

Research

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BACTERIOPHAGES IN FOOD PRODUCTION

NEXT-GENERATION VACCINES

VISTAMILK

NUTRITIONAL MODELLING

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The importance of Science Week and science communication

There are many opportunities and challenges facing society. We are (thankfully) living longer, which challenges the medical community in relation to care of the elderly and age-related diseases. We have pressure on natural resources, and climate change is one of the great challenges of our time. In our own domain of agri-food, food security, the relationship between diet and health, and environmental concerns are major issues. Science and technology has a huge role to play in these societal issues. However, at a time when the need for science and technology is arguably at its greatest, there is a high level of distrust or scepticism among the general public about science. To counteract this, scientists need to communicate more and better about how science can help society. Thus, the importance of Science Week, where science is firmly on the national agenda. Teagasc staff engage enthusiastically in Science Week, whether it is by organising events at our research centres and colleges, organising and speaking at events organised elsewhere, or appearing on radio and TV, etc. It is a fantastic opportunity to get the attention of the public in a positive way. This year we had 1,700 people attending 13 events that we organised as part of the 'Festival of Farming and Food – SFI Science Week at Teagasc', one of 12 SFI-funded regional festivals. Of course science communication continues all year round, and it is important that all scientists recognise the need to communicate about their work. Obviously, communication to the end users of our science – farmers, food companies, policy makers, etc., is of most importance to an applied research organisation like Teagasc. General science communication is also important for the reasons outlined above, and it also encourages school children to pursue careers in science, and helps to build the reputation of the individual and the organisation they work for. In an age when information is all around us, effective communication has never been more important.



Frank O'Mara
Director of Research

An tábhacht a bhaineann leis an tSeachtain Eolaíochta agus le cumarsáid eolaíochta

Tá lear deiseanna agus dúshlán os comhair na sochaí sa lá atá inniu ann. Bímid ag maireachtáil saol níos faide (ar an dea-uair), rud a leagann dúshlán ar an bpobal leighis maidir le cúram a thabhairt do dhaoine scothaosta agus le déileáil le galair a bhaineann le haois. Tá ár n-acmhainní nádúrtha faoi bhrú, agus tá an t-athrú aeráide ar cheann de mhórdhúshláin ar linne. I réimse an agraibhia, an réimse ina n-oibrímidne, is mór-shaincheistean iad slándáil bia, an gaol idir réim bia agus an tsláinte, agus ceistean comhshaoil. Tá ról ollmhór le himirt sna saincheistean sochaíocha sin ag an eolaíocht agus ag an teicneolaíocht. Is amhlaidh, áfach, sa ré seo inar féidir a rá go dteastaíonn an eolaíocht agus an teicneolaíocht níos mó ná am ar bith riamh, go bhfuil méid mór amhrais nó sceipteachais ann i measc an phobail i gcoitinne faoin eolaíocht. Chun gníomhú ina aghaidh sin, ní mór d'eolaithe cumarsáid níos mó níos fearr a dhéanamh leis an bpobal ar na dóigheanna ar féidir leis an eolaíocht cabhrú leis an tsochaí. Dá bhrí sin, is rithábachtach atá an tSeachtain Eolaíochta, ar lena linn a dhíríonn muintir na tíre ar an eolaíocht. Glacann foireann Teagasc páirt ghníomhach sa tSeachtain Eolaíochta trí ócáidí a eagrú inár n-ionaid taighde agus inár gcoláistí, trí ócáidí a eagrú in áit eile, trí labhairt ag ócáidí a eagraítear in áit eile agus trí labhairt ar an raidió agus ar an teilifís, i measc nithe eile. Is deis iontach í aird an phobail a tharraingt ar bhealach dearfach. I mbliana, d'fhreastail 1,700 duine ar 13 ócáid a d'eagraíomar mar chuid de 'Féile na Feirmeoireachta agus an Bhia – Seachtain Eolaíochta Fhondúireacht Eolaíochta Éireann in Teagasc', a bhí ar cheann amháin de 12 fhéile réigiúnacha ar mhaoinigh an Fhondúireacht iad. Ar ndóigh, bíonn cumarsáid eolaíochta ar siúl fud fad na bliana agus tá sé tábhachtach go n-aithníonn gach eolaí gur gá dóibh a gcuid oibre a chur in iúl. Dar ndóigh, baineann rithábacht d'eagraíocht taighde fheidhmigh amhail Teagasc le cumarsáid le húsáideoirí deiridh ár n-eolaíochta, mar atá feirmeoirí, cuideachtaí bia agus déantóirí beartas, i measc úsáideoirí eile. Is tábhachtach freisin ar na cúiseanna thuas atá cumarsáid eolaíochta ginearálta mar go dtugann sí spreagadh do leanaí scoile gabháil do ghairmeacha san eolaíocht agus mar go gcabhraíonn sí le clú an duine aonair agus na heagraíochta a n-oibríonn an duine sin di a bhreisiú. Is tábhachtaí anois ná riamh sa ré seo ina bhfuil faisnéis le fáil mórthimpeall orainn atá cumarsáid éifeachtach.



Frank O'Mara
Stiúrthóir Taighde

Teagasc researchers in highly cited list

Five Teagasc researchers have been included in the global Highly Cited Researchers list for 2018. The list highlights influential researchers as determined by their peers around the globe. This list is compiled based on high citation counts over a decade. The Teagasc researchers on the list are: Paul Allen; Paul Cotter; Orla O'Sullivan; Catherine Stanton; and, Brijesh Tiwari. Paul Allen is a retired Principal Research Officer whose research interests covered a range of cutting-edge approaches to important meat research challenges. Paul Cotter is Head of the Department of Food Biosciences at Teagasc Food Research Centre, Moorepark, and his research

examines the microbiology and microbiomes of food. Orla is a Research Officer and is particularly interested in the role of exercise and diet, specifically whey protein, on the human gut microbiome. Catherine's research includes nutritional aspects of dairy and functional foods, infant gut microbiota, and healthy proteins and fats that are produced by gut bacteria. Brijesh works on the application of novel food processing, and extraction and preservation technologies, among other topics. In total, 33 Irish researchers feature in the 2018 list. The full Highly Cited Researchers 2018 list and executive summary can be found online at <https://clarivate.com/hcr/>.



Paul Allen



Paul Cotter



Orla O'Sullivan



Catherine Stanton



Brijesh Tiwari

Researcher profile

Carlos Álvarez



Carlos is a Research Officer in the Food Quality and Sensory Science Department at Teagasc Ashtown Food Research Centre in Dublin. After completing his BSc in Biology in the University of Oviedo (Spain), Carlos started his PhD in the same university, working in the revalorisation and modification of proteins recovered from pork

blood. After submitting his thesis in 2012, Carlos collaborated with local industries developing new protein-enriched products. In 2014 he joined Teagasc as a post-doctoral researcher on the NutraMara project at Ashtown, where novel extraction processes were implemented to recover proteins from both fish by-products and seaweeds. As a result, a European patent was filed, which is currently being transferred to Irish industry. Subsequent to this he commenced as a Research Officer on the ReValue Protein project. Key outcomes from this project include the development of tailored processes to recover high-quality protein for use as food ingredient

in sports nutrition, for the biomedical industry, and even as raw material for innovative biomaterials. In this regard, a patent is being filed dealing with a novel process to make protein-based films with improved mechanical properties. In February 2018 Carlos was appointed to a permanent research position in the meat research programme, where his focus is on understanding the impact of post-mortem interventions on muscle biochemistry and its impact on meat quality. He is also involved in Meat Technology Ireland (MTI), specifically in RP2, dealing with meat tenderness and applying scientific information to guide meat management systems for Irish

processors. He is currently the project manager in a strategic partnership project with Uruguay, Spain and New Zealand, aiming to optimise smart dry-ageing protocols for primal meat cuts. In addition, he is actively collaborating at national and international level, with both academia and industry, on food waste reduction and food co-products reutilisation. Carlos' hometown, Villablino in the Laciana Valley in Spain, is recognised as one of the most beautiful places for bear and wildlife observation. Carlos is currently the Social Club chairman and the acoustic guitar player in the First Authors, the Teagasc Ashtown resident band.

Cork Discovers

On European Researchers' Night on September 28, the theme of events running across Ireland's second city was Cork Discovers. In UCC on the night, Teagasc researchers helped the public explore the inside of food using virtual reality, explained what makes the perfect crisp and investigated the evolution of food crops over the millennia. Teagasc's involvement on the night was co-ordinated by Orlaith Ní Chonchubhair, Research Support Department, Teagasc.



Cork's science enthusiasts went on a journey of exploration inside our food and also inside Teagasc food labs using virtual reality and 360-degree videography, led by Deirdre Kennedy, Vinay Mishra and Duanquan Lin, Teagasc Moorepark Food Research Centre.

Cereal renaissance in rural Europe

Representatives from 11 EU countries met in Galway in November to discuss novel, practical ways to support the cultivation and market promotion of heritage cereals. Lead researcher for Teagasc, Áine Macken-Walsh, highlighted the importance of sharing different forms of expertise for successfully establishing heritage cereals: "Consumer insights, practical production knowledge, science and business acumen are crucial for small producers to successfully bring new products to the market. Our role in CERERE has practically facilitated that sharing of expertise to happen – it's a highly social process".



From left: Áine Macken-Walsh, Bridin McIntyre, John Hyland, and Maeve Henchion, all from Teagasc's Rural Economy and Development Programme, are pictured at the general meeting of the Cereal Renaissance in Rural Europe (CERERE) Horizon 2020 consortium in Galway recently.

THE TEAGASC WALSH FELLOWSHIPS PROGRAMME

Postgraduate research in agriculture and food areas



280
WALSH
FELLOWS

80%
PhDs



6
TEAGASC
RESEARCH
CENTRES

14%
MAgrSc

6%
MSc



EACH FELLOW
RECEIVES A
GRANT OF
€22K
PER YEAR

98%
OF WALSH
FELLOWS
EMPLOYED

53%
IN INDUSTRY
32%
IN ACADEMIA



THE PROGRAMME COLLABORATES WITH

22
INTERNATIONAL
UNIVERSITIES
IN
12
COUNTRIES



60
WALSH FELLOWS
REGISTERED IN
UNIVERSITIES
AND RESEARCH
INSTITUTES
ABROAD

THE OBJECTIVES OF THE PROGRAMME ARE



DEVELOPING
INTELLECTUAL
CAPITAL



INCREASING
RESEARCH AND
KNOWLEDGE
TRANSFER



SUPPORTING
DEVELOPMENT
IN NEW
AREAS

A week of science success

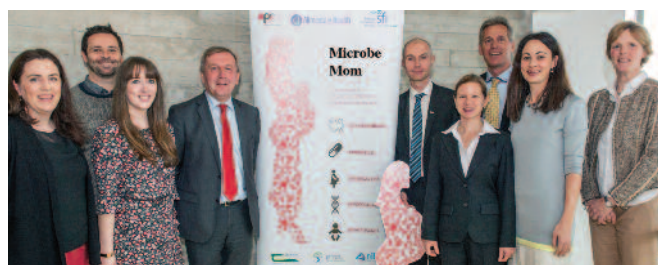
Science Week took place from November 11-18 and, once again, Teagasc was in the thick of the action, running a host of events for all ages across the country. 60 Minute Science was presented by RTÉ broadcaster Rick O'Shea in Kilkenny, and celebrated the local science of the area. In the Teagasc Ashtown Research Centre, A Slice of Science answered some simple-sounding questions with interesting answers, such as "How do we use our senses to relate to food?" In the National Botanic Gardens (see photo on right), people learned about the extraordinary ways plant breeding interacts with food production. The public took part in interactive lab sessions, learned about local sustainable food production, and had the unique opportunity to visit the National Herbarium, which is not usually open to the public, and contains a collection of more than half a million dried and documented plant specimens from Ireland and the rest of the world. Teagasc Science Week events also catered for students in primary, secondary and third-level education. In Johnstown Castle in Wexford, primary and secondary school students were invited to see the work of some of the scientists there. In Teagasc Grange, Co. Meath, students learned about the link between healthy animals and healthy food, and in Moorepark, Co. Cork, the exciting world of new technologies in food science was explored by secondary school students. At Teagasc



Oak Park, second- and third-level students learned the science behind cereal production, while in Teagasc Athenry, they saw demonstrations and exhibits on animal science, sheep breeds and grassland research. During Science Week, a new Teagasc booklet, 'Love Food, Love Science', was launched. The booklet covers a range of topics that are affecting food production and that scientists are exploring from an antimicrobial resistance, virtual reality and genetics perspective. The publication is available on the Teagasc website at: <https://www.teagasc.ie/media/website/publications/2018/Teagasc-Love-Food-Love-Science-2018.pdf>.

