GB (Figure 1). This large range was caused by a spike in N_2O emissions in one of the four years (2010/11). The mean annual emissions from WC for the other three years was 5.2 ± 1 kg N_2O-N/ha. Previous research showed that inclusion of white clover did not increase the N_2O emission on WC pasture compared to GB (Li *et al*., 2011) and this is supported by the results of the present study. Increased emissions from WC compared with GB in the present study were due to fertiliser N and slurry applications and dung and urine deposition by grazing livestock. Changes in weather conditions during this study had a large impact on annual N_2O emissions. Above average annual rainfall led to saturated anaerobic soil conditions in 2008/09, 2009/10 and 2011/12 (Figure 1). This is likely to have caused the predominance of complete denitrification, and hence relatively low N_2O emissions. In contrast, 2010/11 was an exceptional year with exceptionally cold conditions during the winter and low rainfall during the remainder of the year. Freeze thawing during the winter and drying out of the soil during the summer led to substantially higher N_2O emissions compared with the other years.

The average amount of N_2O-N emitted per kilogram of N applied averaged 1.3% for three years (2008/09, 2009/10 and 2011/12) and was 8.2% in 2010/11.

Effect of soil drying and freeze thawing cycles on N_2O emissions

A large portion of Irish soils are wet in nature due to the relatively wet Irish climate, relatively low evapo-transpiration and heavy textured soils with low drainage capacity. The low annual rainfall experienced in 2010/11 allowed the soil at Solohead to dry out more than normal and this stimulated a transition from anaerobic to aerobic soil conditions. Such circumstances promote soil organic N mineralisation and a switch from complete to partial denitrification. Increased N mineralisation creates substrate for denitrifying bacteria while the soil conditions were conducive to partial denitrification and hence the production of N_2O.

The degree of freeze thawing cycles that occurred in winter 2010/11 (December-January) was very untypical of Ireland's mostly mild and wet winters. Minimum mean air temperatures reached -7.7°C and it was the coldest December recorded at Teagasc Moorepark research centre since records began in 1950. Increased emissions of N_2O have been associated with freeze thawing cycles in Scandinavia. Freeze-thawing causes the physical disruption of both soil micro-organisms and soil aggregates. This leads to a release of large quantities of easily degradable N and C for denitrifying bacteria.

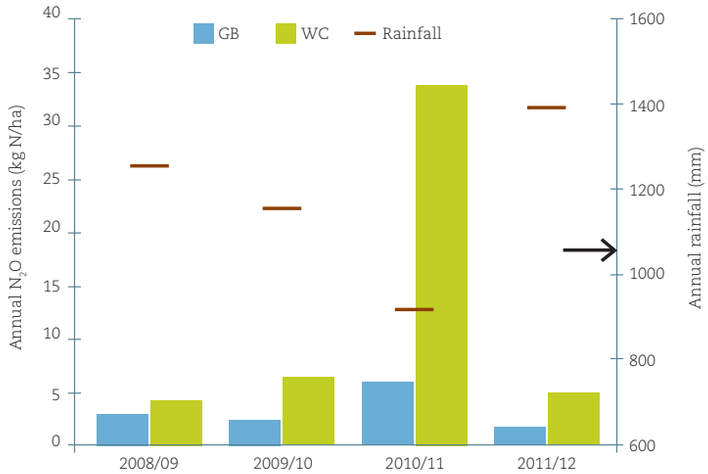

Figure 1: Annual N_2O emissions, from perennial ryegrass/white clover grazed grassland (WC) and perennial ryegrass control plots (GB), and annual rainfall (—) from 2008 to 2012 at Solohead farm. Arrow indicates 10 years average rainfall at Solohead farm (1031 mm/year).

Implications for the agricultural sector and future research

This study shows that N_2O emissions from Irish grassland are very variable and can be directly linked to particular weather conditions. The variation in annual emissions suggests the need for long term studies when quantifying N_2O emissions. The study also highlights the importance of N_2O emissions that may occur due to soil freeze-thawing events on Irish soils under extreme weather conditions. Currently the Inter-governmental Panel on Climate Change (IPCC) uses default emission factors of 1% for N applied as fertiliser N and N in animal slurries and 2% for N deposited on grassland by grazing livestock (IPCC, 2006). The emission factors calculated in the three typical years (08/09, 09/10 and 11/12) were in good agreement with the IPCC emission factors. However, the very high emissions factor in 2010/11 was considerably higher than IPCC values and warrants future research. As climate models are predicting greater weather volatility in the coming decades, there is a need to draw up climate adaptation strategies to cope with any consequent impact on reactive nitrogen loss.

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This work was funded by the EU Framework Programme 7 project Legume Futures.

Europe's role in food and nutrition security

Dr Shenggen Fan, Director General, International Food Policy Research Institute, gave the third in the lecture series 'Grand Challenges for Global Agriculture and Food' at the RDS recently. Dr Lance O'Brien reports.

Dr Shenggen Fan, Director General of the International Food Policy Research Institute (IFPRI), the eminent Washington-based think tank on food policy directed at sustainable solutions to reduce hunger and poverty, presented the third lecture in the Teagasc/RDS series on 'Grand Challenges for Global Agriculture and Food'. Dr Fan is also the Chairman of the World Economic Forum's Global Agenda Council on Food Security and has written extensively on global agricultural development and food security, as well as addressing high-level audiences around the world on these issues. Dr Fan's lecture addressed the role of Europe in ensuring global food and nutrition security.

In his lecture, Fan described how demographic shifts and changing food consumption patterns, along with the effects of climate change and growing scarcity of land and water resources, are placing a huge strain on the global food system. "An integrated approach is needed to sustainably improve food and nutrition," he said, "and Europe has a key role to play."

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Europe's role

As one of the largest global importers and exporters of food, the EU has significant leverage in, and responsibility for, the global food and nutrition agenda. Although the biggest impact on global food security will result from increased production in developing countries, the EU must play its part, both in terms of its domestic food production and consumption and in terms of relevant domestic and overseas policies. Europe needs to protect and maintain its agricultural lands and increase food production. This will mean producing more food with fewer resources, while minimising environmental impact.

Dr Fan called upon European leaders to support an ambitious vision for the post-Millennium Development Goals agenda by putting in place a series of policy actions to end hunger sustainably by 2025. First, Fan urged Europe to increase the overall percentage of overseas development assistance (ODA) devoted to agriculture to 10%, a target that Ireland achieved in 2011. According to the latest OECD data, between 2008 and 2011, European Union member countries of the Development Assistance Committee invested, on average, 4% of their ODA in the agricultural sector.

R&D and technology transfer

In particular, he stressed that the increased investment in agriculture should be largely directed to research and development and technology transfer. Priorities here should include crop and livestock breeding, and agricultural practices that conserve water and land resources. Massive public and private investments in research and development are needed to develop and disseminate the technologies that producers require to sustainably enhance productivity and reduce waste and pollution. Investment in extension is needed to build capacity among farmers and rural dwellers to identify and take advantage of growing opportunities and to cope more effectively with risk and adversity.

He urged Europe to "reform domestic agricultural policies and promote open trade." Such reforms, he stated, involve the elimination of payments to European farmers and engaging in ongoing trade talks with the World Trade Organization member states. Fan praised EU leaders on proposing stricter limits on biofuel mandates, and suggested that they call for the elimination of subsidies supporting biofuels derived from food crops such as palm oil, rapeseed, and soybeans. Instead, he proposed that policymakers should shift such investments to so-called "second-generation biofuels" that are derived from non-food crops.

