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Volume 5: Number 3. Autumn 2010
ISSN 1649-8917

T Research

Research and innovation news at Teagasc

Waste not, want not: producing compost from waste

- Novel animal biotechnologies: a quandary for Irish agri-food stakeholders
- Understanding and facilitating farmers' adoption of technologies
- Meeting your hot water demand

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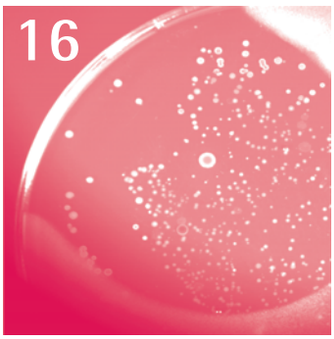

Credits

TResearch
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Agriculture and Food Development Authority

National Development Plan 2007 - 2013

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T Editorial

Teagasc–UCC Strategic Alliance in Food Research

Ireland's future success across the board will depend on building a new culture of collaboration in both the public and private sectors. In particular, public sector organisations that are small by international standards competing for resources and prestige will not individually provide the solutions needed to resolve Ireland's current economic difficulties. As an innovation provider, Teagasc recognises that it must build new and more powerful alliances in order to generate the critical mass that will yield economic dividends to industry at the level that will be required in the future. Increasingly, we realise that the innovation requirements of the agri-food industry are complex, interconnected and multifaceted, and often extend across organisational responsibilities. Solutions must take account of this complexity and draw on the breadth of knowledge and understanding that is available from many disciplines, organisations and sectors.

It was in light of this strategic requirement that Teagasc and University College Cork recently launched a new 'Strategic Alliance in Food Research' designed to drive the long-standing collaboration between the two institutions to a new level and create a 'Food Hub', which will enhance Ireland's reputation as a world centre for fundamental and applied research. This alliance creates a critical mass of expertise and resources and addresses the key strategic objectives of recent policy statements in relation to the development of the smart economy. It represents a critical step in putting in place a co-ordinated R&D support system between the two major providers of food R&D in the country that industry will find to be more efficient and easier to deal with. This step can be built on in future with the accession of other partners.

The launch of the new Alliance represents a further step in driving forward Teagasc's strategy of collaboration as enunciated in Teagasc's foresight report 'Teagasc 2030'. This alliance represents a new model of how two equal partners can come together while retaining their core identities and missions, but bringing their diverse skills and approach to create a new critical mass for the betterment of both organisations, the industry they serve and the taxpayers who fund much of their activities.

Dr Lance O'Brien
Head of Teagasc Foresight Unit

Comhghuaillíocht Straitéiseach Teagasc–COC sa Taighde Bia

Braithfidh rath na hÉireann go forleathan amach anseo ar thógáil cultúir nua comhoibrithe sna hearnálacha poiblí agus príobháideacha araon. Mar shampla, ní bheidh eagraíochtaí earnála poiblí atá beag i dtéarmaí idirnáisiúnta a bhíonn san iomaíocht le haghaidh acmhainní agus gradaim in ann na réitigh atá ag teastáil chun deacrachtaí eacnamaíocha na hÉireann i láthair na huaire a leigheas a sholáthar leo féin. Agus é ina sholáthraí nuálaíoch, aithníonn Teagasc gur gá dó comhghuaillíochtaí nua agus níos láidre a chruthú chun an mhais chriticiúil a bhaint amach, ar mhaithe le díbhinní eacnamaíocha a chruthú don tionscal ar an leibhéal a bheidh ag teastáil amach anseo. Tá tuiscint níos mó againn anois go bhfuil na riachtanais nuálaíochta atá ar an tionscal agraibhia casta, idirnasctha agus ilghnéitheach agus go síneann siad ar fud freagrachtaí eagraíochtúla éagsúla go minic. Is gá an chastacht seo a chur san áireamh sna réitigh agus caithfear úsáid a bhaint as leithead an eolais agus na tuisceana atá ar fáil ó chuid mhaith disciplíní, eagraíochtaí agus earnálacha éagsúla.

Sheol Teagasc agus Coláiste na hOllscoile, Corcaigh, 'Comhghuaillíocht Nua Straitéiseach sa Taighde Bia' le déanaí i bhfianaise an riachtanais stratéisigh seo, rud a dearadh chun an comhoibriú fadbhunaithe idir an dá institiúid a chur chun cinn, chomh maith le 'Mol Bia' a chruthú, rud a fheabhsóidh cáil na hÉireann mar lárnionad domhanda taighde bhunúsaigh agus fheidhmigh. Cruthaíonn an chomhghuaillíocht seo mais chriticiúil de shaineolas agus d'acmhainní agus díríonn sé ar na príomhchuspóirí straitéiseacha a bhí ann i ráitis pholasaí a eisíodh le déanaí maidir le forbairt an Gheilleagair Chlisteachta. Is ionann í agus céim ríthábhachtach i gcur i bhfeidhm córas tacaíochta T agus F idir an dá sholáthraí mhóra T agus F Bia sa tír, a mbeidh sé níos éifeachtúla agus níos éasca don tionscal déileáil leo. Is féidir cur leis an gcéim seo amach anseo le haontachas páirtithe eile.

Is ionann seoladh na Comhghuaillíochta nua agus céim eile i gcur chun cinn straitéis chomhoibrithe Teagasc mar a fógraíodh sa tuarascáil fhadbhreathnaitheachta de chuid Teagasc darb ainm 'Teagasc 2030'. Is ionann an chomhghuaillíocht seo agus múnla nua chun gur féidir le dhá pháirtí chomhionanna teacht le chéile ach a bhféiniúlacht agus misin lárnacha a choinneáil. Tugann siad a scileanna agus a gcur chuige ilghnéitheach leo chun mais chriticiúil nua a chruthú do bhisiú an dá eagraíocht, an tionscail a bhfreastalaíonn siad air agus na gcáiníocóirí a mhaoiníonn cuid mhaith dá ngníomhaíochtaí.

An Dr Lance O'Brien
Ceann Aonad Fadbhreathnaitheachta Teagasc

Published on behalf of Teagasc by
ThinkMedia
PROFESSIONAL PUBLISHING SERVICES
The Malthouse, 537 NCR, Dublin 1.
T: 01-856 1166 F: 01-856 1169 www.thinkmedia.ie
Design: Tony Byrne, Tom Cullen and Ruth O'Sullivan
Editorial: Ann-Marie Hardiman and Paul O'Grady

T News

Researcher profile

Mary Rea

Mary Rea graduated from UCC in 1975 with a BSc in Microbiology, obtaining her MSc two years later. Her PhD thesis entitled 'Discovery of Novel Therapeutics for the Treatment of *C. difficile*' will be presented to UCC this year. From 1976 to 1977 she worked as a research assistant with the Medical Research Council in St Finbarr's Hospital, Cork, before moving to An Foras Talúntais (now Teagasc) in Moorepark as a Research Officer, where she worked until 1981. Following a career break she returned to Moorepark in 1989 on a part-time basis until 1993, when she joined the staff full time. Since 2008, she has held the post of Senior Research Officer in Moorepark.

Until 2005 Mary worked in the Cheese Microbiology Department publishing regularly on various aspects of food microbiology, particularly on Cheddar and smear ripened cheeses. She then joined the Biotechnology Department to work with Paul Ross and his team in the Alimentary Pharmabiotic Centre (APC) working on bacteriocins (antimicrobial peptides) with special emphasis on isolating antimicrobial compounds against gut pathogens particularly those with anti-*Clostridium difficile* activity. Her work on the newly discovered anti-*C. difficile* bacteriocin, thuricin CD, has recently been published as two papers in the prestigious journal *The Proceedings of the National Academy of Sciences* (USA) (see article on p16). Mary's current research interests also include two EU-funded projects, viz. The survival of *Mycobacterium avium tuberculosis* in cheese and The GMSAFOOD project. She also works on the Teagasc/UCC ElderMet project, which investigates gut health in the elderly.

Mary was named APC Scientist of the Year in 2008 and also received the APC Educational Outreach award for 2008. She is a member of the Society for Applied Microbiology. She lives in Fermoy with her husband David, a secondary school teacher, and has three adult children. She is a very enthusiastic member of her local book club, likes hill-walking and gardening and enjoys listening to classical music. As part of the APC, she is involved in educational outreach both with primary schools and adult groups.

Cheese monographs

Teagasc Food Research, Moorepark, has produced two monographs for the Irish milk and cheese industry. The monographs are: 'Cheese manufacture: Quality characteristics of the milk', which examines the impact of milk quality characteristics (composition, microbiological, sensory and functional) on cheese manufacture/quality, and the factors at farm level that affect milk quality; and, 'Cheese manufacture: Control and prediction of quality characteristics', which examines the effects of individual manufacturing operations on cheese quality and sets out a basic approach to quality assurance and design. The monographs are available from Niamh O'Brien, E-mail: niamh.obrien@teagasc.ie.

Teagasc appointments

Declan Troy (above left) was recently appointed as Assistant Director of Research. Declan will lead the Teagasc Food Knowledge Transfer Programme for the Irish food industry. Dr Noel Culleton (centre) was appointed Head of Programme for Crops, Environment and Land Use. Teagasc is combining the research functions of Oak Park Crops Research Centre and Johnstown Castle Environment Research Centre into a single programme encompassing the work of crops, environment and land use, and also including horticulture and forestry. Dr Culleton will provide leadership, strategic management and direction, ensuring integration in the research and knowledge transfer programmes across the different sites.

Dr Cathal O'Donoghue (right) was appointed as Head of Programme for Rural Economy and Development. This new programme will create a powerful unit with the critical mass to deliver significant benefit to the Irish agri-food sector and to be internationally competitive in scientific terms.

IGA Lifetime Merit Award for 2010

Dr Sean Flanagan, retired Teagasc staff member, has been awarded the 2010 Lifetime Merit Award by the Irish Grassland Association, "for his outstanding contribution to the Irish Grassland Association, being the Honorary Secretary and Treasurer for 30 years of its 60 years existence and a council member for 39 years, and for his leadership in research and technology transfer for sheep production, particularly grassland management".

RIA honours Head of Food Research

The Royal Irish Academy (RIA) recently elected Dr Paul Ross, the Head of Food Research at Teagasc, for admission in recognition of his academic achievement. This is the Academy's 225th admission of new Members since it was founded in 1785.

Paul Ross was among only 24 academics on the island of Ireland to achieve this highest academic distinction. The Academy now has 441 Members across the disciplines of the sciences, humanities and social sciences, and in its entire history only 2,833 people have been Members.

Walsh Fellowships Scheme 2011

The Walsh Fellowships Scheme provides fellowships to postgraduates to work on research projects relevant to the Teagasc Research Programme while studying for a higher degree.

Applications for fellowships are made by full-time academic staff in third-level colleges in collaboration with a Teagasc Research Officer. The successful applicants select the Walsh Fellows.

Teagasc now invites applications from academic staff at third-level colleges for its 2011 Scheme. Applications are invited on any aspect of the Teagasc Research Programme in Food; Animal (including pigs) and Grassland Production; Crops, Environment and Land Use; and, Rural Economics and Development. A complete listing of Teagasc topic areas is available on the Teagasc website.

This year Teagasc is inviting "pre proposals" for a limited number of Walsh Fellowship Clusters.

The closing date is September 24 (September 10 for Walsh Fellowships Clusters). For more see: www.teagasc.ie/research/postgrad/wf_scheme_2011.asp.

Teagasc and UCC launch strategic alliance in food research

Photographed at the launch of the UCC/Teagasc Strategic Alliance were (from left): Professor Michael Dowling, Chairman, UCC/Teagasc Strategic Alliance; Mr Brendan Smith, TD, Minister for Agriculture, Fisheries and Food; Professor Gerry Boyle, Director, Teagasc; and, Dr Michael Murphy, President, UCC.

A major step towards establishing a single food research programme in Ireland to support innovation and development in the food industry was taken with the launch of the UCC/Teagasc Strategic Alliance in Food Research. This new alliance moves collaboration between the two organisations in food science and technology to a new level, through the sharing of resources, working to a joint research programme and the establishment of a single portal for food companies to access international quality research and innovation. For more on the strategic alliance see editorial on p.3.

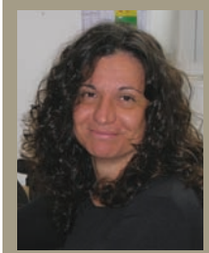
International award for Teagasc and UCC scientists

Teagasc researchers Dr Catherine Stanton and Professor Paul Ross of Moorepark, and Professors Colin Hill and Gerald Fitzgerald of the Microbiology Department, UCC, were awarded the International Dairy Federation's Elie Metchnikoff Prize in Microbiology for 2010.

The Metchnikoff Prize is named in honour of the recipient of the 1908 Nobel Prize, and recognises outstanding scientific discoveries in the fields of microbiology, biotechnology, nutrition and health with regard to fermented milks, and to promote further research and innovation in the dairy industry. They received the award in recognition of their contribution to the study of lactic acid bacteria.

Teagasc Director Professor Gerry Boyle said that this award is richly deserved by the researchers for their outstanding research work over many years on lactic acid bacteria. "Understanding how these bacteria work is so important in our daily lives as they are used in the production of foods such as cheese and yoghurts, but they are also found in the gut and have an influence on our health. Their research has made an extremely valuable contribution to the industry."

IPSAM award



Mariateresa de Cesare, a Teagasc Walsh Fellow based at Teagasc Oak Park Crops Research Centre, won the best student presentation award in the session 'cell and molecular biology' at the Irish Plant Scientists Association Meeting (IPSAM) recently.

The title of her presentation was: 'Development and use of nuclear microsatellite markers (SSRs) for genetic diversity evaluation in Miscanthus (Panicoideae, Poaceae)'.

T News

Supports for publicly funded IP

Following a review of supports in place to encourage the exploitation of intellectual property (IP) emanating from publicly funded research by AD Little, on behalf of Forfás, in 2009, the stakeholder launch of the report 'Review of the Supports for Exploitation of Publicly Funded Intellectual Property' took place recently.

The objective of this study was to determine whether the current IP arrangements for publicly funded research in Ireland are adequate to support the objectives of the SSTI (Strategy for Science, Technology and Innovation, 2006-2013). Over 78 stakeholders from 42 organisations including state agencies, companies, higher education institutes (HEIs) and public research organisations and their respective technology transfer offices (TTOs), participated through round table consultations and one-to-one interviews.

The overall findings revealed that Ireland is making good progress and that policies and guidelines are in line with international good practice. While the national measures appear adequately resourced, up-skilling of staff, long-term funding and communication to stakeholders were deemed critical. Some of the main recommendations include development of a broad set of performance metrics using a balanced scorecard approach and a set of national model agreements and principles, and also revision of national policies and IP guidelines to allow a differentiated approach to deal with IP of various kinds. Overall, the report was welcomed and its findings and recommendations deemed a positive step in improving the commercialisation of IP generated through publicly-funded research.

Sheep 2010

Pictured at the Sheep 2010 event that took place at the UCD Lyons Estate in June are Teagasc staff (from left): Professor Gerry Boyle, Director of Teagasc; Michael McHugh; John Noonan; Mr Brendan Smith, TD, Minister for Agriculture, Fisheries and Food; Frank Hynes and Dr Michael Diskin.

A climate for change

Delegates at the 'A Climate for Change: Opportunities for Carbon-Efficient Farming' Conference in the Mansion House Dublin in June. For a full report on the conference see p8.

Suckler beef open day

Teagasc Animal & Grassland Research and Innovation Centre, Grange, County Meath, recently held an open day to showcase the established 'Derrypatrick Herd', which was set up as a research demonstration unit to showcase the best and most profitable technologies and management practices.

T Commercialisation opportunity

A method for the transformation of plant cells

Teagasc and University College Dublin are seeking partners within the ag-biotech industry to further develop a novel method of transforming plant cells with a view to licensing.

Summary

A novel method of transforming plant cells has recently been developed in Teagasc, Oak Park, in collaboration with University College Dublin, and a patent application filed. It was proven during experimental trials that this technology produces stable transformants at a rate equivalent to current systems when applied to potato, tobacco and the model plant *Arabidopsis*. This process would be of significant interest to companies working on the genetic transformation of plant species for agronomic, neutraceutical and/or pharmaceutical purposes, as current procedures for the transformation of plant cells are heavily restricted by existing patents.

Problem addressed

The primary technique for the generation of genetically modified (GM or 'biotech') crops utilises the bacteria *Agrobacterium tumefacien*s in a process termed *Agrobacterium tumefaciens*-mediated transformation (ATMT). ATMT is used worldwide by scientists in public sector agencies and institutions, private industries (SMEs and international corporations) and universities. Yet, to the end-user of ATMT, adopting the technology for a specific task is problematic as the key patents for this technology have placed a stranglehold on transformation technology.

Solution

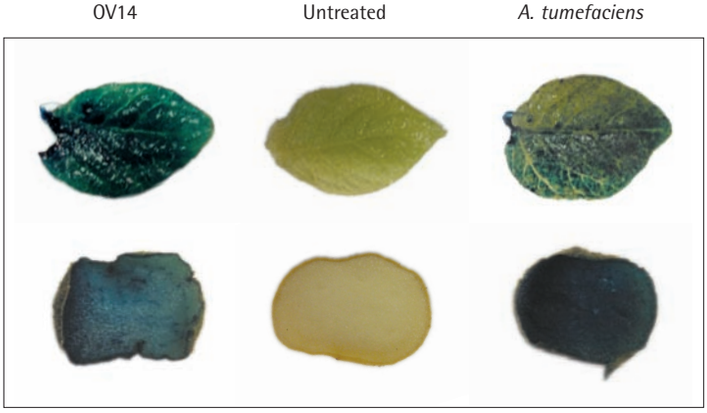
We have identified a novel bacterium (OV14) that will successfully transfer single/multiple gene(s) of interest into plant cells at rates equivalent to standard ATMT. By directly substituting OV14 for *Agrobacterium* in a standard ATMT transformation protocol, we have confirmed stable transgene integration and expression in the model species *Arabidopsis* and two crop species (potato and tobacco) at rates equivalent to that achieved with ATMT. OV14 is genetically distinct from *Agrobacterium* and as such circumvents existing transformation patents on dicotyledonous species. OV14 does not require challenging conditions or processes for its growth and the bacterium will willingly uptake plasmids of varying size.

