TEAGASC

Research

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Dairy processing research – technology highlights

Brexit and the Irish agri-food industry

Hybrid breeding in ryegrass

Milking time tests

teagasc

Agriculture and Food Development Authority

Contents

Teagasc | Oak Park | Carlow

Agriculture and Food Development Authority

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Teagasc hosts World Congress of Food Science and Technology

It was a great pleasure for Teagasc, as a major sponsor and main host, to welcome the cream of the world's food scientists to Dublin for the 18th World Congress of Food Science and Technology, which was held in August in the RDS. With over 500 different organisations represented from over 65 countries, it truly embodied an unparalleled global forum of the brightest minds in food science, research and innovation. Over 1,300 delegates assembled during the congress over five exciting days, attending 80 scientific sessions in which over 250 scientific, industry and policy experts presented new findings, practical experiences and lessons learned in their respective fields. These highly stimulating sessions covered topics that were of global interest and thought-provoking. Topics discussed during the week included food innovation strategies, nutrition and health, future foods, food sustainability and food safety, all of which were judiciously chosen to stimulate lively discussion. Additionally, we had a number of 'Hot Topics' sessions, which focused on new and emerging trends in important food sectors such as meat, dairy, seafood and consumer foods.
As President of the Institute of Food Science and Technology, I would like to thank the two platinum sponsors, Kerry and Teagasc, as well as Science Foundation Ireland, for its very generous support. It was a great honour for Ireland to host this major Congress and the 'green' jersey was put on by many hard-working volunteers, too numerous to mention. Significantly the feedback from the many delegates was that Ireland is perceieved to be truly a nation that strongly supports its food industry, is committed to excellence in food science and technology and has a well-integrated food innovation eco-system system backed up by Government, state agencies such as Teagasc, academia, and industry.

Declan J. Troy
Assistant Director of Research
Director of Food Technology Transfer,
President, Institute of Food Science and Technology Ireland
Teagasc Food Research Centre,
Ashtown, Dublin

Óstálann Teagasc an Chomhdháil Dhomhanda um Eolaíocht agus Teicneolaíocht an Bhia

Thug sé an-phléisiúr do Teagasc mar mhór-urraitheoir agus mar phríomhóstach fáilte a chur roimh na heolaithe is fearr ar domhan go Baile Átha Cliath don 18ú Comhdháil Dhomhanda um Eolaíocht agus Teicneolaíocht an Bhia a tionóladh i mí Lúnasa san RDS. Agus ionadaíocht arna déanamh ar son níos mó ná 500 eagraíocht éagsúil ó os cionn 65 tír, bhí fóram domhanda thar na bearta cuimsithe amach is amach ann de na daoine is éirimiúla san Eolaíocht, Taighde agus Nuálaíocht ar Bhia. Tháinig os cionn 1,300 toscaire le chéile le linn na comhdhála thar cúig lá iontacha; d'fhreastail siad ar os cionn 80 seisiún eolaíoch inar chuir os cionn 250 saineolaí eolaíoch, tionscail agus beartais torthaí úra, eispéiris phraiticiúla agus ceachtanna a foghlaimíodh ina réimsí faoi seach i láthair. Sna seisiúin an-spreagúil sin cumhdaíodh topaicí a bhain suim dhomhanda leo agus a raibh ábhar machnaimh iontu.
Áiríodh ar thopaicí a pléadh le linn na seachtaine straitéisí um nuálaíocht bhia, cothú agus sláinte, bianna don todhchaí, inbhuanaitheacht bhia agus sábháilteacht bhia, agus roghnaíodh iad sin ar fad go stuama chun plé a raibh ábhar machnaimh ann a spreagadh. Lena chois sin, bhí líon seisiúin "Topaicí Bríomhara" againn, inar díríodh ar threochtaí úra agus ar threochtaí atá ag teacht chun cinn in earnálacha bia tábhachtacha amhail feoil, déiríocht, bia mara agus bianna tomhaltóirí.
Mar Uachtarán ar an Institiúid Eolaíocht agus Teicneolaíocht Bia ba mhaith liom buíochas a ghabháil leis an dá urraitheoir platanaim, Ciarraí agus Teagasc, agus le Fondúireacht Eolaíochta Éireann as a dtacaíocht fhlaithiúil. B'onóir iontach a bhí ann d'Éirinn an mhór-Chomhdháil seo a óstáil agus chaith a lán deonaithe díograiseacha a raibh barraíocht díobh ann lena lua an geansaí "glas". Go suntasach is é an t-aiseolas a fuarthas faoi Éirinn ón lear mór toscairí gur náisiún ab ea Éire a thugann tacaíocht láidir amach is amach dá tionscal bia, atá tiomanta don bharr feabhais in eolaíocht agus teicneolaíocht an bhia agus ag a bhfuil córas éiceachóras nuálaíochta bia atá comhtháite go maith agus atá tacaithe ag an Rialtas, gníomhaireachtaí stáit amhail Teagasc, an lucht acadúil, agus an tionscal.

Declan J. Troy
Stiúrthóir Cúnta Taighde
Stiúrthóir um Aistriú Theicneolaíocht an Bhia,
Uachtarán, Institiúid Eolaíocht agus
Teicneolaíocht Bia na hÉireann
Ionad Taighde Bia Teagasc,
Baile na Fuinseoige, Baile Átha Cliath

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Niall Farrelly

Niall Farrelly is a research officer in the Forestry Development Unit at Teagasc, Athenry, Co Galway. His research focuses on relationships between production, in particular the capacity of marginal soils to produce commercial forest crops, increased product utilisation, and management techniques to increase profitability to maximise the output of the sector.

Niall's research focuses on the production of high-value commercial lumber and covers all aspects of the life cycle from seed to sawdust.

Following completion of his primary degree in forestry (UCD) in 1995, Niall worked as a research assistant at Coillte, developing an interest in establishment and crop development. Following this, he worked as a contract researcher with UCD on afforestation trials on cutover midland bogs. He completed a postgraduate diploma in computer science in 1999 in Griffith College and shortly afterwards joined Teagasc in a research position to assess the productivity capacity of Irish soils.

In 2003, Niall became a forestry inspector with the Forest Service, in the Department of Agriculture, Food and Marine, and applied his knowledge to setting up the National Forest Inventory. He returned to Teagasc in 2005 and commenced a PhD in UCD, where he studied the effects of site quality on the productivity of Sitka spruce. The research succeeded in developing an analytical procedure for classification of lands for afforestation grant aid and identifying lands that could be used to accelerate forest planting necessary for increasing the sequestration capacity of Irish forests that has been adopted by the Department of Agriculture, Food and the Marine.

Niall has published extensively on various aspects of soils, forest growth and yield in journals such as *Forest Ecology and Management, Canadian Journal of Forest Research, Forest Policy and Economics*, and *Environmental Science and Policy* and is a frequent contributor to national initiatives compiling various reports in the area of forest policy.

Niall is principal investigator and work package leader on a number of COFORD/FIRM funded projects including forest genetics (FORM), timber forecasting (ForecastModel), windthrow risk modelling (WINDRISK), short rotation forestry (SHORTFOR), and land availability for forestry (CCLAWG). Niall is the current president of the Society of Irish Foresters, where he represents the interests of more than 700 members.

IUFoST 2016

Teagasc was a major sponsor and main host to the 18th International Union of Food Science and Technology's (IUFoST) World Congress of Food Science and Technology that took place recently in the RDS, Dublin, with 1,500 attendees from around the world.

The event began with the inaugural Global Food Summit, which was hosted by IUFoST and was addressed by the EU Commissioner for Agriculture, Phil Hogan, MEP. The summit acknowledged and drew upon the increasingly vital role government advisors play in improving the dialogue and collaboration necessary to tackle current and future global food issues.

The Industry Leader Summit, addressed by the Minister for Agriculture, Food and the Marine, Mr Michael Creed, TD, followed the Congress theme 'Greening the Global Food Supply Chain through Innovation in Food Science and Technology'. Key industry leaders addressed the importance of research to their company's success and innovation strategy, and they identified future research needs. Details of the scientific proceedings can be obtained from declan.troy@teagasc.ie. For more on the event see article on page 10.

Pictured during a visit to the Teagasc stand at IUFoST are (from left): Marializ Gramajo, Universidad Del Valle De Guatemala; Minister for Agriculture, Food and the Marine, Michael Creed, TD; and researcher Ciara McDonagh, Food Industry Development, Teagasc Food Research Centre, Ashtown.

New AFBI CEO visits Teagasc Head Office

Pictured at a recent visit of representatives from the Agri-Food and Biosciences Institute, Northern Ireland (AFBI) to Teagasc Head Office are (from left): Front: Gerry Boyle, Director of Teagasc and new AFBI CEO Elaine Watson. Middle: Frank O'Mara, Head of Research, Teagasc and Jim McAdam, AFBI. Back: Pat Dillon, Head of Animal and Grassland Research and Innovation Programme, Teagasc; Kevin Hanrahan, Rural Economy and Development Centre, Teagasc; and Trevor Gilliland, AFBI.

New programme to support farmhouse cheese sector

Teagasc and Bord Bia have completed a pilot programme that seeks to enable the future development of the farmhouse cheese sector in Ireland.

Designed in partnership with industry, Cheese Institute Fundamentals is a development programme that consists of a series of workshops delivered over 10 months to 12 farmhouse cheese companies. Each workshop included a number of subject matter specialists and addressed topics such as cheese production and ripening, controlling cheese yield, batch variability, food safety and hygiene, whey utilisation, in addition to marketing planning, pricing and negotiations, business planning, key account management, the consumer and market, digital content creation and management.

Teagasc Senior Researcher, Diarmuid Sheehan, said: "Irish farmhouse cheese production has great potential to expand and, based on its positive image abroad, opportunities in export are strong. Cheese offers high-end use versatility with potential for significant added value. Cheese Institute Fundamentals gives us the opportunity to focus on the development of the necessary skill set and expertise required by the industry. We are delighted with the opportunity to address key hurdles from quality to consistency and through to expansion in the sector. This is a long-term training support, which provides a great opportunity to leverage the available Teagasc expertise and the expertise available overseas through our international linkages."

The next phase of Cheese Institute Fundamentals will commence in the coming months with a focus on export.

Participants from the 12 farmhouse cheese companies taking part in the joint Teagasc/Bord Bia Cheese Institute Fundamentals programme along with the course organisers at Roundwood House, Mountrath, Laois.

Rural tourism handbook

A new *Rural Tourism* handbook has been produced by Teagasc's Rural Development Department and part-funded by the Department of Agriculture, Food and the Marine under the Commission for the Economic Development of Rural Areas (CEDRA). The handbook is available on the Teagasc website.

Pictured are (from left): Eilis Carroll, Department of Agriculture, Food and the Marine; Maria Heneghan, rural tourism consultant; with Cathal O'Donoghue and Mary Ryan of the Teagasc Rural Economy and Development Programme.

CAPRI workshop

Early career researchers from around Europe attended the Common Agricultural Policy Regionalised Impact Modelling System (CAPRI) workshop in Dublin in September, co-hosted by University College Dublin and Teagasc. The workshop included a visit to a dairy farm in Co Meath where the participants learned about the expansion taking place on Irish dairy farms.

IJAFR papers

Volume 55, No 1, 2016 of the *Irish Journal of Agricultural and Food Research* contains the following papers:

- The interactive effects of fertilizer nitrogen with dung and urine on nitrous oxide emissions in grassland, Hyde *et al.*
- Additive genetic, non-additive genetic and permanent environmental effects for female reproductive performance in seasonal calving dairy females, Kelleher *et al.*
- Visual drainage assessment: A standardised visual soil assessment method of land drainage design, Tuohy *et al.*
- Impact of slurry application method on phosphorus loss in runoff from grassland soils during periods of high soil moisture content, McConnell *et al.*
- Trends, over 14 years, in the cover of semi-natural hill vegetation on a western hill sheep farm and associated trends in animal performance, Walsh *et al.*
- Effect of nitrogen fertilizer timing on nitrogen use efficiency and grain yield of winter wheat, Efretuei *et al.*
- Effect of a bacteriophage cocktail in combination with modified atmosphere packaging in controlling *Listeria monocytogenes* on fresh-cut spinach, Boyacioglu *et al.*

To view these papers and to sign up for e-Table of Content or new article alerts, see: http://bit.ly/IJAFR2016

Honour for Teagasc potato breeder

Harry Kehoe, retired potato breeder from Teagasc, Oak Park, was conferred with an Honorary Degree of Doctor of Science by UCD, in recognition of his lifetime's work as a plant breeder. Harry commenced with An Foras Taluntais (AFT – now Teagasc), in 1960 and retired in 2003. He led the breeding programme for over 40 years and is described in the Teagasc book *Growing Knowledge – Fifty Years of Research and Development* as "one of Europe's most renowned potato breeders". Throughout his career, Harry worked closely with IPM Potato Group Ltd, and many varieties released during his tenure continue to grow and be successfully marketed in over 40 countries worldwide.

Rooster was one of more than 35 potato varieties bred by Harry Kehoe and his team at Teagasc. Since its launch in 1991, Rooster has become the dominant potato in the Irish market accounting for 60% of the market.

Harry was Oak Park's most successful potato breeder and ranks up with the great international names in potato breeding like Archibald Finley (1841-1921), Donald McKelvie (1867-1947), William Black (1903-1975), Harold Howard, John Clarke, (1889-1980) and Brian Costello.

Given the importance of the potato in global food production, as the fourth major food crop in the world after wheat, rice and maize, Harry's achievements are leaving a lasting legacy around the globe.

CommBeBiz

Pictured at the CommBeBiz stand at EuroScience Open Forum (ESOF 2016) in Manchester recently are (from left): Maeve Henchion, Head of Department of Agrifood Business and Spatial Analysis, Teagasc; Mairead McGuiness, MEP; and Áine Regan, Department of Agrifood Business and Spatial Analysis, Teagasc.The stand featured Teagasc's European Union Horizon 2020-funded research projects.

Microbiome manipulation for mental health

Emerging evidence now suggests that our gut bacteria may influence our brain, and the way we behave. A new book, *The Gut Brain Axis,* edited by Niall Hyland, APC Microbiome Institute and UCC, and Catherine Stanton, APC Microbiome Institute and Teagasc, explores how diet, probiotics and prebiotics can help modulate the microbiome and how such interventions can impact the gut-brain axis. The book also examines the potential for microbial manipulation as a therapeutic avenue in central nervous system disorders in which an altered microbiota has been implicated and explores the mechanisms by which the microbiota may contribute to such disorders. The book also discuss the possibility of positively altering the microbiota in the context of brain function and wellbeing.

Pictured presenting a copy of *The Gut-Brain Axis* to UCC library are (from left): Niall Hyland, APC Microbiome Institute and UCC; UCC Librarian John Fitzgerald; and Catherine Stanton, APC Microbiome Institute and Teagasc,

10 Things to Know About...

Teagasc will once again feature in the science television series '10 Things to Know About...', which will air on RTÉ One later this year. Forestry Researcher Gerry Douglas spoke with presenter Aoibhinn Ní Shúilleabháin about Teagasc's work as part of a collaborative project between members of the GAA Ash Society to help ash growers fully optimise their forests, to create a culture of forest management, to support the ash hurley-making industry and to develop initiatives aimed at addressing the challenges of pests and diseases such as ash dieback.

Ultrasonics conference

Two of Teagasc's Walsh Fellow PhD students Shikha Ojha and Elena Inguglia won the Excellent Oral Presentation award at ULTRASONICS 2016, the second international conference on ultrasonic-based applications: from analysis to synthesis held in Lisbon, Portugal recently.