Leadership

Finally, he encouraged Europe to assume stronger leadership around capacity strengthening efforts at both the regional and national levels. The research, education and extension services in poorer countries are undermined by the quality of the human capital, so there is an urgent need to build capacities in these systems. Specifically, he called for enhanced knowledge sharing between the EU and developing countries through successful partnerships, such as with the CGIAR, and inter-regional knowledge sharing along the same lines as the Programme for South-South Cooperation does.

In conclusion, Dr Fan stated that while agriculture, food security, and nutrition are high on the EU's long-term development cooperation agenda, current estimates of the overall number of people suffering from hunger and malnutrition remain unacceptably high. "There has been much talk [on improving food security and ending hunger]" he concluded, "but we must now 'walk the talk' and follow through on these commitments."

Get with the programme

Niels Gøtke is Head of Division in the Danish Agency for Science, Technology and Innovation. Speaking to Catriona Boyle, Niels encourages Ireland to continue and deepen its involvement in Joint Programming Initiatives.

Niels Gøtke, Head of Division in the Danish Agency for Science, Technology and Innovation recently attended an Irish Presidency of the EU-organised Joint Programming Conference 2013 that took place in Dublin. From 2003 until 2010, Niels was in charge of research and innovation policies within the Ministry of Food, Agriculture and Fisheries, Danish Food Industry Agency (DFIA). He is the Danish representative in the Standing Committee on Agricultural Research and in the KBBE (Kowledge-Based Bioeconomy)-NET Plenary group. He is Vice-Chair of the JPI Agriculture, Food Security and Climate Change (FACCE-JPI). Niels also has experience in the coordination and management of ERA-NETs (European Research Area – Nets) and is the coordinator of the FP7 ERA-NET ICT-AGRI (see article on p32).

Niels Gøtke at the Joint Programming Conference organised during the Irish Presidency of the EU

Niels explains: "In many places, not only in Denmark, traditional agricultural research has been very much under pressure". This is significant because approximately 90% of research funding in Europe is still routed through national funding programmes.

One of the main outcomes of the Dublin meeting was that Member States need to move from planning to implementation of JPI research agendas into their national programmes. Ireland is providing a leadership role in this context; for example, the latest Stimulus call was aligned with the recent Strategic Research Agenda of FACCE-JPI.

For more on Joint Programming Initiatives see http://ec.europa.eu/research/era/joint-programming-initiatives_en.html and for those in the Food, Agriculture and Fisheries, and Biotechnology see: http://ec.europa.eu/research/bioeconomy/policy/coordination/jpi/index_en.htm

For details of the agriculture and food JPIs that Ireland are involved with see: http://www.healthydietforhealthylife.eu/ and http://www.faccejpi.com/

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JPIs

The joint programming concept was introduced in 2008, and since then, ten JPIs focusing on societal challenges have been established. Ireland is currently involved in three JPIs, two of which are in the agriculture and food area: 'Agriculture, Food Security and Climate Change' (FACCE) [Teagasc and the Department of Agriculture, Food and the Marine] and 'A Healthy Diet for a Healthy Life' [Department of Agriculture, Food and the Marine and Science Foundation Ireland].

"Many of these challenges are very big societal challenges, they can not be solved by only one country, they are global and, therefore, it is also the right thing to do – to do things together rather than in each country," says Niels.

"We need also a broad consensus among the European countries of how to align their strategies. That is why we are here in Dublin," says Niels.

Research and extension in Denmark

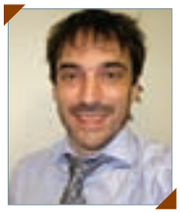
Niels explains that Denmark has a long history of agricultural research – over 100 years , has experienced extension services and is very advanced in the areas of ICT and robotics. The country is also well known for its research on the environment (clean water and the preservation of nature), animal welfare, pig production and organic production.

But, in recent years, Denmark, like the rest of the EU, has been feeling the pinch in terms of resources and funding. This has caused a major restructuring of how research and extension services are carried out.

ERA-NETs and JPIs

ERA-NETs and JPIs (Joint Programming Initiatives) aim to decrease fragmentation of European research through the coordination of research activities carried out at national and regional level. ERA-NETs are top-down activities which are specified by the European Commission. One of the principal aims of an ERA-NET is to formulate and run funding calls for transnational research projects. They operate on a three- to four-year basis and have a specific focus (e.g., the use of ICT in agriculture). JPIs are member-state led activities that have a broader focus (e.g., Agriculture, Food Security and Climate Change) and a much longer timescale. JPIs may use the ERA-NET mechanism (amongst others) to run joint research funding calls, but they also have a role in providing policy makers with scientific input.

Smart agriculture in Europe



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ICT-AGRI is an ERA-NET that aims to align technologies and efforts to meet the emerging challenges in global agriculture.

The ICT-AGRI ERA-NET, of which Teagasc is a founding member, recently launched a Strategic Research Agenda. ERA-NET funding schemes are designed to enhance the coordination and coherence of research activities across Europe through networking and opening national research funding to applicants from across the European Research Area. Here we place the European agenda on 'smart agriculture' in an Irish context.

Food security is now widely acknowledged as one of this century's key global challenges. By 2050, the world will require significantly increased crop production in order to feed its predicted nine billion people. The challenges facing increased food crop production are generally well understood, but differ widely across regions. Globally, water availability and soil quality are major limiting factors. Significant losses in crop yields occur due to pests, diseases and soil degradation; while the effects of climate change will further exacerbate the stresses on crops, potentially leading to yield reductions.

The Royal Society (UK) has outlined that there is a pressing need for a 'sustainable intensification' of global agriculture in which yields are increased without adverse environmental impact (Royal Society, 2009). Similarly, the OECD's 'Green Growth Strategy' concludes that "green growth" is not only desirable and achievable, but it is also essential if the food and nutrition requirements of future generations are to be met (OECD, 2011).

The Food and Agriculture Organization (FAO), in a recent major policy release refer to the "major shift" required to move from homogeneous models of crop production to knowledge-intensive, often location-specific, farming systems (FAO, 2011). These international policy developments have been mirrored nationally with the release of the Irish government's major policy document *Food Harvest 2020* which has at its core "Smart, Green, Growth", based on the sustainable expansion of Ireland's agri-food sector.

The concept of sustainable or ecological intensification aims to increase yield, with fewer inputs and adverse consequences. Automation and information and communication technologies (ICT)-based solutions – including sensors, global positioning and decision-support systems – will play a vital role in the development of sustainable and efficient farming systems. Improved precision farming approaches now offer a range of technologies for assisting farmers in improving efficiency, reducing labour costs and enhancing flexibility on the farm. Information and communication technologies facilitate development of win-win solutions – production benefits and environmental benefits – through the optimised application of inputs, thereby reducing the adverse impacts of agriculture on the environment.

EU coordination of ICT in agriculture

Teagasc is an active partner in the ICT-AGRI ERA-NET which is a cross-thematic ERA-NET spanning three EU Framework Programme 7 themes, namely: Food, Agriculture and Fisheries, and Biotechnology; Environment (including climate change); and Information and Communication Technologies. The overall goal of the ICT-AGRI ERA-NET is to strengthen European research in the area and develop a common European research agenda concerning ICT and robotics in agriculture.

ICT-AGRI recently formulated a Strategic Research Agenda (SRA) to facilitate the full utilisation of R&D capacity across Europe by coordinating and prioritising research activities (Lötscher *et al.*, 2012). The aims of the SRA are to identify future challenges for a sustainable European agriculture, to arrive at goals and solution domains based on ICT and robotic technologies, to determine research and innovation requirements, to create a vision for ICT and robotics in agriculture, and to develop recommendations for SRA implementation.