Intellectual property status

A patent application has recently been filed by Teagasc covering the process of isolating and characterising the potential of OV14 to genetically transform plant tissues.

Competitive advantage of the technology

1. The key advantage of OV14 is that it is genetically distinct from *Agrobacterium* and as such circumvents existing transformation patents on plant species.



Comparative rate of transformation of potato leaf (upper) and tuber (lower) tissues between OV14 and A. tumefaciens *as demonstrated via presence of GUS staining to indicate transformed tissue.*

2. OV14 does not require challenging conditions or processes for its growth and can be integrated into existing ATMT-based protocols with no additional optimisations required.
3. OV14 will willingly uptake and harbour plasmids of varying size through multiple generations.

Of interest to

This technology would be of interest to universities, the public sector, and small and medium enterprises wishing to acquire a novel transformation platform for their gene discovery studies. As some validation and optimisation is still required we are currently seeking partners for such commercialisation with a view to licensing.

Principal investigators

Dr Ewen Mullins, Teagasc, Crops Research Centre, Oak Park, Carlow, Co Carlow and Dr Fiona Doohan, University College Dublin, Belfield, Dublin 4.

How to proceed

For further information, contact Dr Miriam Walsh, Head of Intellectual Property, Teagasc, Tel: 059 918 3477, E-mail: Miriam.walsh@teagasc.ie.

A Climate for Change: Opportunities for Carbon-Efficient Farming

Reducing the carbon footprint of farming could create opportunities for Irish agriculture if research and policies are implemented, heard delegates at a recent Teagasc conference.

"Ireland has a unique opportunity to turn the threat of greenhouse gas emissions into an opportunity for Irish farming". That was the message arising from the international conference 'A Climate for Change: Opportunities for Carbon-Efficient Farming', organised by Teagasc. Over 200 scientists, policy makers, farm organisations, agricultural advisers and stakeholders gathered at the Mansion House in Dublin in June to agree on a proactive approach to minimise the carbon footprint of Irish produce, and capitalise on the global marketing opportunities for low-carbon food. Here, the organisers of the conference report on the discussions and outcomes from this two-day event.

Why do we need to reduce greenhouse gas emissions from agriculture even further?

Agriculture is the only non-Emission Trading System sector in Ireland that has already reduced its greenhouse gas (GHG) emissions (8% since 1990), largely through improvements in efficiency. Therefore, agriculture is not responsible for Ireland's failure to meet its Kyoto target emission levels. However, the new EU strategy is to reduce all emissions by 20% by 2020 (compared to 2005), and this could translate into a 20% further reduction in GHG emissions for Irish agriculture. Paradoxically, the fact that agriculture has already reduced its GHG emissions over the last 20 years will make it harder to make further cuts, as the 'easy' solutions have already been implemented.

So, should livestock numbers be reduced to meet our GHG targets?

The short answer is no. While that may appear to be a 'quick fix' solution, it will actually be counter-productive, not only for agriculture, but also for the environment. It may in fact lead to an increase in GHG emissions at a global scale, through a process called carbon leakage. In a nutshell, global demand for food is rising, and is forecast to continue to rise, not only because of population growth, but also as a result of increased food consumption per capita. Currently, Ireland is the fifth largest exporter of beef in the world. In a scenario where Ireland would decide to cap its food production to meet its own GHG target, the increased demand for food will be met by agriculture in other regions of the world. It is highly likely that the production of meat and milk elsewhere will produce more GHG emissions than if it was produced in Ireland. Indeed, a recent FAO (Food and Agriculture Organisation of the United Nations) report compared the carbon footprint of various dairy systems around the world, and found that our temperate grass-based dairy systems have the lowest GHG emissions per litre of milk produced. Moreover, the conference heard that a reduction in livestock numbers might have significant economic consequences for urban households. A recent economic study by Teagasc is forecasting that beef farmers will simply pass on the reduction in outputs by reducing inputs, and that the reduction in economic activity would be most prominent in the urban-based processing industry and agricultural supply chains.

Then how can we achieve food security and reduce our GHG emissions?

We can achieve both objectives by focussing on reducing our GHG emissions per unit product, i.e., the total quantity of gases emitted to produce one litre of milk or one kilogram of meat. By reducing this 'carbon footprint' of our produce, all countries would compete on a level playing field, and we could achieve both food security and reduced emissions. Interestingly, this is the approach that has already been adopted by many of the supermarkets to promote their products. With our low carbon footprint, this represents real marketing opportunities for Irish agriculture. Indeed, the conference enjoyed a presentation by the vice-president of Danone International, which is currently in negotiations to set up a zero-carbon milk processing plant in

Ireland. This does not mean that we can be complacent about our GHG emissions. Worldwide, countries are making serious efforts to reduce the carbon footprint of their produce. In order to stay in pole position, we must relentlessly pursue our efforts to further reduce our own footprint, by finding further efficiencies within our farming systems. Teagasc operates a large and ambitious research programme on GHG emissions that aims to develop cost-effective measures to produce milk and meat with a lower carbon footprint. These measures span a range of scales, from individual animals to land use change, and all of the three agricultural GHGs: methane, nitrous oxide and carbon dioxide.

Some measures are relatively straightforward, such as promoting the planting of bioenergy crops, or finishing beef animals earlier – this will reduce the total amount of methane they will emit during their lifetime. Other measures are technologically advanced and still under development, such as efforts to manipulate the chemistry of soil microbes to reduce nitrous oxide emissions from grassland soils. Our focus is on developing measures that provide a double dividend, i.e., not only reducing GHG emissions, but also reducing direct costs on farms by improving farm efficiency. Examples include extending the grazing season, improved slurry management and the use of white clover in grass production.

How can we turn this into an opportunity for agriculture?

A lot of work is needed to turn the threat of GHG reductions into an opportunity for farming:

- Teagasc and the Higher Educational Institutes must continue the research to develop knowledge on cost-effective mitigation strategies, so Irish agriculture can stay ahead in the carbon footprint race;
- Teagasc is working closely with the Environmental Protection Agency and the Department of Agriculture, Fisheries and Food (DAFF) to ensure that any improvements in on-farm efficiencies are accounted for in our national GHG inventories. This is a challenging task. Agricultural systems are natural systems; reductions in GHG emissions, while significant from a carbon footprint perspective, may be hard to pick up on against the 'background noise' and variability of emissions that typifies our agro-ecosystems;
- Internationally, there is increasing recognition that, in order to pursue food security and mitigate climate change, we need to shift our focus from reducing agricultural productivity to increasing the GHG efficiency with which we produce our food. In this light, one of the few positive outcomes of the UN Climate Summit in Copenhagen last December was the launch of the Global Research Alliance, led by New Zealand, which aims to co-ordinate global research efforts in this respect. Similarly, this year the EU has initiated a Joint Programme Initiative (JPI) on Food Security and Climate Change, with a similar agenda at EU level. Ireland (the DAFF and Teagasc) is a signatory to both initiatives, and has been given the ambitious task of co-ordinating the activities of the JPI, the Global Research Alliance, the FAO and other international research groups;
- Winning the international race on reducing carbon footprints requires adoption of the cost-effective mitigation measures at farm level, and there is an essential role for farmers and farm organisations, supported by Teagasc's advisory services, to capitalise on this potential;
- The food-processing industry and the retail industry have a critical role in linking the pull of consumer demand for low-carbon food to rewarding low-carbon farm practices. A particular challenge is to develop a common method to calculate carbon footprints for produce, as currently multiple methods are used that can be in conflict at times. Teagasc is currently working with Bord Bia to develop a carbon calculator for beef produce.

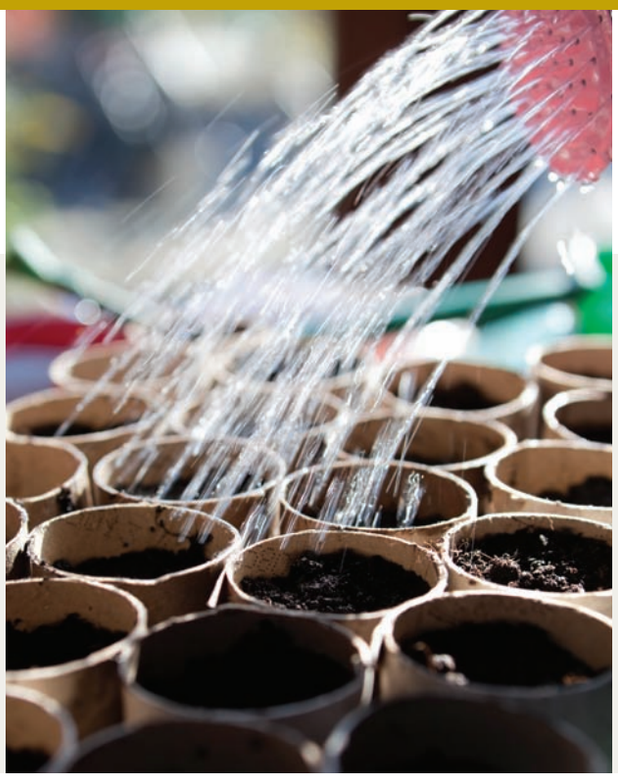
Turning the threat of GHG emissions into an opportunity for agriculture requires all these links in the supply chain to work towards this common agenda. At the close of the conference, Teagasc Director Gerry Boyle announced the launch of the Climate for Change Action Forum, initiated by Teagasc and the Food and Drink Industry Ireland, which aims to bring all stakeholders together to work towards this common goal.

Acknowledgements

Teagasc's research programme on GHG emissions is funded by Teagasc core funding, the Research Stimulus Fund (DAFF), STRIVE (EPA) and Bord Bia. The proceedings of the conference can be found at: www.teagasc.ie/aclimateforchange. See also 'Teagasc Greenhouse Gas Research Highlights' on www.teagasc.ie/publications.

Dr Rogier Schulte is Head of the Environment Research Department and Chair of Teagasc's Working Group on GHG emissions. E-mail: rogier.schulte@teagasc.ie. **Mark Gibson** is an Environment Specialist in Teagasc, Athenry, and Secretary of Teagasc's Working Group on GHG emissions. **Reamonn Fealy** is a Geographical Information Systems and Soils Mapping specialist in the Spatial Analysis Unit, Rural Economy Research Centre, Teagasc, Kinsealy. **Gary Lanigan** is a Research Officer in Teagasc Environment Research Centre, Johnstown Castle. His research focuses on mitigation strategies for gaseous emissions from agriculture. **Laurence Shalloo** is a Senior Research Officer in the Livestock Systems Research Department at Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark. His research focuses on increasing the economic and environmental sustainability of the dairy industry. **Dr Paul Crosson** is a Research Officer on beef systems modelling in the Livestock Systems Research Department at Teagasc, Animal & Grassland Research and Innovation Centre, Grange. **John Finnan** is a Research Officer working on bioenergy and based at the Crops Research Centre at Oak Park, Carlow. **John Spink** is a Senior Principal Research Officer at Teagasc Oak Park Crops Research Centre, Carlow. His research focuses on increasing productivity and efficiency of input use in tillage crops. **Pat Murphy** is Environment Programme Manager, Knowledge Transfer Department, Teagasc, Johnstown Castle Environment Research Centre.

Engineering disease-suppressive composts



Municipal waste and manures will be increasingly used as a source of composting material and have the added potential benefit of suppressing plant diseases. Work at Teagasc Kinsealy has been looking at ways of producing consistently disease-suppressive composts.

The National Strategy on Biodegradable Waste, published by the Department of Environment, Heritage and Local Government in 2006, points to the large gap between projected biodegradable municipal waste (BMW) production and the maximum amount of landfill permitted for BMW under the EU Landfill Directive. The EU Landfill Directive (1999) requires Member States to make use of alternative treatment methods with the aim of producing usable products from organic waste. The EPA report (2000-MS-6-M1) recognises composting as one of the main methods of achieving the goals set out by the EU for reducing the amount of BMW directed to landfill.

Composting organic waste has many benefits over landfill: (1) a reduction in the volume of waste; (2) composting is an aerobic process and therefore produces carbon dioxide, whereas landfill is mainly an anaerobic process producing methane; and, (3) compost can be considered a resource and has the potential to be used as both a fertiliser and a horticultural growing media. However, with the increase in compost production, finding markets for these products is now critical. The potential of composted waste to suppress plant pathogenic diseases has been identified as an area that may encourage the use of these products in horticulture.

Composted organic materials (COMs) have been shown to suppress certain soil-borne diseases. For example, oomycete pathogens such as *Pythium* and *Phytophthora* are more reliably suppressed than true fungal species such as *Fusarium*, *Rhizoctonia*, etc., which are common horticultural diseases. Developing consistent disease-suppressive compost would add to the value of that compost, and help growers reduce their costs through a reduction in pesticide application. With the advent of the Sustainable Use of Pesticides Directive (2009/128/EC), alternative ways of protecting plants from disease is becoming increasingly important. In order to understand how compost can be suppressive, it is important to understand the processes involved.

Composting process

Composting is the biological decomposition of organic matter under controlled conditions. In Ireland the main method of compost production is 'windrow' composting, where the material is heaped in long piles, usually three to four metres high. The composting process itself involves three stages of microbial breakdown of the material, which are defined based on the internal temperature profile of the compost heap. Briefly, they are termed: (1) the mesophilic stage (bacteria that grow best at moderate temperatures) where easily available nutrients (proteins, carbohydrates) present in the initial feedstock drive the metabolic degradation of organic matter and the accumulative respiration drives up the temperature, producing; (2) the thermophilic stage (bacteria that grow best at high temperatures), which completes the utilisation of easily available nutrients; and, then (3), the cooling stage where, after the nutrients are depleted, metabolic respiration decreases and temperatures decrease to approximately 30°C, allowing mesophilic species to once again re-colonise the compost. The disease-suppressive capabilities of compost are linked to the cooling stage, as these re-colonising species have been shown to be predominantly responsible for suppressing plant pathogens.

Mechanisms of suppression

The mechanisms of disease suppression by composted waste are due to both biotic (microbes) and abiotic (primarily ammonium concentration, pH, salt concentration) factors. The presence of these organisms limits the ability of plant pathogens to find a competitive niche. Many of these colonising species act similarly to plant pathogens by growing towards the exudates from plant roots. They colonise the root surface forming a commensal relationship with the plant and become a 'barrier' to pathogen colonisation required for infecting the plant root. The production of antifungal compounds (antibiosis) by these species inhibits the ability of plant pathogens to grow, as does mycoparastism by certain fungal species.

Consistency

There are, however, challenges to producing consistently disease-suppressive composts. The suppression is predominantly biotic and these suppressive species may not always colonise the entire compost pile. Also, the suppressive species may be a once off batch-related phenomenon and not a consistent property of the feedstock. Species of certain bacterial and fungal genera are known to be more potent at disease suppression than others, e.g., *Trichoderma* fungi. Where compost was found to be suppressive, a follow-up sample was obtained from the original composting facility. Only one compost displayed high levels of disease suppression from both the original and follow-up sample. Additionally, composting facilities do not always produce compost from the same waste streams, with organic waste coming from multiple sources and being mixed at

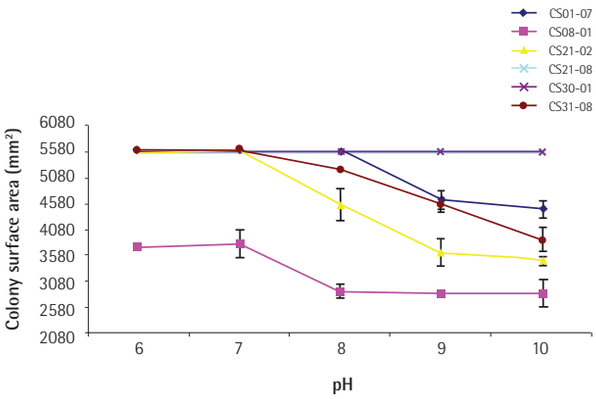


FIGURE 1: Effect of pH on mycelial growth of Trichoderma *isolates* in vitro.

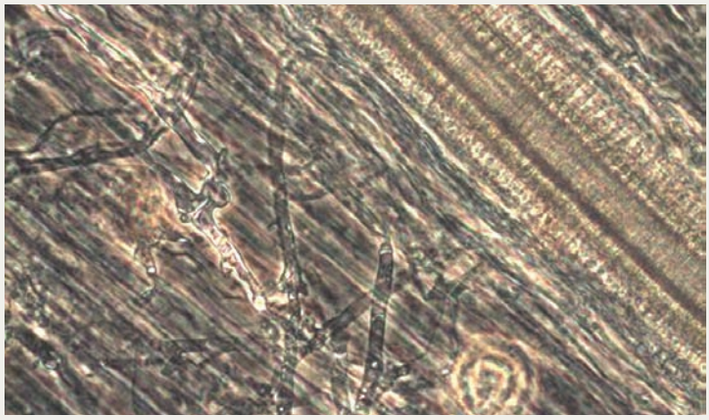


FIGURE 2: Disease suppressive Trichoderma spp. *isolated from compost growing on an onion root.*

different rates. Consistent suppression is crucial if growers are going to adopt and pay for these new products. Therefore, a change of strategy was required.

Compost screening

At the start of this project we investigated 15 commercially produced composted waste materials from Ireland and Europe. These materials came from a variety of feedstocks: greenwaste, household waste, catering waste, animal waste, etc. A high proportion of the composts were a mixture of at least two different feedstocks. These composts were tested for suppression against three different plant diseases. The effect of *Pythium ultimum* on Chinese Cabbage (*Brassicae rapa*), *Phytophthora erythroseptica* on tomato (*Solanum lycopersicum*) and *Fusarium oxysporum* on onion (*Allium cepa*) were investigated in terms of fresh weight when peat growing media was amended with 30% compost. For both the oomycete pathogens *P. ultimum* and *P. erythroseptica*, suppression was assessed based on the mean plant fresh weights; however, consistent suppressive results were obtained for only one compost. Suppression of the fungal species *F. oxysporum* was not observed as often as the oomycete pathogens. These trials indicated that, while there was some evidence that the addition of composted waste to growing media does reduce the symptoms of the diseases, disease suppression is variable. Composted waste materials that contained some amount of animal waste were more likely to display suppressive properties.