Pictured at ULTRASONICS 2016 are (from left): Brijesh Tiwari, Senior Research Officer at Teagasc; Walsh Fellow PhD students Elena Inguglia and Shikha Ojha; and Giancarlo Cravotto, President of the Europen Society of Sonochemistry.

Teagasc national crops forum

The recent Teagasc National Crops Forum discussed the critical aspects of the financial crisis that is currently being experienced by tillage farmers in Ireland. Fiona Thorne, Teagasc economist, presented a paper on the current income on tillage farms from data from the Teagasc National Farm Survey and a detailed estimation of what to expect in the coming years. "Armed with the knowledge of the source and scale of future income, this is the best starting place for making future decisions," said Fiona. James McDonnell, Teagasc Financial Management Specialist, continued the theme, examining farm finances and the implications of reduced income. "Farmers will find meeting repayment deadlines, or making any additional investments, extremely difficult this year," said James. "Planning now is critical to ensure cashflow is adequate for the rest of the season. Teagasc advisors are well placed to help farmers in the coming months," he added.

Success in Horizon 2020 research welcomed

Teagasc has welcomed the announcement that researchers and companies in Ireland have won a total of €274.7 million in funding from the EU Horizon 2020 programme for research projects. The Horizon 2020 programme is an EU programme to support research and innovation across the European Union. Horizon 2020 reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by citizens in Europe and elsewhere. The higher education system in Ireland accounted for €172.5 million of this total and companies secured €79.2 million, including €54.3 million for SMEs. The European Commission has pioneered a new type of project in the agri-food area, known as 'Thematic Networks'. These networks take the results of recent research projects, collate and disseminate them in a usable format for farmers across Europe. In 2016, five thematic networks will be funded by the European Commission, and Teagasc is a partner in all five funded networks. Frank O'Mara, Director of Research in Teagasc, commented: "We are particularly pleased with Teagasc's success in applications for thematic networks. The concept of turning excellent research results into innovation on Irish farms is central to Teagasc's mission and aligns closely with the Irish Government's Innovation 2020 strategy, which aims to make Ireland a global innovation leader. Thematic networks allow Teagasc to exploit our synergistic activities of research, innovation and knowledge transfer."

Low-protein toddler milk

Teagasc Technology Transfer Office details below a novel technology, involving the production of a novel, low-protein milk product designed to meet toddlers' nutritional needs, developed in collaboration with University College Cork (UCC) and key opinion leaders in infant nutrition.

Teagasc and UCC researchers, through the Food for Health Ireland (FHI) research initiative, have developed a method for production of a low-protein milk product that meets toddlers' nutritional needs, but which is also suitable for use by the whole family. We are seeking commercial partners within the infant nutrition/dairy industry to optimise and exploit this method and resulting product.

Background

Dairy products play an important role in toddler nutrition and are, by far the lowest-cost source of dietary calcium and riboflavin. However, studies have shown that infants in the western world have an average protein intake of approximately 2.5g per kg of body weight per day, which exceeds the recommended intake of 1-1.5g per kg of body weight per day. Documented observational data indicates a link between high protein intake during early childhood and a risk of obesity in later life. Many toddlers are fed formulated toddler milk with altered nutritional and taste profile when compared to natural milk, and at a premium cost to consumers. To date, there has been an absence of natural milk product alternatives in this growing toddler market, which this technology aims to address.

Solution

This invention relates to a process enabling the production from cow's milk of a novel, natural reduced-fat, or full-fat, low-protein dairy product, which has been tailored to meet a toddler's typical nutritional needs. As the product is based on cow's milk, its taste is much closer to natural cow's milk than competing formulated toddler milk.

Competitive advantage

The novel milk produced from this process exhibits these key benefits:

- a natural, low-protein alternative to cow's milk tailored to the nutritional profile of toddlers' needs;
- producible as full-fat and reduced-fat products, tastes just like regular cow's milk and can be consumed by the whole family;
- producible in fresh, ultra-high temperature (UHT) and powder formats, and is easily scalable; and
- suitable as a carrier for fortification of other nutrients not naturally abundant in milk, but often lacking in toddlers' diets, such as iron.

Opportunity

A prototype has been developed to a pre-commercial scale, with positive consumer feedback on taste, and is producible in fresh, UHT and powder formats. Teagasc, as commercial lead, wish to partner with a company in the infant nutrition and/or dairy industry in optimising and commercialising this process and resulting product, through a collaborative/licensing arrangement.

Intellectual property and funding status

A patent application was filed by Teagasc and UCC in 2015, claiming a novel dairy product, based on cow's milk, suitable as substitute milk for toddlers. This research was funded by FHI (Enterprise Ireland).

Further information

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Feature

Healthy diets for all

Lance O'Brien,
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The second lecture in the Teagasc Annual Distinguished Lecturer Series was presented in the RDS in March 2016 by Frank Rijsberman. Until recently, Dr Rijsberman was the CEO of the CGIAR Consortium (www.cgiar.org), the world's largest, publicly-funded, international agriculture research organisation, with an annual budget of US$1 billion, and approximately 10,000 employees in over 60 countries. Lance O'Brien summarises the lecture, which was entitled: 'Transforming agri-food systems to achieve healthy diets for all'.

The global agri-food system is doing a poor job of providing healthy food for all, particularly for the growing masses of urban poor. Poor diets have overtaken smoking as the primary cause of ill health globally. Our agri-food system is responsible for 800 million hungry people, two billion malnourished people, 159 million stunted children and two billion overweight or obese people. Global diets are becoming increasingly homogenised and increasingly processed. Moreover, agri-food systems have become more globally interdependent and vulnerable to shocks in areas such as food safety, climate change and food price volatility.

Agri-food systems are also the primary driver of planetary ill health, accounting for soil degradation on 25% of cropped land, deforestation and loss of biodiversity, water scarcity, pollution of lakes and seas, and a contribution to climate change of about 25% of emissions. Together, these failings make agriculture the key risk to keeping humanity within a safe planetary operating space. The traditional focus of the global food security strategy on increasing the productivity of staple cereals will not be enough to solve these issues. Instead, the world will require a radical transformation of agri-food systems. Urgent food system transformation requires scaling up the pace of innovation, which will need increased investments in research, the driver of innovation.

Rapidly emerging, new science and technologies will help us to address these daunting challenges in a more effective manner. The life science revolution that is changing our understanding of the fundamental biology of plants, animals and people has already transformed medicine but is just now reaching agriculture. Accelerating the use of the genetic diversity contained in CGIAR gene banks into CGIAR breeding programmes through the use of genomic selection and gene editing is a critical opportunity. Big data approaches are transforming the retail end of food value chains. Renewed 'political' interest in the bio-economy – with its merging agendas of agri-food, development, and environment – will help strengthen our focus on an agri-food system perspective to address complex issues. Together with a focus on a value chain approach, emphasis on the bio-economy, will also help focus on issues of food waste and loss. Taking advantage of these opportunities will require a holistic agri-food system approach, as well as innovative partnerships.

IUFoST 2016 – Greening the global food-supply chain

More than 1,500 food scientists, engineers, food-industry professionals, regulatory authorities and students from around the world were brought together in Dublin for the IUFoST (International Union of Food Science and Technology) 2016 World Congress of Food Science and Technology. Catriona Boyle reports on some of Teagasc's contributions to the programme.

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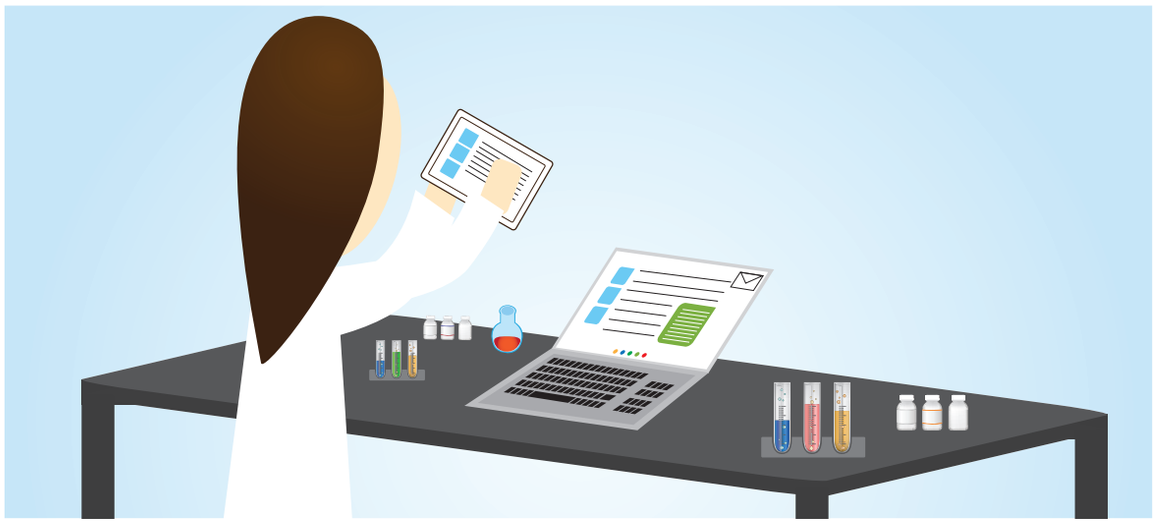
Scientists and social media

Áine Regan, Department of Agrifood Business and Spatial Analysis, Teagasc, discussed the merits of social media as a platform for scientists to communicate their research. Áine explained that science communication should be understood as more than just a means to educate the 'uninformed public' about science. Rather, it enables scientists to engage many different types of citizens in conversations about science in an accessible and interesting manner. She said it allows us to generate better scientific outcomes, translate our science to those who can help us achieve societal impact, increase societal trust in the scientific community, and increase the legitimacy of judgements and decisions that are based in scientific evidence. For scientists looking to communicate their research to the public, social media is an increasingly attractive choice argues Áine: "Today's scientist has unprecedented access to members of the public. We no longer have to rely on journalists to interpret and communicate our science; we can share our research findings and developments directly with the public through social media. Social media is allowing us to not just disseminate our findings in an engaging and entertaining manner; it's also allowing us to have *conversations* with the public – something that is important from a public engagement perspective, but also in terms of creating opportunities to generate actual impact with our research."

However, social media uptake among scientists is low compared to the uptake and influence of social media within society as a whole. In order to understand both the motivations and barriers underlying social media use among scientists, Áine, along with Teagasc's Maeve Henchion, Head of Department of Agrifood Business and Spatial Analysis, carried out qualitative research with food researchers in Ireland and the United Kingdom. The findings, to be released later this year, will feed into the overall work plan of the EU-funded Horizon 2020 CommBeBiz project (www.commbebiz.eu).



Metagenomics for food quality and safety

Paul Cotter, Teagasc Food Research Centre, Moorepark, gave a lecture relating to the potential role for the use of metagenomics for microbiology-based investigations to ensure the quality and safety within the dairy food chain. He noted that recent advances in nucleic acid-based technologies, and next generation DNA sequencing, in particular, have revolutionised our understanding of numerous microbial environments; and that these approaches have been employed with increasing frequency to study specific food-associated microbes and the overall microbiology of the food chain. It was highlighted that while many such studies were initially curiosity driven, the technologies are now beginning to be used in a more applied way to investigate the microbial basis for microbial-related food quality and safety issues. As an example, he then summarised his laboratory's exciting work relating to characterising the flow of microbes through the food-production environment and the identification of the key sources of microbial contaminants in raw milk. He also discussed their recent use of the technology to solve a 70-year-old conundrum relating to the cause of a discolouration defect in certain cheese types. Paul noted: "Metagenomics is revolutionising our understanding of the microbiology of the dairy food chain and has the potential to be similarly used to enhance quality and safety across all food chains."

Future protein supply and demand

Will protein demand triple by 2050 or will it actually decline? Different scenarios for future protein demand, drivers of these scenarios and the potential of existing and novel protein sources was the focus of Maeve Henchion's, Head of Department of Agrifood Business and Spatial Analysis, presentation at IUFoST. Maeve said that research from the Netherlands estimates that global demand for protein could triple by 2050, if demand per capita rises to that consumed by the average American; however, a contrasting scenario – which assumes the projected population of 9.3 billion consumes the amount of protein required for normal functioning of a sedentary adult – shows that demand could theoretically fall by 23 million tonnes. The latter scenario is unlikely given government commitments related to the UN Sustainable Development Goals such as "no hunger" and strong socio-economic and market drivers. However, increased protein supply raises environmental, ethical and health concerns. Thus, it is a significant challenge to balance protein supply and demand without adversely affecting the environment, animal welfare and public health. "The research agenda to address future demand and supply of protein is immense. It will require collaboration between food science and technology and a wide range of other disciplines including social science. Who knows, it may involve meat scientists speaking to entomologists!" says Maeve.

Dairy SMART ingredients

Mark Fenelon, Head of Teagasc's Food Research Programme, described current research at the Teagasc Food Research Centre, Moorepark, on the concept of 'SMART' milk ingredients as a nutritional base for export. Examples of science and technology and end-applications for the scientific platform were presented. The primary focus of the work was on milk protein-based ingredients (dehydrated), designed to form a nutritional base for a food product produced elsewhere and examples of the latest studies on rehydration dynamics of milk protein-based ingredients were given. Novel microscopic techniques (developed by Mark Auty, Teagasc Food Research Centre, Moorepark) were described, including the use of a confocal laser scanning microscope for examination of protein distribution within a powder particle coupled with a high speed camera for capturing subsequent dissolution behaviour. Mark explained that the key to developing SMART functionality in dairy powders is controlling aggregation kinetics through careful selection of ionic environment and processing conditions. He gave examples of applications where aggregated protein and carbohydrate (i.e., Inulin) interaction led to the development of a new product, e.g., a low-calorie particulate fat replacer. Also described were mechanisms for structuring protein and carbohydrate using mechanical forces (microfluidisation); in this example, design of a low-fat yoghurt. Mark said: "Protein aggregation is a key tool in the development of SMART ingredients with specific rehydration properties for reconstitution into new or existing dairy foods such as local dairy products, soft cheese/yogurts, and dairy-based beverages."