The solution domains proposed by the SRA are used by participating member states to inform development of localised solution domains and to serve as a framework against which an expanded vision of the role of ICT-based technologies and

automation solutions for the 'Knowledge-Based Bioeconomy' can be articulated. Teagasc's vision of future developments in ICT in agriculture is informed by the conclusions and technology roadmap provided by the ICT-AGRI SRA document.

Vision for smart agriculture

The introduction and widespread adoption of sophisticated ICT and robotic solutions can profoundly improve agricultural process management, and will pave the way for the development of sustainable, high-intensity crop, animal and food production systems. Precision livestock and crop farming are emerging as real-world solutions for agricultural production in a variety of settings, making the management of individual plants or animals realisable, and more effective, for farmers.

Of distinct relevance to Irish agriculture, advanced technologies in livestock production help to optimise the performance of individual animals. Highly automated feeding, milking and cleaning processes along with closer monitoring and decision-support systems (including disease-risk management and modelling) enable greater profitability and improvements in work-place ergonomics and animal health and welfare. Using modern ICT for the automatic acquisition and interpretation of a wide range of individual animal attributes provides opportunities for producing safe, high-quality products with a lower environmental footprint. Smart systems for automated indoor climate control can help reduce energy consumption and greenhouse gas emissions from animal husbandry, and provide an optimal indoor climate to promote animal health and welfare. In plant production, ICT-driven solutions for the variable-rate application of fertilizers, pesticides and water are commonly used in combination with positioning systems and geographic information systems (GIS) for controlled traffic farming. The ability to apply the right amount of inputs in the right place and at the right time is a great help in optimising fertilizer and pesticide use as well as water management. This has positive effects on soil conditions, water-use efficiency, air and groundwater pollution, and biodiversity. Energy consumption and greenhouse gas emissions from plant production can also be reduced by the systematic use of variable-rate application and controlled-traffic farming techniques, as well as by installing intelligent automated systems for the ventilation and heating of greenhouses.

The development of ICT and robotic solutions needs to take into account Europe's diverse agricultural structures, and needs to be adapted to specific farm situations and individual farmers' needs. Technologies should be user-friendly and inter-brand-compatible in terms of hardware and software components and, therefore, be more easily adopted by farmers. Efficient farm management and information systems (FMIS), with integrated decision support systems, will be an essential tool for everyday farming tasks. Such farm management systems enable optimal management of the information obtained, and enhance decision for improving economic viability and reducing the environmental impact of agricultural production.

Beyond farm level, transnationally compatible information-exchange systems should enable better communication between stakeholders such as advisory services, suppliers, purchasers or public administration. The use of ICT and robotic technologies can ultimately bring stakeholders across the agri-food domain closer together and target increased profitability for all involved parties, along with enhanced environmental sustainability.

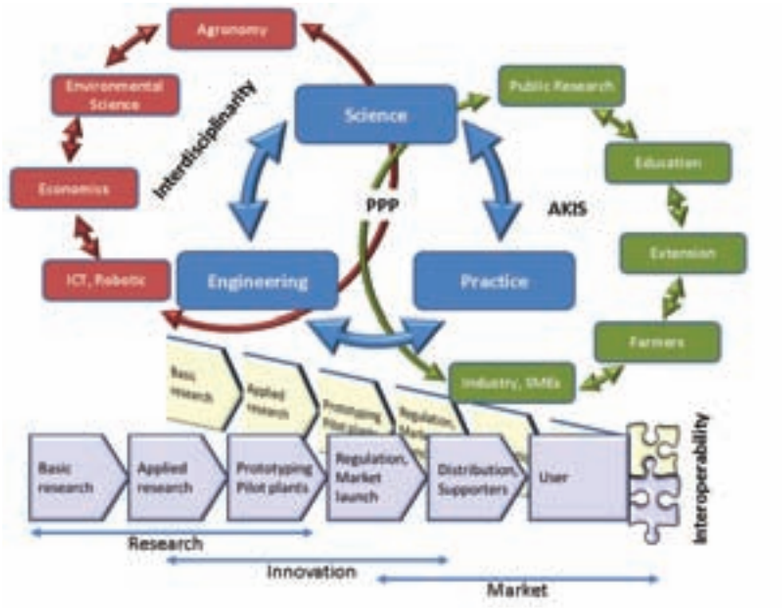

Figure 1. Coordination and cooperation along the research and innovation chain for ICT in agriculture. (PPP= Public-private partnerships, AKIS = Agriculture Knowledge and Innovation Systems).

Agri informatics vision for Ireland

Significant developments have taken place in ICT use in the agriculture and food industry in recent years. Wider deployment of environmental measurements, automatic capture of data from sensors, and the use of GPS-related applications are on the increase, along with farm mapping, and the broader analysis and communication of food traceability. The ability to capture data via multiple on-farm sensors will increase rapidly. The Irish farm and food industry of the future will undoubtedly capture significantly greater amounts of data, need greater integration of data from multiple sources and have the opportunity to leverage multiple uses of these data to ensure enhanced efficiencies.

Teagasc, along with industry partners such as agri-consultants, the European Space Agency, precision agriculture manufacturers, and Geospatial technology companies, can play a lead role in these developments and ensure its own way of developing and interacting with the agri-food industry is at the vanguard of such developments.

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Potato virus in Ireland

Potato Virus YNTN on the left and Healthy plant on the right. Cv. British Queen.

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Teagasc researchers have been using genetic techniques to identify the viruses present in potato crops to see if new, more damaging, variants found on the Continent have made their way to Ireland.

Potato is ranked as the fourth most important crop in the world after maize, wheat and rice and is an excellent source of starch and vitamin C providing more than one third of our daily requirement.

Whilst consumption of potatoes has declined in recent years, €162 million is still spent by Irish consumers each year. In 2012, Ireland produced 8,700 hectares of potatoes. The majority of potatoes grown in Ireland are for fresh market and seed production, although the latter has declined. Potatoes used for processing and fast food outlets tend to be imported. The most common variety grown in 2011 was Rooster, bred by Teagasc, at 56%, followed by Kerr's Pink (10%), British Queens (8%), Golden Wonder (3%), Records (2%) and others (21%).

There are many challenges for growers to produce and maintain healthy crops that are vulnerable to a range of pests and diseases. Consequently, significant quantities and frequent applications of crop protection products are necessary to maintain yield and quality demanded by the market. Whilst by far the most well known disease is Late Blight caused by *Phytophthora infestans*, they are also vulnerable to a range of virus diseases. The number of viruses is increasing on the Continent with more damaging strains developing; however, up until now, we have not known what the situation was in Ireland.

Potato viruses

Aphid-vectored viruses are either transmitted persistently or non-persistently. It takes several hours of feeding for an aphid to acquire a virus that is transmitted persistently. The virus must circulate through the aphid's body for up to 12 hours to the salivary glands before transmission can occur. The aphid remains infective for many weeks or the rest of its life. It takes less than one minute of feeding for an aphid to acquire a non-persistently transmitted virus and the same time to infect another plant, but remains infective for only a few hours.

The most common potato viruses are Potato virus X (PVX), genus Potexvirus; Potato virus S (PVS), genus Carlavirus; Potato leaf roll virus (PLRV), genus Polerovirus; Potato virus A (PVA) and Potato virus Y (PVY), both genus Potyviruses. These viruses can occur in mixed or single infections.