Engineering suppressive composts

A survey of the bacterial and fungal microflora present in the compost samples was undertaken to determine which culturable isolates were responsible for disease suppression. Results from these experiments identified that the most commonly occurring fungal species were from the genera *Aspergillus*, *Penicillium* and *Trichoderma*, and that these genera displayed the most potent and consistent suppression of plant diseases *in vitro*. The isolates of *Trichoderma* were selected for further study based on the lack of animal and plant pathogenic characteristics associated with species from this genus; also, a number of existing biocontrol agents are based on this fungus. We identified that the different *Trichoderma* isolates suppressed plant disease in different ways. Suppression was observed by the production of both diffusible and volatile compounds, mycoparasitism and niche competition.

The isolates were identified by sequencing the DNA between the 18S and 28S ribosomal subunits. *In vitro* tests to determine the ability of these isolates to withstand the composting process indicated that isolates displayed varying responses to pH, salt levels and temperature. Two isolates displayed unhindered mycelial growth at pH (**Figure 1**) and salt level extremes found in Irish COMs. One of these two isolates displayed the highest temperature tolerance (37°C) of all *Trichoderma* isolates studied. This isolate also displayed the highest production of potent diffusible antifungal compounds of all isolates studied and evidence was found indicating mycoparastic characteristics against all three aforementioned plant pathogens.

Benefits to the industry

Our work indicates that this isolate, identified as *Trichoderma harzianum*, possesses the most promising characteristics as a biocontrol agent for inoculating composted waste streams for engineering disease-suppressive composts. The high temperature tolerance allows this isolate to begin colonising the substrate before other mesophilic species become active. The combination of environmental tolerance and all round suppression against oomycete and fungal pathogens gives this isolate the necessary qualities required for colonising compost of various waste streams. If adopted, this will help to increase the use of composted waste in horticulture, decreasing the quantities of plant protection products and fertilisers needed.

This research was funded by the Environmental Protection Agency under the STRIVE programme and Teagasc core funding.

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Conor McGee (not pictured), Teagasc Walsh Fellow, based at Kinsealy Research Centre.
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Fungicide resistance in *Septoria tritici*

Researchers at the Teagasc Oak Park Crops Research Centre have been studying the sensitivity of the Irish *S. tritici* populations to the commonly applied fungicides with the aim of ensuring that any changes in the population sensitivity are detected and precautions are taken to reduce selection pressure for insensitive strains of the pathogen.

Septoria tritici *blotch (STB) on untreated leaves.*

The climate in Ireland is particularly suited to wheat growing and Irish wheat crops have the potential to achieve exceptionally high yields. Unfortunately, it is also this climate that hinders wheat crops from realising that potential. With wet and relatively warm weather during early summer, disease pressure experienced in Irish wheat crops is among the highest in Europe, if not the world. During this period the wet weather disease, *septoria tritici* blotch (STB) caused by the fungal pathogen *Septoria tritici* (or *Mycosphaerella graminicola*) becomes rampant. If left untreated, yield losses of over 50% can occur. With most commercial varieties having at most moderate levels of resistance to the disease, control has become reliant on the prophylactic use of fungicides. Most Irish wheat crops now receive three, if not four, foliar fungicide applications between mid-April and late-June. In all pathosystems the intensive use of fungicides invariably selects for strains of pathogens that are less sensitive or resistant to those fungicides applied and this has been the case with *S. tritici* in wheat crops.

Resistance development

There have been problems associated with fungicide resistance in plant diseases in Ireland and elsewhere since the introduction of the systemic site-specific fungicides in the mid-1970s. Due to their specific nature, these fungicides are more prone to the development of resistance than the older protectant-type fungicides. Single amino acid changes in the pathogen's protein target site can render such fungicides ineffective. While site-specific (often referred to as systemic) fungicides may be vulnerable to resistance development their specific activity is favoured as it can reduce their non-target toxicity, while increasing their potency towards the target pathogen. The introduction of systemic fungicides coincided with an intensification of cereal production in Ireland and has set yield standards.

Fungicide resistance arises through naturally occurring mutations or genetic changes in fungi that make them insensitive to the effects of fungicides. Resistant strains of fungi can initially exist at very low frequencies but multiply rapidly in response to selection pressure from continuous and intensive use of the fungicide to which they have become resistant. Researchers at the Teagasc Oak Park Crops Research Centre have been studying the sensitivity of the Irish *S. tritici* populations to the commonly applied fungicides with the aim of ensuring that any changes in the population sensitivity are detected and precautions are taken to reduce selection pressure for insensitive strains of the pathogen. To achieve these goals, commercial crops within the main wheat growing regions are sampled each year and the sensitivity of the subsequent isolates retrieved are tested. To date, sensitivity analysis has been performed on over 5,000 isolates, providing an exceptional dataset from which current and future changes in sensitivity can be detected.

Loss of the MBCs

The first group of systemic fungicides was the MBC (Methyl Benzimidazole Carbamates) group introduced in the 1970s and by the early 1980s they were being used widely on cereal crops in Ireland for disease control, including STB. By the mid 1980s *S. tritici* populations had become resistant to the MBC group of fungicides and there was complete resistance and not just a reduction in sensitivity. The single amino acid mutation (E198A) in the ß-tubulin protein of *S. tritici* conferred this resistance. Resistance can (depending on pathogen and mechanism) impose fitness penalties, which reduce the viability of resistant strains meaning that they disappear from pathogen populations in the absence of fungicide selection pressure. However, recent studies of *S. tritici* populations in Ireland have shown that very high levels of MBC resistance still exist. This is despite the fact that MBC products have not been used on wheat crops for close to two decades.

Crash of the QoIs

The next major group of fungicides to succumb to *S. tritici's* ability to adapt were the QoIs (Quinone outside Inhibitor or strobilurin-type fungicides). Introduced in the late 1990s, their inclusion in control programmes resulted in enhanced disease

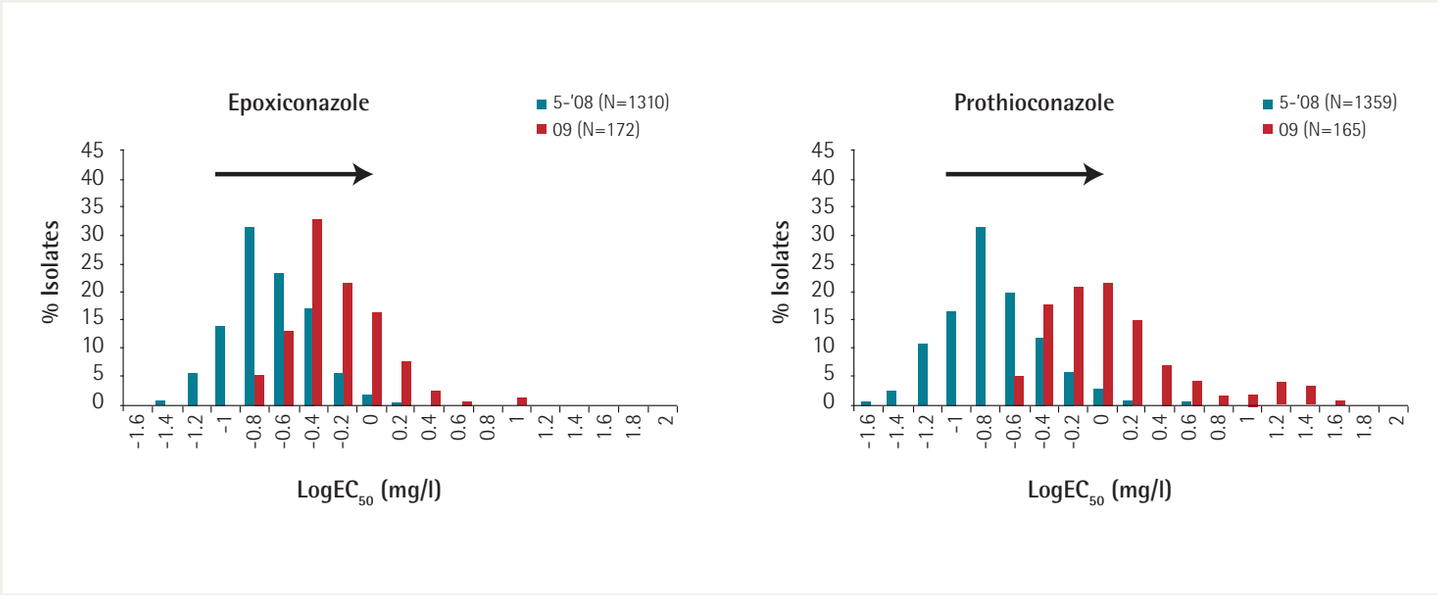

Figure 1. Shift in sensitivity of the Irish S. tritici *population to epoxiconazole and prothioconazole during 2009.*

control. The yields achieved following their usage set new standards in wheat production. During the summer of 2002 poor disease control was observed in some crops where QoI fungicides had been applied. Following isolation and sensitivity analysis, resistance to the QoIs was confirmed in the Irish *S. tritici* population. The speed at which resistance spread throughout the Irish population was unexpected. By the end of the 2003 season, *S. tritici* populations in all crops sampled were overwhelmingly dominated by QoI resistance strains and the QoIs could no longer be relied upon for STB control. Similarly to MBC resistance, the mutation that confers QoI resistance (G143A in the mitochondrial gene cytochrome *b*) has been maintained in the population at extremely high levels despite limited usage of the QoI fungicides on Irish wheat crops since 2003.

Concern for the triazoles!

Since the demise of both the MBCs and QoIs reliance has been placed upon the triazole fungicides to control STB and maintain our high wheat yields. Helped by the introduction of new triazole products with improved intrinsic activity against the fungus over the years, triazole fungicides have been the cornerstone of fungicide disease-control programmes. They have not avoided resistance development and it comes as no surprise that the first major instances of changes in triazole sensitivity detected coincided with their increased usage following the decline in QoI use. Unexpectedly, unlike either the MBCs or QoIs, and contrary to common belief, changes in sensitivity to one have not always been mirrored by changes in the other triazoles. In 2004 changes in sensitivity were first observed to metconazole and tebuconazole, with either chemical rapidly selecting strains of the pathogen less sensitive to both chemicals. This shift in sensitivity – resulting from the CYP51 mutation I381V – had no effect on the most effective and commonly used triazoles: epoxiconazole and prothioconazole. In 2009, shifts in the sensitivity to epoxiconazole and prothioconazole were detected (**Figure 1**). In a reversal of the shift that occurred in 2004, these isolates were sensitive to metconazole and tebuconazole. With such contrasting sensitivities it has been possible to devise anti-resistance strategies. While such strategies are unlikely to prevent the selection of less sensitive strains, they can minimise selection, maintain disease control and hopefully prolong the effectiveness of the fungicides.

Future disease control strategies

After five years of relative stability in terms of *S. tritici's* sensitivity to fungicides, the shift in sensitivity to epoxiconazole and prothioconazole in 2009 again highlighted the vulnerability of wheat production in Ireland. In the absence of host resistance the reliance on fungicides to achieve profitable wheat yields will continue. The expected introductions of new fungicides belonging to the SDHI (succinate dehydrogenase inhibitors) group in the coming years will help. As these are single-site inhibitors the risk of resistance development is high and therefore sensitivity monitoring is essential.

This research was funded by the Teagasc core programme.

Dr Steven Kildea is a postdoctoral researcher in molecular plant pathology and **Dr Eugene O'Sullivan** a plant pathologist (now retired) at Teagasc Oak Park Crops Research Centre.
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Unravelling the mystery of bioactives

DILIP RAI explains how mass spectrometry is being used as a tool to unravel the chemical structures of bioactive molecules at Teagasc Food Research Centre.

Humans have looked to flora and fauna as a remedy for many ailments. As science has progressed, the active components from natural products have been structurally characterised and their biological effects quantified. For example, bioactive compounds are widely known to have antioxidant, anti-inflammatory, and antimicrobial properties among a host of other activities that are beneficial to health. The use of natural products (herbs, spices, honey, etc.) that contain bioactive components as home remedies is still in practice despite the advent of synthetic drugs on the global market. Driven by availability, cost and tradition, the usage of natural products is more widespread in under-developed regions than in the developed nations. However, the advent of the concept of functional foods (foods with a health benefit beyond their nutritional value) has placed renewed focus on mining bioactives from natural sources, and on establishing the underlying rationale for their health-promoting effects.

Bioactive diversity

Bioactive molecules can be divided broadly into four categories: 1) sugars; 2) peptides; 3) lipids; and, 4) small organic molecules or metabolites. Many derivatives of these categories – brought about for example by conjugation of sugars to peptides (glycopeptides), lipids (glycolipids) and metabolites (e.g., glycoalkoloids) – can occur and can be biologically active. The diverse chemical nature of the bioactives, compounded by varying degrees of concentrations in foods, poses a unique analytical challenge for their detection and identification.

EU regulation

New European Union regulations (EC) No 1924/2006 on health claims in food require stringent clinical data to support health claims associated with a particular bioactive compound. To associate a health claim property with a particular bioactive compound, the following is required:

- isolation of the component in a purified form;
- in-depth characterisation of its chemical structure;
- chemical synthesis of the natural compound; and,
- development of dose-response curves linking concentration to biological activity.

This article will focus on structural elucidation of food and plant metabolites that have health-beneficial properties.

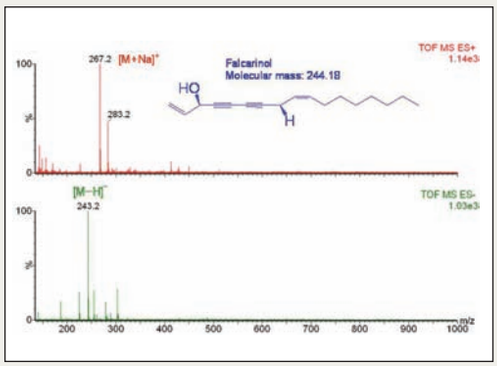
Analytical techniques

Many analytical methods have been applied to detect and identify bioactive molecules in natural products. Traditionally, techniques such as thin-layer chromatography (TLC), capillary electrophoresis (CE), gas chromatography (GC), high performance liquid chromatography (HPLC), and ultraviolet-visible (UV-Vis) spectrophotometry are the most commonly used tools. These methods, on their own, lack specificity and sensitivity and rely on the chemical nature of the analytes (chromophore, i.e., chemical group capable of selective light absorption resulting in the colouration of certain organic compounds), and the environment that surrounds the bioactives. For example, plant/biological matrices often interfere in UV-dependent assays such as TLC, CE and

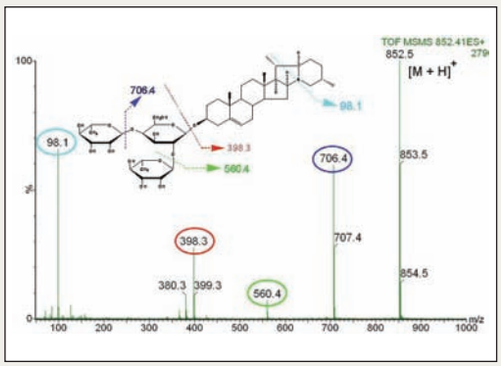
Table 1: Bioactive compounds identified using advanced analytical techniques at Teagasc Food Research Centre.

Source	Bioactive components	Bioactivity/function	Analytical techniques
Carrots and parsnips	Polyacetylene: falcarinol and falcarindiol	Anti-bacterial, anti-inflammatory, anti-platelet aggregatory	– LC-MS – LC-MS/MS – NMR
Potato peel	Glyco-alkaloids: solanine and chaconine	Anti-carcinogenic	– LC-MS – LC-MS/MS
Bacillus sp. CS93 isolated from Pozol (Mexican non-alcoholic beverage)	Lipopeptides: iturins, surfactins and fengycins	Anti-microbial	– LC-MS – LC-MS/MS
Herbs and spices	Polyphenols: approximately 40 different types	Antioxidant, anti-microbial	– LC-MS – LC-MS/MS

Polyacetylene: MS spectral data on positive (top) and negative (bottom) ionisation mode.



Glycoalkaloid: Tandem mass spectrometry (MS/MS) on alpha-chaconine showing the dominant fragment ions.



Lipopeptides: Assignment of lipopeptides detected by LC-MS.

$[M-H]^-$ ion	Assignment	Amino acid at position 6/7
1006.7	C_{13} surfactin	Leu7
1020.7	C_{14} surfactin	Leu7
1034.7	C_{15} surfactin	Leu7
1447.8	C_{15} fengycin	Ala6
1461.8	C_{16} fengycin	Ala6
1475.9	C_{17} fengycin	Ala6
1489.9	C_{16} fengycin	Val6
1503.9	C_{17} fengycin	Val6

FIGURE 1: Mass spectral data and detailed structural information for some of the bioactive compounds using mass spectrometry techniques.

HPLC. Furthermore, quantification using these methods requires reference materials that are not available for all forms of bioactive compounds. GC-mass spectrometry, although sensitive and specific, is laborious, as it requires an additional sample preparatory step (chemical derivatisation) where the non-volatile analytes are made amenable to GC. Thus, there is growing interest in developing novel rapid analytical methods for detection of bioactives in natural plant or biological matrices. With the advancement of mass spectrometry and nuclear magnetic resonance (NMR) spectroscopy, it is now possible to detect and confidently identify many known and unknown bioactive compounds. These modern analytical instruments can be coupled to separation techniques such as HPLC, CE or TLC, thus allowing the investigation of complex mixtures. Mass spectrometry data reveals the elemental composition of the unknowns and their fragments, while the NMR spectroscopy can unveil the conformation of the molecular structure. Under the direction of Dr Dilip Rai at the Food Biosciences Department in Teagasc Food Research Centre, new analytical techniques, including nano-LC mass spectrometry and an LC-NMR spectroscopy, are being pioneered to provide detailed structural information on a diverse range of bioactive components from many sources.

Progress to date

To date, studies have concentrated on the use of mass spectrometric and NMR spectroscopic for the characterisation of bioactive compounds such as polyacetylenes and polyphenols, extracted from vegetables, herbs and spices (**Table 1**). Some of the polyacetylenes have shown anti-bacterial, anti-inflammatory and anti-thrombotic activities, while the polyphenols are known for their strong antioxidant properties. For example, identification of the main bioactive polyacetylenes in carrots and parsnips and 40 different types of polyphenols in herbs (only 20 had in-house standard references) has been achieved. In addition, mass spectrometry has proved to be a valuable tool for revealing some of the degradation products of polyacetylenes in parsnips following different thermal treatments. In a separate study on potato peel extracts using mass spectrometry, alpha-solanine and alpha-chaconine, which are potent anti-cancer glycoalkaloids, have been identified. Likewise, anti-microbial lipopeptides produced by *Bacillus* sp. strain CS93 isolated from a Mexican non-alcoholic beverage have been mapped by the mass spectrometric techniques (**Figure 1**). The bioactive lipopeptides-producing *Bacillus* strains can be harvested from dairy waste or from other fermentation waste in Ireland, so these results will be of interest to dairy and beverage industries. It is also worth mentioning that the standard reference materials for the glycoalkaloids and lipopeptides are not readily available – mass spectrometry is the best way of elucidating their structural identities.