Acknowledgments

The main sponsors of the congress were the Kerry group and Teagasc. For a full list of sponsors and more details on the event see: http://www.iufost2016.com/

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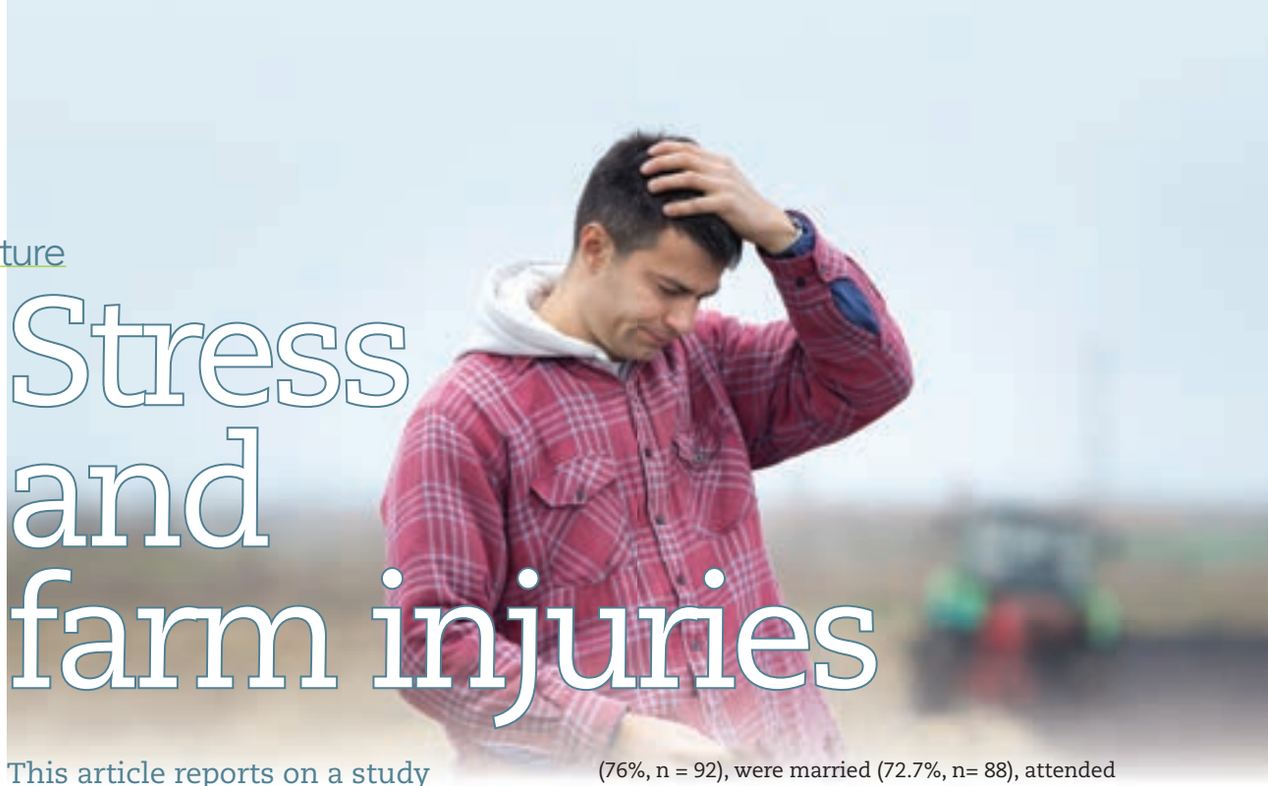
Thanks also to all the Teagasc staff and student volunteers who contributed to the success of this event.

Stress and farm injuries



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This article reports on a study investigating the effects of farm stress, financial worries and social support on farmers' expected injuries. The study has been published in *Frontiers in Public Health, Occupational Health and Safety*, an online open access journal.

Farming is one of the most dangerous occupations both in Ireland and worldwide, with the highest rate of fatalities in any industry. Farmers often work alone, work long hours, sometimes with unreliable equipment in difficult weather conditions with hazardous chemicals and unpredictable livestock. Stress is the normal human response to difficult circumstance, but prolonged stress can undermine mental health and reduce the farmer's ability to deal with dangerous situations. Increased stress predicts farm injury and reduced safety behaviours. The main stressors identified among farmers internationally are: their evaluation of the state of the household economy, presence of unsafe working conditions, injury, ill health or disability.

Since financial worries are among the foremost concerns of farmers, we investigated whether such worries contribute to safety concerns on the farm and, in particular, farmers' expectations of injury. In light of recent changes in milk pricing and the increased rate of fatalities in the sector, we focused on dairy farmers. We tested whether financial worries and general farm stress predicted expected injuries and whether social supports and good mental health provided a buffer against these negative effects. It is our hope that our findings will shape policy and personal interventions to reduce farm accidents.

Sample

In total, 121 active male dairy farmers participated in the study. The sample was recruited at Teagasc events/contacts throughout the country by convenience sampling (response rate, 44%). The majority had farms greater than 48 hectares (59.5%, n =72); most farmers had completed at least secondary level education (76%, n = 92), were married (72.7%, n= 88), attended Teagasc meetings at least 'often' (70.2%, n = 85) and were identified as specialist dairy-type farmer (66.9%, n = 81) or mixed dairy (dairy and cattle) (25.6%, n = 31). Most participants' farms (95%, n = 115) were on a trend of expansion and farm debt was bimodally distributed with a similar proportion reporting debt of less than €50,000 or in excess of €200,000 (37.2%, n =45).

Study findings

Farm stress was measured using the Edinburgh Farm Stress Scale and the average stress levels reported by our farmers were similar to those reported in previous research conducted by Deary and colleagues in Scotland. The highest stress (on a scale from 1 to 5) was reported due to time pressure (3.0), followed by bureaucracy (2.8), unpredictability of the job (2.5), personal hazards (2.5), and financial worries (2.4). Isolation (1.7) was the least likely source of stress, indicating our farmers had relatively high levels of social support (89 of the farmers reported high or very high levels of support). Subjective finanical worries were not reliably related to farm debt and, though overall levels of financial threat did not indicate high distress, some farmers reported very high levels of financial worries.

Farmers' expectations of injury (FEI) was the outcome we were interested in.

This was measured using the 'susceptibility to a farm-related accident/illness' subscale of the Farm Safety and Health Beliefs Scale. We used a structural equation model to map the effects of financial worries (financial threat), other farm stresses (i.e., non-financial farm stress), social support and mental distress on FEI (see Figure 1). Our analysis indicated that non-financial farm stress and financial worries contribute to mental distress and mental distress affects FEI. So, the effects of stress and financial worries on injury are reduced in farmers with better mental health (lower distress). Thus, we found some evidence that good mental health provides a buffer against the negative effects of financial worries and farm stress on expected farm injuries. Social support reduces mental distress (improves mental health) and reduces the increases in expected injuries due to stress and financial worries.

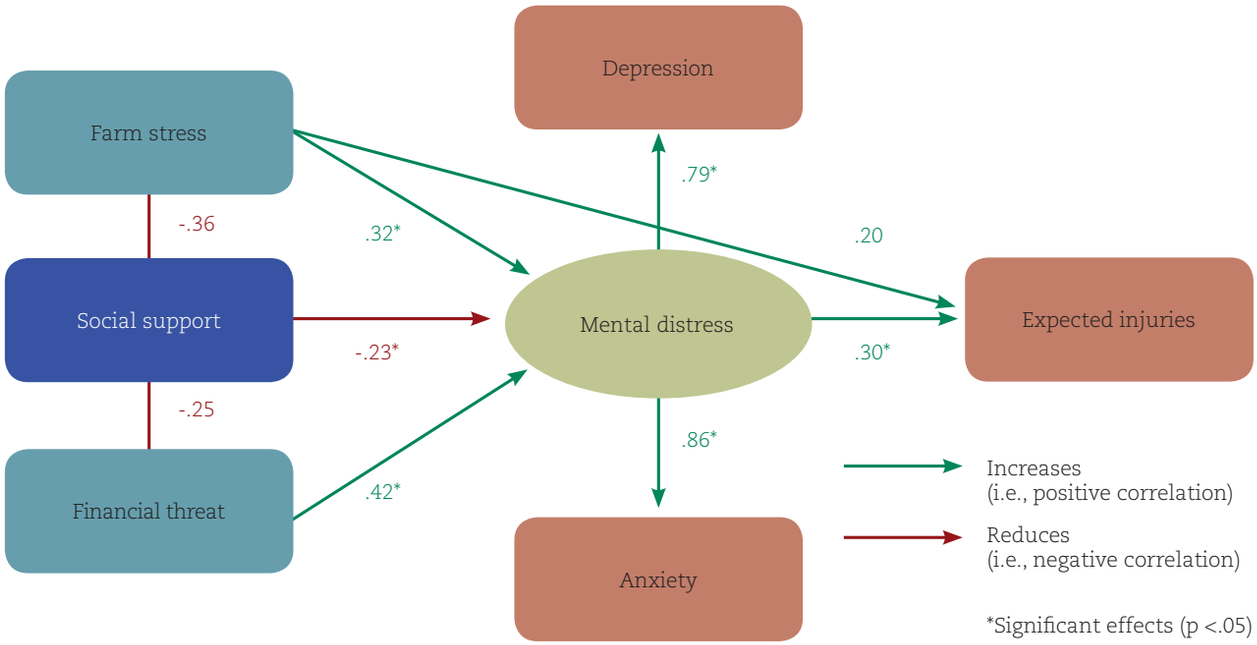

Figure 1. The effects of financial threat, farm stress and social support on expected farm injuries.

Discussion

Our study is one of the first to track the effects of farm stresses, both financial and non-financial on farmers' safety concerns. Previous research from other industries suggests that lone-working conditions and self-employment put farmers at greater risk of stresses giving rise to safety issues at work, but this had not been tested before. The effects of financial threat are of particular interest considering recent market changes that have increased the volatility of dairy farm incomes. Our objective measures of farm financial position did not reliably predict safety concerns, suggesting that the relationship between financial position and stress is more complex than one might expect.

Our study captured a snapshot of farmers' responses to farm stresses. The relationships between the stress, social support, mental health and farm injury are, however, much more interactive and cyclical than this analysis might suggest. For instance, stress and financial worries give rise to mental distress, so there is potential for a vicious cycle when stress and financial worries persist. Chronic stress undermines the farmer's ability to deal with new stressors and makes it more likely that these new stressors will affect farm safety. Dysfunctional coping strategies, such as 'cutting corners', can lead to accidents that reduce the farmers' ability to run the farm. Conversely, there is potential for a virtuous cycle in which increased mental health facilitates further increases in mental heath by encouraging greater contact with social support.

One way to encourage such virtuous cycles is through the provision of support to farmers through extension services. Extension takes the agricultural knowledge and information systems (AKIS) approach, in which the farmer is centrally positioned with access to multiple sources of knowledge and information from research, extension, and education. The AKIS approach provides a framework through which interventions can be developed to enhance farmer health and safety including mental health. Collaboration between farmer representative groups, development groups, and Government departments of health and agriculture is needed to facilitate appropriate interventions. Farmers would also benefit from interventions, such as mental health first aid, that normalise healthy coping strategies and minimise exposure to mental health stigma.

Social support is beneficial in coping with known stressors and financial uncertainty. The trends toward reduced labour input and infrastructural investment in farming have meant that farmers spend more time lone working, which has the potential to increase stress and reduce social support. Peer networks have also been shown to increase farm productivity, so initiatives that seek to connect farmers in groups can have multiple benefits for improving farm safety and productivity.

The study findings generally support the total worker health approach (The National Institute for Occupational Safety and Health, US), which advocates integration of traditional safety and health protection within a broader health-promotion focus that acknowledges interactions between health and wellbeing and workplace injuries.

Study limitations

The study was undertaken by convenience sampling among dairy farmers at one point in time. Though the study had considerable buy-in from the farmers, it is still difficult to access those most in need of financial and social support.

Acknowledgements.

Sincere thanks to Chris Noone of NUI Galway, who provided statistical expertise and is an author of the original article in *Frontiers in Public Health*. The authors would also like to express their thanks to all the farmers who participated in the study and to the Teagasc Advisors, who facilitated recruitment.

Further reading

The study has been published in Frontiers in Public Health, Occupational Health and Safety, an online open access journal and is available at http://dx.doi.org/10.3389/fpubh.2016.00126

Dairy processing research – technology highlights

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Phil Kelly reflects on advances in dairy processing research and development in recent decades and how research at Teagasc Food Research Centre Moorepark has contributed to these advancements.

Ireland's increased milk production output following the country's accession to membership of the European Economic Community (EEC) in the early 1970s defined the shape of the dairy processing industry for decades to follow – a highly seasonal milk production pattern requiring high-capacity, commodity milk-manufacturing processes for the production of butter, skim milk powder, casein and cheddar cheese. Within a decade, the industry experienced at least two international energy crises that influenced future processing equipment design, i.e., increased emphasis on energy conservation and cost competitiveness.

Milk-drying technology

The evolution of two-stage and multi-stage spray driers provided dairy processors with more efficient high-capacity drying, along with better control over powder bulk density, solubility and solvent-extractable free fats in the case of whole milk and fat-filled milk powders. The emergence of X-ray analysis by means of ESCA and XPS to characterise fat on the surface of powders (surface fat) paved the way for a new understanding of drying dynamics during the transition from milk droplets to powder particles, including the potential for microencapsulation.

The introduction of milk production quotas by the EU in 1984 provided a breathing space for industry to explore opportunities for greater value-added generation from the available milk supply. Gradually, a significant ingredient innovation programme began to evolve around commodity manufacture that took advantage of available processing infrastructure, drying technology and associated skills.

Milk protein concentration and isolation technologies

Technologies surrounding the recovery and functionalising of milk proteins became prime movers behind the Irish dairy industry's ingredient programme development.

Developments in curd-pasteurisation methods and improved milk-coagulation processes were major drivers behind the upgrading of acid and rennet caseins from that of industrial products to highly functional

food ingredients. Ireland became one of the EU's leading exporters of casein to the US. In recent years, the withdrawal of EU manufacturing subsidies and the emergence of substitute ingredient processes such as milk protein concentrates (MPCs) lessened the prominence of casein in the national dairy product mix.

Applications of membrane separation technology represent the single biggest technological development in dairy processing since the 1960s. Teagasc researchers Rory Delaney and Kieran Donnelly made a breakthrough at Moorepark in the late 1960s by exploiting reverse osmosis (RO) as a low-cost approach to dewater whey. They also showed that whey proteins could be selectively concentrated using ultrafiltration (UF). Further international membrane developments emerged in the 1990s – nanofiltration (NF) made it possible to simultaneously concentrate and partially demineralise whey, while microfiltration (MF) enabled whey protein concentrates (WPCs) to be upgraded to higher value-added whey protein isolates (WPIs). Mitchelstown Creameries (later Dairygold) invested in groundbreaking ion-exchange technology (Vistec Process/Bio-Isolates) for the production of whey protein isolate a key ingredient used in infant milk formula production. Today, Dairygold features the largest electrodialysis installation in Europe for the production of demineralised whey powder and concentrates – key ingredients used in infant milk formula production.

Ingredient innovation and nutritional functionality

The growth in infant milk formula (IMF) manufacture in Ireland created a supply-chain relationship involving milk production, ingredient procurement, process development and end-product functionality. A platform technology for IMF process validation and formulation development, which models the interactions between ingredient functionality and processing on formulations to ensure satisfactory powder reconstitution in the hands of the consumer, was initiated at Moorepark in 2006. This platform technology is anchored around the diagnostic support provided by advances in laboratory instrumentation e.g., rheology, particle-size measurement and the powder microstructure analytical capability of the National Food Imaging Centre at Moorepark.

Cheese

Ireland's cheddar cheese industry in its earlier years featured significant business partnerships between UK companies such as Express Dairies and Unigate and local dairy cooperatives. These joint enterprises provided market access and technological innovation, e.g., Unigate's associated company, Wincanton Engineering, was responsible for significant mechanisation initiatives with its development of the Wincanton cheese blockformer. Express Dairies successfully blended alcohol and cream to create a unique product concept - Irish Cream Liqueur. Another technological first was Express Dairies' adaptation of yeast fermentation in order to utilise whey permeate as feedstock to produce alcohol at Carbery Milk Products Ltd.

Enclosed vats (Damrow Double-O and Tetra Tebel's OST series) quickly replaced traditional, long, open types because of improvements to cheese-milk preheating, curd cutting and handling – a combination of features that contributed to improved cheese quality and reduced manufacturing losses.

In the 1970s, a worldwide shortage of calf rennet led to a search for suitable alternative milk coagulants. Recombinant DNA technology provided a successful solution in 1990 when Pfizer cloned the genes responsible for rennet secretion by bio-fermentation to produce Chy-Max – a chymosin with enzymatic activity identical to calf rennet.