Microbe mom

A new initiative aimed at discovering the most likely methods of transfer of vital bacteria strains from mother to baby was launched in October by the Minister for Agriculture, Food and the Marine Michael Creed, TD. Bifidobacteria are the main bacteria that nature selects for the newborn gut and have been shown to play a key role in programming the metabolism and immune system. The programme will also explore the impact of the mother's diet and health on her gut bacteria and what bacteria she transfers to her baby at birth, and also the impact of specific probiotic supplements on the mother's health. The project is a joint venture between Science Foundation Ireland (SFI) Research Centre APC Microbiome Ireland in Teagasc, Alimentary Health Group, UCD and the National Institute of Biotechnology Research and Training (NIBRT).



Pictured at the launch are (from left): Grace O'Callaghan, APC Microbiome Ireland, Teagasc; Conor Feehily, Teagasc; Aisling Geraghty, UCD Perinatal Research Centre; Minister for Agriculture, Food and the Marine Michael Creed, TD; Paul Cotter, Teagasc and APC Microbiome Ireland; Radka Fahey, NIBRT; Douwe van Sinderen, APC Microbiome Ireland, UCC; Eileen Murphy, Technical Director, Alimentary Health Group; and, Sally Cudmore, APC Microbiome Ireland, UCC.

Food Innovation Gateways



Pictured at the robotics stand at the Teagasc Food Innovation Gateways event on 'Food Structure – Formation, Functionality & the Future' in the Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, are (from left): Mark Fenelon, Teagasc Head of Food Programme; Sally Gras, University of Melbourne; and, Declan Troy, Assistant Director of Research, Teagasc. Teagasc is using robotics to develop a platform for the measurement of the rehydration properties of powders. A seven-axis robot mimics the movements that humans use to reconstitute powders, such as milk powders. The robot enables controlled rehydration of the powder consistently across batches of products, facilitating measurements free from variability due to human intervention.

10 Things to Know About...

Teagasc researchers featured on two episodes of the television series '10 Things to Know About ...' broadcast on RTÉ One recently. Technology is driving a revolution in precision agriculture and Teagasc's Dermot Forristal and farmer Kevin Nolan appeared on the programme to show off a satellite-controlled smart tractor.

As Dermot explained, smart tractors can make farmers' jobs easier but in the not-too-distant future, there may not need to be a farmer behind the wheel at all as autonomous vehicles continue to improve. Dermot says with satellite positioning and other technology the future of farming will look very different but more productive, and will allow farmers to "apply inputs much more accurately than before. With developments in this technology, we will manage every square metre in a field individually, accounting for soil, crop and grass variability, rather than the one-size-fits-all approach of today". In another episode, presenter Aoibhinn Ní Shúilleabháin met Sara Vero and David Wall at Teagasc's Soil Research Centre in Wexford to find out about some of the 213 different types of soil we have in Ireland.

Digging a cross section into the ground, they discussed the conditions that soil needs to thrive and feed the planet, the problems created from compaction, and the crucial role earthworms play in running a healthy farm.

According to Sara Vero: "Soil provides multiple services to our environment and is the crucial foundation of Irish agriculture. Ireland has a fantastic resource in our Soil Information System, which includes a national soil map at 1:250,000 scale, and we are building on this data to improve the specificity of agronomic advice and environmental policy".

This episode also featured Fiona Brennan and Aoife Duff, who are conducting DNA analysis to investigate how the microbiology and nutrient cycles driven by microbes in the soil are impacted by the structure, drainage, and the farming practices above the ground.



Dermot Forristal, Teagasc Crops Research Centre, Oak Park, Carlow, with presenter Kathriona Devereaux experiencing the future of farming inside a satellite-controlled smart tractor on RTÉ's '10 Things to Know About ... Space'.

Carlow Rooster Festival

The Carlow Rooster Festival took place in October and celebrated one of Ireland's favourite potato varieties. Hundreds of school students visited Teagasc Oak Park to learn more about potatoes. The three-day festival coincided with National Potato Day and events took place around Carlow. Schools from across Munster and Leinster descended on Oak Park and researchers took them through potato breeding, production, old and new farm machinery and farm safety. The Rooster potato was first bred by Teagasc potato breeder Harry Keogh and can now be found in almost every supermarket in Ireland. On the Saturday of the festival, Oak Park opened its doors for a free family fun day where children and parents picked their own potatoes and competed for a €500 prize, took guided tours of Oak Park house and enjoyed cooking demonstrations by local chef Edward Hayden. All proceeds raised on the Saturday went to the charity Embrace FARM, which supports both the survivors of farm accidents and bereaved family members.



Pictured at the launch of the Festival are (from left) front row: Gerry Boyle, Director of Teagasc; Frank O'Mara, Director of Research, Teagasc; Denis Griffin, Teagasc potato breeder and researcher; Derek Shannon, County Carlow Chamber; and, Yvonne O'Toole, President, County Carlow Chamber. Back row: Brian O'Farrell, CEO, County Carlow Chamber; John J. Hogan, Farm Manager, Teagasc Oak Park; John Spink, Head of Crops, Environment and Land Use Programme, Teagasc; Michael Hennessy, Head of Crops Knowledge Transfer, Teagasc; and, Shay Phelan, Tillage and Potato Specialist, Teagasc.

Munster Maths and Science Family Fair

Teagasc recently participated in the 8th Annual Munster Maths and Science Family Fair in Mallow, which attracted over 5,000 attendees. Phoebe Hartnett from the Teagasc Pig Department and Natasha Browne from the dairy research team discussed Teagasc's work to improve pig and dairy cow performance and welfare. A range of the modern technologies were on show to demonstrate the science behind animal production. Sheila Morgan and Grace O'Callaghan discussed the Food Research Programme, while Teagasc foresters Richard Walsh and John Casey outlined how trees intersect with our daily lives, from the new 'living lab' provided by the Mallow NeighbourWood project to 'where does your hurley come from'?

Walsh Fellowships Programme winners 2018

This year's Walsh Fellowship seminar celebrated the 25th anniversary of the Teagasc postgraduate Programme.

The Teagasc Walsh Fellowships Programme is a postgraduate programme offering fellowships to graduates to undertake research in agriculture, food, environmental science, agri-food economics, rural development, horticulture, and other related disciplines. The programme has grown significantly over the years; there are currently 280 Walsh Fellows, with an annual investment of €6m. You can read more about the programme and some of the alumni in the publication 'Celebrating 25 years of Postgraduate agri-food research 1993-2018' included with this issue of *TResearch*. Each year Teagasc organises a seminar to provide Walsh Fellowship students in their final year with the opportunity to communicate and present their research to a general audience, and network with academics and researchers in the agri-food industry. This year we held a competition in each of the programme areas and the best student was selected to go forward to the annual seminar in Johnstown Castle. We would like to thank all of the Walsh Fellows who participated in the competition and congratulate each of the winners, who have provided a brief description of their research below. For more information on the Teagasc Walsh Fellowships Programme and the opportunities available, see www.teagasc.ie.

Eoin O'Connor

Crops, Environment and Land Use Programme Overall Winner of the Walsh Fellowships Seminar

Eoin is based at Teagasc Ashtown, and is supervised by Helen Grogan, Teagasc, and David Fitzpatrick, Maynooth University. Thesis title: 'Genomic, transcriptomic, and proteomic analyses of *A. bisporus* strains showing some resistance/tolerance to mushroom virus X'. The mushroom industry is Ireland's largest horticulture sector, with exports worth over €100m. Since the early 2000s, mushroom production has been negatively impacted by a collection of viruses

known as mushroom virus X (MVX). Not much is understood about the interaction between these viruses and the mushroom host or how they cause damaging symptoms, such as the brown and poor-quality mushrooms associated with *Agaricus bisporus* virus 16. To advance our knowledge in this area, my research examines the gene expression and protein synthesis response of five different strains of *A. bisporus* when infected with viruses in a semi-commercial setting. The results of this work will inform international breeding research in the development of virus-resistant mushroom strains that would reduce losses caused by viruses in the future.

Áine O'Brien

Animal & Grassland Research and Innovation Programme Winner

Áine is based at Teagasc Moorepark and is supervised by Donagh Berry, Teagasc, and Seán Fair, University of Limerick. Thesis title: 'Genetics and genomics of performance in a multi-breed Irish sheep population'.

Breeding goals, whatever the species, must include all traits of importance; moreover, accurate differentiation of genetically elite from inferior individuals is paramount. The objective of this thesis was to develop and deploy the statistical know-how and pipelines for accurate genetic evaluations, using sheep health as a test case. Three health traits were considered (daggingness, lameness and mastitis) and it was concluded that up to 15% of the variability in these traits was due to inter-animal genetic differences. Mathematical strategies underpinned the construction of a bespoke Irish sheep genotyping platform, created to fulfil multiple purposes, while retaining the accolade of the lowest-cost medium-density sheep genotype platform globally. Results contributed to the now-deployed national sheep health index and a low-cost medium-density genotype platform, optimised for Ireland, but available worldwide.



Eoin O'Connor,
overall winner.



Áine O'Brien.



Orla Power.



Sharon Ní Bheoláin of RTÉ with
Teagasc Director Gerry Boyle.



Amy Connolly.



Amar Daxini.

Orla Power

Food Programme Winner and Winner of the IFSTI Medal

Orla is based at Teagasc Moorepark and is supervised by Noel McCarthy, Teagasc, and James O'Mahony, UCC. Thesis title: 'The effect of drying parameters and composition on hydration characteristics of high-protein dairy powders'.

High-protein milk powders are of great commercial importance to the Irish dairy industry. However, they are not readily soluble, which results in flecking in rehydrated products. Adding calcium chelators to high-protein powders increases protein solubility; however, there is a significant increase in viscosity. This causes fouling in membrane filtration systems and spray dryers, resulting in plant downtime and financial loss. We employed transglutaminase to enzymatically crosslink milk proteins. This modification resulted in lower viscosity products, improved rehydration behaviour and contributed to retaining the milk's whiteness. This work addressed key concerns associated with high-protein powders through cost-effective, industrially applicable means, while maintaining protein structure and lending insight into protein interactions with calcium chelators.

Amar Daxini

Rural Economy and Development Programme Winner

Amar is based at Teagasc Athenry and is supervised by Mary Ryan, Teagasc, and Andrew Barnes, Scotland's Rural College (SRUC). Thesis title: 'Understanding farmer decision making in relation to nutrient management planning to improve knowledge transfer methodologies'.

My research aims to understand the factors that influence farmers to adopt and use nutrient management planning practices. In particular, I am interested in the use of soil test results and nutrient management plans (NMPs) to inform nutrient management decisions on farm. Use of such practices has been proven to have benefits in terms of the environment but also in terms of profitability. However, adoption remains below expectations across all farm systems both in Ireland and globally. By understanding such factors,

policy makers can use this information to inform initiatives designed to encourage further use of nutrient management planning and further target such initiatives where appropriate.

Amy Connolly

Knowledge Transfer Programme Winner

Amy is based at the Teagasc Advisory Office in Moorepark and is supervised by Pat Murphy, Teagasc, and Anne Markey, UCD. Thesis title: 'Using nutrient management plans (NMPs) to deliver soil fertility advice'.

NMP Online is a system developed by Teagasc to create NMPs for environmental and regulatory purposes. My research involves an analysis of the system using focus groups and interviews. The main objectives are to determine the attitudes, opinions and impediments to the use of NMP Online by advisors and farmers, and to develop future requirements. Food Harvest 2020 and Food Wise 2025 both identified nutrient management as an area that needs to be improved. At the last renewal of our nitrates derogation, EU Commission officials raised concerns about our water quality. Nutrient management on farms must be improved through nutrient management planning to try to improve our water quality, as our nitrates derogation will be at risk otherwise. If we improve the system, we should improve the NMPs produced and nutrient management overall.

Author

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Next-generation vaccine design

A novel vaccination strategy targeting DNA sensors to overcome deficit in cellular immunity in neonatal calves was the winner of the 2017 **TEAGASC** invention of the year awards.