Benefits to industry

Mass spectrometry and NMR spectroscopy are essential to elucidate the chemical structures of bioactive molecules and thereby adhere to European food safety guidelines on health claims. This will provide food industries in Ireland with a leading platform in the development and production of functional foods.

This research is funded by the Department of Agriculture, Fisheries and Food under the Food Institutional Research Measure. The author would like to thank Dr Nigel Brunton and his research team for providing the samples.

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From bugs to drugs: combating hospital-acquired infections

A peptide effective against *Clostridium difficile*, a bacterium that causes a range of diseases from self-limiting diarrhoea to life-threatening pseudomembranous colitis when normal gastrointestinal tract bacteria are wiped out by antibiotics, has been discovered by researchers from Teagasc and UCC.

The Science Foundation Ireland-funded Alimentary Pharmabiotic Centre (APC) was established in 2003 and is based in University College Cork (UCC) and Teagasc Food Research Centre (TFRC). The aim of the Centre is to carry out research to increase our understanding of the complex environment of the human gastrointestinal tract (GIT), or gut, and its microbial community. The research carried out in TFRC as part of the APC involves mining the flora of the GIT for bacteria that produce bacteriocins (peptides produced by many bacteria that kill other bacteria) that are active against pathogens for both food and biomedical uses.

We were particularly interested in finding compounds active against *Clostridium difficile*, sometimes called *C. diff* for short, which is the causative agent of one of the Western world's most rapidly increasing hospital-acquired illnesses, and is currently estimated to cost in excess of €3 billion per annum within the EU.

C. difficile

Antibiotics have revolutionised the treatment of infections since the middle of the last century and are one of the most important factors in the extended life expectancy of modern humans. However, antibiotics may also play a role in initiating infections, such as *Clostridium difficile*-associated diarrhoea (CDAD). *C. difficile* infections arise following antibiotic treatment as a direct result of disturbing the GIT bacteria, with the eradication of some beneficial GIT flora. Current treatment options for CDAD are limited to two broad-spectrum antibiotics, namely vancomycin and metronidazole, which are not only expensive but frequently result in considerable treatment failures and relapses of infection. While CDAD is more likely to be acquired within a hospital setting, cases of community-derived infection have also been reported. The elderly, and those with a compromised immune system, are most at risk. The appearance worldwide (including in Ireland) of a more virulent strain of *C. difficile* (PCR ribotype 027/NAP-1) poses additional problems for healthcare providers.

Isolation and characterisation of thuricin CD

We have previously shown that a broad-spectrum bacteriocin, lacticin 3147, is effective in eliminating *C. difficile* in a model faecal environment, but also established that there was an associated negative impact on populations of beneficial bacteria including *Lactobacillus* and *Bifidobacterium* (Rea *et al.*, 2007). Therefore, we concentrated our efforts on isolating strains from the human GIT that would specifically kill *C. difficile*. These strains might act as probiotics (live bacteria that are beneficial to the host) for elimination of the pathogen *C. difficile* and, because they specifically kill the pathogen, the impact on the beneficial flora of the GIT would be minimised. The trick here was to look at the spore-forming bacterial populations in the GIT on the basis that a sporeformer would produce a narrow-spectrum antimicrobial against another sporeformer. Screening 30,000 spore-forming bacteria from the human GIT for bacteriocin producers resulted in the identification of a strain of *Bacillus thuringiensis*, DPC 6431, which produces a novel two-component narrow-spectrum bacteriocin with potent anti-*C. difficile* properties, which we have named thuricin CD (**Figure 1**). The research on the isolation and genetic and chemical characterisation of thuricin CD and its efficacy as a therapeutic against *C. difficile* has recently been published as two papers in the *Proceedings of the National Academy of Sciences of the USA*. Thuricin CD was shown to inhibit all strains of *C. difficile* tested – including those strains most commonly associated with CDAD in Ireland. We have determined that thuricin CD has a narrow spectrum of activity, i.e., only inhibits closely related bacteria, and is active at low concentrations and through a wide range of pH and temperatures. The amino acid composition was determined using genetic and chemical sequencing methods.

Subsequently, the Irish team has collaborated with the expert group of Professor John Vederas at the University of Alberta, Canada, to determine a high-resolution structure for the bacteriocin. This shows that the bacteriocin contains highly unusual cysteine sulphur to alpha-carbon cross bridges, which undoubtedly contribute to the uniqueness of these potent peptides. Subsequently, using tandem mass spectrometry and solution nuclear magnetic resonance (NMR) studies, we have determined that thuricin CD contains unique post-translational modifications that are unprecedented among two-peptide bacteriocin systems (Rea *et al.*, 2010a).

Thuricin CD *vs.* conventional antibiotics

Using a laboratory model of the human colon we have shown that thuricin CD compares favourably in terms of controlling *C. difficile* numbers with the currently prescribed antibiotics for treatment of CDAD. Using the sophisticated molecular technique of high-throughput pyrosequencing (this technique is now available as a service in MFRC through the recent purchase of a 454 Sequencer), we demonstrated that thuricin causes very little collateral damage to the other flora in the GIT, unlike vancomycin or metronidazole, which were shown to cause a massive proportional shift of the population of bacteria in the GIT away from those that are considered to be beneficial to GIT health (**Figure 2**). The respective proportions of the three major phyla (groups of bacteria) were altered dramatically with respect to each other, with a large reduction in the major groups of bacteria considered to be beneficial for a healthy GIT (Firmicutes and Bacteroidetes) and a

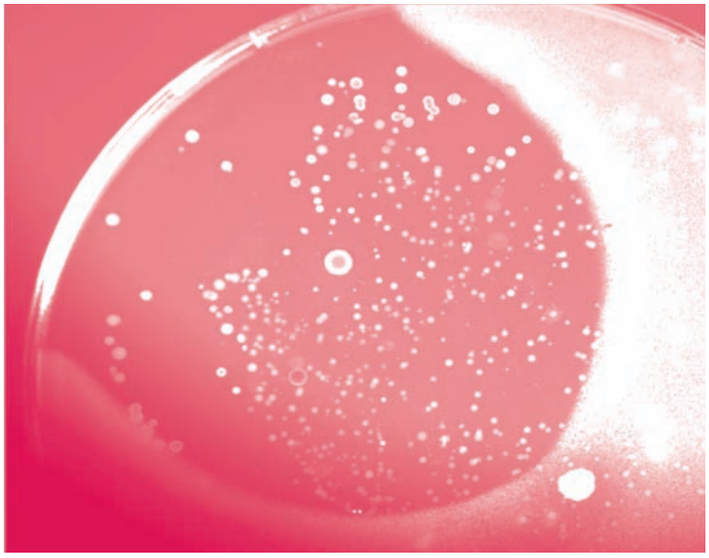

FIGURE 1: The colony of the thuricin-producing strain B. thuringiensis *DPC 6431 on the initial isolation plate showing inhibition in the seeded overlay of* C. difficile *ATCC 43593. The colonies that can be seen growing in close proximity to the producing strain are not inhibited by thuricin, which has been excreted into the agar during growth.*

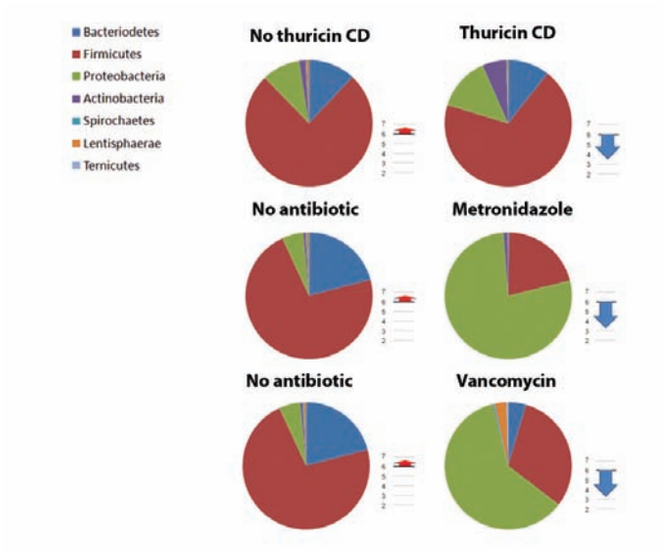

FIGURE 2: Changes in phylum level biodiversity of GIT communities in a model of the distal colon showing the shift from Firmicutes (red) to Proteobacteria (green) when treated with the antibiotics metronidazole and vancomycin, while no significant change was observed when treated with thuricin CD. Red arrows indicate the log increase in cell numbers of C. difficile *in the absence of any antibiotic and blue arrows the log decrease in cell numbers of* C. difficile *in the presence of thuricin, metronidazole and vancomycin.*

dramatic increase in the Proteobacteria, which are not normally found in such abundance in the GIT in the absence of antibiotics. While narrow-spectrum activity is one of the key desirable features in novel anti-*C. difficile* antimicrobials, the fact that thuricin CD also exhibited potency that is comparable to that of its broad-spectrum equivalents makes it a plausible alternative to conventional antibiotic therapies (Rea *et al.*, 2010b).

Thuricin CD as a probiotic

Interestingly, there is now much interest in the use of probiotics to limit CDAD in the hope that perturbations in the GIT flora caused by antibiotics would be offset by the subsequent introduction of a live probiotic strain that could out compete pathogenic bacteria such as *C. difficile*, and it has been shown that the consumption of a probiotic drink was effective in reducing antibiotic-associated diarrhoea in elderly hospital inpatients (Hickson *et al.*, 2007). We have shown that thuricin CD at concentrations sufficient to kill *C. difficile* does not inhibit the probiotic cultures found in commercial probiotic yoghurt or dairy-based probiotic drinks. In this respect, thuricin CD may have potential as a combination therapy, together with probiotic preparations, to protect vulnerable patients from developing antibiotic-associated diarrhoea.

The UCC/Teagasc team has patented this work and has already licensed it to the Cork-based biotechnology company Alimentary Health Ltd with a view to its commercialisation.

This research was supported by the Science Foundation Ireland-funded Centre for Science, Engineering and Technology, the Alimentary Pharmabiotic Centre (APC).

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Listeria monocytogenes – here to stay?

KIERAN JORDAN and EDWARD FOX outline what strides have been made in reducing *Listeria monocytogenes* in the dairy food chain.

Listeria monocytogenes is a bacterium that is the causative agent of listeriosis and is one of the most virulent foodborne pathogens. Listeriosis is most often associated with ready-to-eat, refrigerated and processed foods, such as pre-prepared cooked and chilled meals, soft cheeses, cold cuts of meat, pâtés and smoked fish. Infection in healthy adults usually produces no symptoms, or a mild flu-like illness. However, in certain people, including pregnant women and their unborn babies, people with weakened immune systems and elderly people, it can cause very severe illness or even death.

In the 1980s, *L. monocytogenes* was identified as a foodborne human pathogen. Since then a vast amount of research has been undertaken to understand its physiology, epidemiology and pathogenicity. *L. monocytogenes* is still high on the list of pathogens causing foodborne illness. When such efforts have yielded a great amount of knowledge, with limited success in reduction of listeriosis, is *L. monocytogenes* here to stay?

As a result of the research effort over the last number of years, knowledge of *L. monocytogenes* has increased. For example, it is known that:

- *L. monocytogenes* causes listeriosis and is widespread in the environment. In a survey of Irish dairy farms, Fox *et al.* (2009) found that on average 19% of samples (farm water, straw, faeces, silage, etc.) were positive for *L. monocytogenes*;
- there is increased occurrence of listeriosis across Europe (Goulet *et al.*, 2008);
- there is a susceptible population of young, old, the immunocompromised, pregnant women and their unborn babies. For this population, the infectious dose could be as low as 100 cells/g;
- healthy adults are generally not at risk of infection with *L. monocytogenes*;
- it can grow at refrigeration temperatures and on many foods; and,
- certain strains are persistent in the environment (see later).

However, there are certain aspects of *L. monocytogenes* that are not understood:

- the pathogenicity factors of *L. monocytogenes* are not fully understood;
- the physiological/genetic factors that enable persistence of certain strains are unknown. Biofilm formation (aggregate of microorganisms in which cells adhere to each other and/or to a surface), resistance to sanitisers, or other stress response mechanisms, such as synthesising proteins to aid survival of the organism, have all been proposed to play a role in persistence; and,
- in cases where there is persistence, finding the source of *L. monocytogenes* contamination can be challenging.

In certain people, including unborn babies, people with weakened immune systems and elderly people, listeriosis can cause very severe illness, or even death.

Research at Teagasc Food Research Centre

In recent years, research at Teagasc Food Research Centre (TFRC), has focused on attempts to understand and control *L. monocytogenes*. The areas of work include epidemiology in the processing environment, predictive microbiology, establishing a strain database, persistence, and assistance with the development of a hazard analysis critical control point (HACCP) workbook.

Epidemiology

Pulsed field gel electrophoresis (PFGE), using the enzymes *Apa*I and/or *Asc*I to digest the DNA, is an ideal method for obtaining a 'fingerprint' of individual strains (**Figure 1**). This enables strain comparisons of isolates from different places in order to determine strain similarities. In this way, it is possible to determine if strains isolated from different sources at different times are similar. If they are, this indicates a single contamination event; if not, it indicates possible multiple contamination events. The same strain isolated over a period of several months indicates a persistent strain. In an extensive sampling exercise over a three-year period, strains of *L. monocytogenes* have been isolated from food processing environments. When analysed by PFGE, 50 different strains (unique banding pattern on gel electrophoresis or pulsotypes) were identified. None of the pulsotypes were found at more than one site, implying that each facility has its own individual strains. Four of the pulsotypes were persistent – one of these, with three strains isolated at different times, is shown in Figure 1. Such a sampling programme is very important in identifying and pre-empting problems before they become serious. With this knowledge, cleaning regimes can be targeted, work flows can be adapted or a different approach can be undertaken if there are persistent strains.

Hazard analysis critical control point workbook

Keeping in mind that *L. monocytogenes* is widespread in the environment and can survive harsh conditions, the approach of learning to control it is important. Driven by the Food Safety Authority of Ireland (FSAI), in association with TFRC, the Department of Agriculture, Fisheries and Food (DAFF) and the Irish Farmhouse Cheesemakers Association, a HACCP workbook has been developed for farmhouse cheese processors. This is a proactive approach, which encourages monitoring and record keeping as core activities, with the aim of controlling not only *L. monocytogenes*, but other hygiene issues also.

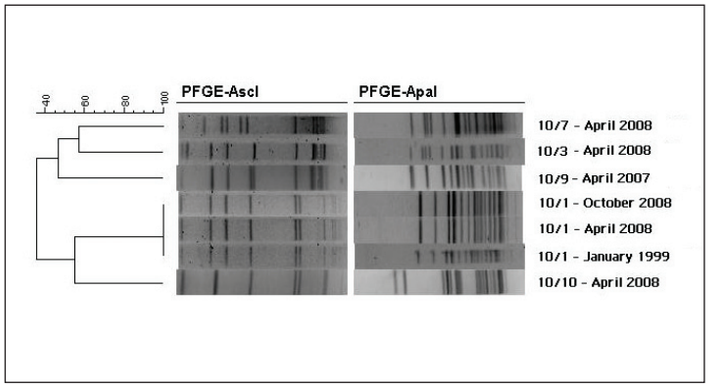

FIGURE 1: PFGE pulsotypes, using the enzymes Apa*I and* Asc*I, from strains isolated from a processing facility. This includes a persistent isolate pulsotype (with eight years between isolations), 10/1, isolated from different sample types at the facility.*

Predictive microbiology

Predictive microbiology relies upon the development of mathematical models that can predict the rate of growth or decline of microorganisms under a given set of environmental conditions, as well as the probability of growth given certain conditions. In that case, growth can be predicted by measuring the environmental conditions, rather than the *L. monocytogenes* itself. This is a more long-term approach of attempting to understand the growth of *L. monocytogenes* and the factors that affect it. At TFRC, we have studied the development of mathematical models for growth of *L. monocytogenes* in food and the probability of growth of *L. monocytogenes* under different conditions, for example, at different water activity values (Schvartzman *et al.*, 2010) (bacterial growth is inhibited at specific water activity values).

Database development

As part of an ongoing project funded by the DAFF's Food Institutional Research Measure (FIRM), TFRC has established a database of PFGE profiles of *L. monocytogenes* strains. Among other things, this will help to establish if there are common strains occurring in different food chains, if there is a link between clinical strains and food strains and help identify where persistent isolates exist.

Persistence

A food processing facility environment with a persistent strain of *L. monocytogenes* has an increased risk of the food becoming contaminated. The short-term approach to this is to increase vigilance and attempt to eliminate the contamination. A more long-term approach is to attempt to understand the reasons for persistence and, therefore, be able to control it. At TFRC we are involved in a project that is studying persistence in a complete systems biology approach. This involves genetics, analysis of the transcription of genes, identification of proteins formed and bioinformatic analysis of the data. It is hoped that comparison of a persistent strain with a non-persistent strain will yield interesting results on the genetic basis of persistence.

Regulations regarding *L. monocytogenes*

In the EU, there are specific regulations relating to *L. monocytogenes* in food. These are set out in EU Regulation 2073:2005 (as amended by EU Regulation 1441/2007 and Regulation 365/2010), and place specific responsibility on the food business operator. In general, absence in 5 x 25g samples of food is required while the food is at the manufacturing premises. In certain foods able to support growth of *L. monocytogenes*, manufacturers must have sufficient controls in place to ensure that the concentration of *L. monocytogenes* remains below 100 cells/g throughout its shelf life. If *L. monocytogenes* is detected in such products, they must be withdrawn from sale unless the manufacturer has evidence (i.e., shelf life studies) to show that the 100 cells/g limit will not be exceeded before the end of the shelf life. In Ireland, the regulations are monitored by the DAFF on behalf of the FSAI.