During the 1980s, cheese starter cultures used by the Irish cheese manufacturing industry were susceptible to frequent incidence of bacteriophage attacks, which resulted in product downgrade and productivity losses. Collaborative research between Teagasc Moorepark and UCC succeeded in developing the 'defined strain starter system', which provided industry with greater cheese-quality assurance.

Cheese has continued to figure prominently on the research programme at Moorepark since 1990 with topics including development of low-fat/low-salt varieties, cheese yields, bacteriophage control and the nucleic acid-based techniques to diagnose microbial-related cheese defects. Successes in cheese diversification include the commercialisation of the well-known Dubliner cheese brand by Carbery Milk Products, and the utilisation of novel ingredient recombination technology for manufacture of localised cheeses in Saudi Arabia by Ornua.

Butter and dairy spreads

Higher capacity continuous butter making machines based on the Fritz process were required to handle increasing volumes of cream. A focus on new, mainland European markets demanded a switch of production methods from sweet cream to lactic butter. Adoption of Dutch organisation NIZO's two-concentrate system – a starter culture and a flavour distillate – simplified lactic butter production without the need for prior culturing of cream in large silos.

During the 1980s, a concerted research effort was made to improve the spreadability of butter by investigating seasonal variation in composition of fatty acids in milk, cream tempering regimes and post-butter production microfixing. Teagasc Moorepark successfully developed a so-called 'mono-butter' concept – an initiative that boosted the mono-unsaturated fat level (high oleic acid) in milk through manipulation of cows' diet.

The launch of a table spread, Clover – a milkfat/vegetable oil blend – by a UK dairy in 1983 represented a major break with tradition, i.e., the co-existence of non-dairy fats with milk fat was, hitherto, generally not countenanced inside a dairy factory. Dairy processors now embraced margarine manufacturing technology as consumers switched preferences to table spreads with much reduced-fat contents, typically 40% to 60%, compared to traditional butter (80% fat). Technological innovation in the case of each product specification relies on careful optimisation of aqueous phase formulation prior to blending with oils to form an initial coarse oil-in-water emulsion. Subsequent crystallisation and plasticisation is achieved in scraped surface chillers with pin workers.

Moorepark Technology Ltd (MTL)

In line with its mission, numerous innovative, large-scale, industry-led projects have been successfully accomplished in Moorepark Technology Ltd's large-scale pilot-production facilities. Examples include production of a hypoallergenic whey protein ingredient based on the hydrolysis of 'traditional' lactalbumin and 'Alphalac' – a highly-enriched whey-protein ingredient containing α-lactalbumin.

Examining milk-production benefits of clover

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What role can white clover play in Ireland's expanding grass-based dairy industry?

The role of white clover

Pasture-based production systems, such as those practised in north-west Europe, New Zealand and Australia, rely on highly productive perennial-ryegrass (PRG [*Lolium perenne* L.]) swards to meet animal feed requirements. Forage legumes offer the opportunity to increase the performance of pasture-based production systems and, consequently, there is renewed interest in forage legumes such as white clover (*Trifolium repens* L.). Worldwide, white clover is the most important forage legume in temperate grazing systems. The inclusion of white clover in grass-based animal production systems can have a number of positive benefits to the system including the potential to increase herbage production, increase animal performance, and replace or reduce the requirement for inorganic nitrogen (N) fertilizer. Traditionally, in mixed-perennial ryegrass white clover swards with low livestock stocking rates, inorganic N fertilizer inputs are reduced due to the ability of white clover to fix atmospheric N and make it available for grass growth. There may be opportunities to combine high inputs of inorganic N fertilizer with white clover to increase the productivity of high stocking rate pasture-based production systems.

Recent Teagasc experiment

An experiment is being undertaken at Teagasc Moorepark investigating the use of white clover in high stocking rate pasture-based systems. The experiment was established in January 2013. The experiment is a fully enclosed systems experiment with three treatments: grass-only receiving 250kg N/ha (Gr250), grass white clover receiving 250kg N/ha (Cl250) and grass white clover receiving 150kg N/ha (Cl150). each stocked at 2.75 LU/ha.

Results are available for the three-year period, 2013 to 2015. Herbage production was similar across the three treatments – 14,527kg dry matter (DM)/ha per year, of which 4,034kg and 3,521kg DM/ha per year was clover for the Cl150 and Cl250, respectively (Table 1). Although there was no difference in herbage DM production between the three treatments, it is interesting to note that the Cl150 treatment had the same herbage DM production as the Gr250 and Cl250 treatments despite receiving 100kg N/ha less than those treatments. The reduction in N fertilizer application resulted in a 4% increase in sward clover content on Cl150 compared with Cl250 (28% vs. 24%; Figure 1). The sward clover content on Cl250 is higher than previously reported at that N fertilizer application rate, most likely due to the increased grazing intensity imposed in the current study. Intensive grazing ensures that pre-grazing herbage mass rarely exceeded 1,500kg DM/ha and grazing to 4cm allows light to penetrate to the base of the sward, resulting in reduced shading of clover plants and stolons by grass in the sward.

Table 1. Daily and cumulative milk production and cumulative herbage production for grass-only swards receiving 250kg N/ha (Gr250) and grass-clover swards receiving 150kg N/ha and 250kg N/ha (Cl150 and Cl250, respectively).

	Cl150	Cl250	Gr50
Milk yield (kg/cow/day)	23.0	23.7	21.9
Milk solids (kg/cow/day)	1.84	1.87	1.75
Milk fat (%)	4.60	4.53	4.61
Milk protein (%)	3.60	3.57	3.64
Cumulative milk solids (kg/cow)	508	514	482
Cumulative milk solids (kg/ha)	1,392	1,408	1,320
Annual herbage production (kg DM/ha)	14,410	14,670	14,500
White clover herbage productionon (kg DM/ha)	4,034	3,521	-

The benefits of clover for milk production are well documented, and agree with the findings of the current study. Milk solids production was greater on the clover treatments (508kg MS/cow and 514kg MS/cow on Cl150 and Cl250, respectively) compared with Gr250 (482kg MS/cow). This difference in milk-solids production occurred from mid-June onwards (Figure 1). The clover treatments produced an additional 72kg to 88kg MS/ha compared to Gr250 (Table 1). In grazed PRG/clover swards, an increase in milk production can occur due to a combination of both feed quality and intake factors. The Cl250 and Cl150 sward had a 10% lower fibre content compared to the Gr250 treatment. In addition, DM intake was greater for the Cl250 and Cl150 treatments (+1.3kg DM/cow/day compared with Gr250) from July to September. The combination of reduced fibre content and greater DM intake likely contributed to the increased milk production on both clover treatments compared to the Gr250 treatment.

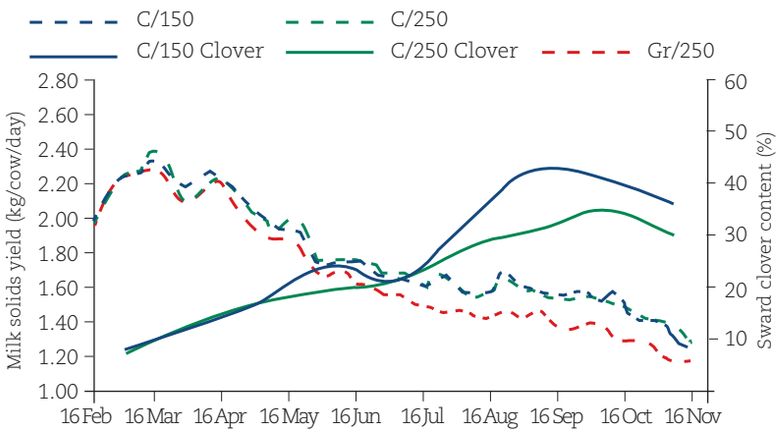

Figure 1. Average daily milk solids production (kg MS/cow/day) from a grass-only sward receiving 250kg N/ha (Gr250), and grass clover swards receiving 250kg N/ha (Cl250) or 150kg N/ha (Cl150) for 2013 to 2015, and average sward clover content for the Cl250 (solid green line) and the Cl150 sward (solid blue line).

Incorporating white clover into grass-based milk production systems in conjunction with high levels of inorganic N offers an opportunity to increase animal performance. In some circumstances, clover inclusion may also provide the opportunity to strategically reduce inorganic N input to high stocking rate grass-based systems.

On-farm white clover evaluation

In the summer 2016, Teagasc Moorepark commenced an on-farm white clover cultivar evaluation on 10 farms across the country. The objective of this project is to evaluate the performance of five white clove cultivars (Chieftain, Iona, Buddy, Aber Hearld and AberAce) sown on a range on soil types, geographical locations and managements. Sowing commenced at the end of April 2016 and continued until mid-August 2016. All white clover cultivars were over-sown into existing PRG swards using an Einböck Pneumatic Seeder (P.J. Callan LTD. Ardee, Co Louth) at a sowing rate of 3.7kg/ha. Eleven weeks post sowing, white clover plant counts will be made to determine emergence rates. Each white clover cultivar will be monitored for a number of years to determine sward white clover content, herbage DM yield, and white clover persistence for each cultivar.

Acknowledgements

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Milking-time tests – from research to practice

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Effective milking management strategies rely on the cow, milker and milking machine operating in harmony. Traditional 'dry tests' of milking machines are carried out once per year by registered Irish Milk Quality Co-operative Society technicians as part of the annual milking machine maintenance schedule and include pulsation tests, vacuum measurements and airflow measurements. These tests are effective in checking that the functionality of the milking machine conforms to the International Standards Specification; however, it can be difficult to diagnose some milking issues through dry tests alone.

Milking-time tests

Some research techniques, such as the use of a VaDia (vacuum diagnostics of milking) vacuum recorder and teat-condition assessments, can be employed at farm level to diagnose problems related to increased milking time, impaired cow comfort or increased rates of intramammary infection. These milking-time tests, or 'wet tests', facilitate analysis of the interaction between the milking machine and the cow, and can identify issues such as over-milking or poor milk let down, which can lead to increased milking times.

The VaDia is a battery-operated data logger, and is small and light enough to be taped to a teatcup during milking (Figure 1). VaDia logs the vacuum data at four points during milking. The data can be downloaded and analysed to identify any vacuum irregularities and, thus, identify where the milking equipment and milking routine are underperforming. An example of the vacuum data recorded during normal milking and during the over-milking period is illustrated in Figure 2. The over-milking period is identifiable by the point

where the mouthpiece chamber (MPC) vacuum increases sharply towards the end of milking. In this example, the entire milking lasted for eight minutes and 27 seconds. The normal milking time was six minutes and 18 seconds and over-milking time was one minute and 58 seconds.

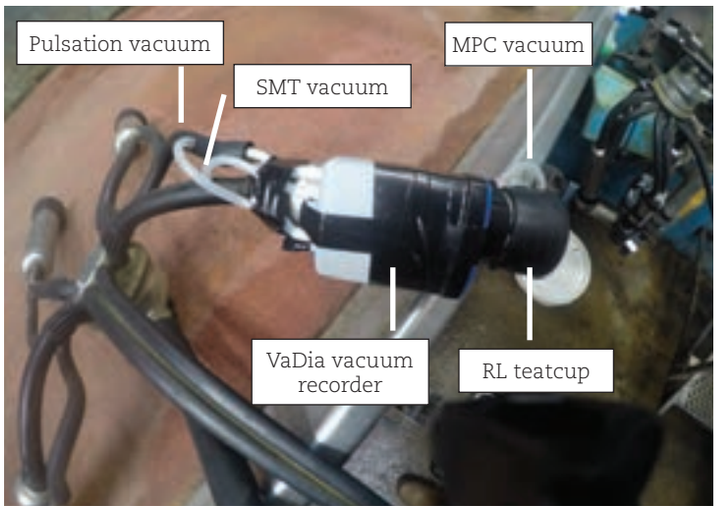

Figure 1. VaDia device fitted to the rear left teatcup of the cluster. Recording points for short milk tube vacuum and mouthpiece chamber vacuum can be clearly seen.

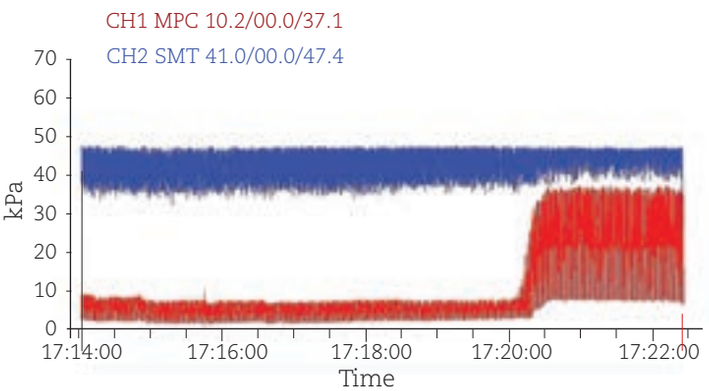

Figure 2. Short milk tube vacuum (in blue) and mouthpiece chamber vacuum (in red) during normal milking and during the over-milking period.

Teat condition assessment

When coupled with cow level measurements of teat dimensions and teat condition, most milking-related issues can be identified and addressed. Classification of cow teat size and condition can be conveniently assessed using a camera with voice recording and a reference grid (Figures 3 and 4). Short-term changes in teat condition include firmness or swelling of the teat-end after milking and swelling at the base of the teat. Factors commonly associated with teat-barrel swelling include over milking, teatcup crawling or high mouthpiece chamber vacuum caused by a mismatch between liner type and teat size. Factors commonly associated with swelling near the teat-end include over milking, high vacuum, pulsation failure or insufficient rest phase of pulsation. Two trigger levels for action have been identified:

(1) Greater than 20% of cows with at least one teat classified as hard or swollen;
(2) Greater than 20% of cows with at least one teat with ringing at the base of the teat (Reinemann *et al.*, 2001).

Figure 3. Measuring teat length and diameter using a camera and reference grid.

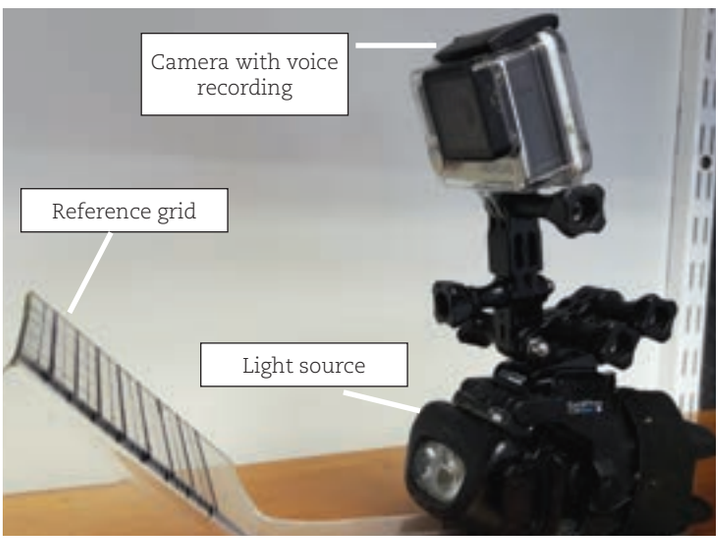

Figure 4. Device for milking parlour assessment of teat condition, teat length and teat diameter.

Longer-term changes in teat-end condition can be monitored by assessing the degree of hyperkeratosis (or roughness of the teat-ends) in the herd. Major factors affecting teat-end hyperkeratosis include teat-end shape, production level, stage of lactation and interactions between milking management and machine factors (i.e., slow milking and over-milking). The trigger level for action is greater than 20% of cows with at least one teat classified as rough or very rough (Reinemann *et al.*, 2001).