The Teagasc invention of the year awards, as part of the annual Bridge Network consortium commercialisation awards (comprising the technology transfer offices (TTOs) of Teagasc, University College Cork, Cork Institute of Technology and Institute of Technology Tralee), recently took place at University College Cork. Multiple inventions were submitted to Teagasc TTO in 2017, and from these, two finalists were selected: Kieran Meade (and Trinity College Dublin collaborators) for their 'Novel vaccination strategy targeting DNA sensors to overcome deficit in cellular immunity in neonatal calves' invention; and, Carlos Alvarez and Anne Maria Mullen (and collaborators) for their 'Procedure to generate transparent, edible and insoluble biofilms' invention. Kieran's invention was announced as the winner on the evening. The winner was selected by an external judging panel following a presentation by both finalists, and Kieran was presented with the award at the ceremony, on behalf of his team.

Innovative activity from research

Inventions are an important measure of innovative activity from research, and invention reporting is an important mechanism used within research-performing organisations such as Teagasc to capture such novel intellectual property (IP) for technical and commercial assessment. This allows the TTOs to assess these inventions/developments for patentability and commercial value, but also to capture non-patentable outputs and discoveries, including new software, databases and valuable know-how. This is a critical first step in the technology transfer process, where such IP may then be protected, thereby facilitating its exploitation by industry through the licensing or assignment of the IP.

Novel vaccine adjuvants

This invention was developed during a Teagasc-funded Walsh Fellowship project entitled 'Development of novel immunostimulators to boost the immune response in cattle', in



Pictured at the Teagasc invention of the year awards (from left): Carlos Alvarez (researcher-finalist); Kieran Meade (winner); Miriam Walsh (Teagasc TTO); Anne Maria Mullen (researcher-finalist); and, Sharon Sheahan (Teagasc TTO).

collaboration with Trinity College Dublin (TCD). It has resulted in a joint Teagasc–TCD patent application filed in 2018, entitled ‘Novel vaccine adjuvants’, and includes co-inventors Ed Lavelle from TCD and then PhD student Ciaran Harte. Given that vaccines hold tremendous potential for reducing the global impact of disease in humans and animals, this project, which focuses on solutions to boost the immune response in cattle through vaccine development, aligns well with Teagasc’s mission and Food Wise 2025 objectives, namely, to develop new strategies to reduce the burden of disease on farm and to help secure the sustainability of the livestock sector and the safety of the food chain.

The partner TTOs are currently working to target existing human and animal vaccine producers, with a view to further developing and licensing this technology for commercialisation purposes in both veterinary and human therapeutic fields, while the researchers are considering further research funding opportunities.

Components of vaccines

At a basic level, most vaccines consist of two components – an antigen and an adjuvant. The antigen is the bacteria or virus that the vaccine is designed to protect against, whereas the adjuvant acts to amplify the immune response to ensure the long-lived cellular memory that is critical for a successful vaccine. The efficacy of current-generation vaccines can be negatively impacted by the presence of maternal antibodies, which inactivate the vaccine, or

they can generate a type of immunity that is not appropriate for the specific disease-causing agent it is designed to protect against.

New adjuvant strategy

This invention involves devising a new adjuvant strategy in bovine cells to do two things: activate the enhanced cellular immunity (rather than just antibodies) required for optimal protection; and, activate innate immune cells to overcome some of the limitations of an underdeveloped adaptive immune system present in young calves. This strategy, known as ‘training innate immunity’, is a very novel concept in immunology. It is anticipated that this new adjuvant strategy would improve the efficacy of current-generation vaccines, as well as contributing to the tailored design of next-generation vaccines. Newer sub-unit vaccines (which contain a component of the bacterial or viral pathogens, rather than the whole organism) are a safer but less immunogenic design, which therefore rely heavily on the adjuvant to drive the formation of memory cells and thereby reduce the need for repeated booster vaccinations. The ability to drive specific protective immune outcomes through the rational adjuvant-mediated targeting of specific cellular pathways has enormous relevance, particularly in activating the immune system in young stock, and this innovation could have potential utility for vaccine design in other livestock species.

Human and animal applications

While the Teagasc–TCD collaboration focused on research into neonatal calves, TCD independently developed a similar technology with applications for human health. For this reason, Teagasc and TCD bundled the IP to file a stronger patent application covering human and animal applications. The partner TTOs are currently working to target existing human and animal vaccine producers, with a view to further developing and licensing this technology for commercialisation purposes in both veterinary and human therapeutic fields, while the researchers are considering further research funding opportunities.

Authors

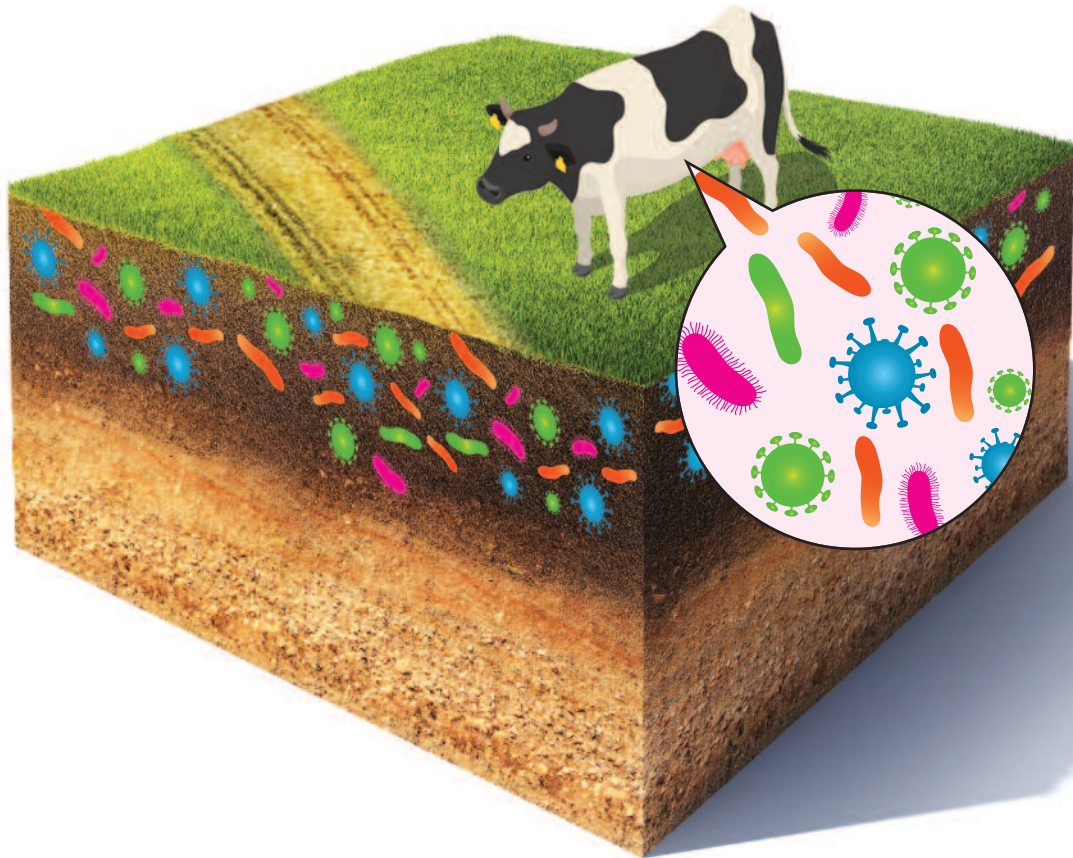
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Harnessing the power of agricultural microbiomes

TEAGASC researchers recently hosted an international conference, entitled ‘Microbiomes Underpinning Agriculture’, that focused on the diverse roles played by microorganisms in agricultural systems, and on exploring what microbiome research can offer to agriculture.

Microorganisms are of fundamental importance to agricultural and food production systems; however, despite their significance, our understanding of how they function remains limited. New technologies enable researchers to better understand these organisms and exploit knowledge gained within agriculture.

Understanding agricultural microbiomes

Microorganisms play a critical role in agriculture, representing a key resource that underpins the agri-food sector. Soils, plants and animals all have a unique microbiome (the community of microorganisms living together in a given habitat) and these agricultural microbiomes perform an array of pivotal functions

essential to system health, sustainability and productivity. An enhanced understanding of these agricultural microbiomes will provide opportunities towards managing agricultural systems in a manner that harnesses the natural power of microbes to provide solutions to global challenges of food safety and security, resource limitation and climate change, and move towards more efficient and sustainable food production systems. Up until relatively recently, insights into these complex microbial communities have been limited. However, the advent of novel molecular technologies has transformed this field, making it possible to study microbiomes in greater depth than ever before through DNA, RNA or protein analysis. This can tell us which microorganisms are present and what they are capable of doing.

Soil microbiomes

Soil microorganisms are critically important to agriculture, food production, and climate regulation. They are the engine of nutrient cycling in soils, playing an active role in soil fertility and nutrient provision to plants. The microbes in soil and on plant roots provide essential nutrients, vitamins and hormones to plants, and prevent pathogen invasion. Greenhouse gases result from microbial processes and understanding their function is key to reducing gaseous emissions that contribute to climate change. Research efforts on the soil microbiome are focused on determining the impact of management, environmental and climatic factors on the soil microbiome, and informing soil management so as to promote soil health, match nutrient availability to plant requirements, and harness the soil immune response to suppress pests and diseases. Knowledge of the soil microbiome is central to the development of sustainable agricultural systems by enabling a reduction in nutrient losses to the environment, increasing carbon sequestration, reducing agricultural inputs, and increasing the resilience of crops to extreme weather events.

Plant microbiomes

While it is generally understood that what you see above the surface typically represents only half of a plant's biomass, what may not be so well known is that microbes co-exist on and within plant structures. These microbes support the plant life cycle, are essential for nutrient cycling and can enhance a crop's performance against environmental change or in withstanding diseases. When it comes to food production, this is critically important. By 2050 we need to be able to sustain a global population of over 9.5 billion people with fewer resources while trying to combat the effects of climate change. Within the EU, this must be achieved within the context of legislation that controls the use of certain plant protection products. Using technologies that characterise a plant's microbiome it is now possible to identify individual 'crop profiles'. The research community is actively testing such profiles to identify strains that can be used by farmers to produce more from less: greater yields with better quality but with a reduced reliance on fertilisers and chemicals.

Soil microorganisms are critically important to agriculture, food production, and climate regulation. They are the engine of nutrient cycling in soils, playing an active role in soil fertility and nutrient provision to plants.

Animal microbiomes

Animal microbiomes underpin livestock production. Ruminant animals lack the ability to digest herbage, relying instead on microorganisms within the rumen to ferment cellulose, and other plant components, into compounds that the ruminant can utilise for energy, and subsequently milk and meat production. Certain microbes are capable of influencing ruminant performance by altering rumen fermentation and outcompeting harmful pathogens. Populations of rumen microbes differ between animals, providing the opportunity to breed cattle for desirable microbiome traits such as improved feed efficiency, health and reduced environmental output. Exploiting this unique symbiotic relationship is key to sustainably meeting the growing demand for animal-based proteins, while reducing the ruminant contribution to global methane production. Current research is focused on better understanding the role of the host animal in regulating the rumen microbiome, as well as the impact of diet and prebiotics on rumen function and animal performance.

Acknowledgements

This conference was part of the Microbiology Society's series of focused meetings and we thank the Society for its invaluable support in organising this event. The conference organising committee was comprised of Fiona Brennan, Kaye Burgess, Fiona Crispie, Paul Cotter, Ewen Mullins, Orla O'Sullivan and Sinéad Waters. The contribution of Paul Smith to this article is acknowledged.

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Food Unwrapped

Airfield Estate recently ran an event entitled ‘Food Unwrapped’ as part of its biannual Food Series.

Aiming to encourage discussion and dialogue around food packaging and examine how consumers are influenced by current trends, the speakers explored a number of topics such as how food packaging affects consumer health, what the future of packaging might look like, and its environmental impact.

Chicken and egg

Airfield Estate’s mission as an educational charity is to provoke curiosity about food and trigger more conscious food choices. Grainne Kelliher, CEO of Airfield Estate, set the scene by demonstrating the diversity and complexity of food packaging. Using the example of an egg, a food that has its own natural packaging, she showed the need for responsible packaging in order to reduce breakages and therefore the wastage not just of the egg, but of all the resources that went into creating it (212L of water and 159kcal of food per egg, not to mention the production of 264g of CO₂ equivalent – roughly equal to driving 1km). She also highlighted that she was able to purchase apples from one retailer in four different types of packaging, making it almost impossible for the consumer to navigate how to successfully either reduce their packaging waste or dispose of it correctly.