New *Listeria* network

L. monocytogenes will probably remain high on the list of foodborne pathogens in the coming years. In order to create awareness and facilitate knowledge transfer concerning *L. monocytogenes*, ***safe***food has established a *Listeria* network, for which Dr Kieran Jordan, TFRC, will be the network facilitator. The purpose of the network is to bring together everybody that is interested in *L. monocytogenes* – industry, regulators, public health professionals and researchers. Collaboration, communication, awareness and sharing of ideas across the island of Ireland will be the focus of the network's activities. Network activities will be launched in the coming months.

Improving food safety

Although widespread in the environment, good hygiene, monitoring and attention to detail in planning, access and work flows of processing facilities can prevent contamination of food with *L. monocytogenes* and improve food safety. Vulnerable groups need to be aware of the risks of *L. monocytogenes* and take appropriate steps (http://www.safefood.eu/en/Publication/Consumer-Information/).

This work was supported by the Department of Agriculture, Fisheries and Food's Food Institutional Research Measure and by the EU 6th Framework project BIOTRACER (www.biotracer.org).

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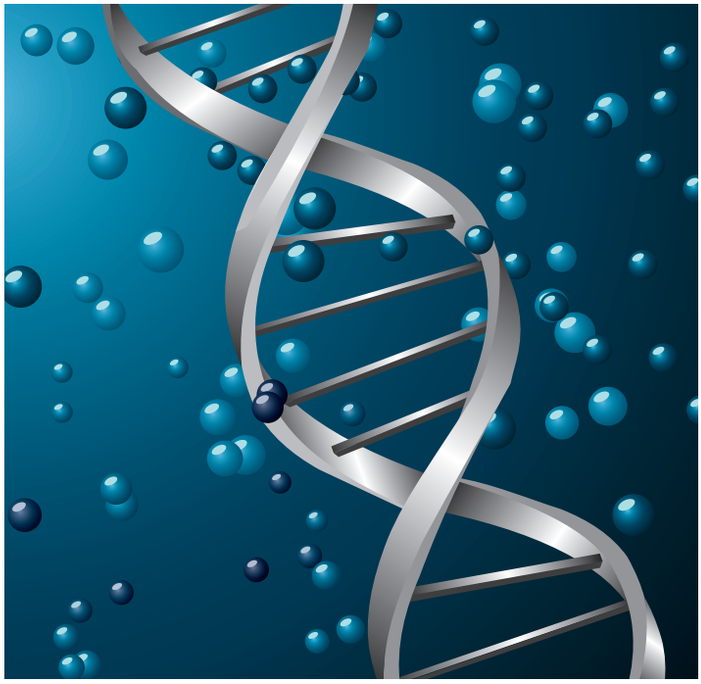
Novel animal biotechnologies: a quandary for Irish agri-food stakeholders



Following the approval and commercialisation of somatic cell cloning in the USA, researchers at Teagasc, DIT and UCC take a timely look at Irish agri-food stakeholders' views on the topic of animal cloning.

Technological innovations are sought by governments as engines of economic growth, but the implications for citizens and other stakeholders must also be considered. Technological innovation, in the area of biotechnology in particular, will often have ethical, legal or social implications that need to be tackled. Effective risk management that addresses such issues is central to enabling technological breakthroughs, as well as minimising the uncertainty associated with their commercial development. In recent times, Europe has sought to increase public confidence in new technologies in the agri-food system through increasing both the transparency of risk analysis and the level of stakeholder participation. Identification of key stakeholders is critical to the debate. In this article, we describe the results of a series of in-depth interviews conducted with expert Irish stakeholders that aimed to frame the likely policy debate and assess the prospects for the future commercialisation of animal cloning.

Advances in biotechnology

As biotechnology advances, there will be more technology available to animal breeding experts. For example, the human genome project allowed for the rapid identification of genes and DNA sequences; this technology was subsequently adopted by the animal breeding industry to select desirable animals for breeding purposes. Modern breeding techniques that incorporate biotechnology look to improve performance in relation to disease control, infertility, efficiency of feed conversion, or food quality assurance, but no breeding technique thus far had produced genetic copies of proven animals. However, this looks set to change with the Food and Drug Administration (FDA) approval, and recent commercialisation, of somatic cell cloning (i.e., mature cell cloning) in the United States of America (USA) (FDA, 2008). Although economic estimations as to the value of animal cloning to the agri-food sector are limited, it has been suggested that the current cost of the cloning procedure may be offset through cloning animals possessing particularly high breeding values (Wall *et al.*, 2009).

European position

Cloned animals intended for use within the agri-food system do not have approval in Europe, and how the technology will be legislated is currently under discussion. The European Food Safety Authority (EFSA) deems that food products from healthy clones do not present any additional risk to consumers, but the European Group for Ethics (EGE) has objected to the use of cloning because of the current animal welfare implications, including the low survival rate for cloned animals, and the potential for welfare problems with the surrogate dams. The acceptability of these welfare standards from a European Union (EU) perspective can be linked to their utility; for example, the European Medicines Agency approved the production of human anti-thrombin from cloned transgenic animals in 2006 (the protein produced treats a hereditary anti-thrombin deficiency that increases the risk of pulmonary embolisms or deep vein thrombosis). However, the views of European citizens and consumers must also be factored into the risk process. Early indications from the European public are that they are wary of the technology and that it poses an ethical dilemma (Eurobarometer, 2008). This research provides an opportunity to examine animal cloning in terms of barriers and opportunities, specifically pertaining to its potential role within the Irish agri-food system.

Methodology

As part of a larger project with Teagasc Food Research Centre, the Dublin Institute of Technology and University College Cork, a series of semi-structured in-depth interviews was used to explore the views of stakeholders in relation to animal cloning. The stakeholders interviewed all occupied senior positions in their organisations, with high potential to be influential in an emerging national debate on cloning. Interviewees came from the public and private sectors including universities and research institutions, semi-state organisations and non-government organisations (NGOs), food companies (processing and retail) and, on one occasion, a religious organisation. They included those likely to be positively disposed to the technology (e.g., animal reproduction scientist, venture capitalist in

biotechnology), as well as those likely to be negatively disposed to the technology (e.g., organic farming representative, animal welfare specialist). The subject of animal cloning was contextualised during interviews against a general background of an evolving food biotechnology sector, and the relevance of this to the Irish agri-food system. Analysis of the recorded and transcribed interviews was facilitated with NVivo8 (QSR International) software. Interviewees (n = 19) were primarily identified through a proprietary contacts database and were interviewed between October 2009 and March 2010.

Results

Overall, animal cloning for food purposes was not viewed as a likely commercial prospect by any of the interviewees. Awareness of the recent commercial development of such technology in the US appeared to be low, with only a single interviewee identifying it as an impending regulatory dilemma for the EU. Knowledge about the role of assisted reproductive technologies (ARTs) in animal breeding varied, with artificial insemination (AI) being the primary reference point for most interviewees. Respondents with a technology background, and who demonstrated knowledge of ARTs, differed in opinion on the commercial viability of techniques such as embryo transfer/splitting. This cohort was quick to differentiate cloning from other reproductive techniques, a trend that was not repeated among other stakeholders. The main reason for the differentiation was that cloning was not seen to assist reproduction, but instead to supersede the fertilisation process and be more closely aligned to a sort of genetic modification process (though no genetic modification actually occurs).

Potential benefits

Among those interviewees who could envisage a role for cloning in the food sector, a number of key factors were identified as being of critical importance in deciding its commercial future. The market performance of the technology in the USA, the required scale of operation, the feasibility of integration into existing farm practices, and resolution of any outstanding questions relating to food safety were specifically mentioned. Representatives from the meat processing and retail sectors hypothesised a possible role for cloning in delivering consumer-driven consistency in meat quality. The potential of harnessing the technology to reduce antibiotic use was also cited. Respondents almost uniformly predicted a negative response among the public to the use of cloned animals for food purposes. Some felt that consumer education could be a positive factor in gaining public confidence; however, several interviewees mentioned associations with human cloning, popular science fiction imagery and concerns revolving around food safety as negative factors. Furthermore, knowledge of animal welfare implications was expressed by specialists in the area as negatively influencing public acceptance.

Ethics

The ethical aspects of cloning animals for agricultural purposes produced divergent responses from stakeholders. Half of the stakeholders mentioned that animal welfare was of primary ethical concern. In one instance, a publicly funded scientist thought cloning was not unethical for welfare reasons, but unethical as it represents a poor return on investment. This view was contrasted with another publicly funded scientist who believed that the poor welfare record of cloning should be factored against its use. One stakeholder suggested that cloning was tantamount to tinkering with nature and would not entertain the idea, while another suggested that the 'hit and miss' and invasive nature of cloning should prohibit its use in the food industry. An organic farming stakeholder had principle-based arguments against cloning and the treatment of animals, with natural processes and the environment being paramount. A beef industry representative believed that profitability should outweigh ethics in making a strategically prudent decision. Representatives from the breeding, farming and public funding sectors echoed these views. The issue of social justice was mentioned by an organic farming representative, who suggested that the cost may make it prohibitive to small farmers; they also suggested that the long-term effects of cloning were unknown and there might be a detrimental effect on the environment. An ethics adviser to the Government questioned the utility of the technology for the production of food. They suggested that the benefit of cloning to consumers and the food industry was not known.

Impact on industry and future work

The views of Irish stakeholders in the discourse on animal cloning for the agri-food sector are of particular interest because, unlike the GM debate in relation to crops, Ireland is a significant producer and exporter of meat and livestock. For this reason the exploitation of cloning in other trading blocs looks set to pose a challenge for Irish and EU policy makers, industry and citizens. The data from the in-depth interviews highlighted that, as yet, there has been little debate on the topic, and the commercialisation of cloning elsewhere has gained little attention. Regardless of when the debate does occur, the animal welfare and consumer acceptability perspectives are likely to have a central role in how the technology is regulated. Further research in this project will focus on examining Irish citizens' perspectives on cloning technology and the issues raised by the expert stakeholders in this paper.

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This work has been supported by a grant from the Technological Sector Research, Strand 1 R&D Skills Programme and the Teagasc Walsh Fellowship Scheme.

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Lamb castration and meat quality

SEAMUS HANRAHAN asks if leaving male lambs entire has an effect on meat quality.

Image courtesy of Bord Bia.

The peak slaughter period for Irish lamb is from May to November and the majority (70%) are slaughtered before the end of the grazing season. Some processors, producer groups and marketeers have expressed concern that leaving male lambs entire undermines the market for lamb because consumers find the eating quality of meat from entire male lambs unsatisfactory. This view hinders the adoption of a well established efficiency that can benefit producers – male lambs left entire grow significantly faster than castrates. Furthermore, meat from entire male lambs has less fat, and thus represents better value for consumers. Since price is a major factor in the purchasing decisions of consumers, and lamb must compete on price with the ongoing efficiency gains in the white meat sector, producers of lamb must exploit every efficiency opportunity to maximise returns, provided product quality is not compromised. My objective in this article is to outline the scientific evidence on the implications, for meat quality and consumer satisfaction, of not castrating male lambs.

Castration and lamb performance

A study undertaken in Teagasc (Hanrahan, 1999) provides a concise summary of the effect of castration on performance and carcass quality. The key results **(Table 1)** show that entire males were significantly heavier at weaning and ready for slaughter 16 days earlier than castrated litter mates. The resulting carcasses were also significantly leaner.

These results are consistent with findings in many other studies. The financial gain to producers from leaving males entire is of the order of €2.50 per lamb under current market conditions – representing a benefit of about 4% in gross margin. In addition, there is the associated consumer benefit of leaner meat. Thus, a summary of eight studies in the US (Field, 1971) shows that castrates had 33% more subcutaneous fat than entire males at the similar carcass weight. It is clear, therefore, that leaving male lambs entire has benefits for both producers and consumers.

Meat quality

There is no single definition of meat quality, and assessment can involve objective measurements, such as chemical composition, and/or subjective evaluation by a trained taste panel or in-home evaluation by families. Evidence from all of these approaches has been reviewed to inform the summary that follows.

In a British study, meat from entire males and castrates, reared on pasture and slaughtered in August at 20 weeks of age, was evaluated by a trained taste panel and by consumers in their own homes (Dransfield *et al.*, 1990). The carcasses from entire males were heavier but had significantly (23%) less fat, and the taste panel failed to identify any difference in flavour, texture or overall acceptability. The consumer ratings of leg roasts for aroma and eating quality showed that the proportion of households that rated the meat as having a "very much better than usual" aroma and eating quality was considerably higher for legs from the entire males (33% and 34%, respectively) than for those from castrates (14% and 19%, respectively). It is clear from this study that entire male lambs yield meat that satisfied consumers at least as well as that from castrates.

In a New Zealand study (Young *et al.*, 2006) entire males and castrates were evaluated over a wide age range (four to 24 months); the animals were at pasture throughout (supplemented with hay in winter). Measurements included a range of laboratory analyses of fat and muscle, and sensory evaluation of fat and lean by a trained panel. There was no difference in meat toughness (shear force) up to age 10 months, but at 13 months the meat from entire males was tougher. The taste panel detected no differences in sensory evaluations up to 13 months of age but there was evidence that some of the sensory attributes diverged when the animals were between 15 months and two years. The authors concluded that the "sex category and age effects give some credence to the idea that older rams are 'sheepier' but that up to 668 days on pasture the effect on flavour is negligible". Results from consumer-based evaluation are exemplified by Sanudo *et al.* (2007) for British lamb. That study included legs from entire males reared in grassland systems and slaughtered when about 7.5 months old (October) and legs from

castrates reared at pasture and slaughtered (unweaned) when four months old. This comparison would be expected to favour the young castrates. The relevant results, based on evaluations by consumers in Britain, Iceland and France, are in **Figure 1**. The advantage of entire males is evident.

It is widely acknowledged that a key disadvantage of lamb, in the eyes of consumers, is that it is too fat and thus poor value for money. A large-scale Canadian study involving consumers tested at 31 supermarkets provides clear evidence on this (Jeremiah, 2000). The author reported that "respondents demonstrated an obvious aversion to fatness" when asked to evaluate an array of packages containing lamb chops. Chops from entire males slaughtered at between 40.5 and 49.5kg live weight were the only exception to this general finding as only 30% were rejected as being too fat compared with 84% for those from equivalent castrates.

There are some well-established effects of diet on meat quality and some of these effects can be more pronounced in entire males. Thus, lambs fed on concentrate have softer (more oily) fat that is darker in colour compared with carcasses from lambs on an all-grass diet (Diaz *et al.*, 2002); this effect is likely to be greater in entire males (Beriain *et al.*, 2000). This evidence indicates that production systems where male lambs are not castrated should not use intensive finishing on concentrate. The results summarised above, and those from many other studies, fail to support the view that meat from ram lambs is less acceptable to consumers. However, it is also clear from the literature that as entire males reach 12 months of age flavour perception begins to favour castrates; this difference is likely to be magnified when the diet is based on concentrate. Results from a study of lamb production in the Limousin region of France, where butchers were concerned by declining quality of local lamb carcasses in late autumn/winter (Jabet, 1999), support the evidence summarised above. The meat trade attributed the decline to the failure of producers to castrate males. However, a key conclusion from this two-year study was that castrating (at weaning) male lambs that were unlikely to be finished until autumn/winter would not solve the quality problem and that some factor(s) other than entire males was responsible for the late-season decline in quality.

Table 1. Effect of castration on lamb growth, carcass weight and age at slaughter.

Trait	Sex category		Significance
	Entire	Castrate	
Growth rate five weeks to weaning (g/day)	282	256	p<0.001
Weaning weight (kg)	31.7	29.9	p<0.001
Sale date	8 Aug	24 Aug	p<0.001
Kill-out percentage	43.0	44.0	p<0.05
Carcass weight (kg)	18.1	18.2	n.s.
Fat score (1 = little fat to 5 = very fat)	2.9	3.3	p<0.01

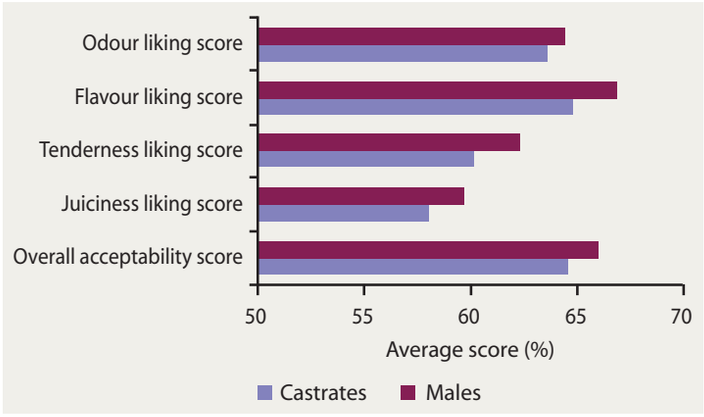

FIGURE 1: Evaluation scores (higher = better) from in-home evaluation of British lamb by consumers in Britain, France and Iceland.

Implications for industry

It is concluded from the available literature that, where lambs are reared on an all-grass diet and slaughtered by the end of the grazing season, leaving male lambs entire has no negative effect on meat quality, whether assessment is laboratory based or through in-home consumer testing. These conclusions are consistent with those of Purchas and Schreurs (2009), who recently reviewed evidence on this matter from a New Zealand perspective.

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Getting the best from grazing

Researchers at Teagasc Moorepark are increasing milk production from pasture using new grazing management technology.

The key objective for Irish dairy farmers seeking to increase farm profitability in 2010 must be to attain higher animal performance from grazed grass. National statistics reveal that average milk fat and protein (milk solids) production per hectare (ha) of dairy farm land remains at 670kg with concentrate supplementation of approximately 700kg per cow. This relatively low level of productivity compares starkly with research targets of in excess of 1,200kg of milk solids per ha with less than 300kg of concentrate supplementation per cow. Low variable or direct costs (of approximately eight cents per litre) are essential in well run grazing systems, and the economic impact of low productivity is evidenced by the relatively high variable and, in particular, feed-related costs associated with Irish farms in recent years (13-14c/l; **Figure 1**).