Benefits of the approach

Combining milking time tests with teat-condition assessment provides a powerful suite of information for assessing milking machine and cow interactive effects. Teat swelling or damage, which becomes evident during these observations, can often be explained by vacuum data obtained through application of the VaDia device. More specific advice can then be given to the farmer in order to address the issues identified.

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Anthelmintic drug resistance in sheep

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A recent study identifies the first cases of ivermectin and multi-drug resistance in sheep roundworms in Ireland.

Irish lamb production is pasture-based with grazing sheep naturally exposed to gastrointestinal nematodes (roundworms). Roundworm infection in lambs results in ill-thrift and occasional death. Even sub-clinical infection results in production losses, in the form of reduced growth rate and light, under-finished carcasses. Sheep in Ireland are generally infected with a number of roundworm species including *Teladorsagia circumcincta* (brown stomach worm), *Trichostrongylus* (black scour worm), *Nematodirus* and *Cooperia*. The level of infection in a flock of lambs can be ascertained by counting the number of eggs per gram of faeces (faecal egg count or FEC).

Anthelmintic drug resistance

For over 50 years, the administration of broad-spectrum anthelmintics has been effective in controlling roundworms in sheep but, in recent years, reports of anthelmintic resistance are increasing worldwide. Anthelmintic resistance can be defined as the inherited ability of worms to survive doses of drugs that would normally kill them. Anthelmintic resistance is detected by a faecal egg count reduction test (FECRT) with resistance declared if the reduction in egg count is <95% and the lower confidence limit is <90%. If only one of these criteria is met, resistance is suspected. Three classes of anthelmintics are commonly used to treat sheep in Ireland – benzimidazole (BZ, white drench), levamisole (LEV, yellow drench) and macrocyclic lactone (ML, clear drench). Resistance to BZ and LEV has previously been reported in Ireland. Resistance to ML (ivermectin [IVM] and moxidectin [MOX]), was suspected but not confirmed (Good *et al*., 2012). The objective of this study was to determine if IVM resistance was present among sheep nematodes in Ireland and if IVM-resistant roundworms were also resistant to BZ and LEV anthelmintics.

Study farms

Four sheep-only farms with suspected IVM resistance were identified and a FECRT carried out on each to establish the efficacy of IVM treatment. The results are shown in Table 1. One farm (B) had clear evidence of IVM resistance with a reduction

in egg count of 77% and a lower confidence limit of 60%. A second farm (A) had suspected resistance with a reduction in egg count of 95% and a lower confidence limit of 87%. The other two farms had no evidence of IVM resistance with reductions in egg counts of 99% and 100%. Lambs from farms A and B were treated twice with IVM and surviving worms were recovered at slaughter, confirming resistant worms were present on both farms. Resistant worms were determined to belong to the species *Teladorsagia circumcincta* with no other species resistant.

Table 1. On-farm faecal egg count reduction test (FECRT) response to ivermectin.

Farm ID (location)	Lambs (n)	Mean faecal egg count (eggs per gram of faeces)		Percentage reduction (confidence interval)
		Pre-treatment	Post-treatment	
A (Cavan)	20	1,352	73	95 (86–98)
B (Wicklow)	20	695	158	77 (60–87)
C (Tipperary)	18	689	6	99 (93–100)
D (Sligo)	20	857	0	100 (n/a)

Evidence of multidrug resistance

The pure populations of isolated *T. circumcincta* were further characterised in terms of their level of resistance to IVM and to the other commonly-used anthelmintics (BZ and LEV). To this end, the worms recovered from lambs on farms A and B were used to infect naïve lambs, which were then treated with BZ, LEV or IVM, or left as untreated controls. Faecal samples were collected from all animals at an appropriate interval post-dosing and egg counts were determined. The resultant FECRT values are shown in Table 2. Both isolates showed evidence of multi-drug resistance, with all three anthelmintics failing to reduce the egg count by more than 95%. For the Farm A isolate, treatment with BZ, LEV and IVM resulted in reductions in egg count of 47%, 92% and 50%, respectively. For the Farm B isolate, the corresponding reductions were 85%, 89% and 73%, respectively.

Table 2. Faecal egg count reduction test (FECRT) with pure populations of *Teladorsagia circumcincta* from Farm A and Farm B.

Isolate ID	Lambs (n)	Percentage reduction (confidence interval)	
		BZ	LEV
Farm A	15	47 (10–68)	92 (74–97)
Farm B	14	85 (59–94)	89 (69–96)

In order to establish levels of resistance to MOX, lambs infected with the resistant *T. cirumcincta* were treated with MOX and worm burdens measured at slaughter. MOX treatment resulted in reductions in mean total worm burden of 97% (Farm A) and 100% (Farm B), and there was no evidence for MOX resistance.

The resistance level of the two isolates to all anthelmintics was also confirmed using *in vitro* tests, namely the larval development assay (for BZ and LEV) and larval migration inhibition assay (for IVM and MOX). Further details of this study can be found in Keegan *et al.*, 2016.

First cases of IVM resistance

The results from this study are confirmation of the first cases of IVM resistance in sheep nematodes in the Republic of Ireland, with *T. circumcincta* identified as the resistant species in both farms. Moreover, multi-drug resistance (BZ, LEV and IVM) was confirmed for the first time in Ireland using both *in vivo* and *in vitro* tests. *T. circumcincta* is the main species associated with multi-drug resistance in Europe and the results of this study are in agreement with those findings. Resistance to BZ and LEV in the Republic of Ireland is believed to be widespread and it is possible that IVM resistance would arise in nematodes that are already BZ and LEV resistant. Considering the increasing frequency of reports of multi-drug resistance in Europe and the result from drench tests conducted nationwide in Ireland, which showed inefficacy of ML on 24% of farms (Keane *et al.*, 2014), the true extent of ML resistance in Irish sheep nematode populations warrants investigation. Furthermore, practices that delay the further development of ML resistance should be adopted now, in order to prolong the efficacy of the currently available anthelmintics. The adoption of improved biosecurity measures around the introduction of new animals into the flock and strategic use of the new ovine anthelmintic classes on the market (the amino acetonitrile derivatives and spiriondoles) are recommended.

Acknowledgments

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Hybrid breeding in ryegrass

One possible route towards hybrid breeding in perennial ryegrass (PRG) is the directed use of self-incompatibility. The genes responsible for this have been analysed in joint research projects with Teagasc and international collaborators.

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Why is hybrid breeding interesting?

PRG (*Lolium perenne*) is the predominant pasture grass of temperate regions where it underpins milk and meat production. Despite its fundamental importance to agricultural productivity, the mechanisms by which it achieves this yield-enhancing effect are relatively poorly understood.

Heterosis (or hybrid vigour) is a natural phenomenon whereby hybrid offspring of genetically diverse individuals display improved physical and functional characteristics relative to their parents. Heterosis has been increasingly applied in crop production in hybrid breeding systems for nearly a century, with the aim of developing more vigorous, higher-yielding and better-performing cultivars. In addition, while it has been exploited to great effect for many plant species, in many species heterosis is exploited in a sub-optimal manner, largely due to constraints linked to their reproductive biology. PRG is one such species. Plant breeding is the primary route for increasing the yield and productivity of the crops that are responsible for feeding the world.

Self-incompatibility and hybrid breeding

A possible route towards exploitation of hybrid vigour in PRG is to radically redesign the way in which PRG is bred, developing alternative hybrid breeding strategies that will increase the rate of genetic improvement of PRG to a level similar to that of cereals. One such alternative – besides the use of cytoplasmic male sterility (CMS) – could be the exploitation of self-incompatibility (SI). Self-incompatibility (SI) is a general name for several genetic mechanisms in angiosperms, which prevent self-fertilisation and thus encourage outcrossing and allogamy. The rate of genetic gain for yield in outbreeding allogamous (cross-fertilising) forage crops like PRG is low, with the decadal average improvement in overall yield of PRG (4%) lagging far behind that of cereal crops (approximately 16%). Because of its obligate out-breeding reproductive system, PRG varieties are populations produced from random inter-crossing of between four and 40 parents, which have undergone prior selection in swards and as single plants. The selection procedure is based largely on full-sib or half-sib progeny tests under sward conditions. In addition, use of multiple heterozygous parents means that it is difficult to introduce and subsequently fix alleles for key traits into PRG varieties. These factors have contributed to low levels of genetic gain in biomass yield for the species.

How does SI in grasses work?

SI in PRG – like in all other grasses – is governed by the complementary action of two gametophytically-expressed genes, denominated S and Z. The SI phenotype of pollen is determined by its own (haploid) S haplotype. The pollen is rejected when the S-haplotype of the haploid pollen matches either of the two S-haplotypes of the diploid pistil. The effectiveness of SI limits to a certain level the efficient production of inbred lines and hybrids in plant breeding. As a consequence, the breeding of turf and forage ryegrasses involves generating synthetic varieties from polycrossing (female parent is known but the male may belong to any of several available strains) selected multiple mother plants. The production of synthetics would make it possible to exploit heterosis effects. On the other hand, in the process of selecting important traits, homozygosity of regions of the genome and homogeneity of these regions across the breeding population would be developed. If the selected traits are linked to S and Z, seed yield of the breeding population could be seriously compromised.

Components of SI

Until recently, none of the gene products of S and Z have been reported to be identified in any grass species. This hurdle is now overcome with the identification of the S locus (Manzanares *et al.*

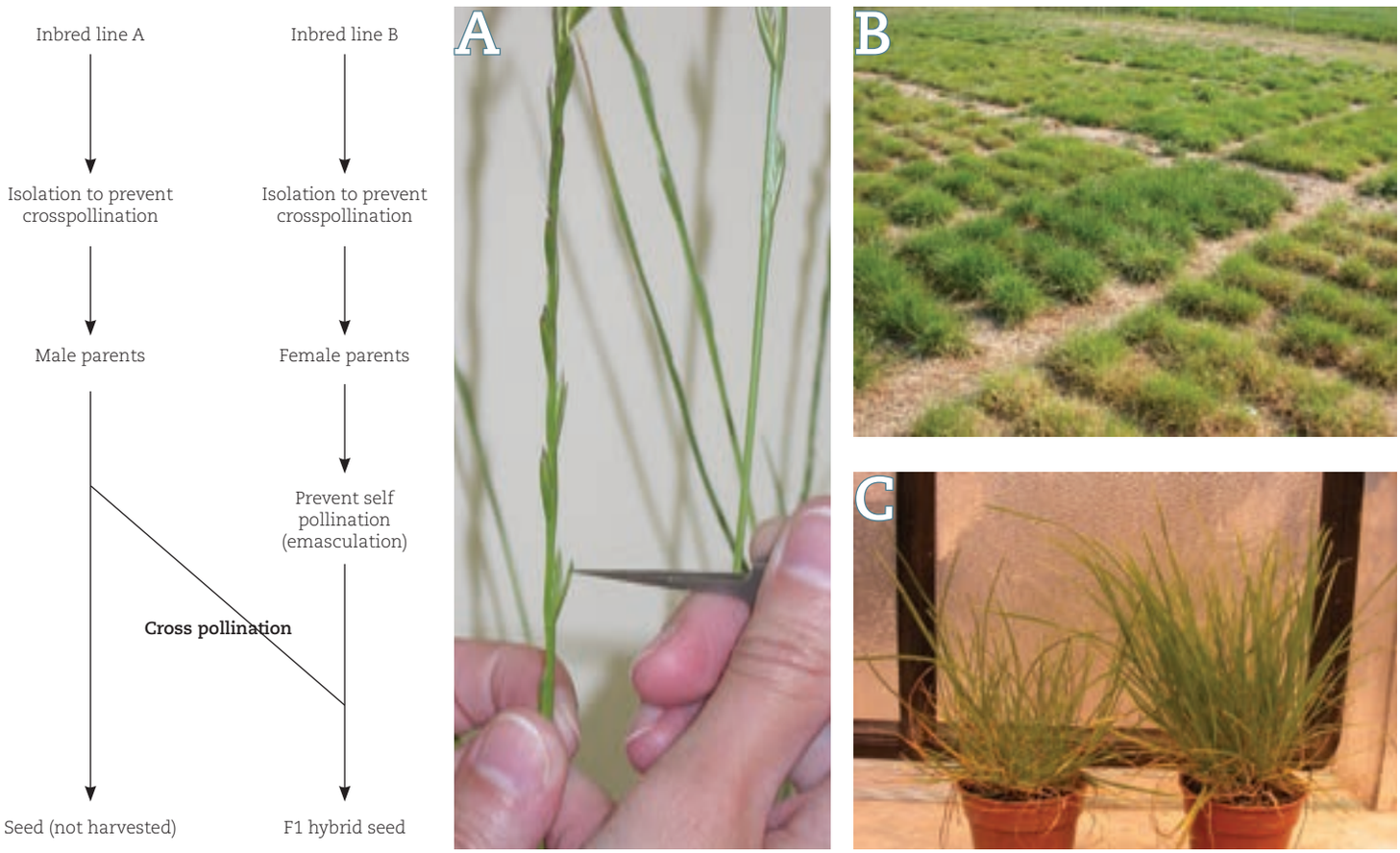

Figure 1. F1 hybrids are a cross between two distinct inbred lines. Such F1 hybrids are uniform and exhibit 'hybrid vigour'. Producing F1 hybrids in an outbreeding grass such as PRG is a long and labour-intensive process if no classified self-incompatibility (SI) system is available to produce directed crosses without emasculation and hand pollinations. If SI is available only suitable lines with a complementary mode in the SI system governing S and Z are required to produce successful hybrid seed. Panel A – emasculation, Panels B and C – differences in crop vigour in different lines in field and pot experiments.

2015) and the Z locus to be reported later in 2016 (Studer *et al.* unpublished). Having gene-specific markers for S and Z could lead to ways of (1) developing new breeding systems to better exploit the huge heterotic potential (vigour exhibited by resulting cross-breed) of the species and (2) maximising seed-yield potential through ensuring maximum allelic diversity in breeding populations. The components of hybrid breeding either do not naturally exist in perennial ryegrass or occur as low frequency mutants. However, work over the last several decades at Teagasc by grass breeder Vincent Connolly has resulted in the assembly of germplasm exhibiting all of the necessary characteristics required for hybrid breeding. Inbred lines of PRG were developed during the experimental CMS breeding programme and constitute the maintainer lines of the CMS programme. These inbred lines are based on a breakdown of the natural, genetically-determined, self-incompatibility system in PRG and represent a near-unique and powerful resource for genome-based studies. Because of this, they have subsequently been extensively employed in the PRG genome-based research programme at Teagasc.

Segregation distortion has been observed in different PRG populations and has led to the suggestion of two modifier loci involved in the two-locus self-incompatibility system. The two loci have been termed F and T. One of these loci is segregating uniquely in Teagasc material, which enables high selfing rates in the otherwise outbreeding crop species. Work is in progress to identify the nature of the underlying locus.

Acknowledgments

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Related publications

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Ten years of GAP regulations

Sreenty Lough, Co Monaghan.

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It is 10 years since the Nitrates Directive farming regulations were implemented in Ireland. In this article, using emerging evidence from the Agricultural Catchments Programme (ACP), we discuss some of the impacts of the regulations over that time.

