

RESEARCH AND
INNOVATION NEWS
AT TEAGASC
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Research

Volume 13: Number 2. Summer 2018

PREPARED CONSUMER
FOODS INNOVATION

GENOMICS OF ANIMAL STATURE

BREAKING BIOMASS

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TResearch Teagasc,
Oak Park, Carlow, R93 XE12

Published on behalf of Teagasc by

Th!nkMedia

The Malthouse, 537 NCR,
Dublin 1, D01 V822.

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Design: Tony Byrne, Tom Cullen and Niamh Short

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Research prioritisation exercise

Research prioritisation, introduced by the Government in 2012, aligns the majority of competitively awarded public investment in research with 14 priority areas, which were grouped into six themes. Two of those 14 areas closely aligned to the work of Teagasc: Sustainable Food Production and Processing; and, Food for Health.

Over the last year, an exercise to refresh these priorities was undertaken. A rigorous exercise, including extensive consultation, was undertaken to develop the evidence base to inform the refresh exercise. Teagasc made a significant contribution to this exercise, led by Ray Kelly, Head of Research Support. While the evidence demonstrated that for many of the priority areas, the focus remains as relevant in 2018 as it was for the 2012-2017 cycle, there have been several revisions and updates to both the themes and the priority areas to reflect changing circumstances in that period. Importantly, Sustainable Food Production and Processing, and Food for Health, both remain in the Food theme, but the Sustainable Food Production and Processing priority area is broadened to reflect the evolution in technology since 2012 and the key emerging priorities in the EU initiative Food 2030, particularly the need for climate smart and environmentally sustainable food systems and the need for circularity and resource efficiency of food systems, and is renamed Smart and Sustainable Food Production and Processing. In addition, the Food for Health theme has retained its original name, but its focus has broadened to cover all of the health benefits that arise from food, as opposed to the previous narrower focus on functional foods and nutraceuticals.

Teagasc's work also relates to several of the other priority areas and themes, such as Energy, Climate Action and Sustainability, Advanced and Smart Manufacturing, the ICT-related areas, and the Innovation in Services and Business Processes area. The Teagasc Technology Foresight 2035 report is referenced extensively in the new report. This research prioritisation refresh has been a very important exercise and will guide national research investment in the short and medium term. The Teagasc research programme is well aligned to the priority areas, and working with the Department of Agriculture, Food and the Marine, as well as other partners and collaborators, we plan to make a significant contribution across these areas in the coming years.



Frank O'Mara
Director of Research

Cleachtadh um Beartú Tosaíochta Taighde

Le Beartú Tosaíochta Taighde, a thug an Rialtas isteach in 2012, ailínítear formhór na hinfheistíochta poiblí i dtaighde a dámhadh ar bhonn iomaíoch laistigh de 14 réimse tosaíochta, atá ghrúpáilte ina shé théamaí. Bhí dhá cheann de na 14 réimse sin dlúth-ailínithe le hobair Teagasc, Táirgeadh agus Próiseáil Inbhuanaithe Bia, agus Bia don tSláinte.

Le bliain anuas, rinneadh cleachtadh chun na tosaíochtaí sin a athnuachan. Rinneadh dianchleachtadh lena n-áirítear comhairliúcháin fairsing chun an bonn fianaise a fhorbairt chun bonn eolais a chur faoin gcleachtadh. Chuir Teagasc cion suntasach leis an gcleachtadh seo faoi stiúir Ray Kelly, an Ceann Tacaíochta Taighde. Cé gur léiríodh leis an bhfianaise go bhfuil an fócas fós chomh ábhartha in 2018 is mar a bhí sé i dtimthriall 2012-2017, maidir le mórán de na réimsí tosaíochta, rinneadh roinnt athbhreithnithe agus nuashonruithe ar na téamaí agus ar na réimsí tosaíochta araon chun teacht le cúinsí ar a tháinig athrú sa tréimhse sin. Go tábhachtach, tá Táirgeadh agus Próiseáil Inbhuanaithe Bia, agus Bia don tSláinte fós sa réimse Bia ach rinneadh an réimse tosaíochta maidir le Táirgeadh agus Próiseáil Inbhuanaithe Bia a leathnú chun teacht leis an teacht chun cinn atá á dhéanamh sa teicneolaíocht ó 2012 i leith agus na príomhthosaíochtaí atá ag teacht chun cinn i dtionscnamh Bia AE 2030, go háirithe an gá le córais chliste aeráide agus córais bia atá inbhuanaithe ó thaobh an chomhshaoil de agus an gá atá le ciorclacht agus éifeachtúlacht acmhainní córas bia agus rinneadh é a athainmniú mar Táirgeadh agus Próiseáil Chliste agus Inbhuanaithe Bia. Chomh maith leis sin, tá an t-ainm céanna fós ar an téama Bia don tSláinte, ach leathnaíodh an fócas leis chun na tairbhí bia a eascraíonn ó bhia a chumhdach, seachas an fócas níos cúinge a bhí leis roimhe seo ar bhianna feidhmiúla agus ar nútraiceodaigh.

Baineann obair Teagasc le roinnt réimsí tosaíochta eile chomh maith agus téamaí amhail Fuinneamh, Athrú Aeráide agus Inbhuanaitheacht, Ardmhonarú Cliste, na réimsí a bhaineann le TFC, agus réimse na Nuálaíochta i Seirbhísí agus Próiseas Gnó. Déantar tagairt go fairsing do Réamhfhéachaint Teicneolaíochta Teagasc 2035 sa tuarascáil úr.

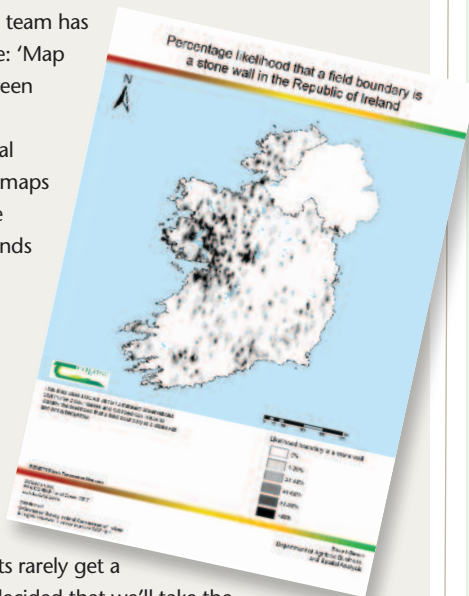
Cleachtadh an-tábhachtach ba ea an athnuachan ar an beartú tosaíochta taighde seo agus tabharfar treoir leis d'infheistíocht náisiúnta taighde sa ghearrthéarma agus san fhadtéarma. Tá clár taighde Teagasc dea-ailínithe leis na réimsí tosaíochta, agus muid ag obair leis an Roinn Talmhaíochta, Bia agus Mara, chomh maith le páirtithe agus comhoibrithe eile, tá sé beartaithe againn cion suntasach oibre a dhéanamh sna réimsí sin sna blianta amach romhainn.



Frank O'Mara
Stiúrthóir Taighde

Map of the month

Teagasc's spatial analysis team has launched a new initiative: 'Map of the Month'. Stuart Green explains: "In addition to undertaking geographical analyses and producing maps for research projects, the spatial analysis lab responds to *ad hoc* requests for contributions. The latter may be for in-house purposes or to inform policy submissions. While dissemination is a key objective of research projects, maps produced in response to such requests rarely get a wider audience. We've decided that we'll take the most interesting map we have produced in each month and present it [on the Teagasc website] to hopefully find a wider audience, and to promote discussion and debate on both the contribution of spatial analysis to Irish agriculture and food, and on the specific maps produced". See www.bit.ly/TeagascMapoftheMonth.



Big Week on the Farm



Teagasc's Laura Boyle pictured with chef, food writer and TV personality Darina Allen.

Well done to all the Teagasc staff who participated in the RTÉ One TV series *Big Week on the Farm*. John Colreavy, Meat Technology Ireland, Ashtown, talked about the perfect steak, while Emily Crofton, Sensory Scientist in Ashtown performed experiments on how our senses affect our taste. Laura Boyle from Moorepark spoke about mother/young behaviour in cattle, David Wall, Environment Researcher at Johnstown Castle, performed expert analysis of the host farm soil, and Mark Plunkett, Tillage Specialist, Johnstown Castle, explained the value of slurry.

BTYSTE winners visit Moorepark



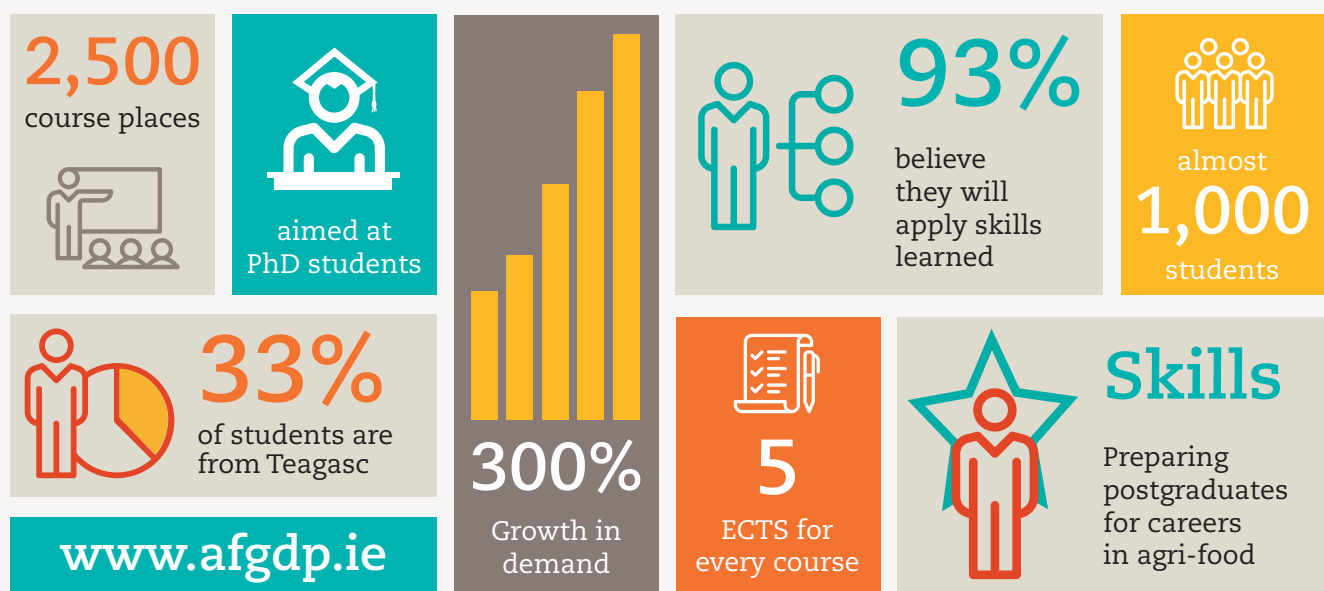
Pictured are (from left): Emer Kennedy, Teagasc Moorepark; Derry O'Donovan, science teacher; Gerry Boyle, Director, Teagasc; winners Darragh Twomey and Andrew Heffernan; Lance O'Brien, Teagasc; John Spink, Teagasc Oak Park; and, Catriona Boyle, Teagasc.

Two of the winners of the Teagasc prize at BTYSTE 2018, Darragh Twomey and Andrew Heffernan (co-winner Neil O'Leary was not

available on the day), visited Moorepark recently with science teacher Derry O'Donovan from Coláiste Treasa, Kanturk, Co. Cork.

AFGDP = AGRI FOOD GRADUATE DEVELOPMENT PROGRAMME

Since 2007 - Only programme of this type in Ireland - managed by UCC, UCD, Teagasc



SFI's Career Development Award programme

Science Foundation Ireland has announced support for 22 early career researchers in Ireland (a €13.7 million investment). Kieran Meade, Teagasc Animal & Grassland Research and Innovation Programme, Co. Meath, received funding for 'The Bovine Epigenome and Susceptibility to Mycobacterial Disease' and Brijesh Tiwari, Teagasc Food Research Programme, Ashtown, Dublin, received funding for 'Novel Technological Interventions for Biofilm'.

Pictured at the Science Foundation Ireland research award announcement are (from left): Andrew Parnell, NUIM; Dara Stanley, NUIG; Mark Ferguson, Director, Science Foundation Ireland; and, Brijesh Tiwari, Teagasc.



Teagasc PhD student wins AES Best Poster award

Teagasc Walsh Fellow and PhD candidate Mary Brennan was recently awarded Best Poster at the 92nd Annual Conference of the Agricultural Economics Society at the University of Warwick. Mary's research, 'The Development of Social Sustainability Indicators using the Teagasc National Farm Survey' was one of 20 posters presented at the conference.

Mary's research involves the development of a suite of indicators to capture the social sustainability of food production in Ireland. These social indicators will complement the indicators of economic viability and environmental sustainability that already exist within the Teagasc

National Farm Survey. The expansion of social sustainability indicators is imperative for the evaluation of policies regarding rural sustainability and development, in addition to providing socioeconomic statistics on current farm and community level conditions.

In collaboration with her supervisors, Emma Dillon from the Teagasc Agricultural Economics and Farm Surveys Department, Athenry, and Thia Hennessy, Dean of Cork University Business School, Mary derived these potential indicators from literature, a series of stakeholder interviews and a survey of farmers that will commence shortly through the Teagasc National Farm Survey.

Understanding the global consumer and sensory perception



Pictured at the 7th European Sensory Science Society's General Assembly and Symposium were (from left): Ciaran Forde, Singapore Institute for Clinical Sciences; Helen King, Bord Bia; Gerry Boyle, Director, Teagasc; Sinéad McCarthy, Teagasc; and, Eimear Gallagher, Teagasc.

What do space food, pharmaceuticals and cosmetics have in common? Attendees at the 7th European Sensory Science Society's General Assembly and Symposium, hosted by Sensory Food Network Ireland, found out in May at Teagasc Food Research Centre, Ashtown. Highlighting international research in sensory science, the event brought together prominent sensory and consumer scientists from more than 15 countries and over 60 different research organisations and industry. To reflect the growing globalisation of our food supply, the chosen theme for the event was 'A taste of culture: understanding

the global consumer and sensory perception'. Speakers emphasised the importance of understanding global markets for European food companies, and how success in these markets relies heavily on having a thorough knowledge of the sensory nuances of different cultures. Opening the symposium, Gerry Boyle, Director of Teagasc, said: "Sensory science is now considered to be a valuable discipline in achieving tactical and strategic goals for innovative product development and consumer acceptance across a wide range of industries".

Researcher profile



Emer Kennedy is a Senior Research Officer working at the Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork. Currently her research is focused on grazing management, calf health and replacement heifer rearing.

After completing her BAgSc degree in University College Dublin, Emer undertook her PhD at Teagasc Moorepark, graduating in 2006. Since then she has held many roles in Teagasc, beginning her career as a postdoctoral researcher, before moving to a Technologist role. After five years as a technologist Emer became a Research Officer, and in the last two years has been promoted to Senior Research Officer. Emer also spent a six-month sabbatical in Australia working with the team in Ellinbank, Victoria, investigating flexible feeding systems. Throughout her time in Teagasc Emer has worked on a large range of projects including the development of grazing

techniques to allow farmers to graze during periods of inclement weather (on/off grazing). She has also undertaken large-scale grazing experiments investigating the effects of early spring grazing management on both sward and dairy cow production performance throughout the entire grazing season. Over the past 10 years Emer has started a large programme of work in the area of calf health and replacement heifer rearing. As part of this work she has investigated strategies to improve colostrum (the first milk the cow produces after calving) management, and many of the outcomes of her work are now being implemented on farms

Emer Kennedy

throughout Ireland. As well as the research component of her current role, Emer also supervises numerous PhD students, facilitates a dairy discussion group and co-ordinates the grassland module of, as well as lecturing on, the UCD dairy business degree. Emer is originally from Kilkenny and likes to get home to her father's dairy and beef farm as often as she can. She loves to travel and aims to visit at least one new country every year! She recently bought a few acres of land with her husband and is in the process of developing her own mini farm, which of course she hopes to stock with a few calves!

Consumers' perception of meat quality

Organic, free-range, high animal welfare standards, and no hormones or antibiotics: a recent study from Teagasc shows that an appetite for these farm-level production practices is evident among a growing segment of Irish meat eaters.