Navigating food packaging

Journalists Rose Costello (*The Irish Times*) and Niall Toner (*The Sunday Times*) articulated how the consumer is bombarded with information from food packaging. Rose outlined what to look for

on packaging material, and what you can learn from it. She highlighted that packaging contains a lot of useful information for the consumer; however, it can be hard to decipher, and she went on to question the producers’ and retailers’ role in the information on packaging and their responsibility to the consumer to be honest and open about their product. Niall spoke from a personal standpoint on the amount of packaging waste we produce in our homes and workplaces, how it is impacting on us all, and how we can attempt to do something about it.

European regulation

Anne-Marie Boland, a Senior Technical Executive in Regulatory Affairs with the Food Safety Authority of Ireland, has an expertise in European and Irish food labelling legislation, and brought attention to the fact that one of the biggest challenges the consumer currently faces is the conflict that exists between our food regulators and the provision of mandatory information on the label, and the producer who wants to promote information that allows for effective marketing of the product. This relationship has become openly strained in recent months, especially with regard to country of origin (which is not compulsory to denote on packaging) and how companies have chosen to colour and promote their product. However, the regulations are constantly being updated; for example, all health claims on packaging must now be backed up by research, which should be available to the consumer.



Enda O'Dowd, NCAD, speaking at Food Unwrapped at Airfield Estate on the future of food packaging.



Grainne Kelliher, CEO of Airfield Estate, discussed the diversity and complexity of food packaging.

Packaging trends and recycling

The second session of the day focused on looking past current food packaging to the packaging of the future. Colm Munnelly from Repak spoke about how current packaging trends present a challenge to waste management companies. He outlined how all packaging is recyclable, but at a cost, and currently no one is willing to explore the cost fully to create facilities and technology to deal with the wide diversity of packaging that is produced. He also emphasised that no matter how recyclable and compostable the packaging is, it is ultimately up to the consumer to successfully deposit the packaging into the correct recycling stream. If the consumer chooses the wrong one, the packaging is likely to end up in landfill.

Barcodes and fTrace

Alan Gormley from GS1 spoke on how barcodes can help deliver information to the consumer. GS1 is a not-for-profit standards organisation that wants to bring traceability and transparency to consumers through a simple barcode scan. Alan spoke about 'fTrace', which is a solution that can enable the consumer to trace their food from farm to fork, from producer to packager and from distributor to retailer, meaning that the consumer will be able to make a more informed decision about the food they choose to buy and eat by simply scanning the product barcode.

Future of packaging

Enda O'Dowd, a lecturer in product design at the National College of Art and Design (NCAD), talked about the future of food packaging. He stressed the importance of allocating responsibility with regard to waste generation and promoted the 'polluter pays' idea, as well as the notion that producers of packaging should begin designing packaging with end of life in mind as well as food preservation and marketing. He also spoke about how increasing automation is driving producers' choice of packaging towards less recyclable constituents and also stressed that the shorter the

supply chain, the less packaging is needed (i.e., eating seasonally and locally will encourage less food packaging and waste).

Complex issue

The final, overriding outcomes from the day were the observations that food packaging is a complex issue with many stakeholders within its conception, construction, use and removal, and that the consumer holds a pivotal role in the system. Consumers must begin to demand packaging that has improved food preservation abilities while being easy to compost or recycle. They should have easy access to as much information as possible about the product while not being distracted by the marketing and, finally, they need to have the confidence and education to successfully separate and allocate packaging into the correct streams for successful end-of-life recycling.

Airfield Estate is a 38-acre working farm, gardens, kitchen, education and food destination, open daily to the public and educational institutions for the purpose of education and recreation. For more information on the speakers from the Food Unwrapped series, to view their talks and learn more about past conferences, please go to www.airfield.ie/food-series.

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VistaMilk

VistaMilk is a new Science Foundation Ireland agri-tech research centre led by **TEAGASC**. It will digitalise dairy production systems through the development and deployment of value-creating information and communications technology.

Globally, agriculture is undergoing seismic disruptions arising from the competing challenges of food security, the environment, and societal needs. The dairy sector is not exempt from this disruption as it faces a confluence of challenges including the rapidly expanding global demand for dairy products, the growing concern over the impact of cattle production on climate change, and the long-term volatility of global dairy markets. Fortunately, the solutions to these challenges are emerging from a parallel revolution in smart and precision agriculture.

Though the early promise of precision agriculture has arguably not been met, recent advances linking novel sensors, networking, and data analytics technologies suggest that successful solutions are imminent.

For Ireland, this disruption presents major threats and opportunities, as traditional dairy production needs to quickly transform itself using these new technologies. Since the abolition of EU milk quotas in 2015, Irish dairy farmers can, for the first time in 30 years, exploit Ireland's international competitive advantage in milk production from low-cost grazed grass. However, the abolition of milk quotas also exposes the sector to global volatility in milk prices, creating a competitive environment necessitating improved farm efficiency, improved processor efficiency and a strategic transition to higher-value-added products. The increased production in the Irish dairy sector will be achieved through expanding the national herd (growing at 3% per annum) but also through the development

and deployment of new knowledge, technologies and decision support systems to maximise the efficiency and effectiveness of the entire production chain.

VistaMilk SFI Research Centre

The €40m VistaMilk Science Foundation Ireland (SFI) Research Centre, which started in September 2018 with a team of over 200 scientists, aims to be an agent of growth for the Irish dairy industry by being a world leader in fundamental and translational research for precision pasture-based dairying. Internationally, the advances developed in the Centre will apply to dairy systems in many countries and will be a catalyst for global growth in the agri-tech sector. The VistaMilk SFI Research Centre represents a unique collaboration between agri-food and information and communications technology (ICT) research institutes and leading Irish/multinational food and ICT companies.

The Centre, under the directorship of Donagh Berry, is hosted by Teagasc in partnership with the Tyndall National Institute (Ireland's national microelectronics institute), the Telecommunications Software & Systems Group (TSSG) at Waterford Institute of Technology, the Irish Cattle Breeding Federation and the Insight Centre for Data Analytics. The value-added partnerships in the VistaMilk SFI Research Centre will go beyond the state of the art in agri-tech programmes globally, which tend to lack critical mass or focus on only one or, at best, a few components of the dairy production chain.

Innovation and sustainability

The vision of the VistaMilk SFI Research Centre is to be a world leader in the agri-food technology sector through innovation and enhanced sustainability across the dairy supply chain, positively impacting the environment, animal well-being and consumer health. This will be achieved by greatly improving the soil-to-gut supply chain connectivity, thereby improving resource efficiency, better meeting consumers' expectations, and improving profitability and resilience. To achieve the vision for the Centre, the resources, capabilities and expertise of the partners will be brought together, to create new innovation opportunities at the interface between agri-food and ICT. It will, for the first time, link the Irish agri-food industry with Ireland's leading technology research institutes in a large-scale innovation ecosystem. The opportunities that arise at the interface between agri-food and ICT will be the basis for the competitive advantage and international reputation of the centre.

The VistaMilk SFI Research Centre represents a unique collaboration between agri-food and information and communications technology (ICT) research institutes and leading Irish/multinational food and ICT companies.

Research themes

To advance the state of the art in agri-food and information sciences, VistaMilk has divided the problem domain into three main thematic areas of consideration, namely:

- soil and pasture: knowledge and tools to sustainably grow a greater quantity of consistently higher quality herbage for consumption by grazing cows;
- cow: achieving a greater volume of constantly higher quality milk through scientifically supported optimised management and breeding strategies; and,
- food: developing higher-value-added dairy products for human consumption, optimised for the predicted milk supply and quality based on predicted grass growth profiles and cow performance from earlier thematic areas.

In addressing these areas, the centre will combine biological sciences with cutting-edge ICT areas:

- sensors: the development of robust, highly sensitive sensor infrastructure based on nano-electrochemical, spectroscopic and/or mechanical sensors integrated with control electronics, firmware, edge computing data analytics and data communications;

- communications and networks: the development of efficient and reliable end-to-end communication protocols for transporting information from various sensors all the way to the fog and cloud computing infrastructure;
- data and data analytics: the development and application of machine learning and statistical modelling techniques, across the dairy supply chain, to predict optimal outcomes for pasture, for cows, and eventually for food production; and,
- decision support: developing and deploying modular-based decision-support resources informed by the multi-level data and associated analytics for use by producers in the pursuit of consistently better performance.

One-stop shop

The research programme will develop new technologies, and advance existing electronic monitoring and actuation technologies, to transform an already world-class dairy sector into a global leader in sustainable agri-tech, specifically addressing pasture-based dairy production, improved processability, and the generation of novel, higher-value-added products. In addition to the creation of new sensing and actuation paradigms, particular focus will be given to developing state-of-the-art analytical techniques applied to large-scale sensor datasets delivered by advanced network and communication technologies. As well as generating novel knowledge-based products, the VistaMilk SFI Research Centre will be a one-stop shop for agri-tech companies in dairying, providing research services, evaluation and integration of technologies in dairy production. The novel combination of the expertise and critical mass in the VistaMilk SFI Research Centre will also enhance Ireland's international reputation as a leader in agri-tech, facilitating new international partnerships as well as attracting new foreign direct investment.

Acknowledgements

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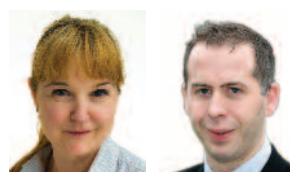
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How much do farmers move?

A study by **TEAGASC**, UCD and WIT found that farmers may be significantly underestimating their levels of daily physical activity.

Physical activity (PA) is hugely important for farmers' cardiovascular and mental health. Measuring PA accurately is a prerequisite to knowing if public health guidelines are being met. This study aimed to explore farmers' PA levels using two different methods (a standardised questionnaire survey and accelerometers), and to compare the results with a view to informing larger-scale farmer health research.

Measuring activity

Fifteen male farmers were recruited at farmer events, and written consent was obtained. Ethical approval was granted by Waterford Institute of Technology (WIT) Research Ethics committee (12/HSES/07). Participants completed the International Physical Activity Questionnaire – Short Form (IPAQ – SF), which has been shown to have good validity and retest reliability for self-reported PA levels. The farmers also wore an ActivPAL professional uniaxial accelerometer (53 x 35 x 7mm and weighing 20g) on the thigh, from waking until bedtime for seven consecutive days, while continuing normal farming activities.

The IPAQ and ActivPAL data were entered onto the Statistical Package for the Social Sciences (SPSS version 20.0). The IPAQ

data were analysed according to IPAQ guidelines with the minutes of walking, moderate and vigorous intensity exercise converted to MET minutes (Metabolic Equivalent of Task, where intensity of PA is compared to energy cost of sitting quietly, which equals 1MET). Descriptive statistics were used for initial analysis of the IPAQ and ActivPAL data.

MET data were compared (comparison of group means) using paired t-tests, with Spearman's correlation test used to explore the relationship between the subjective and objective data.

Results

Participants were aged between 39 and 69 years, with a mean age of 48 years (SD 8.0). Most were full-time farmers with various farm types (intensive dairy, dairy and sheep, suckler cattle, and dry stock cattle) and a farm size ranging from 21ha to 81ha.

The body mass index (BMI) of the farmers ranged from 22.9 to 30.7 with a mean of 26.7 (SD 2.3), which is classified as overweight. According to the ActivPAL data, farmers achieved a range of 8,047 to 19,768 steps per day (median 14,163) (completing more than 10,000 steps per day is the general recommendation for health). Farmers spent approximately two-



thirds of the day sitting/sleeping/lying (mean 16 hours; SD 1.9), with a mean of 4.2 hours (SD 1.0) standing and 2.9 hours (SD 0.9) stepping per day. ActivPAL-calculated MET hours per week (mean 253.5; SD 12) were found to be significantly higher than IPAQ – SF MET hours (mean 125; SD 103) (t-test $p < 0.001$). A non-significant poor correlation was found between the two measures (Spearman rho = 0.182; $p = 0.593$).

Discussion

Given the discrepancy between IPAQ and ActivPAL data, all participants here were, in fact, underestimating their PA levels. This is in contrast with recent findings, including a systematic review, where overestimation of PA using IPAQ was identified as the issue (Lee *et al.*, 2011; Shook *et al.*, 2016). Being so physically active may render it difficult to accurately report PA on the IPAQ, with Maddison *et al.* (2007) reporting a systematic bias towards underestimation of PA-related energy expenditure at higher levels of physical activity.