PLRV is transmitted by aphids in a persistent manner. As its name suggests, it causes the leaves to curl and can make them stiff, dry and leathery.

PVX is transmitted mechanically from plant to plant by machinery, people or animals moving through the crop. It is not easy to distinguish visually as symptoms range from a mild yellowish green leaf

colour to severe mottling with rough leaves. Mottling is more evident following a few days of cloudy weather, and may be almost non-existent after a similar period of bright sunny weather. Plant growth may be stunted and have small leaves.

PVS can be spread mechanically and by some aphid species in a non-persistent manner. Plants can often be symptomless while on others, a slight deepening of the veins occurs. The leaves may be slightly roughened in texture. Some plants may have mild mottling or bronzing of the leaves and may also have tiny necrotic spots on their abaxial surfaces.

PVA is transmitted by aphids in a non-persistent manner. Symptoms include a mild pattern of light green coloured patches alternating with dark green areas on the leaves which can also appear shiny. The leaf surface is usually rougher than normal. The edges of infected leaflets may be slightly crinkled or wavy.

PVY is also transmitted by aphids in a non-persistent manner. There are a number of strains of PVY (denoted by a superscript letter – O, C, N, etc.) that cause varying symptoms depending on cultivar. Some can cause serious damage to potato tubers, manifested as potato tuber necrotic ringspot disease (PTNRD). These factors have resulted in an increase in PVY in potato seed, higher PVY incidence in potato production fields and significant negative impacts on potato yields, for both seed potatoes and those grown for consumption. Different PVY virus strains cause different symptoms. For instance, PVYO causes mild to severe mottling, chlorosis, leaf drop and death, there are no tuber symptoms. PVYC causes stipple-streak, stunting, there are no tuber symptoms. PVYN has subgroups such as PVYNTN and PVYN:O which cause PTNRD.

It is important to note that whilst the individual viruses are transmitted from plant to plant in a variety of ways, they can all be transmitted via seed tubers and build-up over generations due to clonal propagation. They are often at their most damaging from a yield perspective when transmitted in this way.

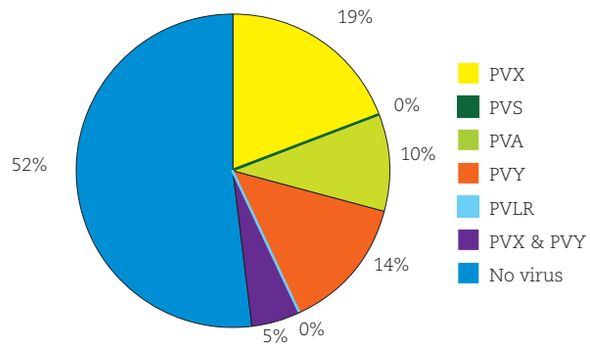
Virus surveying

Virus symptoms are very variable and can be similar to symptoms caused by the crop interacting with particular environmental conditions. A range of serological and RT-PCR identification techniques are used to accurately detect and identify virus diseases.

Teagasc conducts routine virus testing annually of seed produced in the Teagasc potato breeding programme. Similarly the Department of Agriculture, Food and the Marine (DAFM) tests commercial seed crops. Both organisations use serological testing; however, it is not sufficiently accurate to identify which virus Y strains are present.

A survey was carried out in the 2011 growing season in Ireland to assess the prevalence of virus across the country and to identify exactly which viruses were present in Irish potato crops. Teagasc advisors and DAFM inspectors supplied a total of 58 leaf samples comprising 10 leaves each. These were collected from various locations that were showing virus-like symptoms (mosaic, dwarfing, yellowing, necrotic leaf spots). Sap was extracted from the leaves and tested using serological assays for PVX, PVS, PVA, PLRV and PVY. Samples found to be positive for PVY were subjected to further PCR assays to identify if the new more damaging necrotic strains of PVY were present.

In total, 28 of the 58 samples tested positive for virus, six tested positive for PVA, 14 tested positive for PVX and 11 tested positive for PVY. Mixed infections of PVX and PVY occurred in three samples. Ribonucleic acid (RNA) was successfully extracted from nine of the 11 PVY positive samples and further characterised using a multiplex RT-PCR assay. Using this assay, three strains were confirmed as PVYNTN, two as PVYN and one as PVYO with three previously unreported strains. This is significant as the emergence and spread of PVYNTN has led to large economic losses in several countries worldwide but has not previously been positively identified in Ireland. This emphasises the need for careful management of crops to minimise virus infection.



Survey of virus frequency (2011).

Virus management

Because viruses are most damaging when tuber-transmitted, the best way to control virus is to plant certified seed potatoes. PVX and PVS can be reduced by preventing mechanical spread within the field by sanitising tools, minimising movement through the field and spraying the headland, which is likely to have the highest levels of aphid transmitted virus, last. Insecticides are ineffective in controlling non-persistently transmitted viruses as the aphid can transmit the virus before the insecticide kills the aphid. However, crop oils can be used early in the seasons to reduce the efficiency with which the virus is transmitted from the aphid to the crop. Frequent monitoring and removal of plants showing virus symptoms can reduce or completely eradicate virus infection in the crop.

There is a desire in the industry to re-invigorate native potato seed production, as identified in the Tillage Sector Development Plan 2012 (Teagasc Tillage Crop Stakeholder Consultative Group), the country is currently only 77% self-sufficient (producing 22,000t) whereas previously we exported 9,000t of seed potatoes per year. If seed production is to be increased, understanding and accurately identifying virus disease will become even more important.

Acknowledgements

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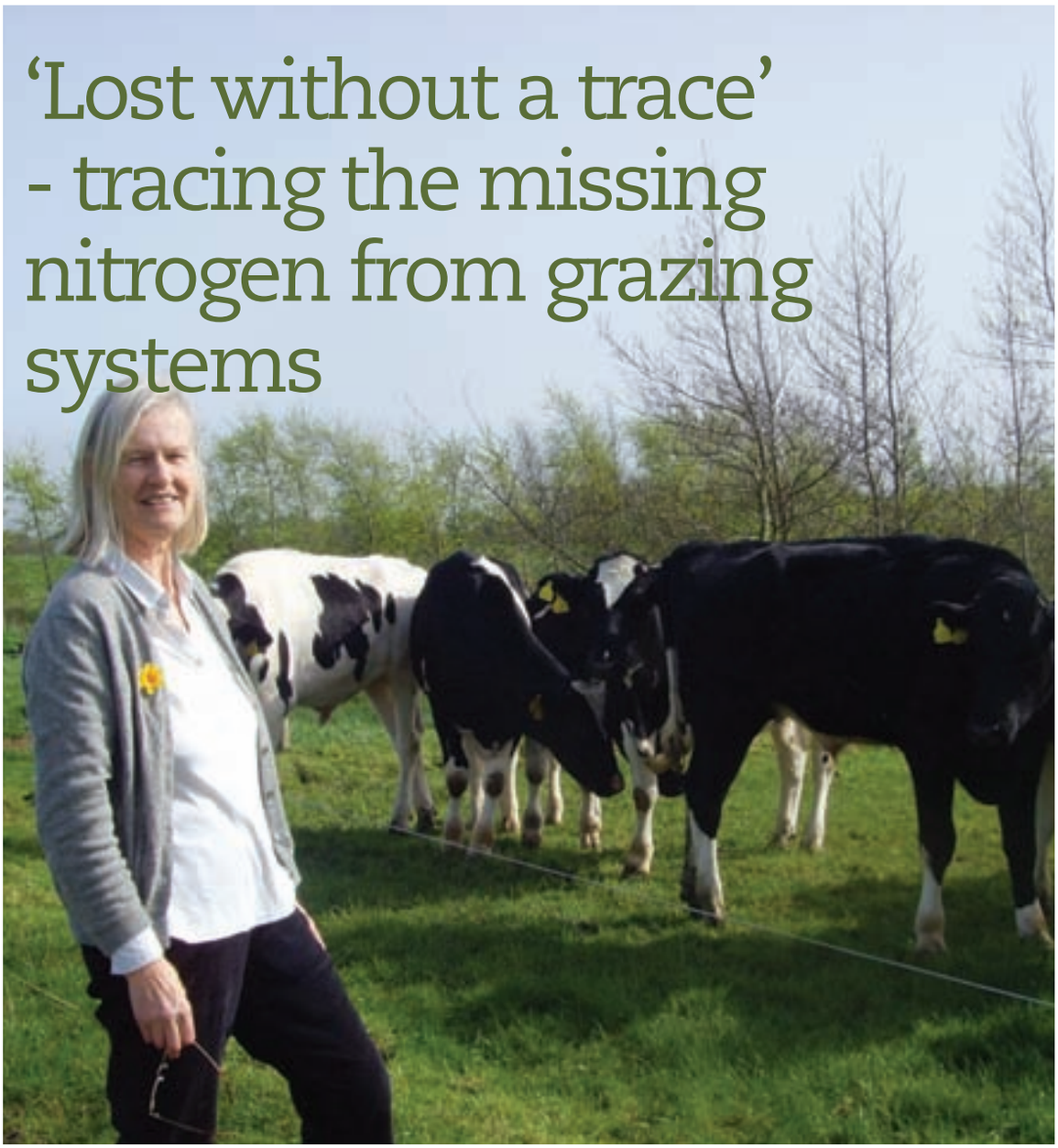
‘Lost without a trace’ - tracing the missing nitrogen from grazing systems