The Teagasc study, published in the *Irish Journal of Agricultural and Food Research*, has highlighted how consumer perceptions are becoming increasingly sensitive to how animals are produced. As part of a wider international study into meat consumer trends, 251 consumers across the Republic of Ireland were surveyed about their habits, behaviours, beliefs and perceptions when it comes to purchasing and consuming meat. The study also found that not only do a significant number of consumers perceive better quality meat when assured of humane animal treatment, a sizeable number also reveal an intention to pay more for meat produced with good animal welfare standards. This indicates that consumers are not just supportive of animal welfare from a 'concerned citizen' perspective; rather, they consider these dimensions as attractive product

attributes that influence their assessments of meat quality and are likely to influence their purchasing decisions.

There is much discussion of a growing disconnect between consumers and how and where their food is produced. The current study indicates an appetite among consumers for more knowledge on specific farm-level production practices. Quality Assurance schemes have a significant role to play in effectively and assuredly communicating to consumers about different attributes related to meat quality.

This paper is available at:

www.degruyter.com/view/j/ijaf.2018.57.issue-1/ijaf-2018-0002/ijaf-2018-0002.xml?format=INT.



Bridge Network new website

The technology transfer consortium Bridge Network has launched a new, mobile-friendly website – www.bridgenetwork.ie.

The new website showcases the consortium's work with industry partners and academic researchers in promoting innovation, knowledge transfer and commercialisation of UCC, CIT, Teagasc and IT Tralee inventions through licensing, patents, and start-up and spin out companies.

"The new website will ensure quick and easy access to information for researchers, inventors, industry partners and other stakeholders and, as a result, will facilitate better understanding and awareness of the impact of the Bridge Network", said Anita Maguire, VP of Research & Innovation, UCC, and Chair of the Bridge Network Governance group. "With the new website, we aim to reach more industry partners and to commercialise more inventions to continue our contribution to the creation of employment both locally and nationally, building on research excellence and creativity", she added.

EFSA biohazard panel

Declan Bolton, Teagasc Food Research Programme, Ashtown, has been appointed for a third and final term to the Biohazard Panel of The European Food Safety Authority (EFSA), based in Parma, Italy. He will join 16 other scientists from across Europe in providing advice on biological hazards associated with food safety and food-borne disease, which provides the scientific basis for new and amendments to current food safety legislation across the European Union.



Declan Bolton of Teagasc Ashtown.

Leading Irish cattle nutritionist scoops BSAS award

One of Ireland's leading experts in cattle nutrition, whose work has helped to identify links between nutrition and reproduction, has been presented with a prestigious award to recognise his contribution to animal science. David Kenny, Principal Research Scientist in ruminant nutritional physiology at Teagasc, was awarded the British Society of Animal Science's Sir John Hammond Award at the society's annual conference in Dublin in April. David received the Award for his work on how biological controls can affect economically important traits in beef and dairy herds.

David is currently leading a €1.2m DAFM-funded project looking at control of the reproductive function in beef cows and heifers, and has recently begun a €1.9m project, funded by Science Foundation Ireland, examining the control of puberty and semen quality in bulls.

Presenting the award, BSAS President Richard Dewhurst said David had made substantial contributions to improving the profitability and productivity of beef cattle in Ireland and across the world: "David's efforts to improve our understanding of the impacts of nutrition on cattle cannot be underestimated". David said he was honoured and humbled to be recognised by the Society.



Innovation to compete in the global livestock industry

The challenges and opportunities facing the agri-food sector were examined recently at the BSAS annual conference, jointly organised with **TEAGASC** and University College Dublin.



The British Society of Animal Science (BSAS) held its annual conference at Croke Park, Dublin, on April 9-11, 2018. This is the first time the conference was held outside of the UK and 500 scientists, vets, policymakers and farmers from across the world gathered to hear about the challenges and opportunities facing the agri-food sector. The theme of the conference this year was 'Innovation to compete in the global livestock industry'. During over 40 sessions, delegates heard from an international line-up of speakers about ground-breaking technologies and innovations across a wide range of topics from aquaculture to precision agriculture, intensive pig and poultry to grass-based beef and dairy production systems, as well as equine husbandry, welfare and health. A brief summary of some of the main sessions is outlined here.

Global food consumption

Sir Charles Godfray, Hope Professor of Zoology from Oxford University, spoke about 'Food security, global health and environmental sustainability: challenges from increasing meat consumption'. He stated that increasing consumption of meat and other animal-sourced foods is one of the most important contemporary trends in the global food system. However, he warned that: "The earth could not support a global population of around 10 billion consuming meat at anywhere near the quantities prevailing today in Europe and North America without radical changes in production methods". Notwithstanding putative health risks associated with the long-term consumption of red and processed meat in particular, the professor argued that in many parts of the world, where diets are still deficient in calories, increased consumption of animal-sourced foods may be desirable. He outlined the results of novel bioeconomic modelling analyses, where the health and environmental consequences of different types of diet were examined, and posed the question whether the livestock industry should view the increasing attention being given to the health and environmental consequences of eating meat as a challenge to be resisted, or an opportunity to be embraced.

Impact of Brexit

In an engaging session on the potential impact of Brexit on the UK and Irish agri-food industries, delegates heard comprehensive viewpoints from Ireland, Northern Ireland and Scotland. Kevin Hanrahan from Teagasc outlined the possible impact of Brexit on Irish agri-food exports to the UK and on Irish farm incomes. His analysis employed data from Ireland-UK trade statistics, and the EU tariff framework, as well as microeconomic data from the Teagasc National Farm Survey. While Irish agriculture has progressively reduced its dependence on the UK export market since joining the EU, Kevin warned that Brexit could dramatically accelerate this process and impose significant economic losses on the sector. The impact would, of course, vary across commodities, depending on their reliance on the UK market. Myles Patton from the Agri-Food and Biosciences Institute in Northern Ireland analysed three possible post-Brexit trade arrangement scenarios available to the UK. The results again indicated variable impacts across sectors, and reflected the extent to which the UK is a net importer or exporter and the degree of international competition within specific sectors. Steven Thomson from Scotland's Rural College (SRUC) gave a comprehensive and thought-provoking presentation on the various options that the UK Government might pursue in terms of agricultural support and trade following Brexit. He challenged the current cost competitiveness of meat production in the UK, as well as the reliance on EU subsidies, and advised animal scientists that continued effort is required to improve the economic and environmental efficiency of livestock production systems.

Microbiome and gut health

Two complementary sessions on the subject of 'Microbiome and gut health' were organised and chaired by Sinéad Waters from Teagasc, the first focusing on pigs and poultry and the second on ruminant livestock. The role of the gut microbiome is central to the health and well-being of all animal species and this research area has become hugely topical in recent years. Paul Wigley, Professor of Avian



Infection and Immunity at the University of Liverpool, delivered a comprehensive presentation on 'The gut microbiome of the broiler chicken', explaining how the microbiome is central to gut health, increased productivity, and carriage of food-borne bacterial pathogens such as *Campylobacter jejuni* in poultry. He explored how the avian microbiome can be manipulated through the inclusion of supplements in feed, including prebiotics and probiotics, as well as competitive exclusion products that are frequently used to improve feed conversion efficiency and reduce the likelihood of pathogen carriage. However, the development and application of such products has, up to now, been largely empirical in nature because of limited understanding of the composition of the microbiome, its variation in the developing bird, and limited description of any mechanism of action of such products. The main aim of Paul's work is to seek ways to 'improve' the microbiome of developing chicks to both enhance development and reduce proliferation of *C. jejuni*. Torres Sweeney, Professor of Animal Genomics at the School of Veterinary Medicine, University College Dublin, presented a paper on 'Supporting the symbiotic relationship between mucosal morphology, immunity and the gut microbiome in the pig'. She spoke about the establishment of the gut intestinal microbiome in the pig and its relationship with the host mucosa, and how that relationship is critical to the lifetime productivity of the animal. Torres detailed how strategic dietary supplementation can ensure an appropriate level of immune reactivity in the gut to accommodate the presence of beneficial and dietary microorganisms, while allowing effective immune/inflammatory responses to clear pathogens. For example, a variety of natural sustainable bioactives that target different components of the gastrointestinal tract environment have been identified. In the ruminant-focused session, Sharon Huws from Queen's University Belfast delivered a comprehensive presentation on 'Understanding the role of the rumen microbiome in animal phenotype'. She explained how the rumen microbiome is diverse, containing bacteria, protozoa, fungi, methanogens and bacteriophages, and is critical to the digestion and utilisation of

feed. It also controls nitrogen use efficiency, methane emissions, and the fatty acid content of meat and milk. In summary, all speakers concluded that the gut, and in particular the rumen microbiome, is very complex in nature, making manipulation challenging and, as such, future progress will require a much greater understanding of the gut ecosystems through enhanced genome sequencing, and functional and bioinformatic technologies. A thorough understanding of the enteric microbiome will facilitate the development of long-term innovative technologies to improve the efficiency of monogastric and ruminant production systems, including reducing the environmental impact, as well as ensuring that meat and milk continue to be safe and nutritious for the consumer.

Acknowledgments

The event was particularly well supported by industry, with over 20 companies and government agencies from across the UK and Ireland offering sponsorship. The author acknowledges the many people who contributed to the organisation and successful running of the event.

Author

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Taking food innovation further

A new prepared consumer food (PCF) centre at **TEAGASC** Ashtown will focus on developing novel, sustainable and innovative food processing, preservation and packaging technologies.

The agri-food sector continues to play an integral part in Ireland's economic recovery and is our largest indigenous industry, contributing €27.5bn in turnover. The sector accounts for around 250,000 jobs or 9% of total employment, and makes a particularly significant contribution to employment in rural areas. Food and beverage exports increased to a record value of €12.6bn in 2017. The Prepared Consumer Food (PCF) Centre at Teagasc Ashtown will support the Irish PCF sector, enabling it to remain vibrant and competitive in both domestic and export markets.

Innovation is a key driver of economic growth and Teagasc continues to be committed to supporting science-based innovation and the delivery of related services to the Irish PCF sector. Teagasc recognises the diversity and complexity of the sector and offers specialist know-how, facilities and services in the broad areas of:

- meat products;
- cereals, breads, biscuits and bakery technology;
- fruit- and vegetable-based products;
- dairy products;
- savoury snacks;
- other food preparations including ready meals, sauces and confectionary; and,
- non-alcoholic beverages.

We also have a strong knowledge transfer base that supports the PCF sector in terms of novel processing technologies, sensory science, nutritional composition and product safety. Teagasc currently provides research and specialist commercial services to a range of clients within the PCF sector, extending from multinational subsidiaries based in Ireland to Irish international food companies, small and medium sized enterprises (SMEs) and food entrepreneurs. Services provided include new product development, shelf life extension, scale-up processing, product testing and analysis.

Pilot plant facilities

The food development pilot plants at Teagasc Food Research Centres in

Ashtown, Dublin, as well as at Moorepark, Cork, are critical anchors in the innovation process and in delivery of services to the PCF sector. The pilot plants facilitate various industries in new product development, exploring process scale-up feasibility, process optimisation, and final product testing. Facilities in Ashtown include a dedicated meat industry development unit, as well as a large food processing pilot plant with state-of-the-art process equipment, incubation space, developmental bakery, test kitchens and a sensory analysis suite. PCF companies account for a significant number of our clients, with a high proportion of meat, dairy and cereal processing companies. Our main interactions in terms of commercial services to the PCF sector take the format of product development, reformulation and analysis.

Brexit challenges

The PCF sector is now entering a huge period of uncertainty as a result of Brexit, and is facing a fundamental restructuring of how our food industry will do business in the UK. The costs of doing business are higher, whereas the UK consumer is under further pressure due to reduced spending power, and retailers are increasingly more aggressive with regards to pricing and promotional demands. Additionally, there are new challenges in transporting goods onwards to Eurozone countries and beyond. It is, therefore, more critical than ever before that the PCF SME companies focus on raising their innovation capacity. Innovation needs to be market led and managed efficiently, bringing new technologies and approaches to the sector. Ireland's PCF sector is particularly exposed to Brexit but yet has great potential for growth (**Table 1**). The gross output of the PCF sector is €4.5bn, €2bn of which is sold domestically, while €2.5bn is exported to other markets. The UK is a very important market for the PCF sector; it accounts for 65% of food and drink exports and comprises 500 manufacturing units spread across the State, directly employing more than 20,000 people. A growing consumer food sector has the potential to lead to a significant number of direct jobs across the country, as well as indirect jobs, as the PCF companies are more labour intensive than other parts of the food sector.



Table 1: Growth of the PCF sector.

PCF	2013	2025 (projected)
Employment	20,600	28,100
Gross output	€4.06bn	€6.87bn
Exports	€2.145bn	€3.74bn
Domestic sales	€1.915bn (40% domestic market share)	€3.12bn (50% domestic market share)
Imports	€2.867bn (60% domestic market share)	€3.02bn (50% domestic market share)

Source: A 10-Year Vision for Prepared Consumer Foods: [www.fooddrinkireland.ie/Sectors/FDI/FDI.nsf/vPages/Publications~a-10-year-vision-for-prepared-consumer-foods-16-09-2014/\\$file/PCF+10+Year+Strategy+-+Final.pdf](http://www.fooddrinkireland.ie/Sectors/FDI/FDI.nsf/vPages/Publications~a-10-year-vision-for-prepared-consumer-foods-16-09-2014/$file/PCF+10+Year+Strategy+-+Final.pdf).

New Government investment

Minister for Agriculture, Food and the Marine Michael Creed TD recently highlighted that his Department, through Teagasc, will be funding a €5m investment in capital equipment for a new PCF Centre in the Teagasc Food Research Centre, Ashtown, to purchase specialist processing and packaging equipment that companies can pilot with a view to scaling up their production and/or operations. The vision for the Centre is to support PCF companies in piloting internal research and innovation capabilities. This will maximise value creation opportunities to address the challenges and opportunities across the industry, and enable adoption of novel technologies to meet evolving consumer demands and expectations. Teagasc expects to launch the PCF initiative in September 2018.

Technological innovations

The main focus of the Centre will be to develop novel, sustainable and innovative food processing, preservation and packaging technologies in collaboration with PCF companies. A range of key enabling technologies will be installed in the PCF Centre, Ashtown, including pulse electric field, shockwave, extrusion, non-destructive drying technologies, supercritical fluid extraction and new packaging capabilities. Innovative product development expertise will contribute to new food product developments, new food ingredients, product reformulations, process optimisation, shelf life extension, and food waste reduction and/or reutilisation, leading to new income streams and recycling of food waste. These aspects are critical in light of delivering high-quality, value-added products to far away markets like China and Eastern Asia. Teagasc will support and partner with companies, collaboratively with Enterprise Ireland and Bord Bia, to deliver products that are recognised by consumers globally as innovative, safe, sustainably produced and of the highest quality.

Further information

On June 12, the PCF Centre will be featured at the 'Beyond Brexit – Making Food Innovation Go Further' event in Teagasc Ashtown. For more information, see www.teagasc.ie/news--events/national-events/events/teagasc-food-gateways.php.

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The genomics of animal stature

Thirty research groups, including **TEAGASC**, have collaborated to publish a paper in *Nature Genetics* explaining the genetic background of stature in cattle.

One of the largest collaborations to be undertaken in cattle research has successfully explained the genetic basis of a large proportion of the variability in cattle stature. The study, which involved 57 researchers from 30 institutes, identified multiple DNA regions associated with animal stature by analysing the DNA of over 58,000 cattle from 17 populations. These results were published in *Nature Genetics* in February 2018, and have paved the way for researchers to use the same approach to map high value traits such as production and efficiency.

The 1,000 bull genomes project

The 1,000 bull genomes project is a global initiative to provide researchers with access to high-quality whole genome sequences on thousands of key ancestral animals. Whole genome sequencing is the determination of an individual's DNA across all of the possibly three billion sites where subtle changes in the DNA between individuals can exist. Although the cost of sequencing is continuously declining, it remains impractical for individual countries to sequence all animals. Therefore, by pooling data within the consortium, all partners can subsequently use these core sets of animals to accurately predict (often called impute) the whole genome sequence genotypes of other individuals at minimal cost. This is achievable because DNA is transmitted in large chunks across generations, thus allowing the DNA inherited from ancestral bulls to be traced into their relatives. Teagasc submitted whole genome sequence data on 142 influential bulls in Ireland to the database. The whole genome of over 600,000 Irish dairy and beef cattle has since been imputed from the 1,000 bull genomes database, providing a unique resource for genomic characterisation of performance in cattle.