While lower genetic potential animals undoubtedly contribute to low productivity, poorly developed grazing practices are also a significant factor. As the primary feed resource and competitive advantage of Irish dairying, grazing management best practice is a prerequisite to high animal performance from grassland. While Irish dairy farmers have made dramatic progress using the Economic Breeding Index to select more suitable animals, and a minority of producers have successfully adopted and developed grazing technology, the uptake of best practice grazing techniques within the industry at large is disappointing and continues to limit the productivity of Irish systems. On that basis, recent grassland research has focused on simplifying best practice management techniques and the fundamental practices required for high productivity grassland systems are outlined here.

Grazing management – the basics

Grazing management for high animal productivity is based on a common sense approach to continuously present adequate high quality grass to the dairy herd while ensuring that the sward is properly conditioned for future grazing events. The following basic management guidelines have the potential to dramatically increase animal performance at grazing.

Stocking rate and calving date

To capture the maximum benefits of grazed grass, the most fundamental management practice must be to have the correct number of cows calving compactly at the beginning of the growth season. Stocking rate (SR), traditionally expressed as cows per ha, is the major factor governing productivity from grass, while a recent review of SR experiments reported that an increase in SR of one cow per ha will result in an increase in milk production per ha of 20%. With a current average mean SR of 1.9 livestock units per ha, mean calving date of mid-March and calving rate of 59% in 42 days, the Irish dairy industry is missing out on significant additional milk production and grass utilisation. From a grassland management perspective, recommended best practice must be to have an SR of 2.5 to 2.9 cows per ha on the dairy platform with 90% of the herd calving in the 42 days after calving start date. The ideal mean calving date will vary with soil type, ranging from mid-February on drier southern soils to early March on wetter Northern soils.

Spring grazing plan

While early spring can be a very challenging time, particularly on wetter soils, each additional day grazing in spring has been shown to increase profitability. The objective in early spring is to feed as much fresh grass to calved cows as possible while stretching the first rotation of the farm area until early April. The spring rotation plan (SRP) is a calendar plan to allocate a planned proportion of the farm each day to the herd from turnout until early April. The plan rations the grazing area each week during spring while ensuring that the herd intake increases as the breeding season approaches.

Grassland management planning at research farms such as Curtins, Moorepark (Co Cork) and Ballyhaise Agriculture College (Co Cavan) has been based on the SRP in recent years. The Curtins 2010 plan, illustrated in **Figure 2**, commenced on February 1, when 0.07ha (700m^2) or 1/100th of the farm was allocated per day to the herd. The plan ended on 1/19th of the farm per day on April 5. By joining these two points with a line we had a planned daily grazing area for each week of the first rotation. (For example, on February 22 we grazed 1/73rd of the farm per day.)

This simple area plan decides how much grass can be allocated to the dairy herd, thus simplifying grazing decisions during the busy spring period. The advantage of using the SRP is to plan the entire first rotation in advance. As the area to be grazed per day is known from the graph, by observing the daily post-grazing residuals, the farmer can decide if additional supplementary feeding is required during each week of spring.

Pre-grazing and post-grazing targets and the grass wedge

Despite the best efforts of farmers to create systems that match feed demand and supply, periods of pasture surplus are inevitable, and in most parts of Ireland, grass growth exceeds feed demand from mid-April through to late September, with growth rates in excess of 50kg dry matter (DM) per ha per day. During this period, grass surpluses are responsible for significant financial losses on commercial dairy farms as animal performance declines due to pasture decay and a subsequent deterioration in feed quality. For many years, it has been understood that animal intake at pasture can be defined in terms of the relationship between pre-grazing and post-grazing sward height. Many studies have shown that high quality productive pastures will only be achieved where post-grazing residual heights are maintained between 3.5 and 4cm during the grazing season. It is recommended that the pre-grazing herbage height of well run grazing systems should be maintained at approximately 8cm to ensure that high animal intakes of high quality pasture are achieved.

While maintaining pre-grazing and post-grazing heights (at 8 and 3.5-4cm, respectively) may seem like a simple grazing strategy, it requires that all paddocks are monitored each week to ensure that a stepped wedge (similar to that outlined in **Figure 3**) is achieved. The wedge is a graphic illustration of the grass supply information (pre-grazing yield or height) in each paddock at a point in time compared to the target levels. Where multiple paddocks are observed to be either

Higher animal performance from grazing can be achieved through improved management practice.

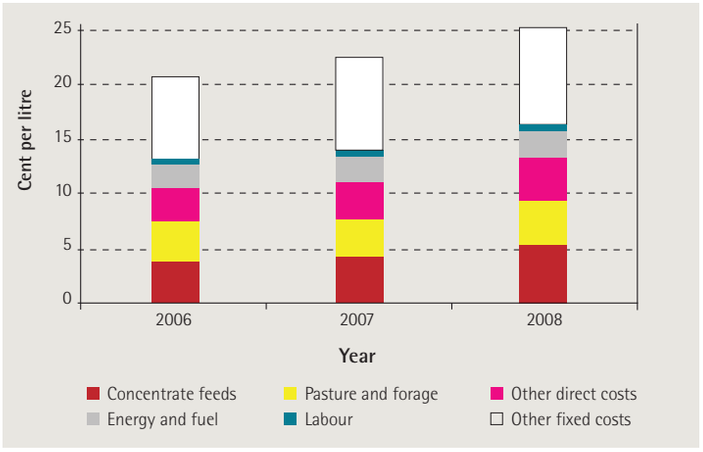

FIGURE 1: Breakdown analysis of the costs of production on Irish dairy farms (2006-2008). (Source: Outlook 2010, Economics of Agriculture Conference, see: www.agresearch.teagasc.ie/rerc/.)

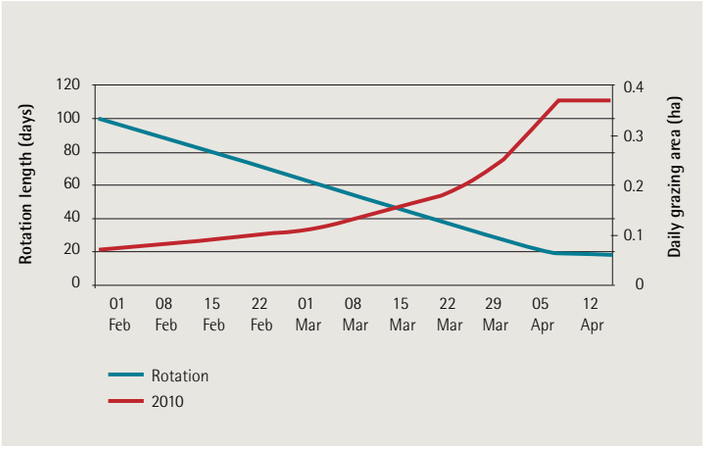

FIGURE 2. Spring rotation plan for Curtins Farm, 2010.

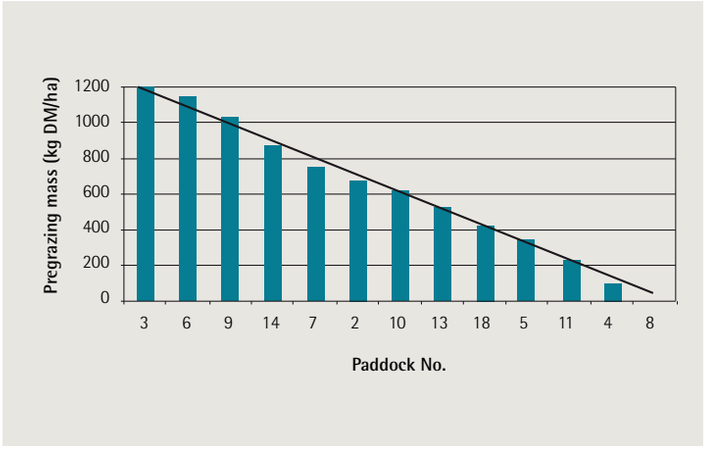

FIGURE 3: An ideal mid-season grass wedge.

above or below the target line, surpluses/deficits exist and immediate action should be taken. Managing to maintain the wedge such as in Figure 3 will make grazing management easier during mid-season.

Managing grass surpluses during the grazing season

The primary role of silage making on the grazing platform is to facilitate good pasture management, and requires early prediction and timely removal of pasture surpluses. Rapid identification and removal of paddocks above 10cm (>1,800kg DM per ha) on the grazing platform is recommended to provide essential flexibility to produce milk from grass based on the continuous provision of excellent quality feed. Such practices also provide a cost-efficient source of higher quality winter feed to buffer the grazing diet during spring and autumn and eliminate the necessity for topping.

Research updates

Weekly updates on research herds at Moorepark are available online at: www.agresearch.teagasc.ie/moorepark.

Acknowledgements

Teagasc Moorepark wishes to acknowledge National Dairy Levy, NDP and EU funding for this research.

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Meeting your hot water demand

A new energy research project at Teagasc Moorepark aims to reduce the Irish dairy industry's electricity consumption and hence its carbon footprint. JOHN UPTON and MICHAEL MURPHY compare oil and electricity for hot water supply on dairy farms.

FIGURE 1: Typical location of an immersion element in a 500L water tank.

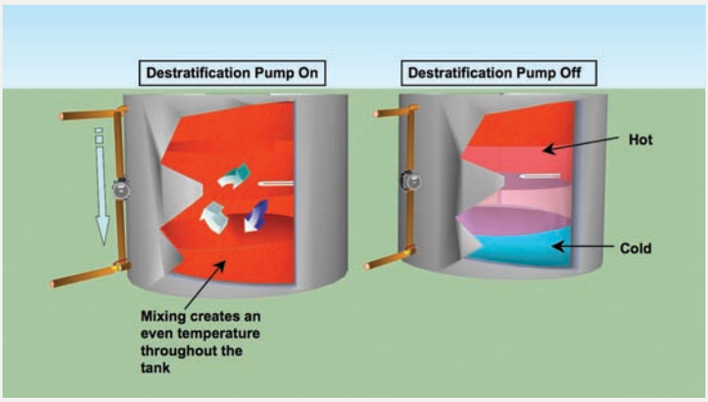

FIGURE 2: Water temperature profile in a mixed and non-mixed hot water tank.

There is a requirement on all sectors of Irish industry to increase their energy efficiency, including agriculture and in particular dairy production as the largest agricultural consumer of electrical energy. The recently established energy research programme in Teagasc Moorepark aims to reduce the Irish dairy industry's electricity consumption, and hence its carbon footprint, at a time when every item of expenditure is being targeted for cutbacks. Evaluation of new technology, such as the use of more efficient cooling technology for milk tanks, solar panels, heat pumps and variable speed vacuum and milk pumps is underway in both laboratory and field experiments. An adequate and reliable supply of hot water is an essential element in the production of high quality milk on any dairy farm. Water used for cleaning milking systems, including milking units, pipelines, receivers, and bulk milk storage tanks, must be available in adequate quantities and at required temperatures for each cleaning process. Failure to have adequate supplies of hot water at required temperatures can lead to rapid increases in bacterial contamination and subsequent reduction in milk quality. Hot water requirements vary from farm to farm and are directly related to the number of milking units, pipeline sizes and lengths, and system accessories (receivers, recorder jars or milk meters, automatic cluster removers, etc.). Generally, a minimum hot water requirement is 10 litres of 80°C water per milking unit for each hot wash cycle plus a reserve for bulk tank washing.

Energy audit

The heating of water is a substantial energy input in the operation of a modern dairy farm. Energy audits carried out by Teagasc Moorepark in 2009 identified water heating as one of the major consumers of electricity, accounting for over 30% of total electrical energy used on three Teagasc research farms. In fact, electricity used by water heating equipment can add up to two kilowatt hours (kWh) per cow per week.

The most common method of providing hot water on dairy farms is electrical water heating, with oil-fired boilers also being a popular choice, particularly on larger dairies. This article will examine the efficiency of both systems and explore their strengths and weaknesses.

Water heating trial

Table 1 displays the results of a recent water heating trial in Moorepark. Some 500 litres of water were heated from 14°C to 80°C with a 3kW immersion element and a 90 British Thermal Unit (BTU) oil-fired burner running on kerosene. The immersion element was located mid way up the cylinder; this is very common on large water tanks of 300L and above.

Figure 1 shows the typical location of an immersion element in a 500L water tank. The volume of hot water available from this tank without using a destratification pump will not exceed two-thirds of the total capacity. It is important to consider this when selecting the size of cylinder required. However, if a destratification pump is used, over 90% of the capacity of the tank will be utilised (see **Figure 2**). Obviously, more energy is consumed to heat the larger volume of water, so destratification should only be used where there is a demand for this increased volume of hot water. A destratification pump is simply a circulation pump fitted to the hot water storage vessel, which circulates the water from top to bottom, overcoming the temperature stratification of the stored water. This pump continually mixes the water in the tank until the final temperature of 80°C is reached.

Table 1: Results of the recent water heating experiment carried out in Moorepark.

Treatment	Heating method	Destratification (tank mixed)	Power (kWh) consumed	Rated power (kW)	Heating time (Hrs)	System efficiency	Useable water (L)	Cost per 100L (€) Night rate/day rate	Kg of Co_2 produced
T1	Electricity	Yes	48.24	3	16.5	79%	411	0.87/1.77	25.6
T2	Electricity	No	30.82	3	10.5	N/A	280	0.82/1.66	16.4
T3	Oil	No	45.5 (4.4L kerosene)	26.4	1.75	84%	415	0.65	12.7

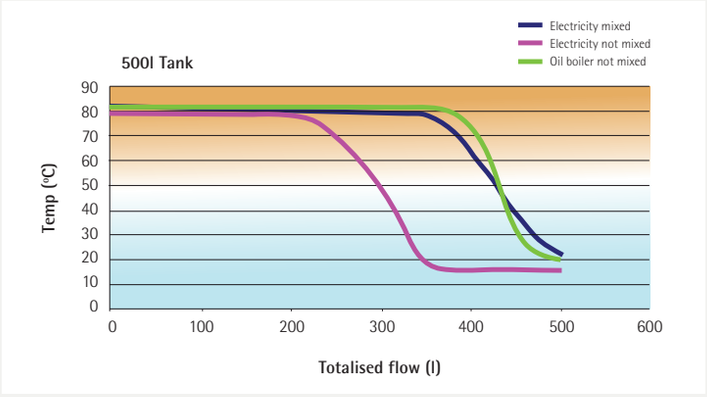

FIGURE 3: Temperature profile of the water as it is drawn from the cylinder for treatments 1, 2 and 3.

Table 2: Tariffs used for calculating water heating costs (Correct on 28/05/2010).

Unit type	Cost per unit (€) (Excl VAT)	Tarrif
Electricity day units (kWh)	0.15	ESB rural nightsaver
Electricity night units (kWh)	0.07	ESB rural nightsaver
Kerosene (litre)	0.61	Based on quote for 1000L

Figure 3 shows the temperature profile of the hot water as it is drawn from the cylinder for each of the three treatments. We can directly compare treatment 1 with treatment 3, as these methods produce similar amounts of useable hot water. The amount of usable water was defined as the quantity of water drawn off from the cylinder between 60°C and 80°C.

Inspection of **Table 1** shows some surprising results. A 3kW immersion element takes over 16 hours to heat the 500L tank to the final temperature of 80°C. This would not be satisfactory, as night rate electricity should be utilised for electrical water heating. This element would not be capable of heating the water on night rate alone. **Table 1** details the cost of heating 100 litres of water from cold to hot for treatments 1, 2 and 3. Tariffs used for these calculations are shown in **Table 2**. The importance of using night rate electricity is immediately apparent. Comparing treatments 1 and 3 shows that the oil boiler can produce 100 litres of usable water at a much lower cost than the 3kW element on night rate and substantially cheaper than the electrical element on day rate. Of course, oil prices can fluctuate, but the price of kerosene would need to increase by 33% from today's price to match the cost of the electrical heating system. The oil-fired system also has a number of other advantages. Firstly, the recovery time is very low and this means that hot water will be available both morning and evening if required, which is an important factor in system selection for many farmers. Secondly, the amount of CO_2 emitted by the oil-fired system is much lower that the comparable electrical system. Naturally, the capital investment of the oil-fired system will be higher than the electrical system, but as **Table 1** illustrates, the savings involved can be noteworthy depending on hot water usage and whether or not night rate electricity is available. In any case, serious consideration should be paid not only to initial purchase cost, but also to running costs and environmental impact.

Benefits to the industry and further work

Renewable water heating solutions including air source heat pumps and solar thermal panels are currently under test in Moorepark for efficiency and viability. Work in this area will be ongoing for the next 12 months and the results of these trials will be disseminated in due course. New technologies to reduce dairy farm electricity consumption are being identified and evaluated on an ongoing basis as part of the larger energy research programme in Moorepark. This programme aims to promote a more energy efficient approach to dairy farming, which in the long term will result in lower energy input costs.

This research is funded by the Teagasc Core Programme and the Dairy Levy Research Fund.

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Cleaning products for milking equipment

To aid Irish dairy processors in meeting trichloromethane regulations for the dairy export market, chemical analysis of cleaning products used for cleaning milking equipment has been carried out by researchers at Moorepark.

Mix at the recommended usage rate – read instructions and measure.

In the relatively recent past there has been a large increase in the number of new products in the marketplace being sold as detergents or detergent-sterilisers for cleaning milking equipment. These products contain various levels of caustic and chlorine as the main ingredients required for cleaning. Caustic (sodium hydroxide) is necessary as the cleaning/detergent agent and chlorine (sodium hypochlorite) acts as the steriliser. The issue of chlorine residues is currently of particular importance from the viewpoint of dairy product export markets. Irish dairy processors are experiencing difficulty in producing products that meet a regulation on the trichloromethane (TCM) content of dairy products. The development of TCM arises from cleaning and disinfecting procedures that involve the use of chlorine.

Appropriate caustic levels in cleaning products

A review by the International Dairy Federation (Reinemann, 2003) has indicated that the common working solution for caustic in a liquid-based cleaning solution is between 200 and 800ppm, where hot water is used for the main wash cycle and the detergent solution is not recycled. Therefore, in an Irish context where the detergent solution is recycled once, working solutions at the upper end of this scale are necessary. Detergent-steriliser products need to have a minimum of 10% caustic (approximate working strength 800ppm) if used in a cold water solution, in order to give satisfactory cleaning. A working strength of 800ppm may also be achieved by using a product containing lower caustic levels at a higher usage rate. However, increasing the usage rate to achieve the correct caustic working solution will automatically increase the working solution of chlorine in the wash solution and this can have a negative effect on chlorine residues. Products containing less than 10% caustic may only give satisfactory cleaning if used with hot water, at least once daily and not recycled. Caustic detergent powder products are commonly used for machine and manual bulk tank cleaning in Ireland. Powder products, unlike liquid detergent-steriliser products, generally contain no chlorine and are designed to be used with cold water, and therefore require a higher working solution of caustic of greater than 2,000ppm.