Additionally, when self-reporting, participants may not have regarded certain regular farm activities as actual physical activity, or may underestimate familiar routes covered as part of their regular working day.

Therefore, an alternative measure of PA may be required for highly active populations, or indeed an occupation-specific instrument that also takes occupation-specific tasks into consideration.

In terms of farmers' cardiovascular and overall health, dietary behaviours that lead to farmers becoming overweight, stress associated with higher work intensities, the intensity of PA undertaken and participation levels in leisure time, sport and exercise also warrant exploration.

Conclusion

This active cohort of farmers largely underestimated their PA on self-report (IPAQ – SF) when compared with their objectively measured PA on the ActivPAL. An alternative to the commonly utilised IPAQ – SF measure of PA should therefore be considered for future research into farmer physical activity levels. This study has demonstrated the feasibility of conducting accelerometry studies with farmers, with advances in wearable technology and reduced device costs to facilitate this research approach.

Acknowledgements

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Strengthening impact from research

A new policy brief offers guidance on how actors involved in research and innovation can meet increasing demands for demonstration of impact from research.

In order to meet demands from policy makers, funders and society for increased demonstration of impact from research, a cultural shift is needed so that all actors involved in research and innovation (R&I) projects consider impact before research projects are initiated. As part of this shift, a better understanding of the pathways through which research leads to impact is critical and this understanding should be co-developed within a multi-actor framework if possible. Such an approach should be supported by an enabling policy, funding and market environment. These were some of the high-level conclusions of a recently completed policy brief on programming research and innovation for improved impact. The policy brief, launched in October 2018, was the outcome of a cross-Standing Committee of Agricultural Research (SCAR) Strategic Working Group (ARCH, AKIS, Food Systems) workshop held in April 2018 and supported by the Common Agricultural and wider bioeconomy reSearch Agenda (CASA) project. The brief primarily targets R&I policymakers and funders in the European Commission and in national ministries. However, it is also intended to provide value to researchers and their institutions.

Background

The fundamental starting point for the policy brief was the acknowledgement that agricultural research and innovation systems are open, complex and changing rapidly. Against this background, there is an increasing demand from public and private funders, as well as from society, for researchers to measure, document and demonstrate the impact of research, over and above traditional scientific impact metrics. However, most of the emphasis to date has been on demonstrating the economic, societal or environmental impacts of research activities *ex post*, or after the research has taken place. Relatively less attention has been paid to the likely effects of initiatives *ex ante*, or before activities actually start; in other words, how to foster impact and generate a culture of impact from the very

beginning of projects. The policy brief identified that from both a research and an innovation perspective, a co-designed and co-delivered multi-actor approach is most likely to deliver on these demands depending on whether research is more fundamental or applied. Such an approach is already happening within some EU funding programmes such as H2020 and EIP Agri. The policy brief acknowledged this but also identified what needs to happen in order for such an approach to become more widespread.

Pathways from research to impact

A key part of that approach is a better understanding of how impact occurs. Douthwaite *et al.* identify three interconnected pathways as a good framework for understanding how agricultural research might lead to impact: technology development and adoption; capacity development; and, policy influence. Crucially, there are strong feedback loops among these pathways, which strengthen the capacity of the system to have an impact. A clear understanding of impact pathways and the feedback loops is key to programming research for impact, and all stakeholders should have these interactions in mind when starting an *ex ante* assessment of research activities. Of course, there are many external influences on these pathways and possible eventual impact. For example, policymakers and funders can influence the enabling environment for research and innovation by shaping the direction of research issues. A variety of funding mechanisms encourage different types of research. Separate to policy and funding effects, market distortions and barriers to the diffusion of new technology and innovations can also hinder impact and what happens along the pathways. Given this complexity and the need to understand impact pathways, a multi-actor and interdisciplinary approach is required where research is embedded within a broader economic, political, social and cultural context.

How to *ex ante* evaluate impact?

So how can *ex ante* evaluation and a better understanding of impact pathways be incorporated into research projects? What is the process? By definition, *ex ante* evaluation, which focuses on how R&I programmes might generate impact, is conducted before implementation. Increasing the focus on *ex ante* evaluation requires a cultural shift, as it means moving from a purely linear approach to change to a multidimensional model of change as exemplified by the impact pathways framework. A better understanding of the interactions between the various elements of the framework, its actors, and how this can be used to generate changes in practices and behaviour is key to programming research that will ultimately lead to better impact. Such an approach to *ex ante* programming, where researchers and other actors construct, in a participatory and strategic manner, a shared vision and identify plausible impact pathways through which research teams and their partners expect to contribute to impacts, is outlined by Blundo Canto *et al.* in a six-stage approach as shown in **Figure 1**.

The policy brief made 12 recommendations targeted at five different audiences. First, research institutions should develop a culture of impact: include all stakeholders in understanding potential impact pathways, and also include use of and achievement of impact indicators as a parameter for assessing researchers. Second, funding agencies should require both *ex ante* and *ex post* impact assessment, and as far as possible, projects and programmes should be co-designed and co-delivered to help achieve this. Existing good examples of *ex ante* assessment in EIP Operational Groups and H2020 projects should be analysed and collated with a view to translation to other programmes. Third, policy makers should foster an enabling environment for impact and provide researchers with the support needed to develop the capacity for this. Also, they should ensure that funding regulations are flexible enough to support impact. Fourth, SCAR Strategic Working Groups should

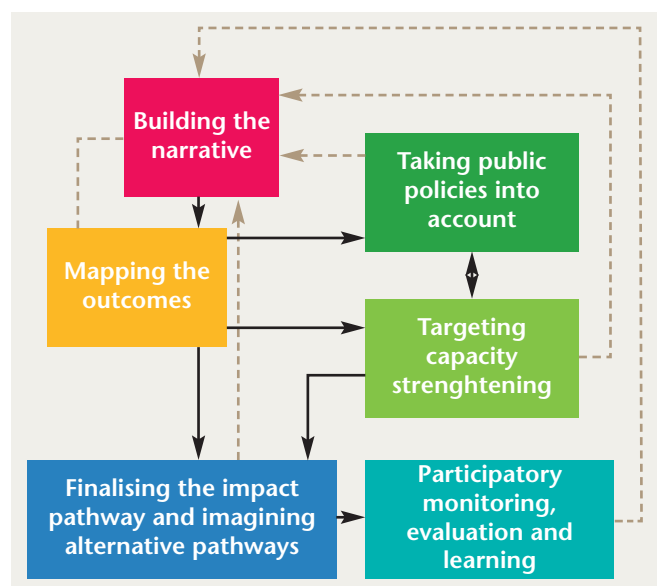


FIGURE 1: Flowchart for *ex ante* programming (source: Blundo Canto *et al.*, 2018).

provide advice on *ex ante* evaluation planning and monitoring. Finally, general recommendations to all actors were to ensure a co-design and co-delivery approach to research and innovation where appropriate: enable regular exchanges between researchers, funding agencies, policy makers and end-users at the national and European level; strengthen incentives and evaluation criteria for research organisations and individual researchers to encourage a focus on impact and a multi-actor approach; strengthen the environment for supporting impact generation by including actors from knowledge transfer organisations as well as innovation support services and innovation brokering where appropriate; and, train researchers in multi-actor and co-creative working methods.

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The policy brief can be accessed at:

<https://scar-europe.org/index.php/akis-documents>

Further information

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Innovative bull production systems and beef quality

In the BullBeef project, **TEAGASC** and collaborators are looking at the profitable production of bull beef to market specification while ensuring optimum quality for the consumer.

Approximately 900,000 male cattle are slaughtered annually in Ireland. The majority of these animals are castrated and 'steers' are perceived to be a unique selling point for Irish beef, particularly in European markets where bull beef production predominates. The superior growth and feed conversion efficiency of bulls, however, make them attractive to producers. The proportion of the male slaughter represented by young bulls varies from year to year (e.g., 12.9% in 2008, 29.3% in 2012 and 21.6% in 2017 – Department of Agriculture, Food and the Marine (DAFM), Beef carcass classification and price reporting section, Annual Report, 2017). Traditionally, bulls were reared indoors on a high-energy ration, which is a relatively expensive production system. Exploiting grazing is one strategy to decrease the cost of production but meeting the abattoir specifications of animal age and carcass fat score and weight is likely to be a challenge. The DAFM, under the Research Stimulus Fund, has funded a large, multi-institutional project (BullBeef 11/SF/322) that has addressed novel production systems for bulls, the impact on beef quality and whether current abattoir specifications are valid from a meat quality perspective. This article gives an overview of the project and some emerging findings.

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The BullBeef project

This project is a collaboration between Teagasc, University College Dublin, University College Cork and INRA (France). The overarching tasks concern the modification of production systems for suckler and dairy-origin bull beef to increase profitability, and the assessment of

the resulting beef for market-relevant quality characteristics. Underpinning research tasks focus on elements from farm to fork that limit achievement of market specifications. These include the impact of slaughter age and castration, the duration at pasture prior to slaughter, the need for concentrate supplementation at pasture, the maturity/breed of suckler bull, and the interaction with carcass intervention strategies. Since carcass fat score is a key market specification, the underlying biology of fat deposition is being explored. Beef colour, eating quality and shelf life are being comprehensively measured.

Recent findings

- When finished from pasture at the same age – ca. 19 months – carcasses from spring-born, suckler-bred, early-maturing breeds were lighter, fatter, and had poorer conformation than late-maturing breeds; bulls had greater growth, liveweight, better kill-out proportion, a heavier carcass, better carcass conformation score and a lower carcass fat score than steers.
- Early-maturing breed steers were adequately ‘finished’ at 19-20 months of age from unsupplemented pasture in all experiments, whereas late-maturing breed steers were finished in some but not other experiments. This inconsistency across studies was likely due to inclement weather-related grazing conditions having an adverse effect on intake and performance.
- Concentrate supplementation during the latter half of the grazing season (i.e., ca. 4-5kg daily for 75-95 days) is a possible strategy for finishing late-maturing breed suckler steers from grass at ca. 19-20 months.
- Compared to late-maturing breed steers, carcasses from late-maturing breed bulls were only adequately finished at 19 months of age when supplemented with concentrates (i.e., ca. 4kg daily for 95 days).
- Carcasses of early-maturing breed bulls slaughtered at 19 months of age from pasture were lighter but adequately finished, with or without concentrate supplementation during the latter half of the grazing season (i.e., ca. 4kg daily for 95 days), whereas the heavier, late-maturing breed bull carcasses were only adequately finished when supplemented.
- Carcasses of both early- and late-maturing breed suckler bulls were inadequately finished from pasture, with or without concentrate supplementation at 15 months of age.

Collectively, these findings indicate that spring-born, early-maturing breed suckler steers can be finished from well-managed pasture in autumn at ca. 19-20 months of age without concentrate supplementation, whereas late-maturing breeds may need supplementation. Spring-born, early- and late-maturing breed suckler bulls produced from pasture under 16 months of age are unlikely to meet market-specific requirements in terms of carcass fat cover, even with moderate concentrate supplementation; however, this carcass fat target (2+) is achievable from well-managed pasture at ca. 19-20 months of age without concentrate supplementation for early-maturing breeds, and with moderate levels of concentrate supplementation for late-maturing breeds.

- Within dairy bull production, the 19-month-old, grass-based system was the most profitable. However, the possibility of a price discount due to the animals being older than the 16 months currently required in many markets needs to be considered.
- There is little commercially important difference in tenderness or overall liking of striploins from continental-breed sired suckler bulls slaughtered between 15 and 22 months of age, or from dairy bulls slaughtered at 16, 19 or 21 months of age.
- There was some evidence that production system *per se* may have a small negative effect on eating quality. For example, when suckler bulls from early- or late-maturing breed sires were slaughtered at 380kg carcass from an *ad libitum* concentrate diet or grazed prior to finishing on an *ad libitum* concentrate diet, the tenderness rating by trained assessors was lower for the grass-based system. The scale of this decrease is unlikely to be detected by untrained consumers.
- Continental breed-sired bulls and steers were compared within two production systems; the striploin from steers was fatter and rated more highly for tenderness and acceptability than the striploin from bulls. The absolute differences in eating quality were, however, small.