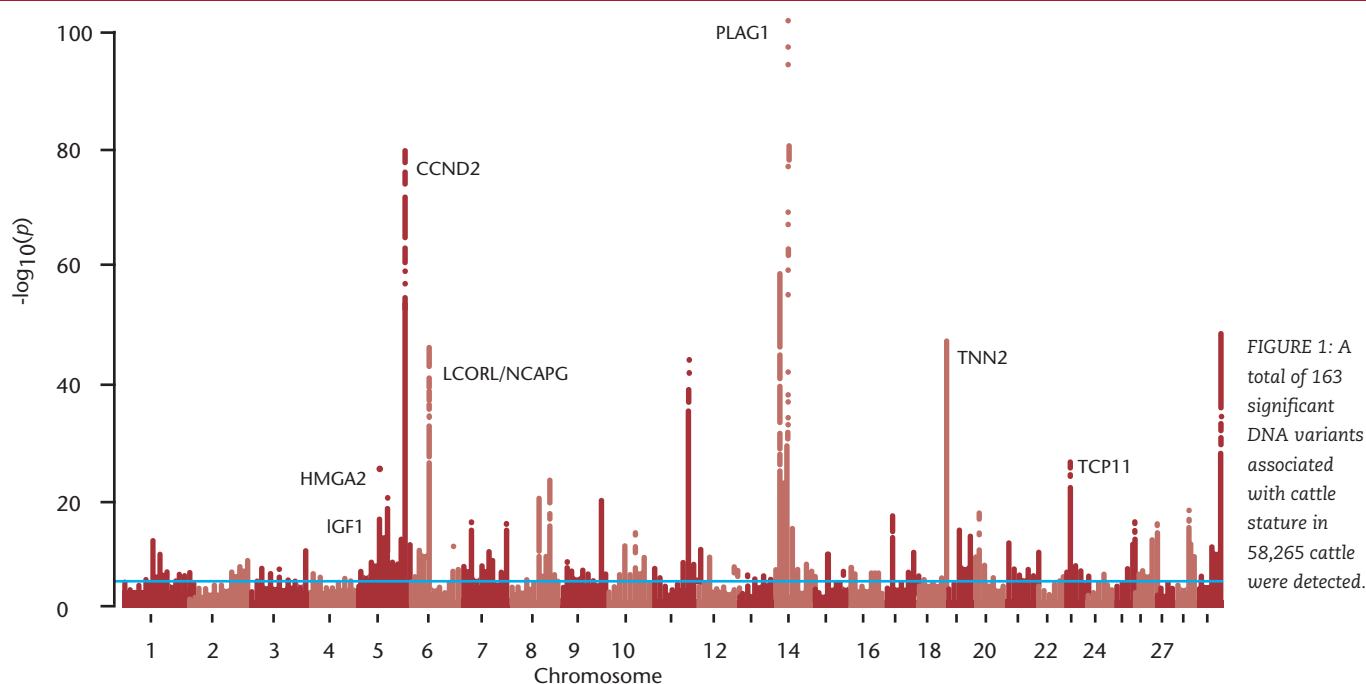
Meta-analysis of stature

Stature was chosen as the trait for initial investigation because it is under strong genetic control, is measured relatively consistently in cattle globally, and is a topic of active research in human genomics. It is also a perfect example of a complex trait, whereby both variability across thousands of DNA sites and environmental conditions contribute to the size and shape of cattle. A total of 5,152 Holstein-Friesian sires with measures of genetic merit for stature in Ireland were analysed by the Teagasc geneticists, and similar analyses were undertaken in each

collaborating country. This involved using the 1,000 bull genomes resource to successfully impute 25.4 million DNA variants into the 5,152 Irish Holstein-Friesian sires. Statistical analyses were undertaken where each DNA variant was associated one by one with stature. Results from each institution were combined to perform one of the largest ever meta-analyses for livestock animals. Results from the combined analyses revealed that the genetic architecture of stature in cattle is influenced by a very large number of DNA variants, and is comparable to that of humans. A total of 163 significant DNA variants associated with stature were detected (**Figure 1**), and cumulatively explained 13.8% of the phenotypic differences between individuals for height. This is similar to humans, where 16% of the phenotypic difference between individuals for height was explained by significant DNA variants. In contrast, however, 13.5% of the phenotypic variation in body size in dogs is explained by just 17 DNA variants. This suggests that the selection for extreme size in dogs has resulted in some DNA variants that have a larger effect on body size than those detected in cattle and humans. The similar genetic architecture in cattle and humans is corroborated by the significant overlap of DNA variants affecting stature in both species; 11 of the 92 genes significantly associated with height in cattle have been previously identified to be associated with stature in humans.

Validation of results

To confirm that the significant DNA variants identified in the study did have a true association with cattle stature, an additional 30,000 cattle, of which 20,000 were from Irish beef herds, were used for validation. The majority of the significant DNA variants identified were validated and could accurately explain between 2.1% and 13.8% of the phenotypic variability in cattle height in the Limousin and Brown Swiss breeds, respectively. In addition, the DNA of miniature cattle from three breeds (Angus, Hereford and Belted Galloway) and a 6,500-year-old wild auroch, an extinct species of large wild cattle, which were the ancestors of modern cattle, were also studied for validation. The DNA from the auroch indicated that many of the significant DNA variants identified in the study actually arose before cattle domestication and breed formation, and that over time, we have selected for shorter stature in cattle relative to wild auroch populations.



Relevance for breeding

This large study confirms that cattle stature, and most likely other complex traits such as fertility and production, can only be explained in part by specific genes. This substantiates the theory underpinning the statistical models of animal breeders, which assumes that there is an infinitely large number of genes, each having an infinitely small effect on performance. Ongoing research by Teagasc geneticists is focusing on further exploiting the 1,000 bull genomes resource to analyse other complex traits such as performance, fertility and health. Ultimately, it is hoped that these large-scale research projects can provide additional knowledge to help improve the accuracy and robustness of prediction equations for animal performance based on DNA variants, and also provide valuable information for the development of tailored management strategies.

Acknowledgements

This research is co-funded by The Department of Agriculture, Food and the Marine's Research Stimulus Fund (MultiGS) and the Science Foundation Ireland Investigator Programme (Precision Breeding). Data and collaboration among the 1,000 bull genomes project is gratefully acknowledged.

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Anthelmintic resistance on dairy calf-to-beef farms in Ireland

While anthelmintic resistance has been reported to be common on sheep farms, **TEAGASC** research has also found resistance in Irish dairy calf-to-beef systems.

Irish beef production is pasture based, with grazing animals naturally exposed to gastrointestinal nematodes (GINs; roundworms). GIN infection in calves can result in ill-thrift, with subclinical infection resulting in reduced growth rate. After their first grazing season cattle generally develop sufficient immunity to prevent clinical disease. Cattle in Ireland are usually infected with a number of GIN species, the most common being *Ostertagia ostertagi* (found in the abomasum) and *Cooperia oncophora* (found in the small intestine) (Murphy *et al.*, 2006). *Ostertagia* is considered more pathogenic than *Cooperia*. Most cattle GIN have a similar life cycle, with free-living and parasitic stages. Eggs laid by mature female worms in the gastrointestinal tract pass out with the faeces. The eggs embryonate and larvae hatch and feed on microbes in the dung. The larvae develop into infective third-stage larvae after approximately four to ten days, depending on weather conditions. The infective L3 larvae migrate out of the faecal pat onto the pasture where they can persist for extended periods. Once ingested by grazing cattle the larvae pass to the gastrointestinal tract, where they develop into adults, mate and lay eggs within approximately three weeks. The level of GIN infection in a herd can be ascertained by counting the number of worm eggs per gram (epg) of faeces (faecal egg count or FEC).

Anthelmintic resistance

Control of GIN in cattle is usually achieved by the administration of broad-spectrum anthelmintics. There are currently three classes of anthelmintic licensed for the control of GIN in cattle: benzimidazole; levamisole; and, macrocyclic lactone. These products have been highly effective in controlling GIN infection in ruminants for over 50

years; however, in recent years there have been a number of reports of anthelmintic resistance worldwide. Anthelmintic resistance is defined as the inherited ability of worms to survive doses of drugs that would normally kill them. Anthelmintic resistance has been reported to be common on sheep farms internationally and recent research in Ireland has shown widespread anthelmintic treatment failure on sheep farms, with 49% of anthelmintic treatments administered to lambs considered ineffective (Keegan *et al.*, 2017). However, the prevalence of anthelmintic resistance on cattle farms was unknown. Anthelmintic resistance is detected by a FEC 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 (Coles *et al.*, 2006). The objective of this study was to determine if resistance to benzimidazole and macrocyclic lactone was present on dairy calf-to-beef farms in Ireland.

Research on 16 farms

Sixteen dairy calf-to-beef farms, geographically spread around the country, were recruited for the study. These farms were required to have a minimum of 40 co-grazing first-season calves. The FEC of the herd was monitored fortnightly from the beginning of May to determine the level of GIN infection by collecting fresh faecal samples from 10 calves in the herd. A composite faecal sample was subsequently generated by mixing 5g from each individual sample, and the egg count of the composite sample determined using the mini-FLOTAC method with a sensitivity of 5epg. Once the herd egg count exceeded 100epg, the FEC reduction test was conducted.

Table 1: Anthelmintic resistance in 16 Irish dairy calf-to-beef farms.

Farm	Reduction in egg count after treatment with macrocyclic lactone (ivermectin)	Reduction in egg count after treatment with benzimidazole (fenbendazole)
1	52 (resistant)	85 (resistant)
2	-228 (resistant)	69 (resistant)
3	54 (resistant)	92 (resistant)
4	-3 (resistant)	93 (resistant)
5	34 (resistant)	98 (susceptible)
6	77 (resistant)	85 (resistant)
7	66 (resistant)	63 (resistant)
8	25 (resistant)	49 (resistant)
9	89 (resistant)	15 (resistant)
10	48 (resistant)	89 (resistant)
11	49 (resistant)	86 (resistant)
12	60 (resistant)	96 (susceptible)
13	78 (resistant)	99 (susceptible)
14	68 (resistant)	99 (susceptible)
15	60 (resistant)	89 (resistant)
16	51 (resistant)	89 (resistant)

Forty calves from the grazing group were weighed, faecal samples collected and the animals were treated with either a macrocyclic lactone product (ivermectin) subcutaneously at a rate of 1ml per 50kg bodyweight (n=20), or a benzimidazole product (fenbendazole) orally at a rate of 7.5ml per 100kg bodyweight. The calves returned to grass, and 14 days post treatment faecal samples were again collected. Anthelmintic efficacy was determined. Results showed that resistance to macrocyclic lactone was found on all 16 farms tested, while resistance to benzimidazole was found on 12 of the 16 farms tested (Table 1). In some cases the egg count increased after administration of the anthelmintic. The results from this study demonstrate that anthelmintic resistance to benzimidazole and macrocyclic lactone can be detected on Irish dairy calf-to-beef farms. Strategies to mitigate the risk of anthelmintic resistance need to be urgently put in place. Good GIN control practices, which reduce selection pressure on nematode populations, need to be urgently implemented. Such practices include avoiding treating too frequently, avoiding suboptimal dosing, and implementing a good biosecurity protocol for bought-in stock.

Acknowledgments

The authors would like to acknowledge the participating farmers and funding from the Teagasc Walsh Fellowship Programme.

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Bio-economic modelling of sheep production systems

TEAGASC research using a bio-economic computer simulation model has assessed the effect of stocking rate and prolificacy potential on the profitability of grass-based sheep production systems.

Stocking rate and ewe prolificacy are key drivers of flock productivity and output across both Irish and international sheep production systems (Keady and Hanrahan, 2006; Ho *et al.*, 2014). Stocking rate and ewe prolificacy have a major effect on profit, with greater numbers of lambs weaned per hectare resulting in greater profit (Teagasc, 2017). Research to date has assessed the effect of stocking rate and ewe prolificacy on flock performance and lamb output (Earle *et al.*, 2016); however, the economic effect was not assessed. The objective of this study was to assess the profitability of Irish grass-based sheep production at varying stocking rates and ewe prolificacy levels using a bio-economic model.

Teagasc Lamb Production Model

The Teagasc Lamb Production Model (Bohan *et al.*, 2016), a bio-economic computer simulation model that simulates sheep production systems, was used to simulate six stocking rate and prolificacy scenarios. The six scenarios simulated included three different stocking rates of 10 (LS), 12 (MS) and 14 (HS) ewes/ha, at two different prolificacy levels: 1.5 (LP) and 1.8 (HP) lambs weaned per ewe joined. All input data was obtained from the Sheep Research Demonstration Flock, Athenry, Co. Galway, Ireland (Earle *et al.*, 2016). Each scenario was simulated on a 20ha farm with a self-replacing March lambing flock. Flock size ranged from 213 to 299 ewes joined to the ram. Grass growth was increased in line with stocking rate and prolificacy, ranging from 10,071kg DM/ha to 14,374kg DM/ha. Grass utilisation was 80%, 85% and 90% for 10, 12 and 14 ewes/ha, respectively. A final scenario was modelled to investigate the effect of grass growth on stocking rate and prolificacy potential, whereby grass growth was maintained at the level achieved by the lowest output system (i.e., 10,071kg DM/ha) while stocking rate and prolificacy were increased, with the additional energy requirements of the flock being supplied in the form of concentrate supplementation. Risk analysis was conducted using the @Risk programme to

assess the effect of variation in key input variables (lamb and ewe mortality, grass growth, fertiliser and concentrate costs, lamb and mutton price) on the profitability of each scenario investigated.

High prolificacy more profitable

Results from the bio-economic model showed that the number of lambs weaned per hectare increased as stocking rate and ewe prolificacy increased, and ranged from 16 to 27 lambs/ha. Increasing the number of lambs weaned per hectare reduced the individual lamb growth rate; however, total carcass produced per hectare increased from 272-474kg/ha. Lamb sales increased from €1,299/ha to €2,219/ha, with variable costs rising from €774/ha to €1,224/ha. The average cost of producing a lamb at low prolificacy was €75 but decreased to €65 per lamb at high prolificacy. This translated into an average net profit of €23/lamb and €35/lamb at the low and high prolificacy potentials, respectively. As the number of lambs weaned per hectare increased from 16 lambs/ha to 27 lambs/ha, net profit increased from €361/ha to €802/ha (**Figure 1**). The greatest net profit was achieved when weaning 1.8 lambs per ewe at 14 ewes/ha (HS, HP), with €2,219/ha in lamb sales, a gross margin of €1,210/ha and a net profit of €802/ha. Increasing prolificacy increased net profit on average by €336/ha, while stocking rate increased net profit on average by €84/ha and €19/ha for an increase from 10 to 12 ewes/ha and from 12 to 14 ewes/ha, respectively.

In general, the bio-economic model showed that increasing the number of lambs weaned per hectare increased net profit per hectare, but the greatest increase in profitability per hectare was achieved at the higher prolificacy level. Increasing the number of lambs weaned without increasing grass growth and utilisation was economically counterproductive. Across all stocking rates, the high prolificacy scenarios were more profitable and had a greater capability to cope with fluctuations in key variables.



Conclusion

The bio-economic model demonstrated that the number of lambs weaned per hectare, along with increased grass production and utilisation, increases net profit. Increasing the number of lambs weaned per hectare reduces the cost of production per lamb and in turn increases net profit per lamb. Increasing the number of lambs weaned per hectare without increasing grass growth and utilisation is economically counterproductive.

Acknowledgements

This research was originally presented at the British Society of Animal Science (BSAS) annual conference in Dublin in April 2018. Funding from the Irish Department of Agriculture, Food and the Marine Research Stimulus Fund MULTIREPRO (15/S/696) is gratefully acknowledged.

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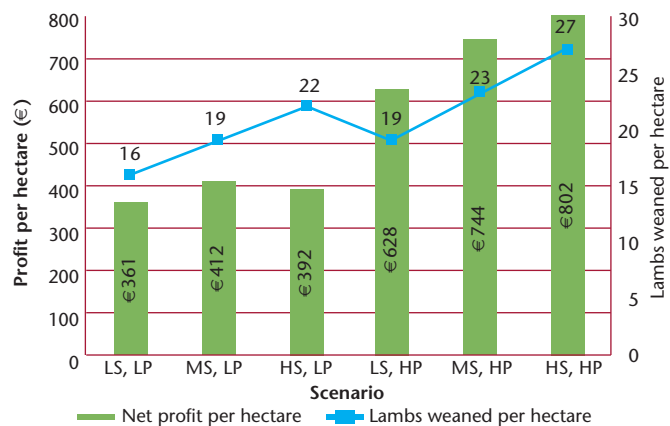


FIGURE 1: The effect of number of lambs weaned per hectare on profit.

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Ewe prolificacy and stocking rate in grass-based systems

A **TEAGASC** study has looked at the impact of ewe prolificacy potential and stocking rate on lamb average daily gain and liveweight output per hectare within a grass-based system.