Appropriate chlorine levels in cleaning products

The preferred chlorine content within a detergent-steriliser product is within the range 3.5-4.5% and, when used at working solution strength of 200ppm, chlorine (hot wash solution) is sufficient for satisfactory cleaning (in the presence of adequate caustic). A working solution of 300ppm chlorine is required for adequate cleaning when cold water is used daily. Chemical residues are more likely to occur if high working solution strengths of chlorine are used, in particular where inadequate rinsing is carried out (14 litres/unit minimum rinse required).
Thus, a liquid detergent-steriliser product of minimum working solution strength 800ppm caustic and 300ppm chlorine used with cold water is necessary for satisfactory cleaning, while a working solution strength within the range 200-800ppm for caustic (depending on if recycled or not) and 200ppm for chlorine is sufficient when used with hot water.

Current investigative study

Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, received many requests from advisory personnel, dairy processors and farmers for information on the detergent products used for the cleaning of milking equipment. Thus, it was considered timely to examine the range of cleaning products currently available, to ensure a good standard of product in terms of its cleaning ability and to give guidance to the industry on acceptable levels for the main product constituents. Samples of detergents, detergent-steriliser and steriliser products, which were sourced on farms or submitted by manufacturers/distributors, were analysed for chemical composition. Products analysed included liquid detergent-sterilisers (n=49), powder detergents (n=17) and sterilisers (n=11).
As observed from this study, caustic and chlorine concentrations ranged from <1 to 25% and <1 to 9%, respectively, in the detergent-steriliser products currently available on the Irish market (Figures 1 and 2). A relatively high concentration of caustic (>15%) in a detergent-steriliser product will allow for lower usage rates while still achieving effective cleaning. A detergent-steriliser containing a 10% concentration of caustic when used at a rate of 360ml/45 litres will give a

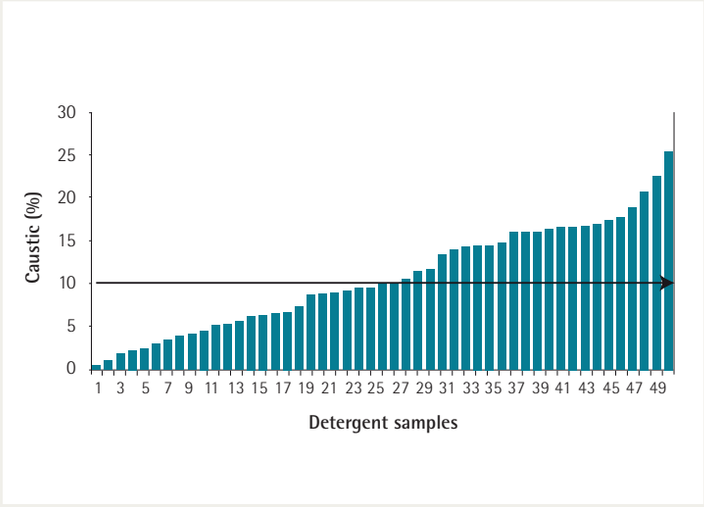

FIGURE 1: Concentration of caustic (NaOH) in detergent-steriliser products.

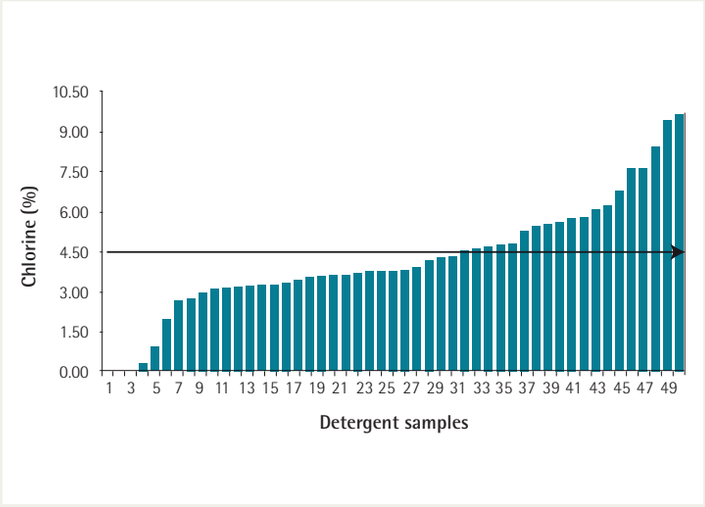

FIGURE 2: Concentration of chlorine (Cl_2) in detergent-steriliser products.

working solution of 800ppm. Detergent-sterilisers with lower caustic content may only give satisfactory cleaning if used with hot water daily. In Ireland, only 40% of parlours use hot water on a daily basis (Kelly *et al.*, 2009), yet many use products that are best suited for use with hot water. In comparison to other countries (e.g., New Zealand) hot water is used for the main wash at each occasion, detergent is not recycled and typical detergent-steriliser products contain much higher levels of caustic (15%) with 4-5% chlorine than many of the products used in Ireland. Forty-eight percent of detergent-sterilisers in this study had caustic levels below the suggested minimum level (10%) and 39% had chlorine levels above the suggested chlorine level (4.5%). It was also observed that products that tended to have lower caustic levels in the formulation also tended to include higher chlorine levels, which may increase the risk of chlorine residues.

All caustic powder products analysed contained working solutions of caustic greater than 2,000ppm. It is considered that all products analysed should give satisfactory cleaning if used as recommended.

Steriliser products (chlorine) are used weekly for sterilising of milking equipment in conjunction with caustic detergent (powder products) cleaning. The steriliser products analysed in this study had chlorine concentrations of between 7% and 11%. It is concluded that these differences in concentrations were not important and that all steriliser products should give satisfactory performance when used correctly.

Choosing a good product and adhering to the instructions and guidelines for that product is vital for effective cleaning. In many instances products were inadequately labelled, with some of the following pieces of information omitted: name of manufacturer; pesticide control service number; content of active substances; directions for use; optimum temperature of usage; equipment for which the product is suitable; expiry date; and, batch number.

Conclusions

The chemical composition of some detergent-sterilisers available in Ireland is not optimum to give efficient cleaning of milk equipment, i.e., the level of caustic relative to chlorine is too low. Choosing a product that meets the suggested level of chlorine will reduce the possibility of chemical residues if usage instructions are adhered to. Adequate rinsing (14 litres per milking unit) of chemical solutions from the plant is crucial for avoidance of chemical residues.

Benefits to industry

It is anticipated that this study will assist dairy farmers to make an informed decision on which products are most suitable when choosing products for milking equipment cleaning. The list established (www.agresearch.teagasc.ie/moorepark/) can be used by both advisory personnel and detergent manufacturers. The list will be amended and updated as new products are introduced, as manufacturers modify the chemical content of their products and as the product registration status is established.

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Selecting genes for performance

Genetic variation in the somatotrophic axis is associated with performance. Researchers from a cross-centre Teagasc team have discovered independent additive effects of variations in genes of this axis on important traits in cattle, which may help to elucidate the genetic architecture of performance in cattle.

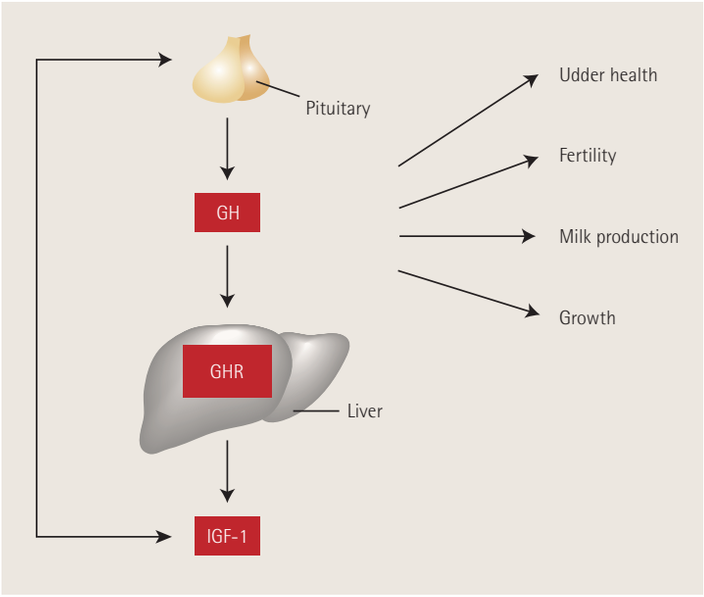

FIGURE 1: The somatotrophic axis is a key regulator of production traits in cattle.

Rationale for the study

The somatotrophic axis, consisting of pituitary-derived Growth Hormone (*GH*) and circulating insulin-like growth factor 1 (*IGF-1*) has been well established as a key regulator of a range of traits in cattle, including health, metabolism, lactation, fertility, body composition and growth. The action of *GH* is mediated by the transmembrane *GH* receptor (*GHR*), which comprises a 24-amino acid single transmembrane domain, an extracellular binding domain and a long cytoplasmic domain. Binding of *GH* to *GHR* activates an intracellular signalling pathway that induces the transcription of many genes including *IGF-1*. This axis controls processes such as fertility and nutrient partitioning necessary for milk production. It was therefore logical that genetic variation in the genes regulating the production of these hormones should also be associated with performance. Elucidating the genetic architecture of how this pathway influences performance is not only useful in developing management strategies to minimise any negative effects to animal performance, but could also be incorporated into breeding programmes to increase genetic gain in key traits through greater accuracy of selection of younger animals. Therefore, a recent collaborative study across four Teagasc research centres led by Dr Sinéad Waters aimed to identify genetic variation in the *GH*, its receptor *GHR*, and *IGF-1* genes of dairy and beef cattle, and to quantify their associations with performance traits in Holstein-Friesian dairy cattle. Associations with performance in beef cattle will also be analysed in the coming year.

Experimental design

The first step to elucidate the genetic architecture of a trait is to identify genetic variation at the DNA level in the key genes in the pathway of interest, which in this study was the somatotrophic axis. Variations in units of DNA (called nucleotides) between members of a species are called Single Nucleotide Polymorphisms (SNPs – pronounced 'snips'). A total of 76 SNPs, not previously discovered, were detected in large regions of the *GH*, *GHR*, and *IGF-1* genes in 22 Irish cattle. These were combined with 33 SNPs previously identified by other international research groups and screened across 848 Holstein-Friesian AI sires used in Irish dairy herds in recent years. DNA from these sires was extracted in Athenry by Dr Dawn Howard and now forms part of the Teagasc DNA bank. These sires are currently used in the genomic selection programme in Ireland. The screening of the sires was undertaken by a commercial company using the Sequenom Mass ARRAY® iPLEX Gold assay. Each SNP was associated with the genetic merit of each sire (based on daughter performance) collected within the national database. This procedure was carried out by Dr Donagh Berry at Moorepark. Relationships among sires were accounted for in the analysis to ensure that the SNP effects estimated were not merely artefacts of the relatedness among animals. The approach of using sires, rather than cows themselves, is superior because the accuracy of the trait under investigation is greater (since it is based on the performance of many progeny). The disadvantage of this approach is that the traits are limited to only those routinely measured nationally. The traits investigated for associations with the SNPs were milk production, udder health, fertility, and animal size. The effects in this article are converted to the scale of estimated breeding value to reflect the performance of the cow herself and not that of progeny as reported in the scientific papers published from this study.

Results

Table 1 shows, for a selection of the performance traits evaluated, how many SNPs in each of the three genes, represented by one tick per SNP, were independently associated with performance. Seventeen novel and 13 published SNPs were significantly associated with at least one of the traits analysed, including milk yield, milk fat and protein composition, milk somatic cell count, calving interval, survival and 11 body size traits. Of major significance was the fact that for several traits including milk fat yield, somatic cell count, survival and carcass fat, SNPs in all three genes were independently associated with performance, reinforcing the key role of each gene on animal performance but even more so the necessity to target key biological pathways when attempting to explain the differences in performance among animals.

Of particular interest was a novel SNP in the 5' non-coding region of *GHR* detected in this study. The effect of one allele of this SNP, coupled with the effect of an allele

Table 1. Number of SNPs (each SNP represented by a tick) in genes of the somatotrophic axis, which were independently associated with a selection of the performance traits analysed, as well as the sum of the favourable effects of one allele difference for each SNP on the breeding value of an animal.

Trait	GHR	GH	IGF-1	Cumulative allele effects
Milk yield (kg)	✓✓			240.0
Milk fat yield (kg)	✓✓	✓✓	✓	11.8
Milk protein yield (kg)	✓✓			3.0
Somatic cell score (log_e units)	✓	✓✓	✓	0.16
Calving interval (days)	✓✓			3.6
Survival (percentage units)	✓	✓	✓	3.0
Body condition score (genetic standard deviation units)		✓✓		1.0
Carcass weight (kg)	✓✓		✓	10.0
Carcass fat (kg)	✓	✓✓	✓✓	57.2
Carcass conformation (scale 1 [poor] to 15 [good])	✓	✓		0.05

for a previously published SNP in exon 8 of *GHR*, was 240kg milk yield in the breeding value for 305-day lactation milk yield. This means that a cow homozygote (two identical alleles of the same gene) for the "high milk" alleles of both SNPs is expected to yield 480kg more milk per lactation than a cow homozygote for the "low milk" alleles of both SNPs. This is almost one genetic standard deviation in 305-day milk yield – implying that the effect is considerable. Although we know from previous international studies that such effects are biased upwards, mainly because these allele effects also include the effects of other alleles co-inherited, the true effect of these SNPs is still expected to be considerable. This is the first international study to show such cumulative effects among these SNPs, and the study design used in the present study, based on 848 high reliability sires, is relatively large.

Because of the many factors affecting cow survival, it is not surprising that SNPs in each of the three genes were independently associated with survival. Survival in the present study is independent of the effects of milk yield, so the reported associations with survival are therefore not due to higher yielding cows surviving longer because they simply produce more milk. Based on the results from this study, 6% more cows, homozygote for the "good survival" alleles of all three genes are expected to survive to the next lactation compared to cows homozygote for the "poor survival" alleles.

This study reaffirms the important role of genes within the somatotrophic axis in animal metabolism, lactation, growth and fertility, and may be potentially useful in genetic evaluations incorporating genomic information.

Expected benefits to industry

The novel SNPs identified in the present study were submitted for inclusion in the next generation of genotyping platforms for use in further genomic studies. For Ireland, knowledge generated in the present study may be used in the next generation of genomic evaluations where prior information of associations and, more importantly, the interactions between polymorphisms may be incorporated to better reflect the complexity of biological systems; such as the system of genomic evaluations is used in French dairy genetic evaluations. Utilising this information may aid in reducing the breakdown in accuracy of the current genomic selection models over generations due to recombination, thereby resulting in increased genetic gain.

Future research

This study was a preliminary study to evaluate the potential role of genetic variation in key genes of the somatotrophic axis in performance. However, results from this study merely suggest an association between these genetic variants and performance and do not imply cause and effect. This means that the associations reported with these SNPs could be an artefact of these SNPs being inherited, more often than not, with the genetic variants actually causing the effects. To aid in identifying the true genetic variants causing the effects observed, all genes in the somatotrophic axis, as well as other genes, are now being fully sequenced in over 1,000 animals to detect all possible DNA variations present. These animals are all part of the Teagasc DNA bank. The association study will be repeated to better refine the location of the regions of the genes that affect performance. These variations will then be tested in an independent population of cows with the final project to undertake more detailed analysis of these variations in the laboratory to elucidate their biological effects on performance. Identifying causative SNPs that affect performance, if successful, will have huge potential within breeding programmes to increase genetic gain through greater accuracy of selection.

This research was funded by the Research Stimulus Fund and Science Foundation Ireland.

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Occupational health problems among Irish farmers

There is increased emphasis internationally on occupational health to complement injury prevention programmes. Research by the Health and Safety Authority and Teagasc aims to assist with the implementation of health promotion programmes.This article outlines the background to the research and gives initial findings relating to musculoskeletal disorders.

Why occupational ill health and injury?

Farming is generally perceived, by both farmers and the general public, as a healthy, outdoor occupation. The reality, however, is that farming is a hazardous activity that presents a range of threats to health. International research has reported links between health and injury levels. An American study established that farmers who report their general health as very good, good, and fair had lower injury rates than those who reported poor health. Hurry, fatigue or stress were contributing factors in most injuries. Similarly, a Finnish study established that farmers who reported health complaints showed a relationship with experiencing higher injury rates. The number of machines used and musculoskeletal disorders present were risk factors for injuries. A study on disability on Irish farms identified illness/disease as primary cause of disability. Farms reporting disability such as arthritis, back problems and heart/circulatory problems experienced a lower family farm income than farms not reporting disability. Therefore, occupational illness and injury are associated with a number of negative consequences such as reduced work ability, lower farm income and poorer quality of life, and these can lead to the onset of other health problems including stress or depression. Farmers' health is influenced by demographic, environmental and personal risk factors, and therefore each farmer is uniquely impacted.

Why musculoskeletal disorders?

When compared with other worker groups, there is limited occupational health research regarding farmers – especially in Ireland. Because of the physical nature of farm work, farmers and farm workers are at particular risk of developing musculoskeletal disorders (MSDs). MSDs have been defined as a group of disorders that affect the musculoskeletal system including the nerves, tendons, muscles, and supporting structures. MSDs are the most common cause of severe long-term pain and physical disability. They can affect the psychosocial status of people, which can impact on their families and careers. However, in many jurisdictions, including Ireland and the UK, such musculoskeletal problems go unrecognised, with underreporting of musculoskeletal injury to the relevant statutory authority such as the Heath and Safety Authority (HSA) and the Health and Safety Executive. Thus, data regarding incidence, prevalence and consequences of occupational injury and ill health are constrained by inconsistencies in injury classification and reporting practices.

The HSA and Teagasc recognised the need to investigate farmer health. They have placed a priority on improving occupational health as a component of their Joint Health and Safety Prevention Initiative in the high risk work sector of agriculture, with acknowledgement that MSDs are among the most prevalent consequence of farm injury. This article features early findings on MSDs among farmers, which are part of a wider study on farmers' health. This project involves multidisciplinary collaboration with the UCD School of Public Health, Physiotherapy and Population Science, and UCD School of Agriculture, Food Science and Veterinary Medicine.