The EU Nitrates Directive (ND) was introduced in 1991 (91, 676, EEC) to protect waters from pollution caused by nitrate from agricultural sources. Since then, European Union (EU) member states have implemented the ND through their National Action Programmes (NAP). The ND was given effect into Irish law by SI, 378 of 2006. The first NAP introduced the Good Agricultural Practice (GAP) regulations and included measures to protect water from agricultural phosphorus (P) pollution, as well as nitrate. The GAP regulations were amended in 2007 and 2009 and, following each of the first and second NAP reviews, they were further updated in 2010 (SI, 106 of 2010) and in 2014 (SI, 31 of 2014). These regulations are mandatory, unless specified otherwise, and implemented on a whole-territory basis – only varying slightly from region to region. From time to time, aspects of the GAP measures such as fertilizer allowances, buffer distances and organic nutrient availability (e.g,. dairy-soiled water) have been revised and updated based on new research findings. Nevertheless, the main focus of the GAP regulations remains the mitigation of potential nutrient transfers of nitrogen (N) and P from agricultural land either from point (e.g., farmyards) or diffuse (soil and fertilizer application) sources via measures targeted at farm management practices.

The Agricultural Catchments Programme (ACP)

Part of the ND implementation is evaluating the effectiveness of the GAP measures, which, since 2008, has been carried out by the Teagasc ACP and funded by the Department of Agriculture Food and the Marine (DAFM). This integrated research/advisory programme, with the participation of over 300 farmers, operates in six intensively farmed catchments ranging from 7.5km^2 to 30km^2. These were chosen to represent a specific combination of landscape soils and farming systems, representing potential risks for N and/or P loss to water. The same experimental approach is taken in each catchment where high spatial and temporal resolution monitoring is carried out across the nutrient cascade, i.e., starting with nutrient sources, through their loss pathways and transformations to when they are delivered to receiving waters. At the same time, social and economic impacts of the GAP regulations are assessed.

Trailing-shoe slurry spreading.

Evidence of change

- Following the introduction of the GAP regulations, Buckley *et al*. (2016a and 2016b) reported declines in farm-gate N and P surpluses (of 14% and 50%, respectively) and increases in N and P use efficiencies (of 2% and 18%, respectively) across 150 specialist dairy farms. This change was driven mainly by reduced use of chemical N and P fertilizers. Milk solids output increased from 405kg/ha to 450kg/ha (at a stocking rate of 1.86LU/ha to 1.84LU/ha) across these farms between 2006 and 2012.
- Murphy *et al*. (2015) reported a decline in P source pressure while maintaining production output in response to the GAP measures in an intensive ACP-monitored dairy grassland catchment (7.5km^2) in Timoleague, west Cork, between 2010 and 2013. The indictors of change included a reduction in average inorganic P-use of 5.2kg/ha/yr, lower average farm-gate P balances (i.e., surplus of applied P over removed P) of 2.4kg/ha/yr, higher average P-use efficiency of 89% relative to previous studies and the proportion of fields with excessive soil P (i.e., Index 4) decreasing from 32% to 24%. While P concentrations in the stream water did not change there were signs of a decrease in P concentration in some of the faster transfer pathways from the soil surface to the stream. The farms in the study maintained milk production figures comparable to the top 10% performing dairy farmers in the National Farm Survey.
- Shore *et al*. (2016) used high resolution P data and found that, while the closed period of slurry spreading is useful for mitigating losses during the risky winter period, there was no evidence of increased incidental nutrient losses causing increased P concentrations in catchment streams, when the closed period finishes. Signals of high P-concentration pulses in streams outside of the closed period were likely linked to incidental losses from manure spreading due to high-rainfall of summer storms.
- Using sediment records from Sreenty Lough (located in the ACP-monitored catchment in Co Monaghan), in an area vulnerable to P run-off from surrounding, poorly-drained drumlin soils, O'Dwyer *et al*. (2013) reported that while agriculture intensified (i.e., increasing from 8kg/ha to 17kg/ha in organic livestock P loading) between 2000 and 2010 there was an apparent increase in lake-water quality. P mitigation measures from the Rural Environmental Protection Scheme, group water scheme initiatives and the GAP regulations were likely key means and measures for the signs in lake recovery.

Future of GAP

The next and third review of Ireland's NAP will be in 2017 and possibly, with it, an update of the GAP regulations. With increased agricultural production targets under Food Wise 2025 and the continuing pressure to meet water-quality targets, the commitment shown by the DAFM in extending the ACP for another four years (2016 to 2019) is very welcome. Indeed, the fact that a continuing role for the ACP features in Food Wise 2025 indicates that the programme is well positioned to provide a platform for robust evaluation of GAP regulations, in addition to assessing new measures to reduce nutrient losses while maintaining or increasing agricultural output.

Acknowledgements

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Synchrotron application in functional foods

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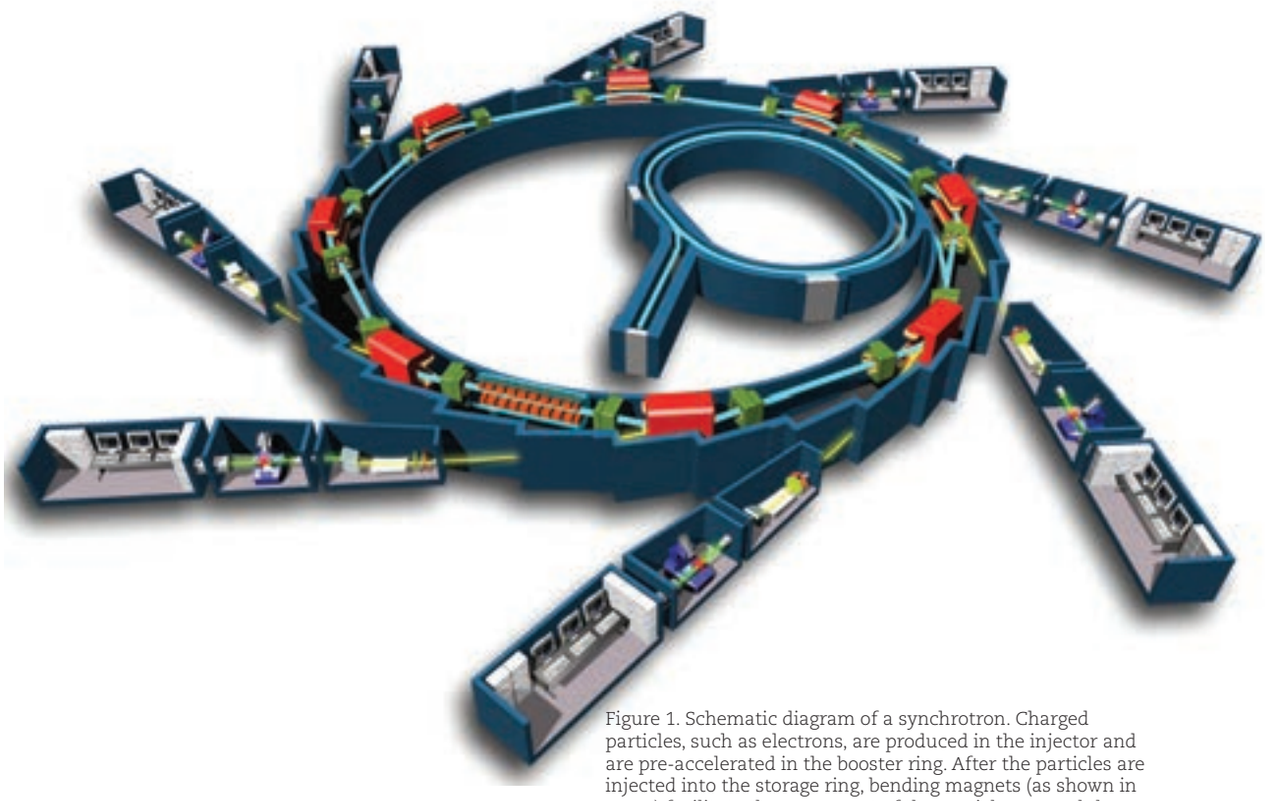

Figure 1. Schematic diagram of a synchrotron. Charged particles, such as electrons, are produced in the injector and are pre-accelerated in the booster ring. After the particles are injected into the storage ring, bending magnets (as shown in green) facilitate the movement of the particles around the ring, while a radio frequency generator holds the particles at a constant speed. Energy from accelerated particles is harvested as 'synchrotron light' in various beamlines. Image courtesy of EPSIM 3D/JF Santarelli, Synchrotron Soleil.

The article details the application of synchrotron light in a phytosterol-enriched milk system in order to improve human absorption.

There are over 60 synchrotrons in the world, with the most renowned being the CERN Large Hadron Collider (LHC) near Geneva, Switzerland. Synchrotrons are particle accelerators, which harness the power of charged particles to further understand the building blocks of matter (Figure 1). These instruments can differentiate structures ranging from subatomic particles to large food matrices. In terms of food science, these machines can be used to further our knowledge of the relationship between food microstructure and function.

High-powered synchrotron light can be used to study a wide range of food science topics, such as the morphology of compounds present in wine during ageing, wheat during baking or ice cream during freezing. In terms of functional foods, the application is relevant as it enables scientists to envision the molecular arrangement of the targeted bioactive

ingredient. Numerous questions regarding the molecular structure of food can thus be answered using a synchrotron; however, its use in food systems has been quite limited. By understanding the structure and behaviour of the compounds present in our food, scientists can gain a more complete picture of how to optimise the functionality of food ingredients.

The research discussed in this article utilises synchrotron technology to analyse how phytosterols, a plant bioactive that lowers levels of low-density lipoprotein (LDL) cholesterol or 'bad cholesterol', can be encapsulated into milk products. The potential for these compounds to be absorbed is dependent upon the solubility of the phytosterols; if the phytosterols are crystalline, their bioaccessibility decreases significantly (Pouteau *et al.*, 2003). Synchrotron light enables us to visualise how phytosterols crystallise within milk fat and how we can use different food ingredients to prevent their crystallisation to create a more effective functional food.

Preventing phytosterol crystallisation

Functional foods are foods with dietary components that provide a health benefit to the consumer that is beyond that of basic nutrition. As the rates of heart disease and obesity rise within society, so does the use of functional foods (Wildman *et al.*, 2016). In accordance, the global functional food market is expected to reach a net worth of $305.4 billion by 2020 (Wood, 2015). In the functional food industry, one of the most common and extensively studied group of bioactives are phytosterols.

Phytosterols, or plant sterols, are naturally-occurring compounds found in nuts, cereals, vegetables, and fruits. They are chemically similar to human cholesterol, which enables them to effectively reduce levels of LDL-cholesterol in the blood. To significantly lower levels of LDL-cholesterol levels, it is recommended to consume > 1.5g of plant sterols daily. In order to consume these levels, dietary supplementation is needed, as the average intake of plant sterols ranges between 160-400mg per day (Lagarda *et al.*, 2006).

Our study utilised milk fat to encapsulate phytosterols, creating a model system similar to milk, in order to study the functional performance of phytosterols. Milk has become a popular carrier for phytosterols, as it has been reported to be more effective at lowering LDL-cholesterol than bread or cereals (Clifton *et al.*, 2003). In order to study how the phytosterol crystallises within the milk system, samples were examined using synchrotron light at the Australian Synchrotron (Melbourne, Australia) in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Samples were melted and cooled to understand how and where phytosterols crystallise within a milk-fat system. These results were essential in developing the knowledge needed to prevent phytosterol crystallisation within formulations.

The next study undertaken at the Australian Synchrotron analysed phytosterols encapsulated within milk with different processing and formulation conditions. Results showed that, by incorporating lecithin and homogenising the formulation into small (200nm sized) droplets, phytosterol crystallisation could be reduced and the stability of the formulation improved. This quantification was made possible by the angstrom-level detail provided through the synchrotron x-rays, allowing phytosterol crystals to be identified and their formation followed as a function of time.

In conclusion, synchrotron light enables us to investigate the crystalline behaviour of phytosterols as affected by model milk systems with different formulations and processing conditions. By understanding how to control phytosterol crystallisation, the functional-food industry can design more bioaccessible and chemical-stable, phytosterol-enriched dairy products. To date, synchrotron use in food has been limited, but studies such as this highlight its potential for charactering food structure in detail, which was not possible before. Understanding the microstructure of food is crucial in the investigation of functional food performance, in order to deliver the safest and most effective product possible to consumers.

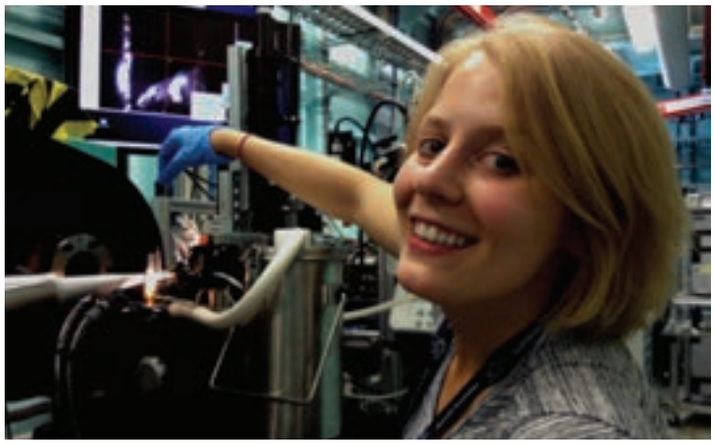

Figure 2. Loading samples into the small and wide-angle x-ray scattering (SAXS/WAXS) beamline in Melbourne, Australia.

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Brexit and the Irish agri-food industry

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The UK faces complicated Brexit decisions for its agriculture sector. This article discusses the impact the various scenarios would have on the Irish agri-food industry.

Given the vote for Brexit, the UK government faces two big policy decisions. These decisions are important for the UK's indigenous agri-food sector. However, they are also important for exporters, such as Ireland, that supply the UK market. The UK must decide upon:

- **British Agricultural Policy (BAP)**: what sort of agricultural policy will the UK wish to pursue?
- **Agri-food trade policy**: what sort of agri-food trade relationship will the UK have with the EU27 and the rest of the world?

British Agricultural Policy

A conservative reform could create a BAP similar to the current Common Agricultural Policy (CAP). This would be favoured by many UK farmers. Support from Brussels would be replaced by funding from Westminster for CAP-style schemes. However, the UK government has regularly advocated radical reform of the CAP – typically involving a much reduced budget. It is unlikely that the UK will radically alter its agricultural policy in the short term. However, over the medium to longer term, the level of support for UK agriculture is uncertain. A radical 'New Zealand style' reform, where UK agricultural support is completely eliminated, is unlikely. However, some reduction may occur and the remaining support may be channelled towards the provision of agri-environmental services.

Different agricultural policies across the UK nations?

The devolved nature of UK agriculture policy may result in differing agricultural policies across the UK. Scotland, Northern Ireland and Wales may favour a greater level of public support for agriculture than in the case of England. Just as in Ireland, the dependence of UK farm incomes (particularly drystock farms) on financial aid is considerable. Changes in support could have significant implications for UK agricultural production and the UK's food import requirements.

The UK's choice of low or high import barriers?

The UK's future trade deal with the EU could mean that it would be within or outside the European single market. If the UK is outside the single market, then there would be some increase in the costs of exporting to and importing from the UK for the Irish agri-food sector.

Outside the single market, it is clear that UK exporters would face the so-called EU common external tariff (WTO tariff) when exporting goods to Ireland and other EU member states. However, with the UK outside the single market, it is not clear what tariffs Irish exporters to the UK market would face. The UK government would decide between two options:

- **No tariffs on imports to the UK:** This would mean that Irish exporters would face greater competition in the UK, as countries such as Argentina, Australia, Brazil and New Zealand would now also have tariff-free access to the UK market. The cost of Irish exports to the UK would not change, but the cost of imports coming from non-EU exporters would fall, as they would no longer be subject to tariffs.
- **EU/WTO tariffs on imports to the UK:** Again, this would mean that Irish exporters would face greater competition in the UK. Irish and other EU suppliers would face new export barriers with the UK that are similar to those currently faced by Argentina, Australia, Brazil and New Zealand. The cost of Irish exports in the UK would increase due to the imposition of tariffs and could exceed the price of exports to the UK from lower-cost non-EU countries.