Ewe prolificacy potential (PP; predicted number of lambs born per ewe per year) and stocking rate (SR; ewes per ha) are two of the most influential factors affecting lamb output (Keady *et al.*, 2009) and the efficiency at which feed resources are utilised in grass-based lamb production systems (Young *et al.*, 2010). Previous studies have tended to focus on efficiency at an individual animal level rather than on overall system efficiency.

Athenry ewe prolificacy and stocking rate study

The objective of this study was to investigate the effect of ewe PP, SR and their interaction on lamb liveweight gain and lamb output at the system level. The study was a 2 x 3 factorial design, consisting of two differing ewe PPs (medium prolificacy (MP) – Suffolk-sired crossbred ewes – a weaning rate of 1.5 lambs per ewe; and, high prolificacy (HP) – Belclare-sired crossbred ewes – a weaning rate of 1.8 lambs per ewe) and three SRs: low (LSR; 10 ewes per ha); medium (MSR; 12 ewes per ha); and, high (HSR; 14 ewes per ha). The study was carried out over three production years. Each treatment was managed in a five-paddock rotational system for the duration of the study. Lamb average daily gains (ADG; g per day) were recorded from birth to finishing.

Animal performance and output

High PP ewes produced a higher number of lambs born per ewe (+0.20 lambs; $P < 0.001$) and per hectare (+1.5 lambs; $P < 0.05$), and weaned an extra 0.18 lambs per ewe ($P < 0.01$) and 2.01 lambs per hectare ($P < 0.01$). SR had no effect on the number of lambs born or weaned per ewe ($P > 0.05$). However, the number of lambs born and weaned differed on a per hectare basis, with the lowest number reported at the LSR, intermediate at the MSR, and highest at the HSR ($P < 0.001$). The HP treatment achieved a 0.45kg higher lifetime (birth to slaughter) lamb ADG per ha compared to the MP

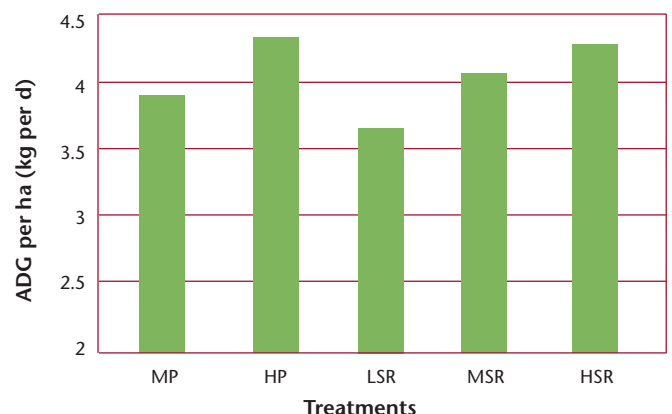


FIGURE 1: Effect of ewe prolificacy potential and stocking rate on lifetime daily lamb liveweight (kg) gain per ha.

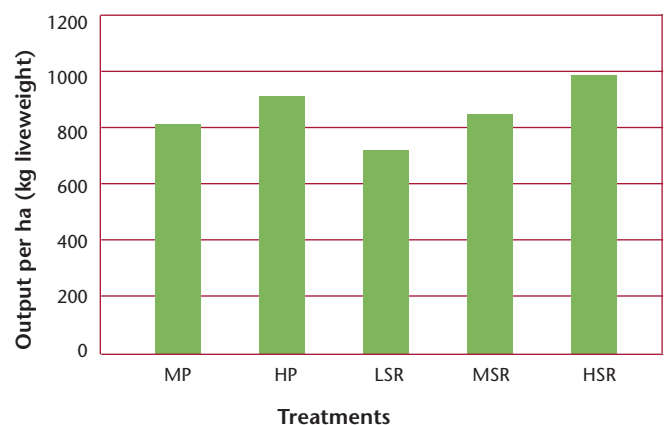


FIGURE 2: Effect of ewe prolificacy potential and stocking rate on total lamb liveweight (kg) output per ha.



treatment ($P < 0.001$; **Figure 1**). Total lifetime lamb ADG per ha was lowest at the LSR, intermediate at the MSR, and highest at the HSR ($P < 0.001$). Total lamb liveweight output per ha also increased with increased PP and SR as shown in **Figure 2**.

Implications for industry

Results from this study demonstrate the potential to increase the level of lamb production and output per ha within grass-based systems by increasing ewe PP and SR. The appropriate SR for a farm will be dictated by its grass growing potential to support a given SR. Increasing ewe prolificacy should always be the first priority, while increasing SR must always be in conjunction with increased grass production and utilisation.

Results from this study demonstrate the potential to increase the level of lamb production and output per ha within grass-based systems by increasing ewe PP and SR.

Acknowledgements

This research was funded under the Teagasc Walsh Fellowship Scheme. It was originally presented at the British Society of Animal Science (BSAS) annual conference in Dublin in April 2018.

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Oestrous cyclicality and uterine health: is there a link?

TEAGASC research is looking at whether there are associations between oestrous cyclicality, uterine health and body condition score in dairy cows.

After parturition, the nutritional requirements of dairy cows shift abruptly, as milk production increases rapidly. It is normal for energy demand (maintenance and milk production) to exceed dietary energy supply, and negative energy balance is common during the early postpartum period. During that period, cows must resume normal oestrous cyclicality (OC) and complete uterine involution in preparation for another pregnancy. Post-partum ovarian cyclicality, uterine infection and body condition score (BCS) are important factors affecting reproductive performance in dairy cows. The aim of this study was to examine the associations between OC, uterine health status (UHS) and BCS during early lactation in first and second parity seasonal calving dairy cows.

Collection of cow phenotypes

Thirty-five dairy herds located in the province of Munster were enrolled in the study. All herds were managed as grass-based seasonal-calving systems. The study population included first (n=1,637) and second (n=1,074) parity Holstein-Friesian and Holstein-Friesian x Jersey cross cows. All enrolled cows calved during the spring season (February to April) of 2015 (n = 24 herds) or 2016 (n = 11 herds). Enrolled herds were visited every two weeks during the postpartum period, and data was captured on each cow at week 3 (14 to 28 days in milk) and week 7 (42 to 55 days in milk). The study data collection schedule is outlined in **Figure 1**. BCS was measured using a 1-5 scale in increments of 0.25. Transrectal ultrasound examinations were conducted to determine OC based on visualisation of corpus luteum (CL) and dominant follicle (DF) structures on the ovaries, and UHS based on visualisation of mucopurulent material in the uterine lumen. Cows were grouped into categories for BCS, OC and UHS according to the following criteria:

- BCS categories: low (≤ 2.5), target (≥ 2.75 and ≤ 3.25) and high (≥ 3.5);
- OC categories: cycling (CyC; CL present), anoestrous (AN; CL absent and DF present), and deep anoestrus (DA; CL and DF absent); and,
- UHS categories: healthy (H), low infection (LI), mild infection (MI), and severe infection (SI).

Associations between week post calving, parity, BCS and oestrous cyclicality

The data analysis verified some already known associations:

- the proportion of cows that had resumed OC was greater at week 7 (92.4%) compared with week 3 (45%), highlighting the importance of early calving date to achieve a high proportion of cycling cows before the start of the breeding season;
- a smaller proportion of first parity cows had resumed cyclicality at week 3 and week 7 (43.4% and 74.1%, respectively), compared with second parity cows (48.7% and 78.7%, respectively); and,
- BCS affected resumption of OC, with the proportion of low, target and high BCS cows that had resumed OC at week 3 (42.9%, 46.0% and 34.8%, respectively) and week 7 (65.5%, 77.6% and 70.8%, respectively) highlighting the importance of nutritional management for early resumption of cyclicality.

Associations between week post calving, parity, BCS and uterine health status

- The proportion of cows that had a uterus classified as H, LI, MI or SI changed substantially between week 3 (2.2%, 25.1%, 60.5% and 12.0%, respectively) and week 7 (27.3%, 48.3%, 23.3% and 0.8%, respectively), highlighting the importance of early calving date to allow time for uterine recovery post calving;

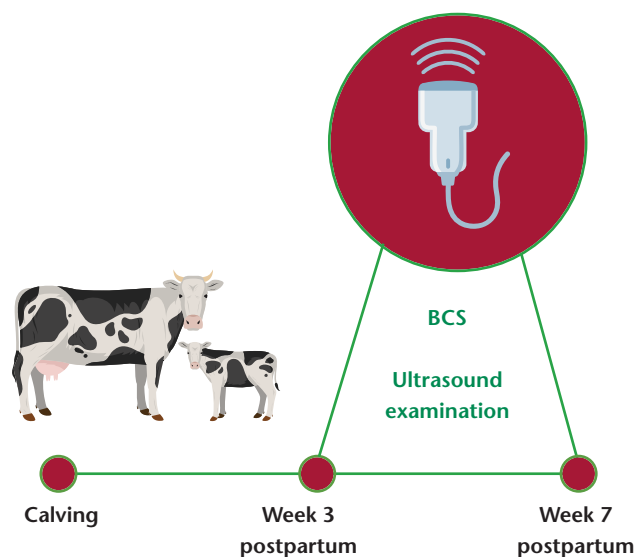


FIGURE 1: Diagram of data collection schedule. BCS: body condition score.

- the proportion of first parity cows that did not have any uterine infection (i.e., healthy uterus) was less than the proportion of second parity cows at both week 3 (1.5% vs 3.3%, respectively) and week 7 (25.6% vs. 30.1%, respectively); and,
- BCS was associated with UHS, with the proportion of low, target and high BCS cows that did not have uterine infection (i.e., healthy uterus) at week 3 (20.7%, 28.1% and 21.1%, respectively) and week 7 (21.4%, 28.5% and 12.5%, respectively) highlighting the importance of nutritional management for prompt uterine recovery after calving.

Associations between oestrous cyclicity and uterine health status

An association between OC and UHS was detected, whereby cows that did not have uterine infection at week 3 and week 7 post partum (i.e., healthy uterus) had increased likelihood of having resumed OC compared with cows that were categorised as having mild or severe uterine infection (Figure 2). This could also be looked at the other way, whereby cows that had resumed OC by week 3 and week 7 had less likelihood of having uterine infection. The most common cause of uterine infection in cattle is bacterial contamination of the uterus in the immediate post-calving period. The bacteria produce endotoxins, which in turn attenuates secretion of gonadotropin-releasing hormone (GnRH) from the hypothalamus. Inadequate GnRH release prevents the frequent pulses of luteinising hormone from the pituitary gland that are required to promote follicular development and ovulation. Therefore, uterine infection may delay resumption of OC. On the other hand, each oestrus event causes uterine contractility, and helps to evacuate mucopurulent material from the uterus. Hence, early resumption of cyclicity may aid early clearance of uterine infection. The collective findings highlight the importance of achieving and maintaining a compact calving pattern in seasonal calving systems.

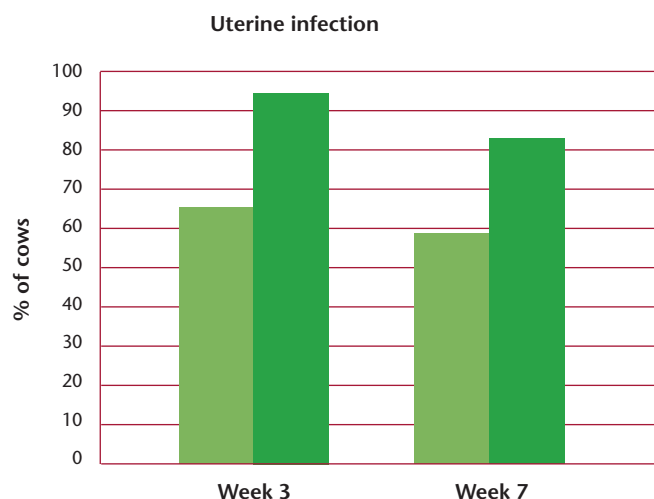


FIGURE 2: Incidence of uterine infection in cows that did or did not resume ovarian cyclicity at week 3 and week 7 postpartum.

Acknowledgements

The authors acknowledge the Irish Department of Agriculture, Food and the Marine for funding this project through Research Stimulus Fund (RSF) award 13S528 and the Teagasc Walsh Fellowships Programme. We are also grateful to the dairy farmers involved in the study, and to Pat Lonergan (UCD) for his collaboration on the project.

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Making light work: X-ray fluorescence spectroscopy

From radiography in medicine to revising the periodic table of elements, X-ray fluorescence spectroscopy has an interesting past and an even more interesting future in the agri-food sector.

X-rays have been around since 1895 when Wilhelm Roentgen noticed a fluorescent glow coming from crystals on a table next to the cathode ray tube he was working on. He concluded that this was a new type of ray able to excite the electrons in the crystals nearby and causing the phosphorescent glow. This invisible ray, capable of passing through solid material, quickly caught the attention of scientists and medics as advances led to radiography, and in 1896 the technique was used on the battlefield to locate bullets in wounded soldiers.

Analytical applications came in 1909 when Charles Barkla established a link between X-rays and the atomic weight of a sample, which not only led to elemental analysis but to revising the system used for numbering the elements, known today as the periodic table of elements. By later establishing a relationship between frequency (energy) and atomic number, scientists were able to identify elements using X-rays, which is the basis of X-ray spectroscopy today.

X-ray fluorescence applications in agri-food

Capable of analysing solids, liquids and powders, X-ray fluorescence (XRF) has mostly been used in geology and mining applications for rapid screening of rocks and ores. Non-destructive analysis of samples using XRF ensures that samples are preserved for archaeological and geo-archaeological applications to explain the human past. But it is the qualitative and quantitative abilities that have applications in the agri-food sector, and by coupling the 'what' and 'how much' with non-destructive analysis in a range of sample types, scientists at Teagasc have developed this technique to examine soils, sediment, grass, dairy waste and milk powders.

Nutrients and trace elements in grass samples

Nutrients and trace elements in grass can depend on stages of growth and soil type, and elemental analysis of grass is a useful measure of both plant nutrition and ability to meet the minimum requirement of essential elements for animal health in pasture-based systems. Conventional analyses involve strong acid or alkaline digestion followed by analysis of the filtrate by either colorimetric analysis, atomic absorption or inductively coupled plasma (ICP) analysis. In routine analytical laboratories, backlogs are common due to high sample throughput, which then delays farmers receiving results, reducing the results' value. Recently published work by Teagasc (Daly and Fenelon, 2017; Daly and Fenelon, 2018) is the first to evaluate the application of energy dispersive XRF (EDXRF) for grass analysis and provide a method to determine major nutrients (phosphorus [P], potassium [K], magnesium [Mg] and calcium [Ca]), and trace elements (copper [Cu], manganese [Mn], zinc [Zn] and sulphur [S]).

Comparing 'old' and 'new' methods

To evaluate a new method, we needed to assess the level of agreement with conventional techniques or 'gold standard' methods. With access to an existing archive of 600 grass samples with known values of some major nutrients and trace elements in grass P, K, Mg, Ca, Cu, Mn, Zn and S, we compared XRF measurements with ICP values with very positive results. Firstly, XRF measurements of grass samples were carried out using the theoretical equations developed in XRF theory to quantify elements in a sample. While this approach is widely used in geology and pharmaceuticals for pure materials, environmental samples with complex matrices present a bigger challenge. For some elements the theoretical approach worked, but for others, there was a noticeable difference (or bias) in the results. This observation allowed us to



The range of agri-food samples currently being analysed using XRF: biosolids and dairy waste; grass; soil; and, milk powder.

develop empirical calibrations specific to each element by using grass samples as standards, and also to 'matrix match' and fine-tune the theoretical calibrations. In **Figure 1**, to determine the percentage of P in grass, three calibration approaches were compared: an empirical (EMP) (based on grass standards); theoretical (FP); and, a matching library (FPML). Best agreement was observed when empirical and matching library calibrations were used to calibrate the XRF frequencies with concentrations. This work demonstrated that bespoke empirical calibrations improved the accuracy and precision of the results. Using standard samples based on the same matrix type can minimise matrix effects of absorbance and enhancement due to the presence of other elements in the sample. This is especially relevant for environmental samples with complex matrices such as soils, sediments, grains and grass samples. We have found that XRF is a viable alternative to digestive techniques for elemental determination across a range of agri-food samples.

Acknowledgements

This research is supported by Teagasc core funding.