The final outcome of this project will be blueprints for bull beef production, with associated costs and meat quality implications.

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Nutritional modelling – the next frontier for Irish pasture-based systems

A **TEAGASC** project is addressing how we can utilise nutritional modelling to gain a greater understanding of nutrient supply and requirements of pasture-based animals.

Introduction

Nutritional models quantify an animal's nutrient demands, which change across physiological stages, while also quantifying the supply of nutrients, which is highly variable from pasture-based diets. The use of nutritional models in pasture-based systems is limited, with conflicting reports surrounding constraints to more efficient milk production in these systems. The Cornell Net Carbohydrate and Protein System (CNCPS) is a mathematical model designed to evaluate the nutrient requirements of cattle over a wide range of environmental, dietary, management and production situations. The model also uses estimations of carbohydrate and protein degradation and passage rates to predict the extent of ruminal fermentation, microbial growth, and the absorption of metabolisable energy (ME) and metabolisable protein (MP) throughout the gastrointestinal tract. Therefore, application of the CNCPS has the potential to help quantify the nutrient(s) first limiting milk production output and feed conversion efficiency in pasture-based systems.

Dairy cow nutrition research programme

The overall objective of this research is to develop and implement a dairy cow nutrition programme that increases the competitiveness of the Irish dairy industry. In order to achieve this, it is necessary to build a solid foundation comprising three main pillars in dairy cow nutrition.

Pillar 1: The feed

Measuring forage composition is an integral part of understanding nutrient supply to livestock. An example of this can be seen in the neutral detergent fibre (NDF) estimate. Currently, NDF is reported on feed analysis output as an indicator of feed quality and plant maturity. However, NDF is not a uniform fraction and requires further analysis to understand its nutrient supply to the animal. Numerous animal studies have shown that when forages of different *in vitro* digestibility but similar NDF concentration are fed, significant increases in dry matter intake (DMI) and milk production can be achieved. NDF can be fractionated into two pools, one that is unavailable to microbial digestion (uNDF) and a potentially digestible pool (pdNDF), which is calculated as NDF minus uNDF. Further fractionation can occur, with a three-pool system approach, assigning fast, slow and undigested pools to the total NDF (**Figure 1**). These fractionation schemes can provide nutritionists with better information about the heterogeneity and digestibility of NDF, and the dynamic nature of the pool sizes that may influence feed intake and energy supply. This novel feed chemistry analysis was performed on spring and autumn Irish pastures at Cornell University. The rate at which the pdNDF pool degraded was faster for spring compared to autumn pasture (9.53 versus 7.76% hour⁻¹, respectively). Furthermore, the extent to which NDF was digested was greater for spring compared to autumn (9.75 versus 15.50% uNDF, respectively). Predictions of the ME per kg of dry matter of the swards showed that spring pasture had a greater energy density and also supplied a greater quantity of MP to the animal. By

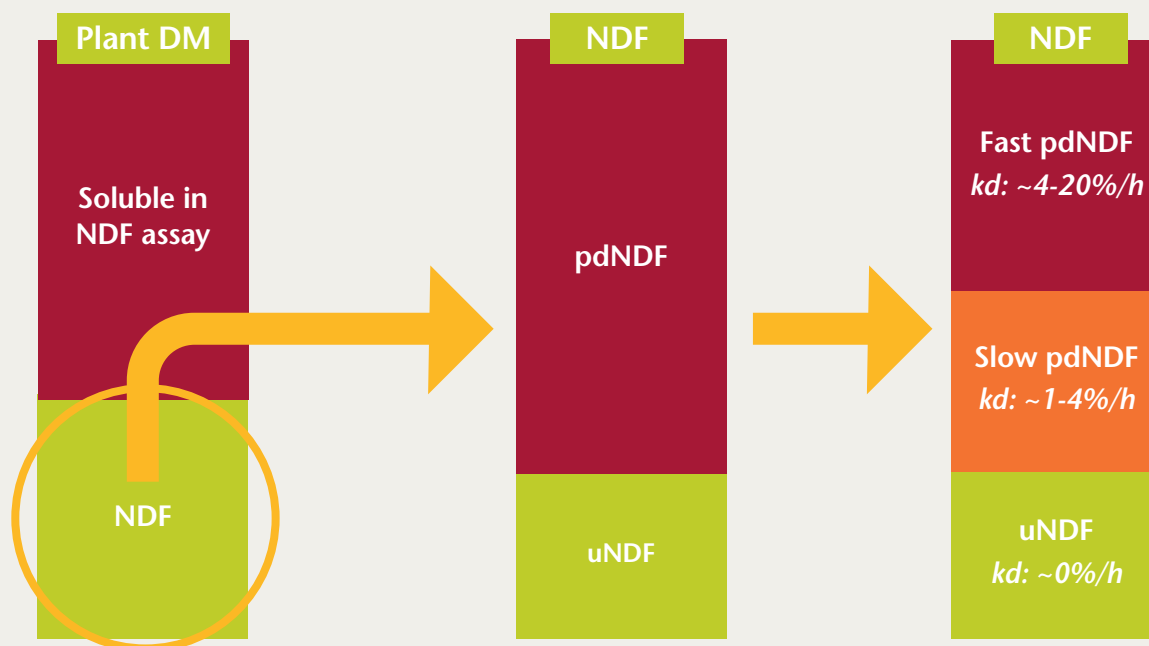


FIGURE 1: Fractionation of feed NDF according to the three-pool system.

implementing new feed chemistry analysis, as described above, a more accurate prediction of the nutrient supply to the animal can be achieved for pasture-based systems.

Pillar 2: The cow

In combination with an accurate description of the feed, *in vivo* animal variables and their potential impact on the nutritional value of the feed requires quantification. These variables include passage rate, rumen degradative ability, rumen pH and ammonia dynamics, and microbial growth rates. To mechanistically describe this biology of the grazing dairy cow, new experimental techniques need to be implemented. In the summer of 2017, 10 ruminally cannulated cows participated in an omasal flow experiment, which allows the digesta leaving the rumen to be sampled periodically across the 24-hour day. The animals were fed fresh pasture or pasture plus 3kg DM of a starch supplement. To complement this procedure, rumen evacuations and faecal sampling were also carried out to help quantify amino acid flows and total tract digestibility. Laboratory analysis of the samples collected in this study is still ongoing, with results of the experiment to be published by summer 2019. These types of mechanistic experimental procedures will provide greater knowledge of how pasture swards impact outcomes such as intake, digestibility, milk solids production and feed conversion efficiency.

Pillar 3: The nutritional model

The third challenge is to incorporate this new knowledge of feed and animal physiology into a functional model to predict animal requirements and performance potential at pasture. Currently, evaluation and refinement of the CNCPS is being undertaken to assess its potential application in pasture-based systems. An initial evaluation demonstrated a moderate capability of the CNCPS to predict the first-limiting nutrient (MP or ME) with coefficient of

determination (R^2) = 0.67. This evaluation was conducted before new knowledge on the feed and *in vivo* variables was generated, and it is expected that incorporation of these data will improve the predictive capability of the model when simulating high-quality pasture diets.

Future application

Teagasc is building both a robust decision support tool and a multi-year Irish feed library that can be utilised to support the Irish farmer and the wider industry. Using this approach, Teagasc will be better equipped to support producers in terms of nutritional advice and intervention practices.

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Labour and stress issues on farms: a review of spring 2018

TEAGASC research examined the challenges faced by dairy farmers in spring 2018.

Irish dairy cow numbers have increased by 33% (342,500) since 2010 to over 1.4 million. As a result the workload on Irish dairy farms has markedly increased, and is compounded by inadequate facilities on some farms, limited experience of large-scale dairy farming (<5% of farmers were milking >100 cows in 2005; Kelly *et al.*, 2017), and recent extreme weather events (Storm Ophelia in 2017, Storm Emma in spring 2018 and drought conditions in summer 2018). Spring 2018 created challenges for farmers due to poor grass growth, excessive rainfall, snow and inadequate feed availability. These challenges, combined with the workload associated with compact calving, resulted in increased stress and workload for farmers, their families and employees. To understand the scale and depth of the issues faced by farmers this spring, a survey of dairy farmers was completed.

Survey

In May, Teagasc dairy advisors completed a survey consisting of 20 questions with their dairy discussion groups. To obtain robust information allowing little room for inappropriate interpretation, 17 questions were close ended and three questions were open ended. In total, 349 responses were collected from 37 discussion groups in 12 counties. The collected data was transcribed into SurveyMonkey and analysed using descriptive statistics. Open-ended questions were analysed using thematic analysis. The average number of dairy cows calved in spring on each farm was 160 (range: 8-740). The average area of land on the milking platform was 54ha (range: 5-260ha). Although the sample was not nationally representative (participants tended to have a larger herd size than the national average), the results can provide valuable insight into spring 2018. The main challenges that caused farmers stress were:

- weather;
- workload and labour; and,
- feed issues.

All three issues are interlinked and the weather is critical because it impacted on both workload and feed, with the severity of the impact varying between farms. A total of 41% of farmers purchased additional hay/silage this spring and 55% were concerned about conserving enough silage for the coming winter.

Facilities

Farmers were asked to self-assess the facilities on their farm. Calving, calf rearing and slurry storage facilities were considered to be adequate on 73% of farms. Farmers had on average 17 units in the milking parlour and were milking nine rows of cows. On average, there were 154 cubicle spaces for cows (0.97 cubicles/cow) while 33% of farmers had fewer than 0.8 cubicles/cow. As a result of the conditions experienced this spring, 34% of farmers were planning on investing in facilities and infrastructure.

Labour-saving practices

Only eight farmers did not implement any labour-saving practices, whereas 341 (98%) farmers implemented one or more practice. Labour-saving practices utilised on farm this spring are illustrated in **Figure 1**. Using a contractor to spread slurry was the most commonly used practice (74%), while contract feeding was the least (6%). One-third of farmers were using once-a-day milking. A recent study reported that the most labour-efficient farmers were milking once a day for four weeks in spring (Deming *et al.*, 2018). In all, 90% of farmers agreed that there is scope for improvement of work practices and organisation on farms, indicating that farmers recognise the need for change.

Farmer and employee workload

On average, farmers estimated that they worked 86 hours per week (12.4 hours per day) and took less than one day off during March. Working long hours may negatively impact on health and

Did you implement any of the following practices this spring?

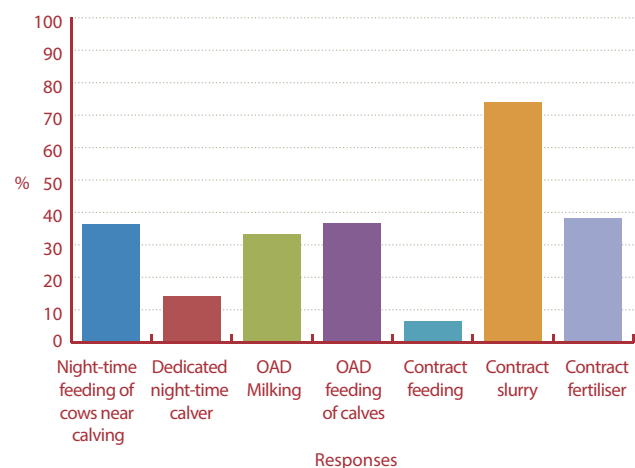


FIGURE 1: Percentage of farmers that implemented labour-saving practices in spring 2018. OAD = once a day.

safety, as the literature indicates that the rate of accidents increases when people work more than 48 hours a week. On average, in addition to the farmer, there were two people working on each farm and these comprised one family member, 0.4 full-time employees, 0.5 part-time employees and 0.2 students. Family members worked on average seven hours per day for six days per week, while full-time employees worked 9.6 hours per day for six days. When asked to identify the best thing they did this spring to cope with the workload and weather challenges, taking on extra help was mentioned by 20% of farmers and was the most frequently occurring theme. Farmers recognised the importance of having enough people and excellent employees on farms. Some responses included: "had excellent staff"; "took on a part-time worker"; and, "had enough help".

Hiring staff

Half of the responding farmers were not looking to hire employees this spring. For the 50% of farmers that were seeking to hire additional labour, their responses to a question regarding labour availability in spring 2018 are outlined in Figure 2. A total of 58% found it difficult or very difficult to find help, while 14% were unable to hire someone. Some 15% are planning to hire extra labour for spring 2019. Given the challenging labour market, farmers should also improve farm facilities and adjust work practices to reduce the requirement for hired labour. These changes will also make the farm a more attractive place to work for any potential future employees.