What is clear is that both of these UK trade policy outcomes would reduce the differential between the price of Irish exports to the UK and exports to the UK from non-EU countries.

Opportunities for the Irish agri-food sector

If the level of financial support offered by the UK government to UK farming under the BAP is lower than under the CAP, could UK production fall, and could this provide the Irish agri-food sector with greater export opportunities? The outcome would depend on several factors:

- the sie of the reduction of direct income support under a future BAP, as compared to the CAP;
- the supply response from UK farmers to reduced levels of decoupled direct payments (i.e., by how much will UK production contract); and
- the trade policy setting (whether Irish exports to the UK face tariffs and whether other non-EU suppliers faces higher or lower tariff barriers).

Lower UK output of beef, sheep meat, butter or cheese might be expected to create opportunities for Irish exporters. However, the competitiveness of Irish exports to the UK market would depend on the tariff levels applied by the UK.

The Brexit policy uncertainty facing the Irish agri-food sector is unlikely to be resolved rapidly. The UK will be slow to trigger Article 50, the formal notification that opens its exit negotiation. In the meantime, uncertainty concerning future access to Ireland's most important market could persist to 2020 and possibly beyond then. The challenge faced by the Irish agri-food sector (and Irish agri-food policy makers) is to prepare for a world where the UK is not as important or lucrative a market for Irish agri-food exports as it is right now.

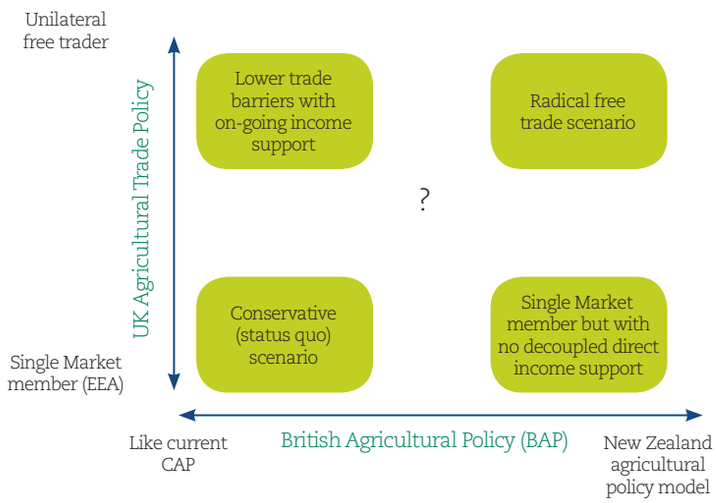

Figure 1. UK agricultural and agri-food trade policy choices following Brexit.

Further Reading

Donnellan T., and Hanrahan K. (2016) Brexit - Potential Implications for the Irish Agri-Food Sector Report. Available online: https://www.teagasc.ie/publications/2016/brexit---potential-implications-for-the-irish-agri-food-sector-report.php [Accessed July 15, 2016].

Farmers' awareness of climate change

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A 2014 survey shows the extent to which Irish farmers are aware of issues relating to greenhouse gas emissions and climate change and their attitudes towards them.

The agriculture sector is the largest contributor to greenhouse gas (GHG) emissions in Ireland; accounting for 32% of total emissions. The Teagasc marginal abatement cost curve (Schulte and Donnellan, 2012) has identified a range of abatement practices but, it is difficult to confidently forecast the actual emissions reductions that will be delivered. Adoption will depend on the suitability of the mitigation technology, the cost of the technology and farmers' willingness to use the technology. Farmers' awareness and attitudes towards climate change and agriculture's contribution to GHG emissions are likely to influence mitigation technology adoption.

Survey data collection

A survey was conducted through the Teagasc National Farm Survey (NFS) to establish farmers' understanding of the relationship between agriculture and GHG emissions and their willingness to address the issue on their own farm. Data was collected between July and December 2014. Fourteen questions relevant to climate change were incorporated into the survey, with a response rate of 86% (828 farmers).

Farmers' perceptions of global climate change

Over half of the farmers surveyed, 53.3%, agreed that man-made GHG emissions are contributing to global climate change and changing weather patterns, while only 18% disagreed, indicating a relatively high level of awareness and acceptance among farmers that climate change is real. However, when questioned on what contribution agriculture makes to GHG emissions, many had either a contrary understanding or no understanding of the actual position.

Figure 1 compares the farmer response to the statement that man-made GHG emissions contribute to global climate change and changing weather patterns. Most farmer categories show high levels of agreement with this statement, especially in the case of cattle 'other' and specialist tillage farms. Specialist sheep farmers were an exception, with many saying that they 'didn't know', which may reflect the fact that much of the discussion and research within Ireland relating to agricultural GHG emissions have focused mainly on bovine emissions.

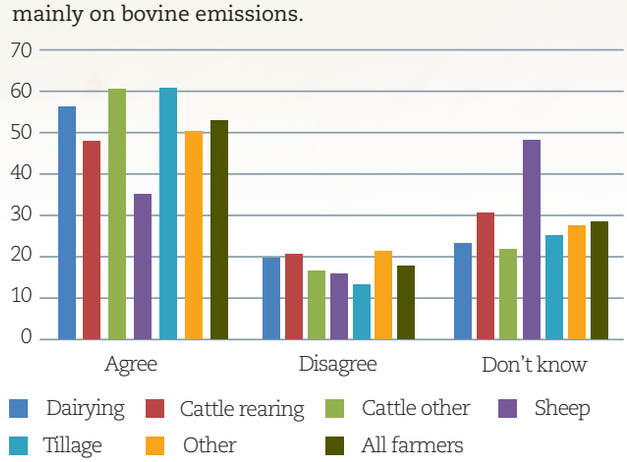

Figure 1. Farmers' perceptions of the contribution of man-made GHG emissions to global climate change and changing weather patterns across farm sectors.
Source: Authors' survey of farmers in the Teagasc NFS.

Activities contributing to agricultural GHG emissions

Farmers were asked to rate their level of agreement or disagreement with the contribution made by different activities to agricultural GHG emissions in Ireland. Results point to either a lack of awareness or a limited understanding among farmers about the major sources of GHG emissions (Figure 2). Methane (CH_4) and Nitrous Oxide (N_2O) emissions from the production of livestock accounts for the bulk of GHG emissions from Irish agriculture; and yet, when asked if they accepted that livestock production was an important source of GHG emissions, 27.9% of farmers were unsure and 30.2% of farmers either disagreed or strongly disagreed with the statement.

Similarly, a large proportion of farmers, 41.2% and 34.7%, were uncertain whether tilling and application of fertilizers, respectively, contributed to agricultural GHG emissions. In contrast, 69.4% of farmers either agreed or strongly agreed that deforestation is an important source of GHG emissions. Given that the contribution of deforestation to climate change in a global context has media prominence, this may be shaping some farmers' false interpretation of the main contributors to GHG emissions in Ireland.

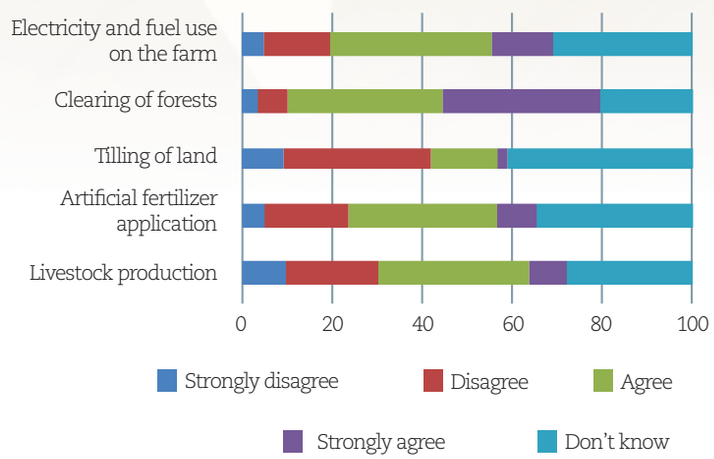

Figure 2. Farmers' perceptions of important causes of agricultural GHG emissions. Source: Authors' survey of farmers in the Teagasc NFS.

Impact on production decisions?

Questioned on whether they expect climate change to have a negative effect on their future production, 27.7% of farmers felt that climate change will be a problem only in the long term (more than 20 years), while 29% expected no impact at all. This suggests a significant proportion of farmers are unconvinced that climate change will have any significant negative impact on farming. This is relevant in the context of persuading farmers to adopt GHG mitigation technologies.

Willingness to incur cost increase

The largest proportion of farmers, 77.6%, stated that they would not accept an increase in production costs to reduce GHG emissions by 5%. Only 18% would be willing to tolerate an increase in production costs of between 0% and 5% to reduce their GHG emissions by 5%. Few farmers would accept an increase in production costs of more than 5%. These results imply a limited appetite for the adoption of mitigation measures that have a positive cost.

Implications and conclusions

The results suggest that, at the time of the survey, the majority of farmers agreed that man-made GHG emissions contribute to global climate change, however there was still a lack of awareness of the extent of the contribution made by agriculture. Farmers' limited understanding of the topic highlights the timeliness of initiatives such as the Beef Data and Genomics Programme and the roll-out of the Teagasc Carbon Navigator to Irish farmers. Finally, the observed high proportion of farmers unwilling to incur additional costs to reduce their GHG emissions, justifies the Teagasc strategy of focusing on the adoption of low- and negative-cost abatement technologies.

Acknowledgements

We are grateful to all the farmers who took part in the survey. This study was funded by the Environmental Protection Agency in Ireland as part of the STRIVE Doctoral Research Scholarship programme.

We would also like to acknowledge the financial support of Teagasc. We would also like to thank the staff of the Teagasc National Farm Survey for their assistance in undertaking this research.

References

Schulte, R. and Donnellan, T. (2012) *A Marginal Abatement Cost Curve for Irish Agriculture*. Teagasc submission to the National Climate Policy Development Consultation, Teagasc, Oak Park, Carlow, Ireland.

Unhealthy diet – unhealthy climate

Should environmental impact be a consideration in dietary guidelines? New research aims to provide insight into the impact of current Irish diets on the environment and how such patterns align with health guidelines.

Research is ongoing in Teagasc in conjunction with University College Cork (UCC) examining the carbon footprint of Irish food-consumption behaviours. While significant attention has been given to the consequences of diet on human health and food production/processing on the environment, less attention has focused on the dynamics between diet, health and environment. In the EU, with the exception of Germany and Sweden, climate considerations are not included in deliberations around national dietary guidelines. However, given the well-established impacts of the agri-food sector on the environment, it is reasonable to argue that sustainability considerations should be taken into account when formulating dietary guidelines. This research provides insight into the impact of current Irish diets on the environment and also considers the impact of distinct dietary patterns on greenhouse gas (GHG) emissions and how such patterns align with health guidelines.

The Irish food carbon footprint

GHG emissions associated with food production are measured in carbon equivalents (CO_2eq) to produce a carbon footprint, which is used to give an indication of the climatic impact of the food we consume. In general, plant-based foods are low in GHG emissions, whereas foods from animal sources are high. Nevertheless, foods from animal sources provide many essential nutrients necessary for good health; hence environmental and human-health issues should be considered together to ensure socially optimal outcomes for both. The aim of this study was to determine the quantity of (GHG) emissions associated with food consumption patterns among Irish adults. Extensive detail on foods consumed was available from the National Adult Nutrition Survey, which collected information over four days of all foods and beverages consumed for 1,500 Irish adults. Each food consumed was multiplied by a CO_2eq conversion factor to generate the carbon footprint associated with the amount of food or drink consumed by each individual.

The results show that the average Irish adult generates 6.5kg CO_2eq daily arising from the food they eat. These levels of dietary emissions were comparable to other European nations, such as the UK, and were slightly below the EU average of 7.1kg CO_2eq. More than two-fifths of GHG emissions came from red meat, with dairy and starchy staples contributing approximately one tenth each. Other groups, such as carbonated beverages, fruit and vegetables, legumes, pulses and nuts made minimal contributions to overall emissions.

Who has the biggest carbon footprint?

To consider the impact of different dietary patterns on the environment, segmentation analysis was undertaken. Segmentation is commonly used in market research to identify distinct groups of consumers who share similar characteristics. Food consumption carbon footprint (by food group) was used as the segmentation variable. The analysis identified three meaningful segments. They were labelled 'Traditional', 'Western' and 'Prudent' and accounted for approximately 50%, 25% and 25% of the sample population respectively. The differences in the contributions of foods to overall emissions by segment are outlined in Figure 1.

The Western segment had the highest carbon footprint of the three groups, generating an additional 1kg of CO_2eq per day compared to the other two. They also had the highest contribution from alcohol (>10%), processed meat and carbonated beverages. Despite the fact that the Traditional segment was characterised by the highest intake and contribution from red meat, they did not differ in their overall carbon footprint when compared to the Prudent segment which had the lowest red-meat consumption. Disproportionate contributions to the Prudent segment came from fruit and vegetables, which contributed approximately 4% of emissions compared to 2.5% overall. The Prudent segment adhered to a greater number of dietary guidelines by consuming higher quantities of fruit and vegetables, coupled with achieving dietary guidelines

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for fat and carbohydrates. Adherence to dietary guidelines was not consistent between groups, however. Despite complying with dietary recommendations for fat, the Western segment had the lowest intakes of fruit and vegetables and very greatly exceeded the weekly recommended units of alcohol.

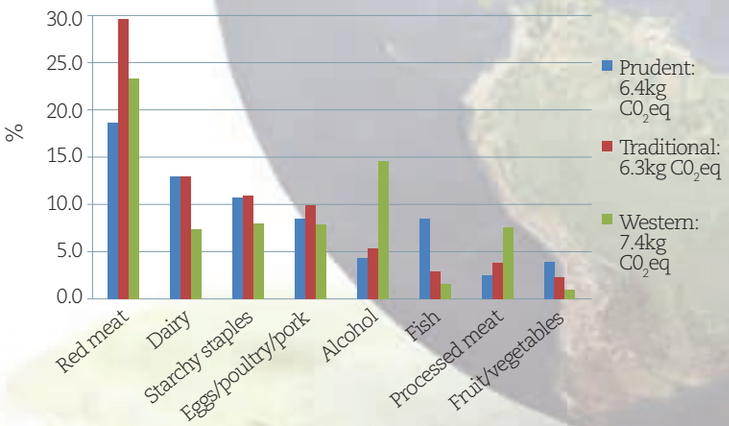

Figure 1. Percentage contribution of significant food groups to overall segment carbon footprint.

Strategies to achieving sustainable healthy diets

The incorporation of climate considerations into national dietary guidelines is problematic due to the complexities of simultaneously achieving dietary guidelines and reducing GHG emissions associated with food consumption. Red meat is frequently targeted to reduce carbon emissions, yet it is the sole source of certain essential nutrients in our diet; thus, eliminating this from a diet could present new health challenges. Furthermore, this study has shown that consumers with high red meat consumption (Traditional) have a very similar dietary carbon footprint to low red meat consumers (Prudent). Moreover, Western diets, characterised by high alcohol and processed meat consumption, had the highest carbon footprint. This indicates that any food-policy instruments developed for health and sustainability reasons should be holistic in nature rather than concentrating on one food group.