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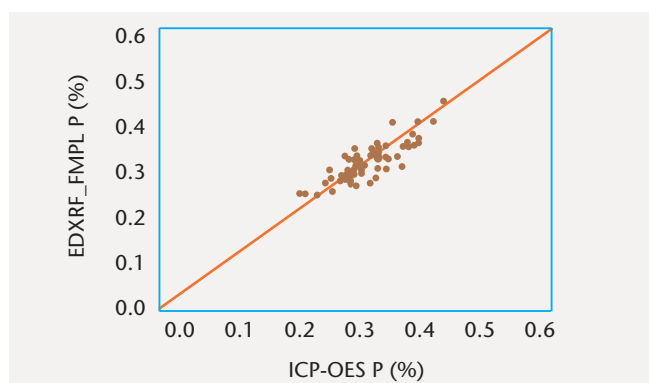
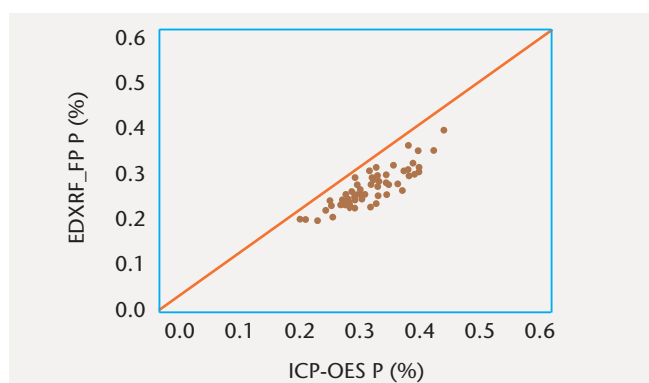
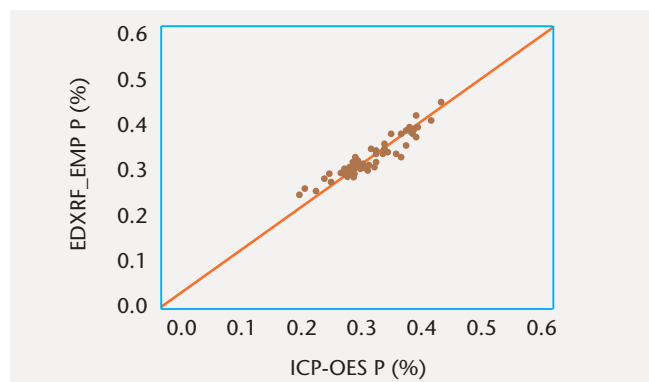


FIGURE 1: Comparison of the percentage P in grass using theoretical calibration XRF, and the improved agreement when empirical grass standards were used.

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Breaking biomass

Research into pre-treatment of energy crops will hopefully lead to more efficient production of liquid biofuels, thus meeting growing energy demands.

Global interest in renewable energy has grown over the last decades driven both by efforts to mitigate the effects of climate change and fuel security concerns. Renewable energy, however, is not a new concept, being the only form of energy available to mankind until the use of fossil fuels became widespread during the last few centuries. Biomass was the first fuel of any kind; the invention of fire to combust biomass provided a means of warmth, protection and nutrition for early humans. Biomass can be used as a source of heat but, additionally, both electricity and transport fuels can be produced from it.

Energy use in Ireland is divided almost equally between heat, electricity and transport fuel usage, and biomass is currently used in Ireland to generate heat in open fires and biomass stoves and boilers; to generate electricity in Edenderry power station, where it is co-fired with peat; and, to power vehicles, as petrol and diesel sold in Ireland have to contain a minimum percentage of either biodiesel (in diesel) or ethanol (in petrol).

Liquid biofuels from biomass

Woody biomass can be burnt to generate heat and electricity. However, it is much more difficult to convert woody biomass into liquid biofuels, because woody biomass consists of a tightly bound mixture of lignin, cellulose and hemicellulose, which needs to be broken down first before the conversion process can begin. This initial breakdown process is called a pre-treatment step. This is an expensive step, which adds considerable extra cost to the production of liquid biofuels from woody (ligno-cellulosic) feedstocks. As a consequence, liquid biofuels are generally made from waste or food crops. Current bioethanol (ethanol manufactured from biological sources) production comes from food crops such as corn, sugar cane and sugar beet, while biodiesel is manufactured from crops such as oilseed rape and soybeans. However, the use of food crops for the production of liquid biofuels has negative consequences.

Food crops are generally grown on the most productive soils and the use of good land to produce feedstocks for liquid biofuel production makes it more difficult to meet the growing demand for food. Additionally, the

use of food crops for liquid biofuel production has often distorted food prices. Consequently, as demands for liquid biofuels increase, alternatives to food-based liquid biofuels are needed. Liquid biofuels produced from ligno-cellulosic biomass can offer an alternative if the cost of the pre-treatment step can be reduced, particularly if the ligno-cellulosic biomass can be produced on land that is not used for food production. Fast-growing energy crops produced on marginal land could supply a significant amount of biomass to supply the growing demand for liquid biofuels without compromising global food production, but only if the technology for cost-efficient biomass pre-treatment can be developed.

Pre-treatment research

Research at the Institute of Technology, Carlow, has sought to increase the efficiency and reduce the cost of biomass pre-treatment. Biomass contains ~45-50% cellulose, 25-35% hemicellulose and 15-20% lignin. Thermochemical techniques can be used to manufacture second-generation biodiesel or bioethanol from biomass; such techniques generally produce a char together with a gas, which can be synthesised into a range of fuels. Bioethanol can also be produced from ligno-cellulosic biomass by biological methods in which enzymes are used to convert cellulose and hemicellulose to sugars, which are then fermented to ethanol. Pre-treatment is necessary to achieve high yields of sugar from the cellulose and hemicellulose present in biomass. Effective pre-treatments disrupt cell walls and crystalline structures to allow enzymes to access the biomass structure. Pre-treatment can be classified into several categories: physical (milling, grinding); biological (use of microorganisms and fungi); chemical (use of acid or alkaline reagents or organic solvents); and, physico-chemical (steam explosion/autohydrolysis and wet oxidation). This research has concentrated on the use of chemical pre-treatments applied to a range of energy crops that can be grown in Ireland.

In this research, four different energy crops (willow, miscanthus, hemp and switchgrass) were treated with a range of concentrations of four different pre-treatment chemicals (sodium hydroxide, methanol,



sulphuric acid and ammonia). The optimum pre-treatment chemical was found to be crop specific. Pre-treatments employing ammonia proved most effective for willow and hemp. Sulphuric acid pre-treatment generated highest yields from miscanthus, while methanol pre-treatment generated the highest yields from switchgrass. The efficiency of a range of enzymes for converting cellulose to simple sugars was also tested, and the enzyme with the highest efficiency was also dependent on the feedstock. To maximise conversion efficiency, it is important to match both the pre-treatment chemical and the enzyme to the crop being used as a feedstock for the production of second-generation ethanol. Critically, it was also found that the efficiency of the conversion of cellulose and hemicellulose to ethanol could be significantly enhanced if the conversion of cellulose/hemicellulose to simpler sugars could be combined and done in the same step as the fermentation of these sugars to ethanol. The combination of these two steps is referred to as simultaneous saccharification and fermentation, saccharification being a term used to describe the conversion of polysaccharides such as cellulose and hemicellulose to simpler sugars.

The use of different pre-treatment chemicals has also to be considered from an environmental perspective, as the use of pre-treatment chemicals can affect different aspects of the environment such as the quality of the air, water and soil. Our study used life cycle assessment techniques to quantify the impact of pre-treatment choice on a range of environmental receptors, global warming potential, eutrophication, acidification, photochemical oxidation demand, and marine and human ecotoxicity. The results showed that no one pre-treatment chemical provided a minimum impact across all of these environmental receptors, although organic solvents such as methanol had the lowest global warming potential. In many respects, this is the most critical environmental receptor to be considered when comparing bioenergy processes, as the primary driver for bioenergy is climate change mitigation.

Second-generation biofuels can offer an alternative to first-generation biofuels without competition between food and fuel. The economics of

second-generation biofuels need improvement but this research has shown that the cost and efficiency of the costly biomass pre-treatment step can be significantly enhanced to lower the overall cost of the conversion of ligno-cellulosic biomass to ethanol.

Acknowledgements

This project received funding from the Teagasc Walsh Fellowship Programme.

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WaterProtect: towards sustainable herbicide use

The Irish section of a major European research project will examine pathways of herbicide movement in an Irish field setting to ascertain its occurrence in water sources.

Modern agricultural practices use herbicides throughout most phases of grass and crop growth to maintain and increase productivity. However, some herbicides can be leached or washed off soil surfaces, and can eventually be detected in drinking water sources. MCPA, used to control rush and broadleaf weed growth, can be particularly mobile once applied. Key questions are:

1. Do we understand enough about this process of herbicide loss to water?
2. Do current practices require modification to minimise this loss?

The EU Horizon 2020 project WaterProtect, running from June 2017 until May 2020, aims to address these questions. The project is a large collaboration between seven case studies located in Belgium, Denmark, Spain, Poland, Romania, Italy and Ireland. The Irish case study is led by Teagasc, with Wexford County Council, Glanbia Ingredients Ireland Ltd and Ulster University working as partners. The Irish research will focus on assessing the transport pathways and behaviour of herbicides, with a special focus on MCPA applied to an Irish field site, and the usefulness of specific measures for mitigating the losses to aquatic systems. Two other EU-funded projects, Horizon 2020 'Fairways', which includes a Northern Ireland case study, and INTERREG VA 'Source to Tap', an exclusively cross-border Irish project, are addressing different aspects of sustainable herbicide use. The investment in three large-scale projects across Ireland

relating specifically to sustainable MCPA use is an indication of how important this topic has become.

Pesticides – usage and environmental occurrence

From the most recent estimates, 78 and 114 active substances are in use in grassland/fodder and arable crops in Ireland, respectively (PCD, 2012; PCD, 2013). In terms of weight, this corresponds to approximately 600 tonnes and 1,150 tonnes, respectively, of active substances being applied to grassland/fodder crops and arable crops annually. While legislative steps have been enacted to govern the control and use of pesticides, monitoring of drinking water resources has shown an increase in the number of public water supplies that are failing to meet the legislative standards (**Figure 1**). At the end of 2016, 63 supplies serving over 900,000 people had open investigations due to failures to meet the acceptable pesticide quality standard stipulated by the legislation (EPA, 2017). While these observed failures relate to all pesticides, monitoring has illustrated that MCPA is mostly responsible for the exceedances. Failures were mostly evident during May, June and July, and again in September/October, which typically coincide with periods of MCPA application to grassland for the control of rush, ragwort and thistle (*ibid*). Pesticides can enter water bodies via a number of pathways, including surface run-off, erosion, leaching, drain flow and spray drift. The movement and fate of pesticides in the environment via these pathways depends on many factors including the soil type and structure, subsoil geology, soil pH, soil microbiology, soil moisture, application timing and pesticide formulation. MCPA in particular has been shown to have the potential to be highly mobile in the environment post application due to its high water solubility and low sorption with the soil, which is consistent with its detection in drinking water sources. Due to the number and varied nature of potential pathways, a considerable number of mitigation measures have been investigated (vegetative buffers, riparian buffers, constructed wetlands, spray drift reduction, etc.), albeit with varying success. The WaterProtect research aims to assess the pathways of herbicide movement, particularly MCPA, in an Irish field setting. A greater understanding of pathways is required for evaluating risks to drinking water resources, and is necessary to identify potential mitigating factors.

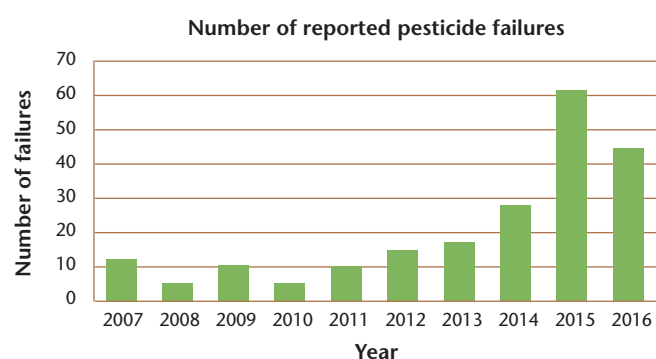


FIGURE 1: Number of public water supplies with reported pesticide failures (EPA, 2017).

WaterProtect: Irish research

The research will be conducted in two agricultural catchments in Wexford that have been monitored extensively as part of the Agricultural Catchments Programme (ACP) (Figure 2). One catchment has mostly free draining soils with arable crops, and the other has mostly poorly drained soils and is dominated by grassland for beef and dairy production. The research will investigate the occurrence of MCPA in groundwater through the sampling of private water wells in both study areas. Approximately 162,000 households in Ireland rely on private wells for their water provision (CSO, 2012); hence, it is important that this water is of appropriate quality. This investigation will assess seasonal well water quality and also the importance of groundwater as a receptor and pathway for pesticide contamination. On a field scale, the study will then focus on MCPA and its behaviour and fate post application for rush control treatment in a poorly draining impermeable grassland field (Figure 2). Once applied, monitoring will evaluate its movement via subsurface drains, shallow groundwater, overland flow and surface water streams. This will be achieved through the use of high-resolution monitoring as well as passive samplers, which are capable of providing overall average concentrations of MCPA lost via surface water streams. Combined with case studies across the EU, and with partner projects in Ireland, the results will provide a new knowledge base for policies and management practices relating to sustainable MCPA use into the future.

Acknowledgments

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 727450. Disclaimer: this publication only reflects the authors' views and the Commission is not responsible for any use that may be made of the information it contains.

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FIGURE 2: Overview of the grassland catchment and evidence of overland flow after a rainfall event on a poorly drained field where MCPA would typically be used for rush control.

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Phage-based biosensors for pathogen detection

Researchers at **TEAGASC** and Queen's University Belfast are developing a bacteriophage-based biosensor for the detection of food-borne pathogens.

The threat to our socioeconomic balance and healthcare system from bacterial contamination of food has become a global burden. The World Health Organisation estimates that 600 million people in the world (approximately one in 10) fall ill following consumption of contaminated food every year, and of these, 420,000 die. With the changing of food preparation and food styles over recent years, where more processed and ready-to-eat foods are available, cooking processes have altered significantly, and thus the risk of consuming food products containing pathogenic bacteria has increased. Food-borne pathogens such as *Campylobacter*, *E.coli*, *Salmonella* and *Listeria monocytogenes* are responsible for numerous outbreaks of disease and the recall of food products worldwide. The gold standard for detection of food-borne bacteria is still conventional culture-based diagnostic protocols, due to their sensitivity and the benefit of yielding colonies that can be subjected to diagnostic tests. However, these methods are time consuming and labour intensive. The development of simple-to-use diagnostics for end product or process line testing is essential to ensure that the integrity of the food chain is maintained.

An introduction to bacteriophage biology

Bacteriophages have existed alongside bacteria for billions of years and have evolved systems that may be exploited for our benefit, such as the use of bacteriophages to detect food-borne pathogens. A bacteriophage (phage) is a virus that infects bacterial cells. Phages are the most abundant biological entity found naturally, with an estimated number of 10^{31} phages present in the biosphere (Casey *et al.*, 2017). In order to survive and replicate, phages hijack their host bacteria's metabolism. Phages are acutely host specific, meaning that they only infect particular bacteria through recognising certain receptors present on the host bacteria's cell surface. Phages can use a number of cell surface moieties as receptors, such as glycolipids, integral membrane proteins and flagellar proteins used by *Salmonella* phages, and wall teichoic acid (WTA), lipoteichoic acid (LTA), polysaccharides, S-layer proteins and PIP protein used by *Lactococcus* phages (Figure 1). The

recognition of the bacterial host by the phage occurs through receptor-binding proteins, which are generally located in the tail of the phage. Once phages encounter their host bacteria, they attach to the surface of the cell via these receptors in their tail proteins and begin to degrade the cell wall. Following this, phages inject their genetic material through the tail and into the host cell. Depending on the phage life cycle, this intracellular phage will eventually result in the lysis of the host cell and release of newly formed phages into the environment.

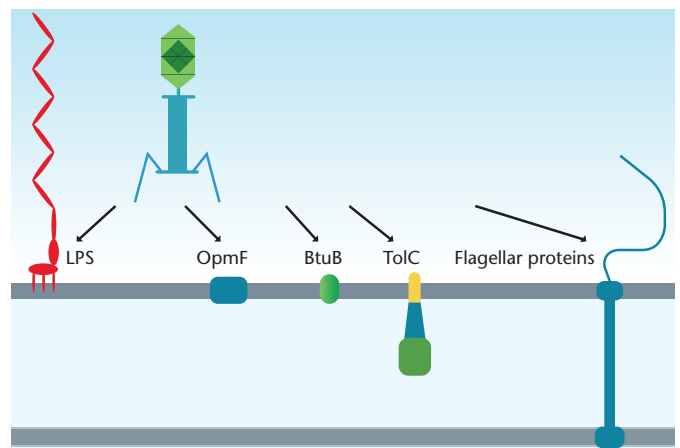


FIGURE 1: Potential cell surface moieties that phages can use as receptors.