Musculoskeletal disorders among farmers in Ireland

The aim of this research was to:

- identify subgroups of farmers at greater risk of MSDs;
- quantify the impact of MSDs in terms of quality of life, health service utilisation, work ability and farm income;
- systematically evaluate a range of farming operations and farmer perceptions to provide new knowledge, which will inform future risk assessment, health and safety education and health promotion interventions in agriculture; and,
- contribute to the development of tailored primary and secondary health promotion initiatives, thereby supporting Teagasc's and the HSA's activities in promoting improved health and safety practice on Irish farms.

Health, musculoskeletal disorder and lower back pain survey

A questionnaire was developed to investigate health problems among farmers in Ireland. Quota sampling was used to access a minimum of 100 farmers from each of the National Farm Survey (NFS) farm enterprise systems, namely dairy, dairy and other, cattle rearing, other cattle systems, mainly sheep and tillage. The questionnaire was distributed at Teagasc courses, farm walks and events.

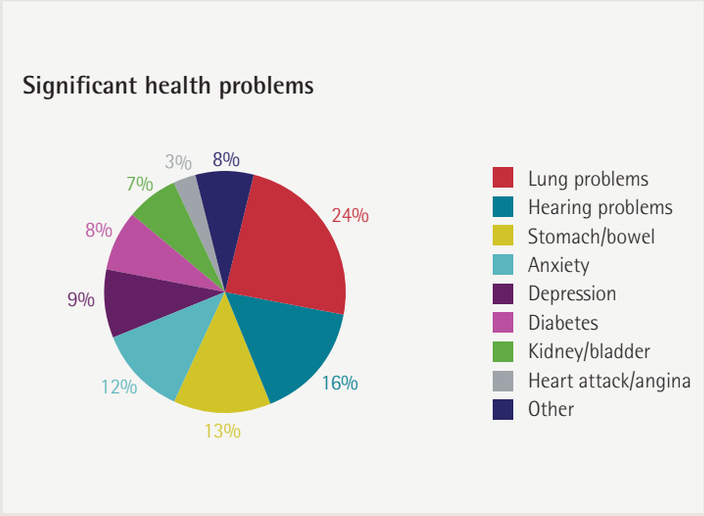

FIGURE 1: Significant health problems reported in the previous year (n=123).

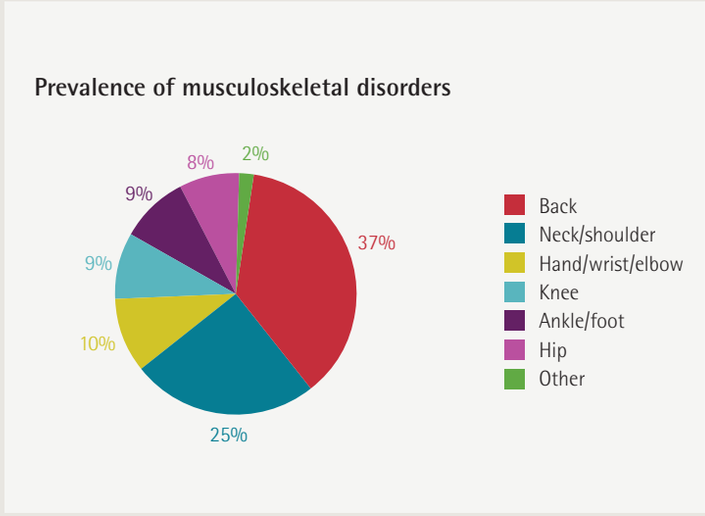

FIGURE 2: Prevalence of musculoskeletal disorders in the previous year (n=585).

Survey findings

Respondents were 18 to 85 years of age (median=46) and farmed a median of 53 hectares of farmland. Full-time farmers accounted for 65% (n=372) of the population. Respondents were predominantly male (92%, n=551).

Of the 600 farmers surveyed, 21% reported having a significant health problem in the previous year (**Figure 1**). On specific questioning regarding MSDs, 50% of farmers (n=325) experienced an MSD in the previous year. The most commonly experienced MSDs (n=585) were back pain (37%) and neck/shoulder pain (25%). In the questionnaire MSDs were defined as any bone, joint or muscle problems lasting 24 hours or more in the last year. Lower back pain was defined as an ache, pain or discomfort in the lower back, whether or not it extends from there to one or both legs. Back pain refers to a combination of upper back pain and lower back pain. Back pain was found to be significantly more prevalent among full-time farmers. Fifty percent of farmers reported having had lower back pain at some point in their life. The most common reason cited for this was lifting incorrectly or lifting heavy materials.

Other MSDs experienced in the previous year included hand/wrist/elbow pain (10%), knee pain (9%), ankle/foot pain (9%) and hip pain (8%) (**Figure 2**).

On comparison of profiles of farmers with and without an MSD, no significant differences were found in age, years farming, farm enterprise or engagement in work off farm. Only the mean number of hours worked per day was found to be significantly higher among those with an MSD. Farm enterprise was not found to be a factor in influencing the development of MSDs. Farmers reporting hip problems were significantly older, had farmed over a longer period, had worked longer hours and comprised more full-time farmers.

Future work

Overall, this study established a high prevalence of MSDs among farmers in Ireland. It did not, however, establish any link between farm system and the prevalence of MSDs. While a range of other factors thought to contribute to the development of MSDs was explored, only a longer number of hours worked on the farm was found to be associated with a higher risk of MSDs. Further research as to the potential causes of MSDs in farmers is in progress in order to inform preventive health strategies. Results will be used to help devise new ill health and injury prevention programmes. Part of this will involve working with the HSA to create video footage on MSD risk factors for use in promotion of preventive health strategies.

This research is funded by the Health and Safety Authority and the Teagasc Walsh Fellowship Scheme.

Acknowledgement

The participation of farmers who completed questionnaires is appreciated.

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Understanding and facilitating farmers' adoption of technologies

This article describes an initiative designed to improve the effectiveness of the Teagasc technology transfer process. This is an important component of improving innovation on farms.

Teagasc employs an innovative strategy in the scientific development and extension of technologies to enhance the competitiveness of Ireland's agri-food sector. Research activities in biological and food sciences develop technologies, while farmers' adoption of technologies is facilitated by social science research, knowledge transfer activities, and education programmes. Technologies developed by Teagasc are available to stakeholders in the agriculture sector through a range of media. Teagasc's upcoming launch of a web-based 'Compendium of Technologies' will profile and promote the organisation's suite of technologies. These technologies are applicable to the Irish agri-food sector, with a significant proportion targeted directly for use and application on farms. This latter group of technologies is designed to improve the profitability, competitiveness and sustainability of Irish farm enterprises.

In order to support the uptake of technologies by farmers, attention must be paid to the processes and key determining factors underpinning successful knowledge transfer. A new Teagasc research and knowledge transfer initiative seeks to explore these processes and factors in collaboration with client farm families. This article presents an introduction to one of the projects that forms part of the initiative.

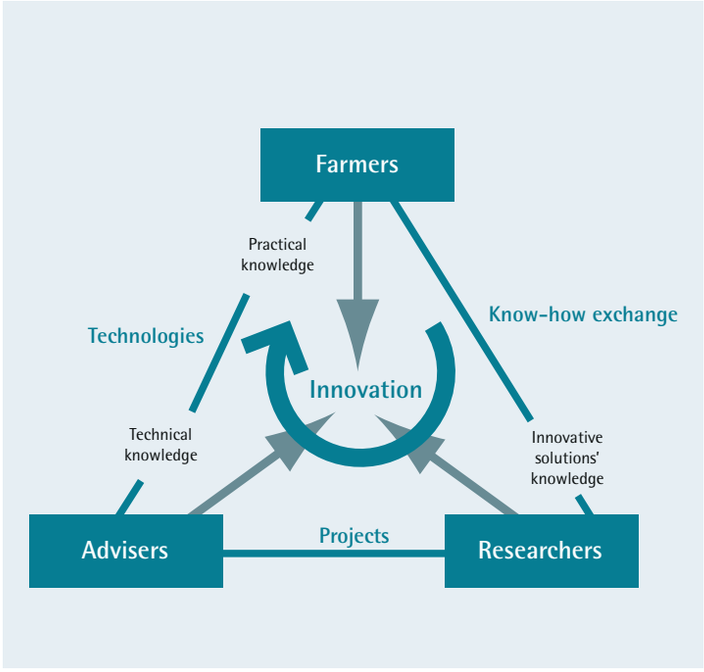
Field research

A research project entitled 'Qualitative Analysis of Farmer Behaviour' studies the factors that influence farmers' uptake of technologies. The empirical research exercises involve ten in-depth case studies: five farms participating in the BETTER Farm Beef Programme and five counterpart non-participating farms. The case studies focus on the attitudes and opinions of family members who participate in the farm enterprise towards individual technologies, and their past and current experiences of knowledge transfer processes. By exploring their attitudes, opinions and experiences, the complex factors influencing the adoption/non-adoption of technologies are being identified.

Decision-making on the farm: an overview

Commercial farms can be influenced to a significant degree by economic factors in how decisions are reached in relation to the adoption of technologies and the operation of the farm enterprise in general. The operators of commercial farms typically invest in and use a range of technologies on a broad scale and are involved in knowledge transfer processes. Farms that are less commercially oriented are often slower to invest in and adopt technologies, and the non-adoption of technologies has consequences for the efficiency, productivity and viability of such farms. Many traditional family farms across Europe are not operated or managed as commercial farms. A significant proportion of these farms are operated as family farms, which are recognised as having particular traits in terms of how they are operated and managed.

The sociological literature notes that a defining characteristic of family farms is the influence of social and cultural factors, in addition to economic factors, on how decisions relating to the farm are reached. Three forms of capital are identified as influencing family farm decision-making: cultural capital; social capital; and, economic capital. **Economic capital** essentially means material wealth. The meanings of cultural and social capital are more dynamic, however. **Cultural capital** can be described as representing the values and customs (as well as the practices and possessions that are symbolic of these values and customs) that are important to and prestigious to farmers. Some technologies are conducive to farmers' cultural capital, while others may



Adapted from: http://www.taslab.eu/framework.htm

potentially undermine or renegotiate cultural capital. For example, genetic breeding is perceived by some farmers to displace and undermine their own lay and practical knowledge of breeding. While cultural capital in such instances can be a focus of resistance, it is important to remember that cultural capital changes over time. Knowledge transfer processes, involving farmers as interactive participants, can contribute to changes in cultural capital and new forms of cultural capital.

Social capital also influences farmer decision-making in a significant way. Social capital can be described as the value of social relationships and networks. Farmers, and other social groups, often do not opt to take decisions that can lead to an undermining of social relationships or social ostracism. For example, farmers' decisions about the adoption of technologies are often influenced by the opinions of their peers. Some farmers will not adopt technologies if they feel that their peers disapprove. On the other hand, some farmers' decisions to adopt technologies are positively influenced by their peers' adoption of the same technologies. The adoption of technologies can therefore be seen as a social rather than an individual process, influenced by farmers' desire to maintain or enhance social capital.

Participatory action research: contributing to effective knowledge transfer

So how can such research findings be used in a practical way to support and enhance knowledge transfer activities? Participatory action research (PAR) involves a partnership of farmers, advisers, and social scientists to share knowledge in driving success and innovation in the knowledge transfer process. Venues for PAR are the interactive and participatory knowledge transfer tools employed by Teagasc, such as discussion groups, farm walks, and monitor farms.

Teagasc has pioneered these participatory tools for knowledge transfer in the Irish farming sector. The discussion group, for example, is acknowledged to be particularly effective in knowledge transfer, largely attributed to its facilitation of a farmer-oriented learning process. In order to be effective, however, discussion groups require support in effective planning and facilitation. By identifying through social science research the key factors that arise in technology adoption from a farmer perspective, strategies to underpin effective planning and facilitation of discussion groups can be developed and enhanced. PAR involves a communicative process between farmers, advisers and social scientists in addressing key factors of importance to farmers when considering technologies and their adoption. PAR can lead to the adjustment of existing technologies in order to enhance their usefulness and acceptability to farmers, or to the development of new technologies. One of the main advantages of developing knowledge transfer processes that are based on PAR is that farmers, together with advisers and social scientists, are co-drivers of the processes. This has the result that the knowledge transfer process is more effective as a learning tool and that it has more innovative outcomes. When farmers are co-drivers, their forms of cultural, social and economic capital frame and contextualise the knowledge transfer process. New information is thereby translated through the knowledge transfer processes into a form that is more accessible, acceptable and useful to farmers. Through PAR, knowledge transfer processes are enhanced by farmers' practical knowledge of key problems and ideas of how to solve them. Conversely, where drivers in knowledge transfer processes are advisers and/or scientists, farmers can become passive subjects. As a result, for both farmers and advisers, the knowledge transfer process is less dynamic and less innovative in terms of what is learned from and developed through the process.

Primary data collection and field research for this project is ongoing and the PAR phase will follow in 2011.

This research is funded by Teagasc's Core Programme.

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T Events

SEPTEMBER

September 7 — *Ballykisteen Hotel, Tipperary*

Teagasc Agri-environment Conference 2010

The Teagasc Agri-environment Conference 2010 will provide a forum for those working in the agri-environmental arena to receive an update on the most topical environmental issues affecting agriculture in Ireland. The Conference will focus on practical outcomes from current agri-environment research and advisory experience, as well as examining policy drivers and their potential impacts.
This year's event will comprise an indoor conference in the morning followed by a farm walk on the Solohead Research Farm in the afternoon. The morning conference will hear from experts on environmental research and policy, while the afternoon farm walk will consist of a number of stations located on the Solohead Research Farm, which will provide delegates with a practical insight into the work carried out by the Teagasc Environmental Programme.
mark.gibson@teagasc.ie — www.teagasc.ie/events

September 13-16 — *Seven Oaks Hotel, Carlow*

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

The 2010 European Association for Potato Research Pathology Section meeting will be jointly hosted by Teagasc and the Agri-Food and Biosciences Institute (Belfast). The three-day meeting will deal with all aspects of potato pathology, with a special emphasis on new threats to potato posed by changes in the behaviour of existing pests and pathogens, as well as by new species. The meeting will also include an excursion to the Teagasc Crops Research Centre in Carlow, home of the Teagasc potato breeding programme.
Speakers will include: Colin Fleming, AFBI Belfast, on 'Emerging nematode threats'; and, Lars Christoffersen, Head of Sector (Plant Health), Food and Veterinary Office, European Commission, on 'The importance of phytosanitary controls for sustainable potato production'.
potatoes@teagasc.ie — www.teagasc.ie/events/EAPRpathology2010

September 14 — *Keadeen Hotel, Newbridge, Co. Kildare*

National Tillage Crops Forum

In the 'Technology & Margins' session there will be talks on: winter cereals varieties for 2010; crop choice and margins for 2011; weed control in winter cereals and oilseed rape; and, soil organic matter and soil analysis.
The 'Grain Marketing Forum' will cover a grain market overview and price risk management tools, and there will be a panel discussion on developments in the Irish grain market.
Jim.OMahony@teagasc.ie — www.teagasc.ie/events

September 16 — *County Arms Hotel, Birr, Co. Offaly*

National Organic Conference

An exciting panel of speakers will explore the challenges and opportunities for organic producers at this year's Conference. The 'Processor's Perspective on Market Opportunities' features: Vincent Clery, Glenisk Dairies; John Purcell, Good Herdsmen; and, John Flahavan, E. Flahavan & Sons Ltd.
The 'Successful Organic Brands' section features: Omega Beef Direct; Drumeen Farm; Kearns Organic Growers; Mossfield Cheese; and, Clanwood Farm.
The 'Adding Value' section will feature: developing a new product; branding; and, funding new enterprise.
The 'Soil Nutrition – the Challenge to get it Right' features: nutrient budgeting; composting; and 'A Farmer's Perspective'.
helen.mcnulty@teagasc.ie; Tel: 091 845217 — www.teagasc.ie/events

OCTOBER

October 14 and 15 — *Teagasc Food Research Centre, Ashtown*

Agricultural Economics Society of Ireland (AESI) 1st Annual Conference and Young Researcher Seminar

The conference will include a keynote address, as well as contributed papers on themes such as agriculture, the environment, rural development, food marketing, land use and development economics. The Young Researcher Seminar will provide postgraduate students with the opportunity to present their research findings to an audience of their peers.
secretary@aesi.ie — www.aesi.ie; Tel: 01 805 9502

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

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

This is a unique opportunity for all stakeholders of the grassland industry to come together to discuss the future needs of the sector. The conference will focus on the livestock production requirements from perennial ryegrass as a feed source in temperate climates. The discussion on day one will focus on grass breeding and evaluation. A workshop and site visits will take place on day two. Visits to the Department of Agriculture, Fisheries and Food Crop Variety Evaluation Site at Ballyderown Farm and Teagasc Moorepark's Grassland Research Programme will take place following the workshop.
margie.egan@teagasc.ie — www.teagasc.ie/events

October 19 — *Horse & Jockey, Thurles*
October 20 — *Cavan Crystal Hotel, Cavan*

National Pig Conference

The guest speaker for this conference is Derek Armstrong, BPEX, and the theme for the panel discussion is 'Focus on the Slaughter Pig'. Topics will include: grain quality; future sources of pig feed; lean meat; condemnations; *Salmonella* control; livers; pleurisy, etc.; carcass damage; and, disease eradication programmes.
ciaran.carroll@teagasc.ie

NOVEMBER

November 7-14 — *Nationwide*

Science Week 2010

Teagasc will host a series of Science Week events at its research centres nationwide.
catriona.boyle@teagasc.ie — www.teagasc.ie/events www.scienceweek.ie

November 17 — *Charleville Park Hotel, Charleville*
November 18 — *Mullingar Park Hotel, Mullingar*

National Dairy Conference

niamh.allen@teagasc.ie

November 18 and 19 — *Teagasc Food Research Centre, Ashtown*

International Conference on Hyperspectral Imaging

Hyperspectral imaging is a powerful new tool to collect spatial and spectroscopic data from food and other types of samples. It requires specialist techniques to extract the useful information from the complex images collected. Ireland already has a presence in this field. This conference, the second in the series, aims to bring together experts from many imaging fields from across the globe to share experiences and accelerate applications.
gerard.downey@teagasc.ie — www.teagasc.ie/ashtown/events/2010/201006-22.asp