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The removal of milk quotas in 2015 is expected to lead to an increase in total dairy production in Ireland, with an associated increase in nitrogenous fertiliser usage. This may have implications for N loss to the atmosphere and groundwater. Current regulations pertaining to nitrogen management are to be reviewed in 2013 in view of the water quality targets set out in the Water Framework Directive. Anne Baily, Walsh Fellow at Teagasc – Johnstown Castle, reports on her studies, tracing the ‘missing links’ in the nitrogen cycle from a dairy farm.

Completing the nitrogen cycle

Efficient use of nitrogen (N) is a critical environmental as well as an agronomic issue and is subject to ongoing, worldwide, research. Most of the world’s nitrogen exists in the form of dinitrogen (N_2), which is not directly available to plants. Artificially produced fertilizers and the grazing cycle can leave a residue of reactive N accumulating in the biosphere. Denitrification is an important natural process for converting reactive N back to benign atmospheric N_2. However, incomplete denitrification (where reactive N is partially denitrified to nitrous oxide gas) can lead to nutrient enrichment of a waterbody (by nitrate leaching to drainage systems or groundwater) or emissions of greenhouse gases such as nitrous oxide (N_2O) to the atmosphere. So, what are the implications for intensively grazed grasslands in Ireland?

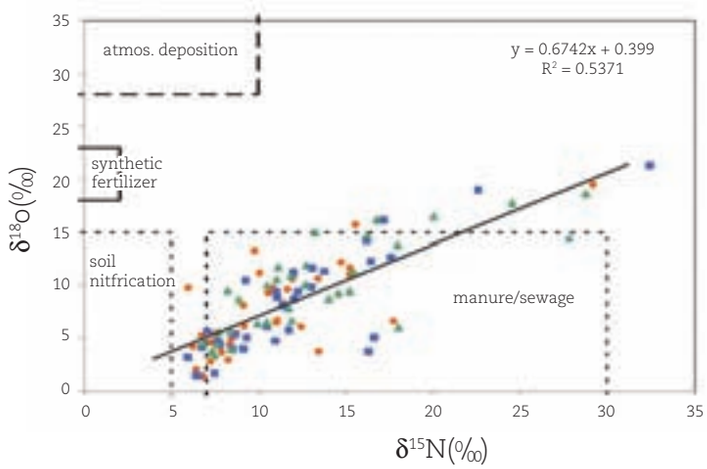
Losses to air

An initial 18-month study measured and compared N_2O emissions from higher and lower grazing intensity management systems, focusing on timing, type and level of fertilizer application. Although cumulative N_2O emissions from the more intensive treatment were almost twice as high as emissions from the extensive treatment, the proportion of fertilizer N lost for a complete farming year was relatively low in comparison with the few existing annual emission measurements in Ireland. The only days when N_2O emissions were high were from the second to fifth days after application of CAN fertilizer during May, June and July; after ^{15}N labelled nitrate enrichment, results followed a similar pattern, i.e., N_2O fluxes increased quickly but were generally below the limits of detection by day eight. It appears, therefore, that fluxes were triggered by addition of nitrate rather than ammonium fertilizer. However, during earlier applications of ammonium the weather was much cooler and the highest emissions during this study always occurred when soil temperature and water filled pore space (WFPS) were high. These data suggest that timing, type and level of fertilizer applications will be a key to minimising N_2O emissions.

A major question remained: did the relatively low level of emissions result from the 'little and often' fertilizer application regime, from meteorological factors or from a large proportion of fertilizer N being lost to the atmosphere as N_2? A concurrent study using the ^{15}N gas flux method was designed to measure both N_2O and N_2 emissions to cast further light on this question and, as in the long-term study, to compare results between treatments over three 12-day periods in June and September 2009 and March 2010 (Baily *et al.*, 2012). Cumulative emissions of N_2O and N_2 were not significantly different between treatments but, temporally, emissions were much higher in June and September than in March. However, over each sampling period N_2 cumulative emissions were much higher than N_2O emissions (by a factor of *circa* 5 in June and September and by a factor of *circa* 2.5 in March) indicating that the benign N_2 was the major gaseous emission derived from this soil in generally warm, wet conditions.

Losses to water

In a further study, the stable isotopes of nitrate ($\delta^{15}N$ and $\delta^{18}O$) were used to investigate the source of nitrate concentrations in 28 shallow groundwater wells on the dairy farm, as well as their spatial and temporal variation (Baily *et al.*, 2011; Fenton *et al.*, 2011). Organically derived nitrogen was the predominant source contributing to groundwater nitrate concentrations (Figure 1). The distinct low temporal variability in the isotopic data suggested constancy in nitrate sources and processes over time across the study site. Soil heterogeneity and groundwater depth were important factors influencing the wide spatial variation in nitrate concentrations in the wells. Using the $\delta^{15}N$ and $\delta^{18}O$ isotopes of nitrate it was possible to see where denitrification was occurring and, in some cases, to relate this to soil type and depth. Longest vertical travel times through soil were estimated to be up to three years for nitrate leaching from field application to groundwater. Policy makers and catchment managers should take this 'time lag' into account so that realistic timescales



Sources: Predominanantly manure

Processes: Volatilization, Nitrification, Denitrification

Figure 1: Sources and processes influencing isotope values.

are set from inception of nitrate reduction programmes to first detection of improvements in groundwater quality – or, indeed, with regard to potential impacts from increased intensity (Fenton *et al.*, 2010).

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The future of fruit and vegetable production

Selection of Irish-grown salad crops

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As recently highlighted at the Teagasc National Protected Crops Conference consumer demand for fruits and vegetables grown under protection is increasing and in order to react to this changing trend we need to continue adopting new technologies to fulfill the growing demand for Irish salad and fruit crops, explains Dr. Michael Gaffney.