Bacteriophage-based biosensor for pathogen detection

Recent years have seen the development of biosensors as novel methods of pathogen detection, which are designed to overcome the many limitations of conventional detection platforms. Biosensors are selective, sensitive, cost-effective, rapid and, more recently, portable devices. The platforms that have leveraged phage-based probes have used primarily intact bacteriophage particles as the recognition element, and have successfully detected pathogens in various food matrices (Figure 2). However, significant disadvantages are associated with such biosensors,

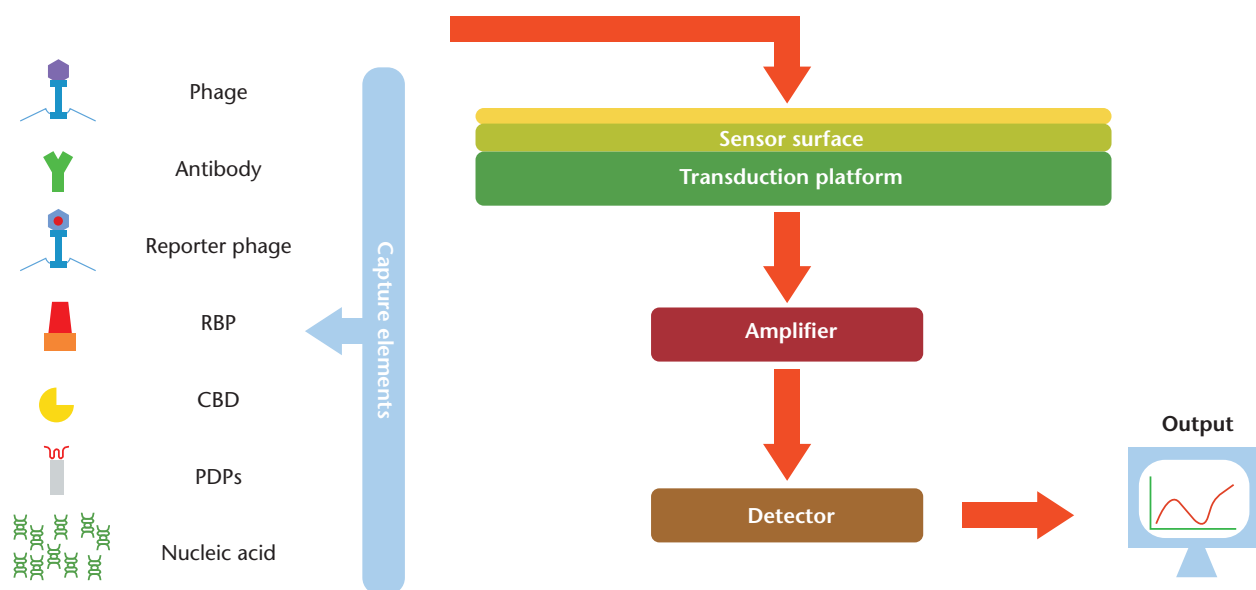


FIGURE 2: The components of a biosensor showing various biorecognition elements that may be attached to the sensor surface.

including the large size of the intact phage particles, making it difficult to integrate them into certain platforms, and the potential of infection and lysis of cells at certain time periods, which will result in a decrease of signal. To avoid these difficulties, research is now focusing on the use of phage-derived molecules as the biorecognition element in the biosensor.

Rapid diagnostic test for *L. monocytogenes*

Our research aims to develop a rapid diagnostic test for *Listeria monocytogenes*, a food poisoning bacterium that is particularly associated with ready-to-eat foods. *Listeria*-related economic losses now run into the billions per year worldwide, following many high-profile epidemics in recent years. Two independently successful technologies will be combined: the rapid portable nature of biosensors based on planar waveguide technology; and, the extraordinary specificity of bacteriophage-host interactions for *L. monocytogenes* detection. To date, novel phages against *L. monocytogenes* strains of the 4b and 4e serotypes have been isolated from mushroom compost. The genome sequences of two of these phages, phage vB_Lmo_188 and phage vB_Lmo_293, were elucidated and identified as belonging to a recently defined group of *Listeria* bacteriophages known as orthocluster IV. Their specificity for *L. monocytogenes* strains of serotypes 4b and 4e was determined to be likely to be due to a small cluster of putative tail fiber genes, which were thought to function in bacterial-host recognition. Through a series of mutational analysis experiments, the receptor-binding proteins in the phage tails were identified (Casey *et al.*, 2015). Recombinant production of these proteins is ongoing, with biosensor integration of these phage-derived affinity proteins planned as the next stage. By harnessing phage receptor-binding proteins, a rapid real-time test can be developed for the online monitoring of key serotypes of *L. monocytogenes* food matrices with improved sensitivity over current methods.

Acknowledgements

Aidan Casey (Teagasc), Kieran Jordan (Teagasc) and Aidan Coffey (Cork Institute of Technology). This research was funded by Teagasc

(ref. 0027), the Teagasc Walsh Fellowship Scheme (ref. 2016034), a safefood mini-project, and the Department of Agriculture, Food and the Marine's Food Institutional Research Measure (FIRM; ref. 11F008).

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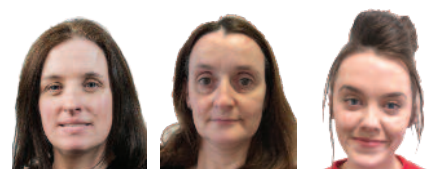
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Marine antimicrobials for the food industry

The MabS project is investigating the antimicrobial potential and genetic aspects of the biosynthesis of tropodithietic acid and other metabolites in marine-derived *Pseudovibrio* species to develop antibacterial agents for the meat industry.

Food is an essential means for humans and other animals to acquire the necessary elements needed for survival. However, it is also a transport vehicle for food-borne pathogens, which can pose a threat to human health as well as to the food industry. Antibiotics are typically used to tackle these pathogens and enhance the human health system; however, selective pressure among bacteria allows the development of antibiotic resistance. Thus, the emerging antibiotic resistance among pathogenic microorganisms is a matter of great concern (Lucera *et al.*, 2012). Unfortunately, progress in the discovery and development of new antibiotics that may be used to tackle these pathogens has lagged behind the pace with which resistance has developed. Recently, marine ecological niches have been established as promising sources for new antimicrobials to combat antibiotic-resistant strains of pathogenic microorganisms. Marine bacteria, fungi, cyanobacteria, sponges and other organisms produce a number of pharmaceutically useful compounds possessing antibacterial, antifungal and antimycobacterial activities. With the efforts of researchers around the world, the total number of approved drugs from the marine environment has risen from four in 2010 to seven in 2014 (Choudhary *et al.*, 2017).

Antimicrobial potential of *Pseudovibrio* genus

Pseudovibrio species are ubiquitous in the marine environment and, in particular, in communities within marine sponges. After being first isolated and described from seawater in Taiwan in 2004, they have been isolated from ascidians, tunicates, algae, coral, tube worms, and from a plethora of marine sponges. Our group has isolated and identified a number of *Pseudovibrio* species from Irish marine sponges with anti-*Salmonella* activities. Infections caused by food-

borne pathogens, such as *Salmonella* spp., are a major public health problem worldwide and the consumption of pork products containing salmonellae is a major source of food poisoning. Thus, there is a clear need to identify novel products to control the threat both to human health and the pig industry in Ireland.

Antimicrobial activity within *Pseudovibrio* spp. has previously been reported in different biological assay systems owing to the production of various bioactive secondary metabolites. *Pseudovibrio* species are known to produce specific bioactive compounds, such as heptyl prodigiosin and tropodithietic acid (TDA). TDA (Figure 1) is a sulphur-containing compound with a unique structure consisting of a dithiete moiety fused to tropone-2-carboxylic acid, which is believed to co-exist with its tautomer, thiotropocin, previously identified in *Pseudomonas* spp. TDA has been shown to have a strong inhibitory activity against a range of marine bacteria, such as *Proteobacteria*, *Actinobacteria*, *Firmicutes* and *Bacteroidetes*, the fish pathogens *Vibrio anguillarum* and *Vibrio splendidus*, as well as marine algae and a range of human pathogenic bacteria (Harrington *et al.*, 2014). Moreover, in a recent study, we have been able to detect and characterise a unique analogue of TDA, namely methyl-TDA, and a number of cholic acid derivatives together with amino diols and triols in the *Pseudovibrio* W64 strain. These metabolites have previously been reported to possess antimicrobial activity.

Understanding biosynthesis of TDA

In genomic 'mining' studies, the *tdaA* and *tdaB* genes were found to be involved in the production of TDA, and further studies confirmed that these genes are expressed from between 24 and 48 hours of growth. The comparative analysis of various strains has indicated that

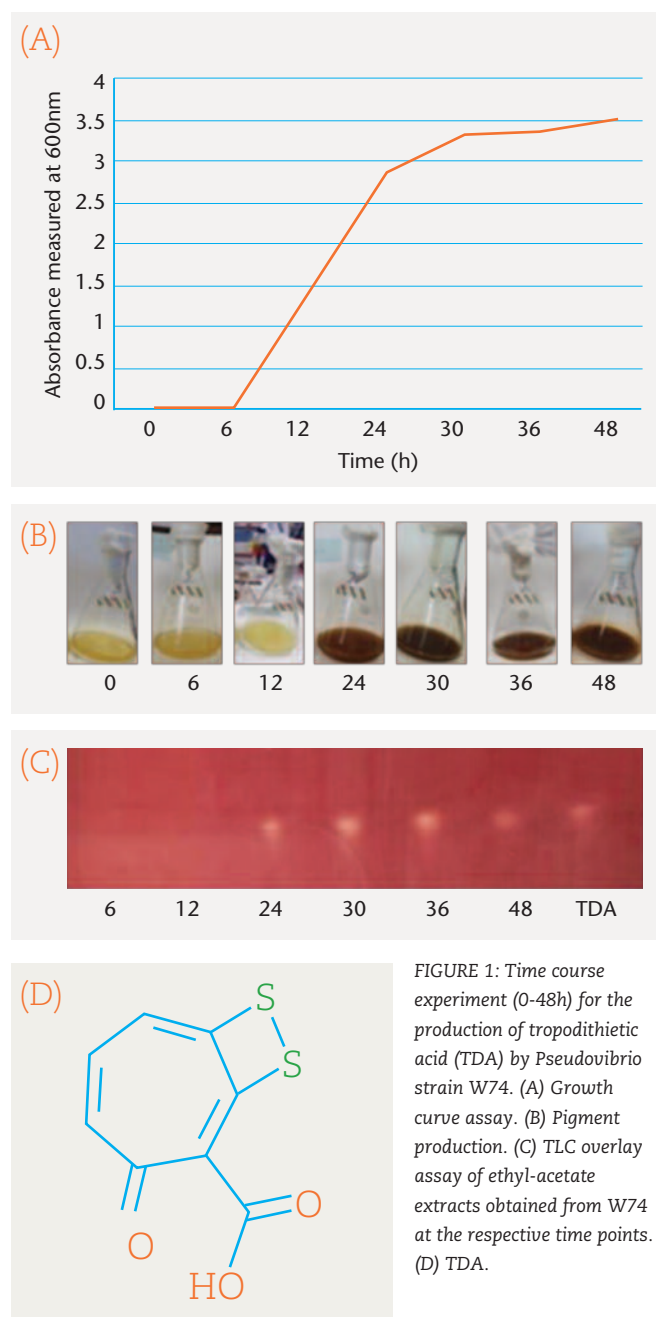


FIGURE 1: Time course experiment (0-48h) for the production of tropodithietic acid (TDA) by *Pseudovibrio* strain W74. (A) Growth curve assay. (B) Pigment production. (C) TLC overlay assay of ethyl-acetate extracts obtained from W74 at the respective time points. (D) TDA.

the *tda* genes show a high degree of homology in most of the marine *Pseudovibrio* isolates (>94% of similarity). Moreover, higher levels of TDA production in some isolates appears to be due to differences in the regulation or production of TDA among marine isolates, and is also independent of any growth effects (Harrington *et al.*, 2014).

Future prospects

In recent years, because of a greater degree of consumer awareness and concern regarding health risks of synthetic chemical additives, foods preserved with natural additives have become popular. To inhibit growth of undesirable microorganisms in food, the antimicrobials can be directly added into the product formulation, coated on its surface or incorporated into the packaging material. As our search for new antibiotics continues, TDA, or some of its analogues produced by marine sponge-derived *Pseudovibrio* isolates, has the potential to be a template for clinical development. Indeed, synthetic modification focussing on structure-activity relationships

resulting in analogues with enhanced antimicrobial activity, can result in the discovery of new antibiotic-like molecules, thereby helping to combat the emergence of bacteria resistant to common antibiotics. These studies clearly indicate that the *Pseudovibrio* genus holds the potential to be a source of new antimicrobial compounds other than TDA. The metabolites from *Pseudovibrio* can be evaluated as antibacterial agents either as single molecules, or in combination, to observe their synergistic effects. Hence, these compounds may find application as antibacterial agents for use against various food-borne pathogens such as *Salmonella*, to help control the microbiological and physicochemical shelf life of food products and, in particular, porcine-based products.

Acknowledgements

The MabS project is funded by the Irish Department of Agriculture, Food and the Marine under the Food Institutional Research Measure (FIRM 11/F/009). Contributions of Elaine Lawton and Lynn Naughton to the MabS project are acknowledged.

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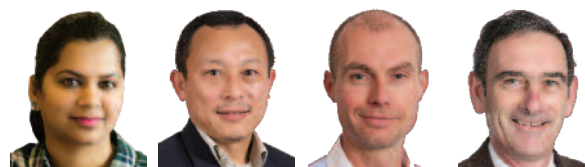
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Profiling on-farm demonstrations in Ireland

A team of **TEAGASC** research and advisory staff has collected information on the profile of Irish demonstration farms.

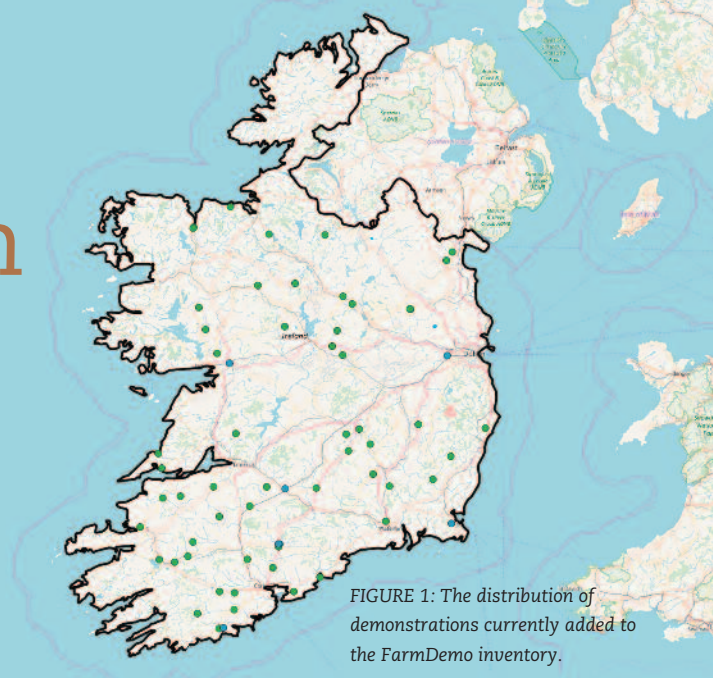


FIGURE 1: The distribution of demonstrations currently added to the FarmDemo inventory.

Introduction

There is ample evidence that farmers tend to be most influenced by farming methods demonstrated by their peers. In this context, the literature suggests that demonstration activities hosted by farmers on their own or research farms can prove effective in supporting farmer-to-farmer learning. The aim of the FarmDemo survey (serving two EU Horizon 2020 consortia: 'AgriDemo-F2F' and 'PLAID') is to profile on-farm demonstrations across Europe and present them in a comprehensive geo-referenced database (<http://www.farmdemo.eu>). The survey takes a broad definition of 'demonstration' farm, which includes open days, farm walks, monitor farms, focus farms (such as restaurant chain McDonald's farms) and industry, e.g., processor-owned farms.