Conclusion

Along with the weather, inadequate facilities, animal health issues and underutilisation of labour-saving techniques resulted in increased workload on farms. One-third of farmers are planning on making investments in facilities and infrastructure. Farmers should be cognisant of labour and potential future

If you were looking to hire, or hired someone this spring, how easy was it to do so?

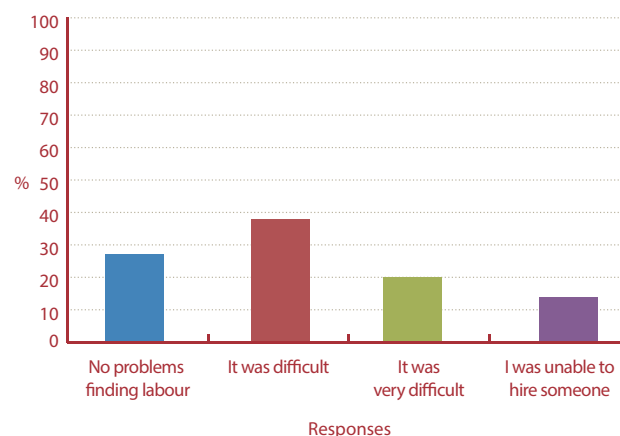


FIGURE 2: Labour availability to work on dairy farms in spring 2018.

changes or expansions when making any on-farm investments. To reduce the workload on farm during spring, farmers should adopt more labour-saving practices to reduce the requirement for hired labour.

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The animal health implications of contract heifer rearing

TEAGASC researchers are leading a national four-year study into the biosecurity risks associated with an emerging collaborative farming enterprise – contract heifer rearing.

What is contract rearing?

Contract rearing (CR) involves sending heifer calves from their farm of origin to an external holding to be reared for an agreed fee and duration. As the Irish dairy industry adapts to milk production in the post-quota era, increasing emphasis is being placed on sustainable dairying practices. Maintaining high standards of animal health and welfare is an integral component of any sustainable livestock enterprise.

As the national herd continues to grow in size, the inevitable increase in stocking rates will exert pressure on land and labour resources. This has resulted in growing interest in collaborative farming enterprises. One such enterprise that has emerged is contract heifer rearing. According to the National Farm Survey, 5% of specialist dairy farmers participated in CR in 2015 (Kinsella and Curran, 2017). This figure is expected to rise in line with continued post-quota dairy herd expansion.

The benefits and pitfalls of contract rearing

In order for CR to succeed as a viable enterprise, there must be benefits for both the dairy farmer and the heifer rearer. For the dairy farmer, CR offers the potential to maximise productivity from limited resources.

For the rearer, CR offers the opportunity to supplement income using existing infrastructure and facilities. In addition, heifer rearing presents an opportunity for retired dairy farmers to continue their involvement in the dairy industry, offering expertise and experience without the same intensive labour requirements.

Biosecurity can be defined as the measures taken by herd owners to minimise introduction and dissemination of disease within the farm. Movement of animals is the most important route for transmission

and spread of disease, however, and hence contract heifer rearing may pose a major challenge to herd biosecurity. With CR, heifers from multiple source farms may be co-grazed and housed, with potential resultant transmission of infectious agents. Subsequent re-introduction of these heifers to their pathogen-specific naïve source herd may result in disease breakdown.

Knowledge gap

At present, there is a knowledge gap surrounding CR practices in Ireland, particularly in relation to the possible associated biosecurity risks. To address this, a Teagasc/UCD study began in spring 2018 with the aim of assessing the biosecurity implications of CR in Ireland. The study will follow the performance (health, fertility, productivity) of home- and contract-reared heifers from birth to first lactation. This longitudinal study will identify biosecurity risk factors associated with CR, and also examine their associations with the health status of the source and rearing herds/farms.

Demographics of contract rearing in Ireland

A total of 120 farms were recruited after using animal movement data records and a national public awareness campaign to identify suitable herds. These herds comprised 67 source dairy farmers sending heifers to contract rearers, and 53 control farmers rearing heifers at home. During spring 2018, each farm was visited and approximately 6,500 heifer calves >2 days old were identified, weighed and health-scored. In addition, blood, nasal and faecal samples were taken as required.

On average, source dairy farms had more heifers (67 heifer calves/herd) than control farms (43 heifer calves/herd). The most

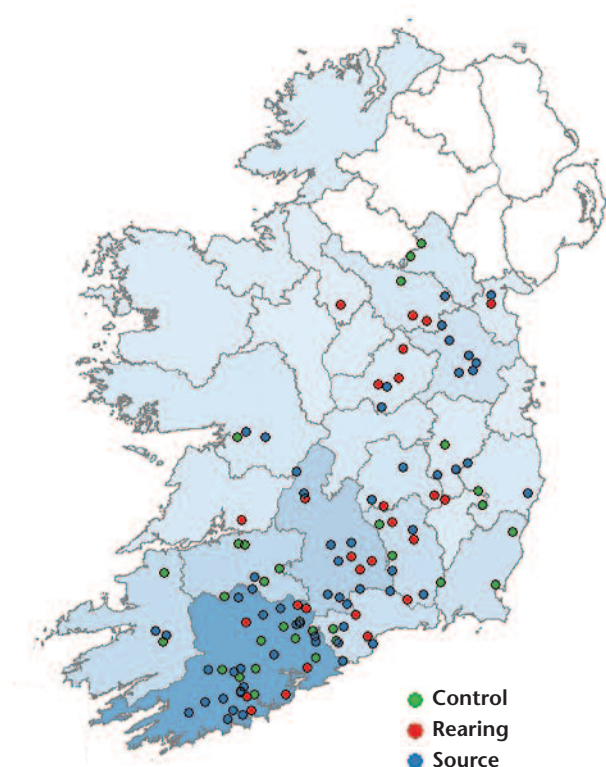


FIGURE 1: Location of source, control and contract rearing farms nationally.

common CR arrangement was one source dairy farmer: one contract rearer (67%), followed by two source dairy farmers: one contract rearer (30%). The majority (75%) of source dairy farmers sent heifers to a contract rearer in the same county (**Figure 1**), and almost half of source dairy farmers (48%) were located in Co. Cork. The majority (53%) of source dairy farms sent their heifers out for rearing between two and four months of age, and the majority (56%) expected to bring them back between 18 and 21 months of age (**Figure 2**).

Conclusions to date

Heifers being sent for CR are most likely to:

- originate from larger than average herds;
- be sent for rearing between two and four months of age, to a contract rearer within the same county; and,
- return from contract rearer at 18-21 months of age.

Further farm visits and data collection will characterise the management and biosecurity practices, and animal health, production and fertility outcomes associated with CR, and the implications of these findings for national herd biosecurity.

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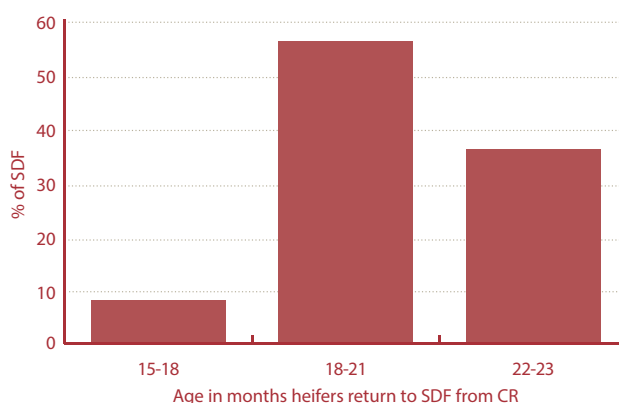
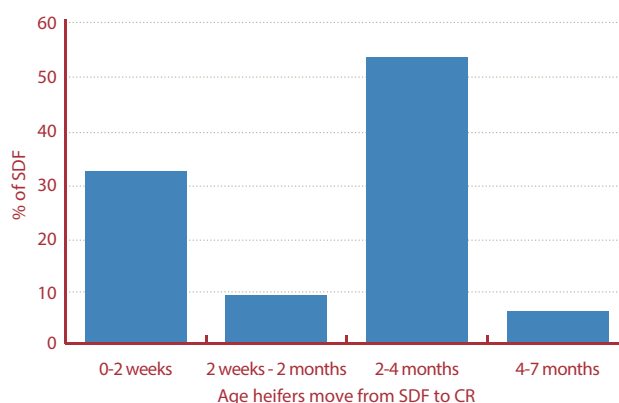


FIGURE 2: Age that heifers leave (top) and were expected to return to source dairy farms (bottom). SDF = source dairy farms.

with farm visits and data management, our project collaborators in AHI, DAFM, ICBF, Teagasc KT, UCD and the University of Ghent, and the farmers who are participating in the study.

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Technology acceptance in nutrient management

Good, bad or indifferent: **TEAGASC** researchers investigate the importance of farmer perceptions in the adoption of nutrient management plans.

The agricultural sector will play an important role in reaching the goals set out in the Water Framework Directive 2000/60/EC (WFD). Strict nutrient management can reduce the risk of nitrogen (N) and phosphorus (P) mobilisation and transfer to water bodies, with positive outcomes for water quality and farm level profitability (Buckley and Carney, 2013). A technology acceptance model (TAM) was employed to assess the probability of farmer acceptance of a nutrient management plan (NMP) underpinned by a soil test. A key purpose of the TAM is to provide a basis for tracing the impact of external variables on internal beliefs/perceptions, which in turn influence/drive attitudes towards use (A), subsequent behavioural intention to use (BI), and actual system use (Davis, 1989), as outlined in **Figure 1**. Within this framework, two specific variables are developed, which are hypothesised to be fundamental determinants of user acceptance: 'perceived usefulness'; and, 'perceived ease of use'. Perceived usefulness is defined as "the degree to which a person believes that adopting a particular management practice would enhance his or her job performance", and perceived ease of use is defined as "the degree to which a person believes that using a particular management practice would be free of effort" (Davis, 1989).

Survey of farmers

The research is based on a survey of farmers across 12 agricultural catchments, six of which are in the Teagasc Agricultural Catchments Programme. Of the farms surveyed (n=376), not all of those that had a soil test progressed to developing an NMP. In all, 86% of farms soil test, whereas 63% of farms have an NMP (**Table 1**). The data shows that farmers who do not have a soil test are more likely to have extensive livestock farms, have smaller farms, and are more likely to have an off-farm job. Soil testing and NMPs are also mandatory for farmers involved in an agri-environmental scheme (GLAS – Green, Low Carbon, Agri-environment Scheme) or farms

applying for derogation under the Nitrates Directive (ability to farm at 2.94LU/ha versus 2LU/ha). Four categories of farmers are identified based on their soil testing and nutrient management planning behaviours (**Table 2**). Farms that adopt best practice on a voluntary basis and farms that adopt neither are of particular interest from a policy perspective. This formed the basis of the research questions: what are the driving forces that influence farmers to adopt both practices voluntarily? And, how are these farms different to farms that adopt neither practice?

Specific questions were used to assess the perceived usefulness and the perceived ease of use of adopting an NMP (**Table 3**). Responses were scored from strongly disagree to strongly agree on a scale of 1-5. Results from questions 1-4 are grouped together to create a variable perceived usefulness and questions 5 and 6 define perceived ease of use (Davis, 1989).

Predictors of future intent

Across all categories, farmer beliefs about the perceived usefulness and perceived ease of use of an NMP are highly significant predictors of future intention to adopt and use, even on farms that do not currently have a soil test or an NMP. Voluntary adopters rate perceived usefulness to be significantly more important than the perceived ease of use, indicating that farmers using the technology place more importance on the usefulness and potential benefits (e.g., economic) of an NMP. This highlights the fact that users are often willing to cope with some difficulty of use if they believe in the usefulness of the technology; however, no amount of ease of use can compensate for a perceived lack of usefulness.