Protected cropping refers to crops grown under some sort of protective structure, such as a glasshouse or polytunnel. Each year over €550 million of vegetables and €500 million of fruit are sold in Ireland, making them the two largest fresh produce categories. The protected cropping sector is currently the second largest horticultural sector in terms of farm gate value (€79 million), after mushroom production. Nationally our consumption of salad crops is increasing and there is an increasing demand for more Irish grown produce. Major advancements in three key areas in protected cropping, light, energy and crop protection have the potential to help growers meet this demand.

Let there be light

At the most basic level plants need light to grow. Photons are absorbed by pigments (chlorophyll), captured by glucose, fixing carbon dioxide and water, releasing oxygen. In high intensity horticulture, such as tomato production, where you can have 22,000 plants per hectare, the competition and demand for light is great. While irrigation, heating and carbon dioxide demand can be manipulated up to recently supplementary lightning was not economically feasible. The use of High Pressure Sodium Lamps (HPS) also caused other problems, as heat they emitted meant that they had to be located 2 to 3 metres above the crop. However, the advent of Light Emitting Diode (LED) lighting systems has overcome some of these limitations. LEDs emit less heat, meaning that strips of lights can be placed within the crop. This means that leaves that were previously shaded from overhead light remain productive and, therefore, do not need to be removed (leading to reduced labour costs). Theoretically crops could now be lit for 24 hours a day; however, six hours of darkness is required to avoid too much starch accumulating in the chloroplasts. LEDs can increase tomato yield by 10-15% while also reducing energy consumption by around 30%.

Developments however continue to move ahead. Some new commercial LED systems allow you to adjust or

'tune' the spectrum of light which is emitted leading to the new phrase 'light recipe'. Even though plants evolved in full sunlight, they don't utilize all the wavelengths that sunlight provides and LEDs can be used to focus the spectrum on blue, medium red and far red wavelengths, focusing the spectrum energy where it is most beneficial to plant growth. Light recipes are currently being designed to promote stem elongation, flowering, fruiting and even to halt crop ripening, giving growers the option to avoid market over-supply. LEDs are also being developed to emit UV light. Commercial farms in Denmark are currently using UV lamps to control fungal diseases in ornamental crops. A daily 1.5 second exposure to UV light has eliminated the need for fungicides on the nurseries where these systems have been installed. It is a strategy not without risk, as a 2-2.5 second exposure will kill the crop.

CO_2 and energy

In the last decade the volume of gas used to produce tomatoes and peppers has fallen from 60 m^3/m^2 of production area to 30 m^3. This has been a reaction to rising fuel costs and achieved by optimising fertilisation regimes and climate control strategies. Importantly, heating systems also produce Carbon Dioxide (CO_2), which is crucial for crop growth. Ambient CO_2 levels are approximately 370 ppm. If the vents remain closed within a glasshouse, the surrounding CO_2 levels can fall rapidly to 270 ppm, decreasing the rate of photosynthesis, causing a 20% or more reduction in yield. However, if the vents are opened to allow CO_2 into the glasshouse, heat will be lost. Therefore, supplementing CO_2 is crucial. Optimal CO_2 levels for most high intensity crops is between 600 to 1,000 ppm, although the economic benefit decreases drastically after 700 ppm. Obviously CO_2 supplementation must coincide with good light levels to drive photosynthesis. With sufficient light and CO_2 levels at 1,000 p.p.m, photosynthesis is increased by 50%. Heat demand in crops such as tomatoes and peppers is highest from January to April and demand falls off over the summer months. Heat and CO_2 creation is the second highest input cost for growers. The approximate cost per hectare for heat from a gas boiler is approximately €70,000. In order to reduce the cost of heating, some Irish nurseries are installing Combined Heat and Power (CHP) plants. A CHP converts a fuel, for example natural gas, into heat, electricity and CO_2. While CHP units can run off biomass, natural gas is more popular for edible crops as the CO_2 can be directly piped into the glasshouse, whereas the flue gas from biomass currently requires expensive scrubbing units. The input cost of producing a Mega Watt hour of heat with a CHP is actually double that of a conventional gas boiler, however the electricity created can then be exported. In Holland, where this technology is an industry norm, using figures of €0.035/kWh for gas and €0.065/kWh for exported electricity, the net cost per Mega Watt hour is €28, as opposed to €38 using a conventional gas boiler. However, the difference in installation and set up costs is significant: for example, to heat a 2.5 Ha tomato nursery, a conventional gas boiler would cost €80,000 as opposed to €1.2 million (approximately) for a CHP engine, additional heat storage tanks and connection to the national grid. Whereas it is common for Dutch nurseries to use the electricity created to power supplementary lights, in Ireland the economics mean it is necessary for the electricity generated to be exported to the national grid.

Picture Courtesy of Philips Horticultural Lighting and Cambridge HOK

Crop protection

Resilient cultivation is a new concept, centered on stressing plants to activate their own immune response. In 2001, the concentration of fertiliser salts (electrical conductivity) within irrigation water in a glasshouse would have been 3 ms/m^3, it is now 4.5 ms/m^3, leading to a stressing effect on the root systems, causing them to grow quicker. Normally glasshouse crops are grown on substrates such as rockwool or peat, with one of perceived benefits of these being that they are relatively microbiologically barren. Now, much effort is ongoing to increase the microbiology of these substrates: beneficial microorganisms such as *Trichoderma harzianum* are drenched onto plant root systems to fill niches that may otherwise be occupied by plant pathogens. In addition, biostimulants such as seaweed extracts and amino acids are being used to stimulate the metabolic processes within the plant. This strategy is leading to stronger plants that are less susceptible to disease.

The future for protected cropping

While it is now feasible to grow food crops without natural light, economically it may be some time before it's a commercial reality. Crops such as lettuce are currently being grown in multilayer systems in Holland, Denmark and the US in glasshouses and it is likely that these systems will become more popular. In Ireland, traditionally you can achieve 4.5 harvests of lettuce under glass in a year; with these multilayer systems, 30 harvests or more would be possible from the same area. In this age where reducing carbon footprint is all important, this form of food production is already very sustainable and clean. Glasshouses operate nutrient recycling systems so no nutrients are lost, run off water is collected, re-analysed and recycled. It takes 1 m^3 of basalt to produce 50 m^3 of rockwool slabs, which can produce 350,000 kg of tomatoes and then be recycled into 8 m^3 of bricks. Each hectare of tomato grown in Ireland fixes over 125t/ha/year of CO_2. Also, with increasing water shortages in the large fruit and vegetable production areas supplying Europe, such as Spain, Italy and Israel the sustainability of importing these crops must be assessed. Over 28,000 tonnes of tomatoes were imported into Ireland in 2011, which equates to just less than 6 billion litres of fresh water (214 litres to produce a Kg of tomatoes). Increasingly glasshouse heating is moving towards sustainable heat production sources such biogas produced by anaerobic digestion or using secondary (waste) heat produced by industrial processes. The utilisation of theses heat sources and other developing technologies will allow Irish producers to continue to successfully compete and replace imported produce.

To buy, or not to buy: that is the functional food question

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Ongoing research in Teagasc is investigating consumer receptivity to functional foods in order to identify new market and product development opportunities.

Being consumer-orientated in product development - through having an understanding of ever changing consumer patterns, trends and food preferences - has been identified as a critical factor for the growth and competitiveness of the Irish food industry in the *Food Harvest 2020* report. This report also recommends that new product development should be targeted at products with added-value potential, such as functional foods.