Methodology

The FarmDemo survey aims to partially populate a comprehensive database of demonstration farms in Europe, which will be ultimately self-populated by farmers, researchers, advisers and others on an ongoing basis. The aim of the survey is to collect data on demonstration farms, testing the information categories that will eventually be used to structure the database, and generating information for the first swathe of database entries. In Ireland, 117 individuals participating in, or organising, demonstration farm programmes (particularly representing the sheep, beef, dairy and organic sector) and/or demonstrations on research farms, have been contacted. So far, 59 farmers (19 beef, 34 dairy, six sheep including one organic) and 20 organisations (Teagasc and external organisations) involved in on-farm demonstrations have

been profiled using the FarmDemo survey for the purposes of populating the database (Figure 1). Actors involved in demonstration farms will be contacted on an ongoing basis to encourage self-population of the database and achieve maximum representation of all Irish demonstration farms. Furthermore, in-depth case studies of demonstration events in agroforestry and tillage are underway.

On-farm demonstration approaches in Ireland

When were on-farm demonstrations first used?

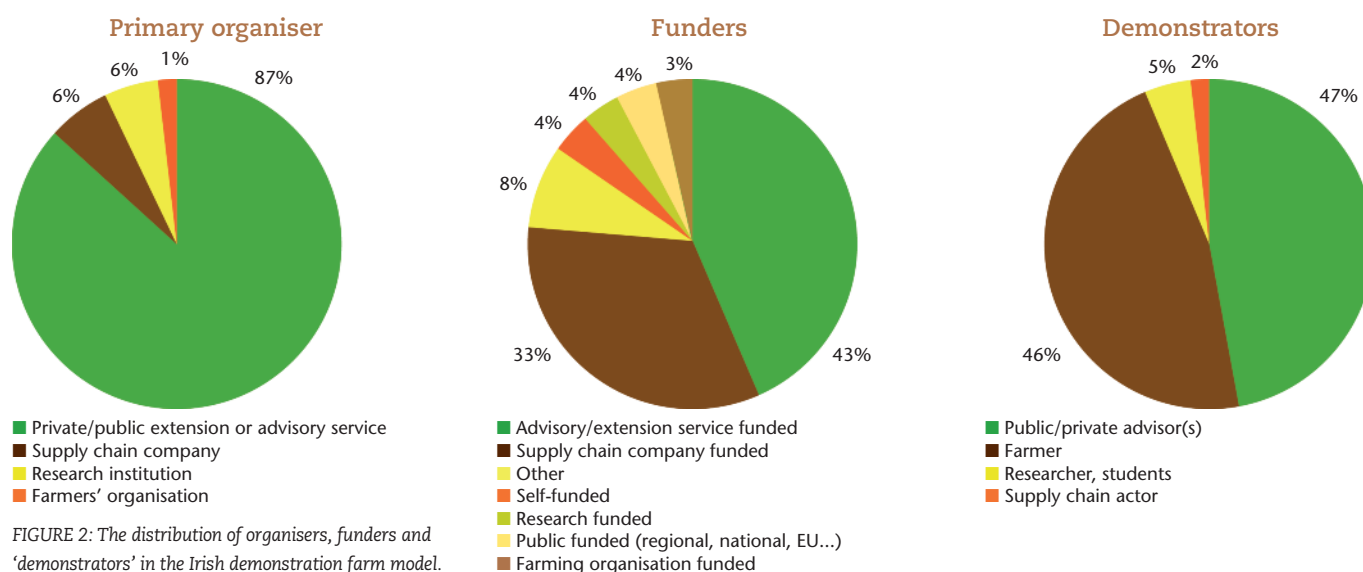
The use of demonstrations on organisation farms in Ireland can be traced back to 1839 (the Royal Dublin Society's annual Spring Show) (O'Loughlin and Sullivan), 1907 (An Foras Talúntais [AFT] agricultural demonstration stations in Ballyhaise and Athenry), and 1963 (AFT dairy research farm Moorepark) (Miley M., 2008). There is photographic evidence of demonstrations on private farms taking place as early as 1974 (O'Loughlin and Sullivan). Since the 1990s, there has been a tendency towards the co-ordinated organisation and delivery of demonstration events on 'ordinary' farms in collaboration with industry partners.

What is demonstrated in Ireland?

It is important to note that the 59 farms that we have profiled thus far do not comprise a representative sample of all Irish farms on which demonstration activities occur. However, the sample of 59 sheep, beef and dairy farms gives us a partial insight into their demonstration activities. The standard FarmDemo survey found that the following topics

Table 1: Range and distribution (by sector) of demonstration topics.

Demonstration topics	Beef	Dairy	Sheep	All
Pasture management	95%	100%	100%	98%
Animal nutrition/feeding	84%	82%	100%	85%
Housing and rearing systems	89%	74%	100%	81%
Animal health management and welfare	79%	74%	100%	78%
Quality enhancement and promotion	68%	74%	100%	75%
Strategies to reduce risk of antibiotic resistance development	79%	62%	100%	71%
Technologies	37%	62%	100%	58%
Business development (e.g., business planning, cost efficiency, labour management)	-	-	-	54%
Climate change mitigation and adaptation	31%	35%	17%	32%
Waste management	21%	35%	33%	31%
Biodiversity and nature management	21%	29%	33%	27%
Processing to food/feed	11%	12%	0%	20%
Renewable energy and energy efficiency issues	0%	26%	0%	15%
CAP/State subsidies and schemes	-	-	-	14%
Machinery	16%	12%	0%	12%



were most prevalent on Irish farms (Table 1): pasture management; animal nutrition and feeding; housing and rearing systems; animal health management and welfare; quality enhancement and promotion; and, strategies to reduce risk of antibiotic resistance development. In addition, 54% of demonstration farmers reported that on-farm demonstrations focused on business development, planning and labour efficiency issues. Topics focusing on the environment, such as biodiversity and nature management/climate change mitigation and adaptation, as well as the topics processing to food/feed, machinery and waste management, were less prevalent (Table 1).

How are the demonstration activities organised and funded?

Teagasc is leading a number of 'joint programmes' co-funded by other actors (categorised as 'supply chain company' and 'other') across Ireland (Figure 2). On the demonstration farms profiled thus far, the Teagasc adviser is stated to be the 'main demonstrator' and occupies 47% of the role as demonstrator (Figure 2).

What is the role of the farmer (according to the farmer)?

On the farms profiled thus far, the demonstration farmer is most commonly stated as the 'secondary demonstrator'. Most demonstration farms in Ireland host up to three events per year and these are both 'smaller' (approximately 20 farmers) and 'larger' (80-1,000 participants) events. It was reported that the nature of the farmers' roles varies between farmers and reflects the size of the event. The majority of farmers considered the demonstration activities on their farms to be initiated more by an external organisation than completely farmer led. Farmers in Ireland, as opposed to some other countries in Europe, generally do not lead their own demonstrations independently of their extension programme or local/programme adviser. The five main motivations for Irish farmers to host demonstration activities (selected from a predefined list of categories) were: information gathering/sharing; competitiveness/productivity; monetary/financial; educational and training opportunities; and, research implementation.

Who attends demonstration farm events?

Demonstration farmers reported that more than 75% of attendees were male and women are underrepresented. The majority of attendees were described as aged over 40.

Conclusions

The study reported here has outlined the profile of 59 Irish demonstration farms (non-representative). Future research by the AgriDemo-F2F consortium will be undertaken to complete the FarmDemo inventory and to identify novel approaches to enabling peer-to-peer learning EU wide. For more information, visit AgriDemo-F2F – www.agridemo-h2020.eu/; and, PLAID – www.plaid-h2020.eu/.

Acknowledgements

The authors wish to thank the farmers, advisers and specialists who contributed to this study. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 728061.

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British and Irish perspectives on Brexit

Analysis of sentiment on social media can be an important addition to policy making. Here we analyse the divergent response to Brexit on social media in Ireland and the UK.

What are people in Ireland most concerned about in relation to Brexit? What about people in Great Britain? Are both groups concerned about the same issues or are there notable differences? How have the concerns of both groups changed over time? These are all interesting questions that policymakers would like to know the answers to as they develop Brexit strategies. They are questions that we can go some way to answering by applying data analytics techniques to the publicly available data people post on social media platforms like Twitter, Facebook and reddit. While much has been said in political circles and in the media, the public also have views on critical issues such as Brexit. Teagasc and UCD recently conducted a study to compare the Twitter discourse surrounding Brexit in Ireland and Great Britain across a 14-week time period. Using data analytics techniques, this study frames the issue as a corpus comparison problem in which the online discussions of different groups are treated as different corpora to be compared.

Approach

We collected Brexit-related tweets from January 15 to April 23, 2017. The official Twitter application programming interface (API) allows researchers to collect tweets based on specific search terms and specified locations. We used a variety of Brexit-related search terms (for example *brexit*, *#brexit*, *hardbrexit*, and *softbrexit*) and defined regions covering Great Britain and Ireland. We collected a total of 1,210,402 tweets – 72,652 tweets from Ireland and 1,137,750 tweets from Great Britain.

To extract the different topics present in the tweets from Ireland and Great Britain we applied a technique called Jensen–Shannon divergence (JSD), which can identify the words and phrases (“divergent terms”) that are prominent in one corpus, but that are not prominent in the other. We can apply the same technique to multiple corpora. To understand the change over time, we divided the data into multiple corpora, each covering a week, to find the terms that are prominent in one week but which then lose attention.

What are people talking about?

Figure 1 shows the most divergent terms between British and Irish Brexit-related tweets. A bar to the right (green) indicates that a term was more common in Irish tweets, while a bar to the left (brown) indicates a term that was more common in British tweets. The length of the bars indicates how divergent a term was.

From **Figure 1** we can see that the most divergent terms are *northern*

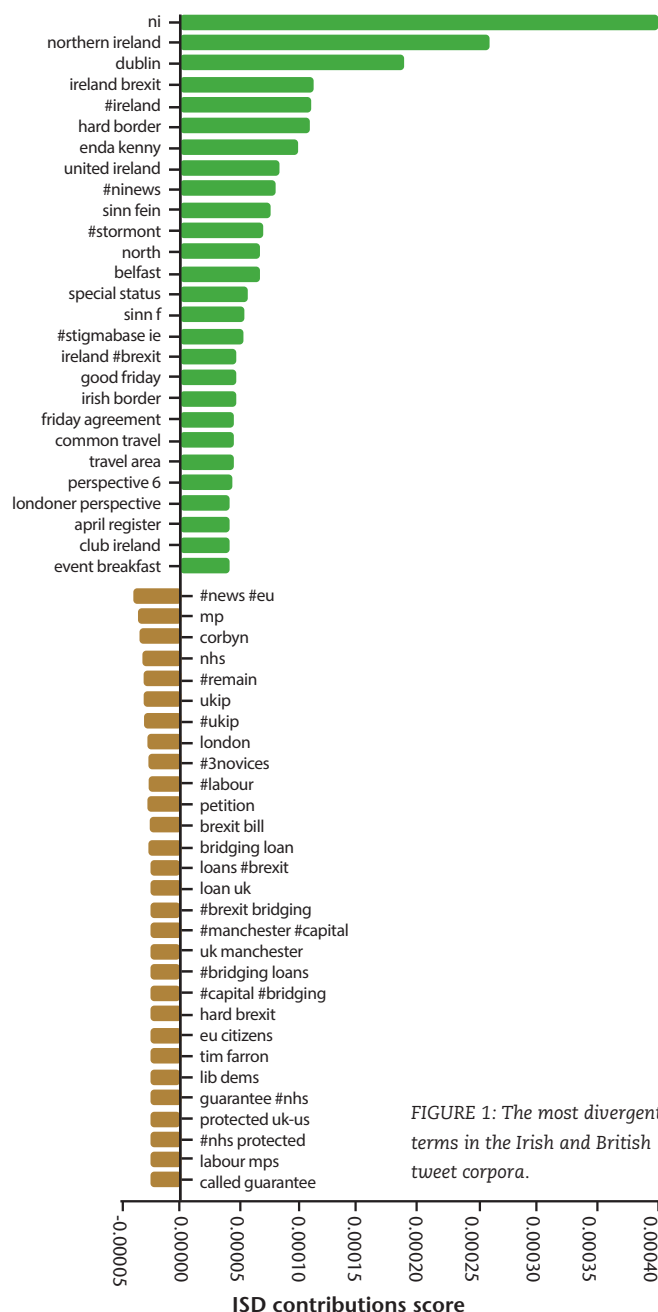


FIGURE 1: The most divergent terms in the Irish and British tweet corpora.

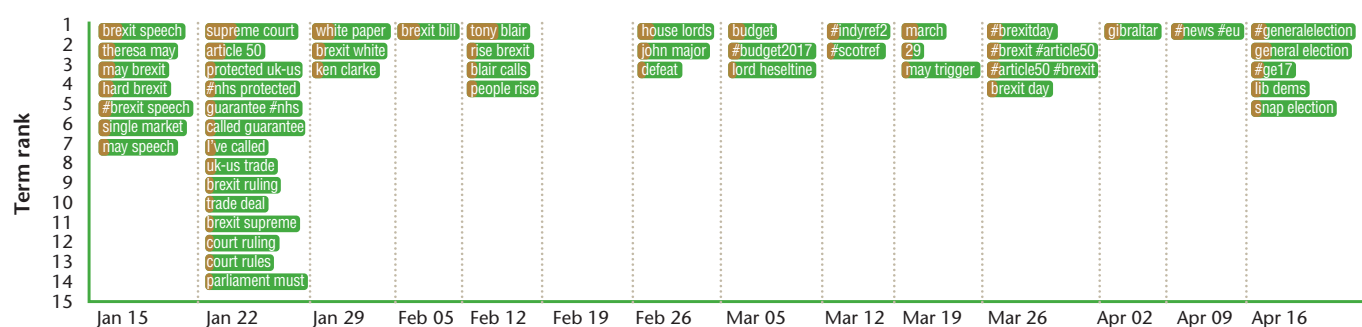


FIGURE 2: The most divergent terms in the British tweet collection over the period studied.

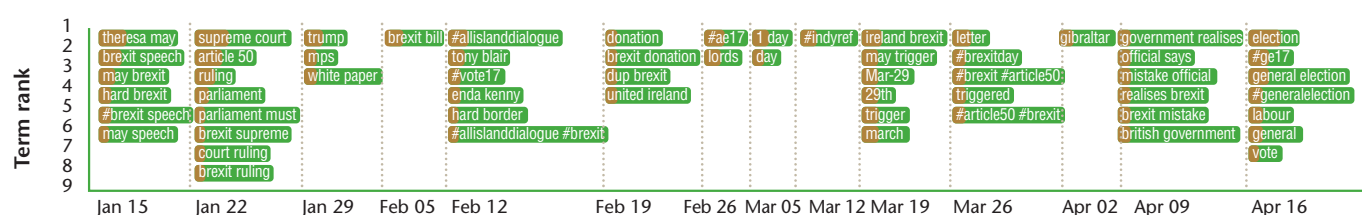


FIGURE 3: The most divergent terms in the Irish tweet collection over the period studied.

ireland and its abbreviation *ni*, which are prominent in tweets from Ireland but not in tweets from Great Britain. This illustrates that the key difference between the concerns surrounding Brexit expressed on Twitter by people from Ireland versus Great Britain is a focus on the impact on Northern Ireland and, in particular, its border with the Republic of Ireland. We see this echoed in other divergent terms like *stormont*, *hard border*, *sinn fein*, *united ireland*, *good friday*, *friday agreement*, *common travel*, and *enda kenny*. Conversely, the British tweets seem focused on more local issues such as *corbyn* (the British Labour Party leader Jeremy Corbyn), *#ukip* (the Eurosceptic United Kingdom Independence Party), and *nhs* (the UK's National Health Service), and potential impacts of Brexit such as *eu citizens*, *hard brexit*, and *london*.

The evolution of attention

Figure 2 shows how the top concerns over Brexit by people from Great Britain changed over time. In general, before February, they were concerned with topics surrounding British Prime Minister Theresa May's speech, Article 50, and the Supreme Court. In contrast, during February and March, their concerns seemed to become distracted by many other issues when considering Brexit, like Budget 2017 and the Scottish independence referendum, as evidenced by the presence of terms *#budget2017*, *#scotref*, and *#indyref2*. However, at the end of March, the topics around Article 50 came back to the public sight. Theresa May signed the letter to trigger Article 50 and instigate Brexit on March 29, which also explains the high ranks of phrases *#brexitday*, *may trigger*, *#article50* and *#brexit* at that time.

Figure 3 shows the most distinctive phrases from Irish tweets over the studied time period. The result shows an extremely similar situation to the British one. Overall, from January 15 to April 23, the focus of Twitter attention to Brexit in Ireland surrounds May's speech, the triggering of Article 50, the Scottish independence referendum, and the British general election. There are some differences, however, evidenced by the appearance of terms like *united Ireland* and *hard border*.