Placing responsibility solely on consumers to address environmental challenges, with recommendations to reduce or stop eating meat for sustainability reasons, is unlikely to lead to significant changes. As evident above, many have not taken on dietary recommendations for personal health benefit, thus, it seems unlikely that they will do so for a more distant societal benefit. In addition, attempts to replace red meat with plant protein sources, for example, could result in a higher water footprint, while associated land use change and potentially higher inputs such as fertilizers may not result in the intended reduction in carbon footprint. Therefore, while the health and environmental agenda may have a common goal to reduce average levels of meat and alcohol consumption, one cannot expect that a reduction in consumption will occur solely through advising consumers to change behaviour, nor can one assume that the desired reduction in carbon footprints will be achieved through this approach. In tandem with consumer behavioural change strategies, strategies that increase efficiency of production at every stage of the food chain and produce more sustainable food products are necessary if we hope to witness desired reductions in the dietary carbon footprint while simultaneously maintaining or improving diets.

Acknowledgments

We would like to thank the Irish Universities Nutritional Alliance for access to the original NANS data, and to all of those who took part in the survey.

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Mapping Irish uplands using satellites

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Ireland is one of the few countries in Europe not to have a national programme for mapping land cover and land use. We need maps of land cover and land use to make improvements, in a range of areas, e.g., agricultural management, environmental management, policy implementation, and calculation of greenhouse gas (GHG) budget. Here, we describe the efforts to improve national infrastructure for mapping land cover and use.

Land cover represents what is on the ground, e.g., improved grassland, barley, or concrete. Knowing this sort of information with a high level of detail and how it changes year on year, can tell us a lot about the current state of the environment and the economy. Land use tells us what that cover is being used for or what produced the cover; thus, grazing, tillage, and urban expansion are examples of land uses. Annual land-use maps tell us a great deal about the state of agriculture production, the location of resources and the potential for expansion.

Land-cover mapping practice

It's not possible to manually map every field and forest in Ireland, instead we use earth-observation systems, and optical and radar satellites that can image Ireland in a single day. As a latecomer to land cover mapping, Ireland can take advantage of emerging best practice for land observation systems that try to describe the wide variety of covers and uses that occur on an area of land, rather than attempting to give each area a single label. We identified best practice as the use of satellite imagery in combination with existing official mapping information to give every area of land a cover and use designation.

Teagasc and partners have been researching various techniques that can overcome problems specific to the application of earth observation to the Irish landscape. One of these projects is the Environmental Protection Agency (EPA)-funded Towards Landcover Accounting and Monitoring (TaLAM) project, which aims to show how the new digital map of Ireland, Prime 2 from Ordnance Survey Ireland (OSI), can be combined with satellite imagery to produce land-cover maps for Ireland. TaLAM placed an emphasis on upland areas. Prime 2 maps all the country seamlessly – every road, every building, every field – as separate objects and satellites can be used to give more information on these objects. In mountain and upland areas, however, there are no objects and Prime 2 leaves them blank. An important objective of the TaLAM project was to design a method that could fill in the blanks and map the land cover in these large, unenclosed areas.

Making maps meaningful

To ensure TaLAM outputs would be acceptable and useful to the professional community, we solicited the opinion of officials and experts on mapping and reporting land cover change in Ireland. Using the Crowd Wise consensus building approach, participants were introduced to a range of scenarios and, after discussion, individuals voted anonymously to rank each scenario from their least to most preferred choice.

For enclosed lowland fields, the preferred option was for areas bigger than 0.5ha to be labelled with the percentage of all land cover classes within the area. For unenclosed upland regions, the preference was for the region to be broken up to create PRIME2-type polygons of 2ha to 5ha in size, with all covers mapped as a percentage and updated at five-year intervals.

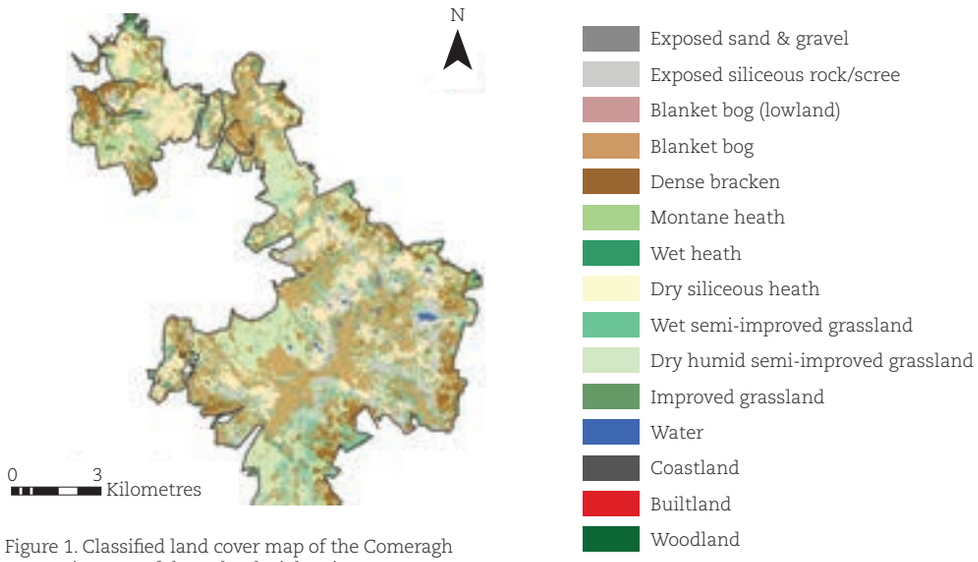

Figure 1. Classified land cover map of the Comeragh Mountains, one of the upland trial regions.

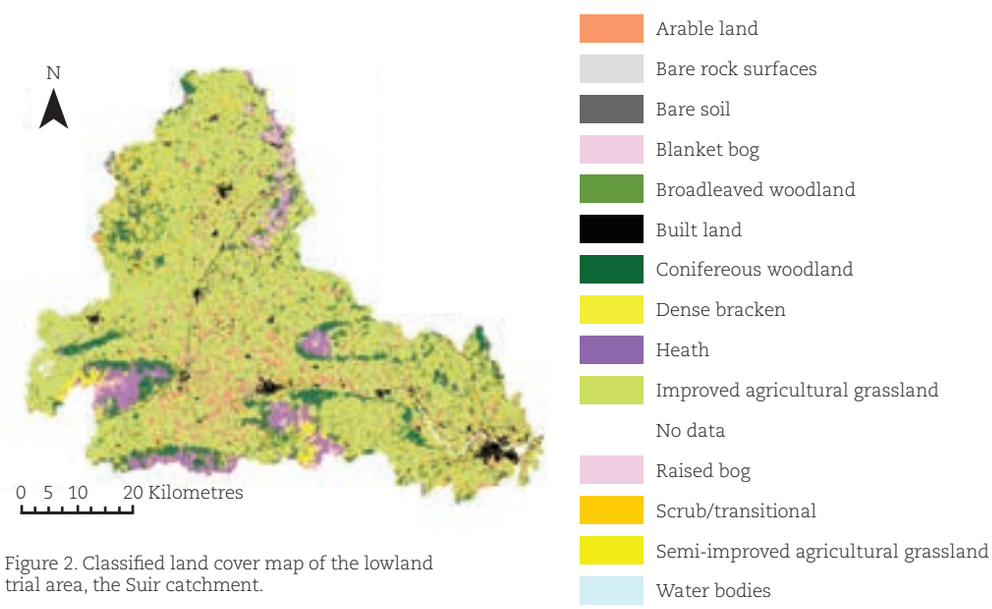

Figure 2. Classified land cover map of the lowland trial area, the Suir catchment.

Lowland and upland trials

The Suir catchment was the lowland trial area and using a machine learning technique, called a Random Forest Classifier, very high overall accuracies (>92%) were achieved for a land cover map of enclosed areas automatically created from satellite images (NASA's Landsat-8 satellite).

Methods for classifying the upland regions focused on the Galtee Mountains, Comeragh Mountains and Mount Brandon. We concluded that medium spatial resolution (~15m) imagery acquired from optical and microwave sensors is adequate for mapping and monitoring upland vegetation into broad categories. Such imagery cannot replace the detailed mapping of habitats that is sometimes needed, especially for biodiversity monitoring, by conservationists and ecologists; therefore, the satellite mapping must be complemented by field mapping for such uses.

Radar systems, in this case from a Japanese Aerospace Agency satellite called ALOS, send out a beam of microwave energy and record the reflected response. They are good at spotting change and distinguishing between different types of land cover due to the influence of water content and roughness on the reflected response. These radar images were combined with optical imagery from the lowland areas along with other mapped data on soils and topography.

All this data, along with ground references, were fed into an algorithm (Random Forest Classifier) that uses hundreds of simple decision trees and combines the outcomes to give the best result when compared to the training data. For example, the trainer gives a number of examples of, for instance, an area of bracken-dominated hillside. The Random Forest classifier then sifts through all the input data from the satellite and finds the combination of characteristics that best defines bracken.

Overall, accuracy in the uplands was 94% across the three sites but this did vary across classes, with forestry and built areas having a high level of accuracy (98%) but wet and montane heaths achieving only 84% accuracy.

The satellite data will never entirely replace field work and a programme to provide field data for a national land cover map is needed. Automating the process for identifying change and updating national land cover maps remains a challenge, but with more image data available this will become a realistic possibility.

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John Finn, CELUP, Johnstown Castle, Teagasc and Christoph Raab, PhD Candidate, Department Wildlife Sciences, Georg-August University, Gottingen, Germany were partners on the project

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Funding

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OCTOBER

October 4 — *Hodson Bay Hotel, Athlone*

Teagasc National Beef Conference 'Practice into Profit'

Optimising profits in calf to beef systems is the first of two sessions at this year's conference. It will explore finishing strategies, calf health and sustainable, profitable practices. The second session will address breeding techniques to maximise profitablility, such as genomics and accurate recording.
Contact: loreto.ferguson@teagasc.ie www.teagasc.ie

October 5 — *Teagasc Food Research Centre, Ashtown, Dublin 15*

A Quality Experience: Sensory Evaluation in Food Quality Control

This one-day workshop from Sensory Food Network Ireland will discuss the importance of consistent sensory quality in the food and beverage industry. The workshop will introduce delegates to sensory evaluation in quality control and demonstrate how sensory testing can assist companies in delivering reliable products of consistently high quality to consumers. The workshop will include a combination of talks and practical exercises, and experienced speakers from industry and academia will present on the day.
Contact: mary.reilly@teagasc.ie
http://sensoryfoodnetworkireland.ie/save-the-date.html

October 7 — *UCD, Dublin*

AVTRW conference

The scientific programme will reflect new developments in veterinary science across the island of Ireland including AFBI, Teagasc, Animal Health Ireland, DAFM, UCD and TCD. Talks will focus veterinary education and cutting edge developments in animal health and veterinary research. Keynote speakers include: Professor Louise Cosby, AFBI, 'Challenges of Current Virus Threats to Animal Health and Strategies for Prevention and Control'; Dr Peter Nettleton, Moredun, '50 Years of Virology: from Arboviruses to Zika going Viral'; and Professor Martin Greene, Nottingham, UK 'Udders and Uncertainty: Adventures in the Control of Bovine Mastitis'.
Contact: kieran.meade@teagasc.ie

October 13 — *RDS, Dublin*

The Irish Forum for International Agricultural Development

Dr Ousmane Badiane, Co-Chair of the Montpellier-Malabo Panel of Experts and Africa Director for the International Food Policy Research Institute (IFPRI) will give the keynote address at the The Irish Forum for International Agricultural Development (IFIAD). This will be followed by a series of workshops. IFIAD is a voluntary platform bringing together organisations and individuals from the Irish agri-food sector to share knowledge and good practices for the benefit of agricultural development work in support of Ireland's overseas development objectives. Founder members of the new forum include Vita, Teagasc, Irish Aid, the Department of Agriculture, Food and the Marine, Gorta-Self Help Africa, Concern Worldwide and Trócaire.
Contact: info@ifiad.ie

October 19 — *Lyrath Hotel, Kilkenny, Co Kilkenny*

Soil Fertility Conference -'Efficient Fertiliser Use for Tillage Crops'

This conference will focus on latest research findings for the efficient use of fertilizers in sustainable tillage crop production in Ireland. Teagasc will launch the fourth edition of its nutrient advice manual *The Green Book – Major and Micro Nutrient Advice for Productive Agricultural Crops.*
Contact: sarah.lacey@teagasc.ie www.teagasc.ie

October 19-21 — *University College Dublin*

10th International Life Cycle Assessment of Food 2016

The conference is structured into four broad themes. The first will look at specific environmental processes and services as addressed by life cycle assessment (LCA) including soil, biodiversity, ecosystem services, water and land use. Theme two will look specifically at animal agriculture with contributions on dairy, beef, pigs and poultry, post-farm processing and whole chain studies. Theme three will look at interaction with humans and human systems, including contributions on crop systems, waste, processing, diet, nutrition, behaviour, and health and food innovation. Theme four will address various aspects of how LCA is used, with contributions ranging from data, methods and tools, through socioeconomic methods, to product environmental footprint (PEF), labelling and policy. Teagasc researchers contribute to the organising committee.
Contact: sinead.lawlor@conferencepartners.ie
http://lcafood2016.org/programme/

NOVEMBER

November 13-20 — *Teagasc locations nationwide*

Science Week – Festival of Farming and Food – SFI 'Science Rising' at Teagasc

Each year during Science Week, Teagasc research centres open their doors to second- and third-level students to enable them to find out about the research carried out and to explore careers in agriculture and food research.
This year, as part of the Science Foundation Ireland Science Week festivals programme, visitors from Teagasc Trinity Access Programme, Carlow IT Lifelong Learning Centre and members of the general public will be invited to events at Teagasc centres.
The annual Teagasc Walsh Fellowships seminar takes place at the RDS, Dublin, on Thursday, November 10. The guest speaker is Dr Nora Khaldi, Founder and CSO, Nuritas.
Contact: catriona.boyle@teagasc.ie (Science Week)
hilary.king@teagasc.ie (Walsh Fellowships seminar) http://www.science.ie/

November 23 — *Teagasc, Food Research Centre, Ashtown*

Novel Processing Technologies Gateways

Food industry representatives will have an opportunity to see the latest developments in terms of novel food processing at the 11th Food Innovation Gateways event, which will showcase significant expertise, technical services and emerging technology opportunities relevant to stakeholders and will provide a unique opportunity to meet and interact with the key researchers.
Contact: gateways@teagasc.ie www.teagasc.ie

November 29 — *RDS, Dublin*

Outlook 2017

The Outlook Conference will provide information on the short term economic outlook for dairy, cattle, sheep, tillage and pig enterprises on Irish farms. Estimates of the economic performance of Irish farmers in 2016 and forecasts for 2017 will be presented by economists from Teagasc's Agricultural Economics and Farm Surveys Department.
E-mail: marian.moloney@teagasc.ie www.teagasc.ie

DECEMBER

December 6 — *Rochestown Park Hotel, Cork*

Teagasc National Dairy Conference

This one-day event will look at the Irish dairy industry's position since quotas ended. Topics will include: managing larger herds, managing finances when prices are low, calf health and farmer wellbeing.
Contact: tom.odwyer@teagasc.ie www.teagasc.ie

For a full list of all Teagasc events including food industry training see: https://www.teagasc.ie/food/food-industry-development/
For presentations from previous Teagasc events see: https://www.teagasc.ie/publications/