Functional foods are those that promise health benefits beyond basic nutritional needs. The market has grown significantly, and further growth is predicted despite the recession (Leatherhead, UK, 2011). Leatherhead currently estimates the global market to be worth $25bn, showing an increase of nearly 32% over the five-year period of 2007-2011. Europe accounts for 29% of this market with an estimated worth of more than $7bn. It is therefore a category of interest to consumers from a health perspective and represents a significant opportunity to the food industry.

While the market is growing, a thorough understanding of consumer needs is still required to increase likelihood of success and to identify unmet needs. Given that more than 40% of our food exports go to the UK, this population are of particular interest to focus on. Information on this market can be extracted from existing datasets such as PERIscope. The PERIscope survey is Bord Bia's biennial study that monitors Irish, British and Northern Irish consumers. The survey provides a detailed perspective on more than 3,000 consumers' attitudes and behaviour regarding food-related issues.

Awareness of functional foods

Awareness of the link between food and health dates back to Hippocrates famous quote "*let food be thy medicine*" in 400BC. Yet, nearly two-and-a-half thousand years later, just over one-third of Irish and UK consumers have heard of functional foods. However, consumers who were aware of functional foods were also more likely to purchase them. PERIscope research has shown that 60% of those likely to buy functional foods in the future had previously heard of functional foods. This contrasts with only one in five or 20% of consumers who had not previously heard of functional foods that were likely to purchase functional foods in the future. In order to identify marketing and new product opportunities that are consumer centric, the needs, attitudes and characteristics of the functional foods consumer as well as the non-consumer were investigated. Consumers were segmented into three groups based on their likelihood to purchase functional foods in the future: likely, unsure and unlikely.

Consumers who indicated that they were likely to purchase functional foods in the future differed in many regards from those who were unlikely or unsure regarding future purchase. Previous research has shown that older adults and, in particular, women are most likely to use functional foods. However in this research, there was no significant difference based on gender or age across the three categories. Therefore, there may be opportunities to promote functional foods to younger groups and men as well as older adults and women. Social class differences were observed whereby those in ABC1 social groupings indicated that they were more likely to purchase functional foods, while C2DE groups were more unlikely to purchase functional foods. This suggests that perceptions relating to price may be a limiting factor.

Self-reported cooking skills were good in all three groups; however, the likely to purchase group reported considerably better cooking skills. While all three groups showed some degree of interest in cooking, level of interest was much lower in the unsure and unlikely groups. For this reason, products that override the cooking chore and promote convenience are likely to be well received by these consumers groups. On the other hand, consumers who were likely to purchase functional foods cooked from scratch more frequently. This could signal an opportunity to develop and market functional ingredients, which could be targeted at consumers with well honed cooking skills?

Health attitudes

Health attitudes were examined across all three groups. While all three groups assigned some importance to diet and health, it was strongly evident in the likely to purchase group. Those unlikely to purchase functional foods in the future were more blasé about their health and did not perceive that they had strong control over their own health. When asked how healthy they considered their diet to be, those in the unlikely and unsure groups considered their diet to be unhealthy. In addition, they were more likely to state that their diet stayed the same or became less healthy in the past year. Hence, even a decrease in the health quality of their diet does not drive this group to purchase functional foods. Therefore, as health is not a primary driver of food choice for them, an alternative or additional primary benefit from functional foods should be highlighted.

The likely to buy functional foods group were also more likely to purchase the foods themselves with traceability, traditional foods and local foods playing an important role in the food acquisition task. While all consumers placed importance on labels - such as natural, fresh, calcium source, build healthy bones - this importance was significantly higher in the likely to buy functional foods group. Hence, it appears that this group is more engaged and aware of food labels, origins and claims.

Consumers also answered statements regarding foods that they would eat more of if they were trying to become healthier. Interestingly, more than two-thirds of the sample who were unlikely or unsure regarding future functional food purchase stated that they would eat more foods fortified with vitamins and minerals and products that claim to lower cholesterol/blood pressure if they were trying to become healthier. This contradiction in attitude raises the question: does the term 'functional food' lend some confusion as to what the food does in the mind of consumers not positively disposed to the concept? This finding presents a challenge to identify a better route to communication regarding the concept of functional foods and identifies other benefits for these consumers who are not necessarily driven by health.

Drivers of food choice

People positively disposed to the functional food concept place high importance on diet and health. Therefore, opportunities that incorporate novel uses of functional ingredients that further promote health in a natural and traceable way would be well received by this food-involved group. However, the challenge remains to increase market penetration in the group of consumers less positively disposed to the concept of functional foods. This requires an in-depth focus on the drivers of food choice within this group as consumption of functional foods is unlikely to be driven by health. Hence, framing of health in relation to diet will have to be placed in the context of other motives such as convenience, taste and lifestyle.

Acknowledgements

Access to the PERIscope database was granted with kind permission from Bord Bia

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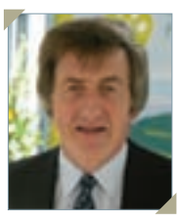
‘SMART’ ingredients for the dairy sector



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The word ‘SMART’ has been used as a prefix to distinguish the next generation of phones, televisions, cars, windows, etc., and is associated with new or superior functionality: these products have been described as having intelligent or more clever design compared to the norm. This article introduces the concept of ‘SMART’ ingredients which can be defined as high-value milk protein-based ingredients (dehydrated) with enhanced nutritional or physical properties for use in food products processed elsewhere in the world.

A growing world population and increasing middle class is driving demand for high quality nutritional products containing dairy proteins, particularly in emerging markets which traditionally had little, or no, history of dairy product consumption. This, coupled with the abolition of quotas in 2015, provides the dairy sector with an opportunity to expand by a predicted 50% (*Food Harvest 2020*) by the year 2020. Consequently, there is a requirement for targeted dairy chemistry/technology based research in the ingredient sector to support the Irish dairy processing industry if it is to respond to this increase in supply. As these emerging markets are located mainly outside Europe, the most convenient means to deliver Irish milk to these distant markets is in dehydrated (spray dried) form. The food research progamme at Moorepark has been aligned with this need through the amalgamation of core scientific competencies such as protein chemistry, soft matter physics, food structuring, and dehydration/rehydration dynamics for engineering of ‘SMART’ protein base powdered ingredients for export. The aim is to provide technology platforms that utilise large volumes of milk, through the development of smart protein ingredients and expertise in the technologies required to optimise their use in end products. The target functionalities of these ‘SMART’ ingredients is

primarily physical (ultimately rehydration mechanics and ability to impart structure in foods) but also nutritional. The ingredients are targeted at two sectoral levels, i.e.:

- ingredients with specific rehydration properties to allow reconstitution into large volume dairy foods e.g., soft cheese/yogurts, desserts, etc; and/or,
- nutritional base for beverages including infant formulas, dietary products, aged care products, protein bars, therapeutic and medical products including supplements.

The newer generation of high-protein based ingredients such as milk protein concentrates (MPCs) and native micellar caseins are attractive for formulation in many foods and nutritional products because of the near-native state under which proteins are separated from milk using relatively mild process conditions afforded by modern, large scale membrane filtration technologies. However, a critical consideration in the usage of these ingredients in high protein food matrices, such as cheese and high protein bars is their dispersion and hydration characteristics. The latter needs to be considered at the design stage of development, with a focus of the ingredient application/ usage. Otherwise, the ingredient may fail during secondary processing or by compromising product quality during subsequent storage. Differences in dispersion and hydration most likely account for the extensive variation in quality of commercially available MPCs. Nevertheless, new equipment technologies, which, for example, aid dispersion of ingredients in high-solids applications, may sometimes be required to fully exploit the use of SMART ingredients. The solution is to design 'SMART' function by thermal and ionic manipulation of milk proteins in liquid state and develop new hydration dynamics during milk-pretreatment, manipulation of the solvent phase by ionic conditioning, membrane separation, drying and reconstitution.