Conclusion

Brexit has the potential for massive impact across Ireland and Great Britain. In this article we have demonstrated one approach to understanding the concerns of different groups of people through the use of data analytics techniques on social media. Of course, this comes with the caveat that this analysis reflects a self-selection bias in terms of people and organisations that choose to express themselves on Twitter and we should be conscious of the ongoing issue of the presence of automated bot accounts on Twitter. Nonetheless, we believe that this kind of analysis can be an important addition to the policy-making toolbox.

Acknowledgement

This project was supported by the Teagasc Walsh Fellowship Programme.

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Co-designing extension interventions: bridging science and practice

Multi-actor, transdisciplinary approaches are increasingly being recognised as essential for knowledge transfer. This article provides snapshots of two such projects, each of which co-designed practice-ready extension tools.

Multi-actor, transdisciplinary approaches have become mainstream across many policy and research funding programmes, such as the EU's Horizon 2020 and EIP-AGRI programmes. The driver of this is official acknowledgement at policy-making level that scientific knowledge alone is insufficient to achieve innovation on the ground. The perspectives and knowledge of different professional and end user communities must be incorporated at the design stage, and iteratively to project completion, a process called multi-actor, transdisciplinary co-design.

By definition, multi-actor approaches must include different actors (such as end users) as partners from the beginning and throughout the progression of projects (as distinct from *ad hoc* stakeholder consultation). Transdisciplinary (as distinct from multi- or interdisciplinary) projects, by definition, require non-research partners, such as farmers and advisers. Authentic and rigorous implementation of multi-actor, transdisciplinary approaches requires methodological supports to create conditions in which different actors are supported to work in a mutually enriching way. In this context, participatory learning and action (PLA) methods can be practised to achieve excellence in multi-actor work. While social scientists are common practitioners, PLA is a transdisciplinary method and thus can be used by any trained actor.

Controlling Johne's disease

Research conducted by McAloon *et al.* (2017) identified sociological factors (i.e., farmers' routines, practices, beliefs and values) regarding animal health and implications for disease management, specifically implementation of critical control points (CCPs, following HACCP) to control Johne's disease at farm level. The research findings were channelled into a transdisciplinary co-design process, involving the interrogation of the findings by groups of farmers, veterinary practitioners, veterinary scientists, policy-makers, farm advisers, and co-operative representatives. In a sequence of workshops, the multi-actor groups co-designed a suite of practical actions to implement the CCPs at farm level. The process evolved to include an artist and graphic designer, who worked with the multi-actor team to translate the practical implementation actions into interactive and visual tools. In

addition to recording templates (e.g., hygiene, calving etc., necessary for implementing the HACCP approach), information briefs and storyboards (illustrated stories) were co-designed.

Based directly on farmers' and other actors' stories, storyboards have diverse purposes. They present 'how to' information graphically, while also incorporating in vernacular language the social (relationship), cultural (pride) and economic (monetary) factors that arise in decision-making. Veterinarians and advisers can use storyboards to prompt discussion with farmers of contentious or sensitive issues, deflecting the focus onto a hypothetical case rather than focusing on the farmers personally. Storyboards were developed to show the negotiation of particular beliefs/values held by farmers in relation to disease control, necessary for practical implementation of the CCPs. Together with information briefs and CCP recording templates, the storyboards are presented in a comprehensive printed document, and in an interactive PDF for use on touchscreen and conventional devices such as tablets, androids and computers (Figure 1).

Managing grass

The AgileTECH project aimed to understand the relevance and use of existing scientific knowledge regarding grassland management among farmers. In this context, the project co-designed a method for use by advisers in a discussion group context. Sheep, beef and dairy farmers and farm advisers were involved in five focus groups, which were recorded, transcribed and analysed. The analysis informed subsequent co-design stages, involving scientists, specialists, farm advisers and graphic designers. A group facilitation method to encourage farmer engagement with grassland management was co-designed and prototyped by the group. The method reflects findings from across the focus groups conducted with farmers and advisers and contains four main elements: building farmer-adviser rapport and approaching 'goal setting' with clients, which was identified as a crucial first step; building 'Managing Grass Action Plans', which takes a flexible approach to supporting farmers to identify cost-effective, impactful and achievable actions on their farms; use of storyboards (illustrated stories) to facilitate the group to address social (relationship), cultural (pride) and

Johne's Disease

A Control Strategy

Johne's is a disease of cattle that affects the gut, causing diarrhoea and wasting. The disease is caused by bacteria called MAP (*Mycobacterium avium* subspecies *paratuberculosis*) which is mainly in the dung of infected cattle, but also in their milk and colostrum. Cattle are generally infected as calves but do not show any signs until adulthood. One-off tests to diagnose Johne's only pick up a some infected animals. However, if you test regularly over time, with the help of your vet in reading results, you will know a lot more about Johne's in your herd than if you don't test at all.



FIGURE 1: Johne's disease: a control strategy.



Teagasc Open Innovation projects.

economic issues associated with managing grass; and, finally, a discussion group self-evaluation method ('health check') to improve group functioning (organisation, trust, solidarity, learning, fun and enjoyment). The group facilitation method is presented in print and interactive PDF form, accompanied by a customised carry bag containing the co-designed resource materials required to implement the extension method. Over 20 farm advisers (Teagasc and the co-operative sector) have received training to use the method and are currently practising it and generating feedback on its use.

Conclusions

These projects have utilised PLA methods to support multi-actor, transdisciplinary co-design processes. Co-designed outputs have been generated, which are currently in use directly by farmers and by professionals such as veterinarians and advisers. In the future, more co-designed outputs will be generated by projects and policies that increasingly demand a multi-actor approach. However, it is also the case that organisational cultures and professional value systems require adaptation to embrace co-designed outputs that have animated

elements and vernacular language suitable for end users. The growing collection of digital co-designed extension tools is stored on Teagasc's www.FarmAppvice.com, which is a web-based library for advisers.

Acknowledgements

The author gratefully acknowledges those who participated in PLA training and expertly co-facilitated the co-design processes (researchers at UCD, Teagasc Rural Economy Development Programme and Teagasc Animal & Grassland Research and Innovation Programme); the role of the Centre for Participatory Strategies (CPS) in providing PLA expertise; the Community Knowledge Initiative (CKI), NUI Galway; over 100 farmers, advisers, veterinarians, specialists and others who contributed their valuable knowledge in the co-design process; and, the artists and graphic designers. These projects were funded by the Department of Agriculture, Food and the Marine (Join to Farm 11/S/151; AgileTECH 11/S/148; and ICONMAP 11/S/141). Additional funding was provided by Teagasc for the extension tools.

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Understanding the farmer-farm relationship in later life

Research from NUI Galway looks at the complex and deeply emotional relationships older farmers have with their farms, and the impact this has on family farm transfer.

With a steady decline in the number of young farm families reported as being key in the demoralisation of rural communities, and the recent declaration by European Commissioner for Agriculture and Rural Development Phil Hogan that a priority for future CAP reforms must be a focus on generational renewal, it is increasingly clear that a major challenge presents itself in the area of intergenerational family farm transfer. While attempts to confront the global demographic trend of an ageing farming population and a low level of land mobility have added significantly to existing knowledge in this field, there are numerous, intricate emotional facets affecting the older generation's farm transfer decision-making process, which for the most part have been neglected (Conway *et al.*, 2016). The outcome is a derailment of the process in many cases. This research brings into focus the suitability and appropriateness of previous and existing farm transfer policy strategies, by presenting an insightful, nuanced analysis of the deeply embedded attachment older farmers have to their farms, and how such a bond can stifle the necessary handover of the farm business to the next generation.

Data collection

In order to generate a comprehensive insight into the multi-level farmer-farm relationship in later life, questionnaires were initially distributed to a randomly selected sample of farmers in attendance at a series of 'Transferring the Family Farm' clinics delivered by Teagasc in 2014, which were held at 11 locations throughout Ireland. A list of copyright questions derived from the International FARMTRANSFERS Survey, refined for Irish conditions, were then included in the 2014 Teagasc Land Mobility Farm Survey to validate, strengthen reliability and build on the quantitative data gathered at the clinics. Finally, interviews were conducted with a 10% sample of questionnaire respondents who gave their consent to be interviewed in order to peel back the layers and broaden the two farmer survey responses.

Results

Empirical findings from this study illustrate a clear disconnect between previous and existing farm transfer policy measures and the

mindset of their targeted population. Older farmers were found to have developed a deeply rooted familiarity and sense of belonging in their home environment later in life, which is notably distinct from the outside world. The senior generation therefore find it almost impossible to visualise what their lives would be like if they no longer lived on the farm or worked in an agricultural environment. The farm setting, and the daily and seasonal habitual routines that occur therein, also offer therapeutic-like benefits to farmers, by improving their quality of life in a secure and intimate arena. Take for example Aoife, a 68-year-old mixed livestock farmer from the Midlands:

"Space is the most wonderful thing in the world to have. If there was something or another bothering me, I find there is nothing better than to just walk up the fields early in the morning or late in the evening, and look back across the land, and watch all my lovely cattle grazing and thriving ... your head would be a lot clearer after that".

Findings also reveal that the farm provides the farmer with a sense of legitimate social connectedness within the farming community. The farm and its associated practices provide a fulcrum around which social interactions can take place. It is therefore almost impossible to untangle a farmer's everyday social interactions from their farm. A farmer's relationship with their farm is also found to extend beyond the physical setting and social milieu to represent a space and environment that has a temporal depth of meaning. The farm represents a mosaic of the farmer's achievements over their lifetime as well as being a landscape of years of hard work and memories.

Conclusion

Farming is more than an economic activity. The so-called 'soft issues', i.e., the emotional issues, identified in this research, are the issues that distort and dominate the older generation's decisions on the future trajectory of the farm. Such issues have resulted in



intractable challenges for succession and retirement policy over the past 40 years. These really are the 'hard issues'. Policymakers and practitioners must therefore re-examine their dominant focus on economic-based incentives encouraging the process when reforming and developing future initiatives and strategies, and become more aware of and knowledgeable about the farmer-farm relationship identified in this research to maintain the quality of life of those concerned.

As there are no bodies or services currently in existence in Ireland suited to the older farmer's interests and needs, the full report on this study published in the *International Journal of Agricultural Management* (Conway *et al.*, 2018) recommends the establishment of a national voluntary organisation that specifically represents the requirements of the senior generation of the farming community in rural areas, equivalent to that of younger people in rural Ireland, i.e., Macra na Feirme. A nationwide organisation, with a network of clubs in every county, would allow older farmers to remain embedded 'inside' their farms and integrate within the social fabric of a local age peer group, while also providing them with opportunities to develop a pattern of farming activities suited to advancing age. This would contribute to their overall sense of self-worth, amid the gradual diminishment of their physical capacities in later life. Collaborating with their younger counterparts in Macra na Feirme on various campaigns and activities would also allow the older farmers to retain a sense of purpose and value in old age. Such measures have the potential to finally unite farm transfer policy efforts with the psyche of their intended audience, after decades of disconnect.

Acknowledgements

We are grateful to the farmers who took part in this research. Funding was provided by the NUI Galway Doctoral Research Scholarship Scheme. We would also like to thank Teagasc for their assistance with this research, in particular for allowing us to conduct surveys with their farming clients.

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JUNE 2018

June 9-13

Teagasc Moorepark, Fermoy, Co. Cork

19TH INTERNATIONAL FARM COMPARISON NETWORK ANNUAL DAIRY CONFERENCE

Under the topic 'Dairy Farm Technology: Past – Present – Future', 80 dairy researchers from 45 countries all over the world will come together to discuss farm-related topics, world dairy market developments and the validation of International Farm Comparison Network (IFCN) data. The IFCN brings together researchers from institutions, dairy boards, government-related centres, dairy farmers, and private and public organisations from around the world. Participants discuss the most recent dairy developments, farm analysis results, methods, share local insights and discuss market outlook.

www.bit.ly/ifcndairyContact: fiona.thorne@teagasc.ie

June 12

Teagasc Ashtown Conference Centre, Dublin

TEAGASC GATEWAYS – BEYOND BREXIT – MAKING FOOD INNOVATION GO FURTHER

The Irish food industry faces a real challenge with the advent of Brexit. Like many Irish companies, those in the food sector export a sizeable proportion of their output to the UK and are exposed to uncertainty over regulations, customs and exchange rate volatility. As such, the role of research and innovation has never been more important. Learn what our researchers can do to support you in Brexit-proofing your business. In addition to the exhibition, there will be a number of national and international speakers.

www.bit.ly/BeyondBrexitTeagascContact: tara.heffernan@teagasc.ie

June 12-13

Teagasc Agricultural College, Clonakilty, Co. Cork

3RD INTERNATIONAL WORKSHOP ON HIGH TEMPORAL RESOLUTION WATER QUALITY MONITORING AND ANALYSIS – HIGHRES 2018

This workshop will be hosted by the Agricultural Catchments Programme (ACP) for about 40-50 participants. The intention is to bring together catchment scientists and managers in an international forum to discuss experiences of high temporal resolution water quality monitoring.

Approximately 25 papers will be presented, followed by roundtable talks and a visit to the Timoleague catchment, which is monitored within the ACP.

www.teagasc.ieContact: pererik.mellander@teagasc.ie

June 17-21

Rochestown Park Hotel, Douglas, Cork

27TH EUROPEAN GRASSLAND FEDERATION GENERAL MEETING – SUSTAINABLE MEAT AND MILK PRODUCTION FROM GRASSLANDS

Teagasc is hosting the 27th EGF general meeting. The scientific programme includes: resilient plants for grass-based ruminant production systems, adapting grassland systems to the dynamics of climate and resource availability; appropriate livestock for grasslands, key characteristics of animals adapted to and suitable for grasslands; environmental influences on grassland systems – consequences of climate change, mitigation strategies, and impacts on ecosystems; social and economic impacts of grass-based ruminant production; big data and smart technologies in grassland; and, knowledge transfer to stakeholders.

www.egf2018.com/Contact: EGF2018@abbey.ie

June 18

Galway Bay Hotel, Salthill, Co. Galway

ANNUAL GLOBAL FORUM CONFERENCE OF THE AGRI BENCHMARK BEEF AND SHEEP NETWORK

A comprehensive programme will feature internal workshops on sheep and beef, international comparisons, latest developments on beef and sheep markets, farm analysis, and field trips to sheep, cow-calf and beef finishing farms. The perspectives of beef and sheep production for the next two to three years will be identified and quantified. A full day of the Conference is dedicated to the Global Forum with Irish and international policy analysts and decision makers of the beef and sheep value chain on June 18. The conference is jointly organised by Teagasc and the agri benchmark headquarters (Thünen Institute of Farm Economics).

www.bit.ly/agribenchmark2018Contact: anne.kinsella@teagasc.ie

June 26

Teagasc Grange, Co. Meath

BEEF 2018 TEAGASC BEEF NATIONAL OPEN DAY

Under a theme of 'Enhancing Knowledge' this event aims to help beef farmers build on their abilities within their farming business. BEEF2018 is your opportunity to see first hand the results of Teagasc's comprehensive research and innovation programme, and to meet Teagasc research and advisory staff. Villages include: Grassland; BETTER beef; dairy calf-to-beef; health and reproduction; feeding and meat quality; environment; education; and, health and safety.

www.teagasc.ieContact: edward.oriordan@teagasc.ie

June 28

Teagasc Johnstown Castle, Co. Wexford

THE SQUARE (SOIL QUALITY ASSESSMENT RESEARCH PROJECT) WORKSHOP

SQUARE is an Irish research project, led by Teagasc, and funded by the Department of Agriculture, Food and the Marine Research Stimulus Fund (RSF). The aim of SQUARE is to evaluate the status of soil quality in Ireland and to enhance understanding of functional soil capacity for sustainable management. This workshop will present the final outcomes of SQUARE to an audience of different stakeholders. This will include a combination of talks on the three components of soil quality (biological, physical and chemical) and practical exercises, with experienced speakers from industry and academia presenting.

www.teagasc.ie/environment/soil/research/square/Contact: Giulia.Bondi@teagasc.ie

JULY

July 7

Teagasc, Mellows Campus, Athenry, Co. Galway

SHEEP2018: FARM TO FORK

This is a major industry event with an expected attendance of 15,000 people. It is a continuation of the sheep events that are jointly run by Teagasc, the Department of Agriculture, Food and the Marine, University College Dublin, Bord Bia, Sheep Ireland and the *Irish Farmers Journal*. This year also celebrates the designation of Galway, West of Ireland 2018, European Region of Gastronomy. Galway County Council is also a partner for this year and there will be a significant food element to this year's event.

www.teagasc.ie/sheep2018Contact: norina.coppinger@teagasc.ieFor a full list of Teagasc food industry training events see: www.teagasc.ie/food/food-industry-developmentFor presentations from previous Teagasc events see: www.teagasc.ie/publications