At a greater scale, the strategic direction is to build competency within Ireland in the area of spray drying and ingredient development for utilisation of the expected expanding milk pool. Consequently, there is a requirement for subject matter experts working directly in dairy chemistry and related processing technologies within the country, coupled with an increasing need for training to develop future graduates and expertise for the Irish Dairy Industry. The latter output, i.e., development of future resources is of critical importance for a sustained dairy industry within Ireland.

Expected impacts for end users arising from the elaboration of a programme based around 'SMART' ingredients include:

- Potential to expand the current product mix with the inclusion of SMART ingredients with higher margin for export. It is essential that new markets with added value are located to offset the extra capital investment (large expenditure may be required for new processing equipment, e.g., membrane plants and spray dryers) required to process extra milk.
- Development of longer shelf life dairy powders for export
- Development of expert competency groups to support the area of protein chemistry in relation to dehydration (spray drying) and rehydration science.
- A validated pilot scale platform for replicating the manufacturing processes for new dairy ingredients such as MPC and their end-use dairy foods, e.g., nutri-cheese, traditional foods or infant formula.
- Trouble-shooting capability – enables ingredient-related industrial problems to be replicated in the pilot plant and diagnosed with supporting analytical capability, including sensory (flavour chemistry) and microstructure (National Food Imaging Centre at Teagasc). The function should provide a critical platform for any dairy processor investing in new separation / drying equipment for utilisation of the milk pool.
- Development of future 'subject matter experts' in the area of dairy science and processing technology to provide sustainable human resources (Graduates; researchers), with the correct skill set for the growing dairy industry.

Researchers believe that building a platform of sciences and know-how around the concept of 'SMART' ingredients will improve the scientific understanding of fundamental physico-chemical and micro-structural factors controlling functionality in foods based on dairy ingredients. The target is to use this knowledge to prompt strategic thinking and lead to new innovations within Teagasc and Irish dairy sector. Given the predictions for the expansion in milk, the main beneficiaries of the 'SMART' ingredient programme will be the Irish agri-food sector.

This research is funded by the Food Institute Research Measure (FIRM) of the Department of Agriculture, Food and the Marine, Teagasc core funding and the Dairy Levy Fund.

Events

JUNE

21 June — *University College Cork, Lecture Theatre G02*

APC Celebration of Science and Launch of Next Phase

Minister for Agriculture, Food and the Marine, Simon Coveney, and Sean Sherlock, Minister for Research and Innovation, will attend this event at the Brookfield Health Sciences Complex in UCC. The event will encompass the APC Research Symposium, as well as an evening reception. It is of interest to researchers and industry players involved in gut health research and development and will be invite only.

23 - 26 June — *UCD, Dublin*

Greenhouse Gases & Animal Agriculture Conference (GGAA 2013)

The conference is being organised by Teagasc and University College Dublin. This scientific meeting will attract speakers and delegates from throughout the globe and builds on previous successful meetings in the series. The meeting will focus on advancements in the areas of animal derived GHG mitigation since the last meeting in Banff, 2010. Some financial support is available to help participation by delegates from least developed countries. Conference Sessions include:

- Policy and industry context for greenhouse gases from animal agriculture
- Techniques for measuring greenhouses gases – enteric methane, soil and manure-derived gases
- Microbiology of the rumen, soil and manure in relation to greenhouse gas emissions
- Mitigation strategies - enteric methane, soil and manure-derived gases
- Modelling of livestock greenhouse gas emissions

Conference website: www.ggaa2013.ie; Scientific queries: richard.dewhurst@teagasc.ie; Registration queries: ggaa2013@conferencepartners.ie

26 June — *Teagasc, Oak Park, Carlow*

Oak Park Crops Open Day 2013

This Open Day will offer attendees the chance to see the field experiments at Teagasc, Oak Park, Carlow and discuss with researchers and crop specialists the latest methods for optimising crop production. A wide range of field experiments will be on display, including

- Oilseed rape cultivation and management trials
- Cereal disease control
- Winter wheat and Spring barley varieties
- Nitrogen management in cereals
- Spring barley growth experiments

For more information contact: eleanor.butler@teagasc.ie

26 June — *Abbey Court Hotel, Nenagh, Co. Tipperary*

Teagasc National Farm Health & Safety Conference

A leading expert on the psychology of accident prevention will speak at the National Farm Health and Safety Conference which is taking place on Wednesday 26th June at the Abbey Court Hotel, Nenagh, Co. Tipperary. Professor Stephan Van den Broucke from the Faculty of Psychology and Education at the Catholic University of Louvain, Belgium, will present 'Designing more effective Farm Safety programmes – Understanding what drives safe behaviours'.
All are welcome to attend the event. No booking is required.
Contact: Mr John McNamara, Teagasc Health and Safety Officer: Tel: 00353 (0) 51 644537 / Email: john.g.mcnamara@teagasc.ie

27-28 June — *Teagasc Food Research Centre, Ashtown, Dublin 15*

42nd Annual Food Research Conference

The 42nd Annual Food Research Conference is being hosted by Teagasc at the Teagasc Food Research Centre, Ashtown, Dublin 15 on Thursday 27th & Friday 28th June 2013. For the last 41 years, the annual conference has been organised and hosted by UCC. It is now planned to hold this event at a different location each year. This conference allows post-graduate students the opportunity to present their research in form of an oral or poster presentation.
For more information please email: FoodResearchConf@teagasc.ie

JULY

3 July — *Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork*

Moorepark'13 Irish Dairying: Countdown to 2015

Expansion in the dairy farm business should only be undertaken if it increases profit and provides a better lifestyle to the farm family. When EU milk quota is abolished farm profitability will be dependent on maximising profit per hectare, i.e., stocking your farm to match grass supply. This major Open Day will provide the roadmap to deliver these goals for the Irish dairy industry.
For further information please contact Ms Margie Egan: 00 353 (0) 25 42292; margie.egan@teagasc.ie

SEPTEMBER

September 4 — *Kilkenny, venue TBC*

Dairy Expansion Conference

Covering business planning, cashflow management, risk management and financing expansion. Followed by a field visit to the Greenfield dairy farm in Kilkenny. For more information contact: abigail.ryan@teagasc.ie

September 11 — *Derrypatrick*

Grange Open Day

Efficient beef production from the national suckler herd is of major importance and is central to economic prosperity in beef farming.
Indeed, targets set in the Harvest 2020, require a significant contribution from the suckler sector. This open day will focus on the Derrypatrick suckler cow herd.
For more information visit www.teagasc.ie

OCTOBER

October 9 — *Southern region, venue TBC*

Dairy Calf to Beef Conference

The focus of the conference will be on Dairy Calf to Beef Systems. There will be papers on the different production systems for both dairy males and traditional beef breeds bred from the dairy herd. A number of farmer speakers will outline their farming systems and the economics of each system will also be outlined. The afternoon session will comprise of a marketing forum where key industry stakeholders will describe what the different markets require. For more information please contact pearse.kelly@teagasc.ie

For a list of Teagasc's Food industry training schedule please see: http://www.teagasc.ie/food/research/training/schedule.asp
For presentations from previous Teagasc events see: http://www.teagasc.ie/publications/