Impact on knowledge transfer

This research applied the TAM to explore the effect of ease of use and usefulness of an NMP on adoption rates. Results indicate that perceived usefulness is the strongest predictor, which indicates that

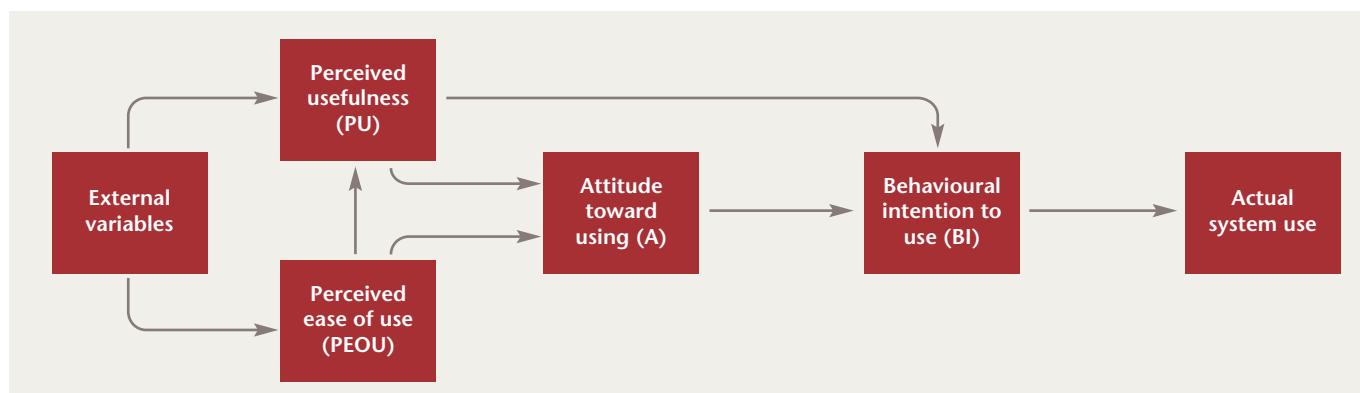


FIGURE 1: Technology acceptance model. Source: Davis, 1989.

Table 1: Percentage of farmers that have and use an NMP (n=376).

| Technology | Percentage that have a soil test or NMP | Percentage that have and use a soil test or NMP |
|------------|---|---|
| Soil test | 86.7 | 78.9 |
| NMP | 62.5 | 60.3 |

Table 2: Farm categories based on technology usage (n=376).

| Category | Frequency of technology use | Percentage of farms |
|--------------------------------|-----------------------------|---------------------|
| 1. No soil test and no NMP | 50 | 13.30 |
| 2. Soil test only | 91 | 24.20 |
| 3. Soil test and regulatory | 170 | 45.21 |
| 4. Soil test and NMP voluntary | 65 | 17.29 |

Table 3: Survey questions to assess the underlying perceived usefulness and perceived ease of use of an NMP (n=376).

| Variable | Mean score (1=strongly disagree; 5=strongly agree) |
|---|--|
| Perceived usefulness | |
| 1. NMP increases my profits | 4.29 |
| 2. NMP increases production | 4.14 |
| 3. NMP is better than no plan | 4.12 |
| 4. NMP is important to my farming needs | 4.07 |
| Perceived ease of use | |
| 5. NMP results are easy to use | 3.96 |
| 6. NMP results are easy to understand | 3.94 |

perceived or actual benefits are an important determinant in technology adoption. Farmers are also influenced by the ease of understanding and ease of use of that technology. This has important implications for knowledge transfer in relation to the adoption of new or relatively complex technologies.

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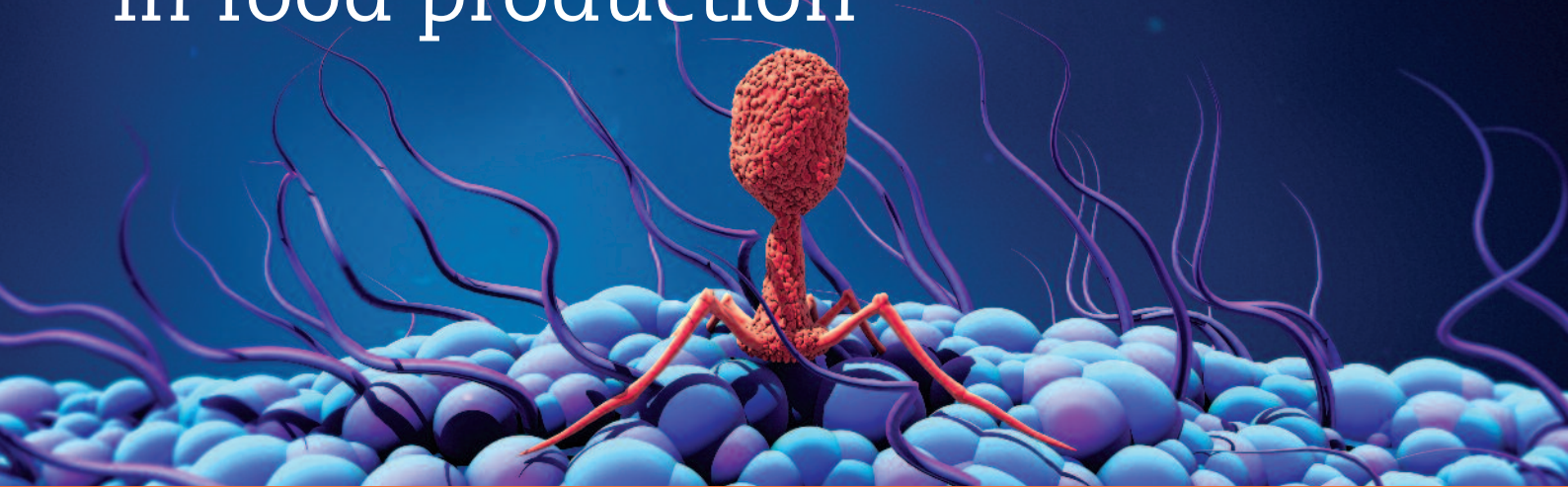
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Bacteriophages for environmental decontamination in food production



TEAGASC research is looking at bacteriophages as agents to control *Listeria monocytogenes* in food production/processing.

Bacteriophages are viruses that specifically infect bacterial cells (**Figure 1**). First discovered in 1915 by Frederick Twort, initial research showed their promise in the targeted killing of pathogenic, disease-causing bacteria.

With the discovery of penicillin in 1928 by Alexander Fleming, the research focus turned more to drug therapy. However, in recent years, due to the increasing emergence of antibiotic resistance in pathogenic bacteria, the focus has again turned to the use of bacteriophages to inactivate these bacteria.

In the food industry, controlling the levels of food-borne pathogens is essential to avoid public health issues and for the safety of the products in order to prevent recalls/withdrawals. *Listeria monocytogenes* is a pathogen widely distributed in nature and has the ability to survive many different and hostile environments. It can cause listeriosis, mainly in immunocompromised groups such as infants, the elderly and pregnant women.

The symptoms can vary from gastroenteritis to abortion and encephalitis, with a mortality rate that can be up to 30%.

For those reasons, controlling the presence of *L. monocytogenes* in the food industry is important.

Bacteriophages have several characteristics that make them attractive agents for controlling food-borne pathogens. These include their self-perpetuating nature, stability, and specificity in targeting the host bacterium without impacting

the other microflora. In food production/processing, bacteriophages have potential application directly on the food, or in controlling the pathogen in the food production/processing environment; for example, in mushroom production.

The use of bacteriophages directly on food has been approved by the United States Food and Drug Administration, and in some cases by the European Union, through the use of products such as the bacteriophage-based ListShield and Listex. However, the use of bacteriophages to control *L. monocytogenes* in the production/processing environment has not been fully assessed.

Endolysin theory

Endolysins (lysins) are phage enzymes that allow new bacteriophage particles to be released from the host cell through degradation of the cell wall. Along with another enzyme, called a holin, the bacteriophages can literally create holes in the inner cell membrane, allowing the endolysin to cleave specific residues of the peptidoglycan structure of the cell wall and destroy it. Endolysins are usually composed of an active domain (amidase) and a cell wall binding domain, specific for the host bacteria. It has been shown previously that, when purified, endolysins, which can be purified from virulent or temperate bacteriophages, have the ability to kill

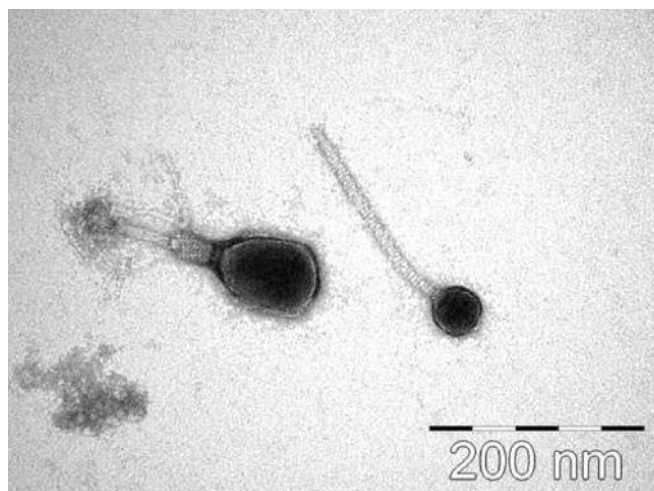


FIGURE 1: Bacteriophages are viruses that specifically infect bacterial cells. Photo provided by Horst Neve.

the target bacteria by 'lysis from without'. Such evidence is the basis for the exploitation of a bacteriophage-based protein targeting *L. monocytogenes* in the food production/processing environment.

Work at Moorepark

At Moorepark, temperate bacteriophages specific for *L. monocytogenes* were isolated from wild mushroom samples. The genome of one of these bacteriophages, phage 293, was sequenced and analysed for the presence of an endolysin gene. The active, or amidase, domain of the endolysin was cloned in *E. coli* in order to produce large amounts of purified protein.

The advantage of this technology, which produces recombinant proteins, is that additional genes that would compromise the safety of the process are not carried. The purified enzyme fragment has been tested in *in vitro* experiments against *L. monocytogenes*, demonstrating antimicrobial activity (Figure 2). Tests are still ongoing to characterise the enzyme and its anti-listerial activity against *L. monocytogenes* biofilms. The pilot-scale mushroom production facility at Ashtown will be used as a model food production facility to assess the efficacy of the purified amidase *in vivo*.

Phage biocontrol: some considerations

As with other pathogen control agents in the food industry, bacteriophage-derived products must fulfil certain criteria if they are to be applied:

- effectiveness demonstrated – the efficacy of the phage-derived products depends on the type of matrix they are applied on, and on the concentration of pathogens and bacteriophages or bacteriophage-derived proteins;
- regulatory approval must be obtained;
- production and purification should be economic – large-scale production is possible with endolysins; and,

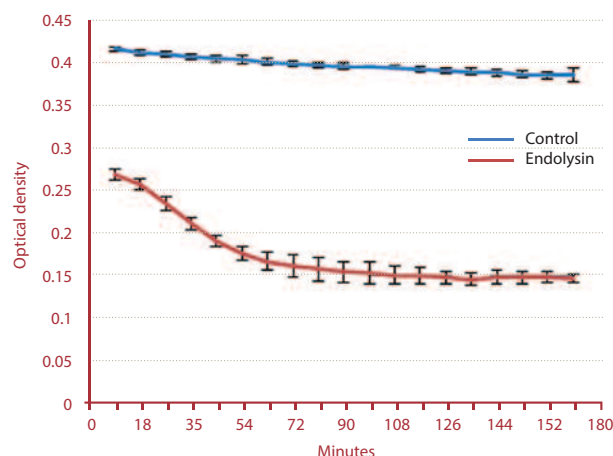


FIGURE 2: In vitro experiment testing purified endolysin against *L. monocytogenes*.

- safety – there are no known undesirable effects related to bacteriophage applications, although research is still ongoing.

Acknowledgements

This study was supported by the Department of Agriculture, Food and the Marine under the Food Institutional Research Measure project 14F881.

Further reading

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Ensuring the safety of mushrooms

TEAGASC research is looking at ways to control *Listeria monocytogenes* biofilm production and possible application of biocontrol agents in mushroom production environments.



Listeria monocytogenes is the causative agent of listeriosis in humans. Despite listeriosis being relatively rare, it is a major concern for the food industry, not only due to the severity of the symptoms and the very high hospitalisation and fatality rates (20-30%), but also because of the issues with product recalls/withdrawals. It poses a threat to all fresh fruits and vegetables, including mushrooms, due to its ubiquitous presence in the natural environment. There have been no reports of listeriosis due to the consumption of fresh cultivated mushrooms (*Agaricus bisporus*). Nonetheless, studies have shown that *L. monocytogenes* can be found in mushroom production facilities, which therefore poses a risk of product contamination. Across Europe, a number of *L. monocytogenes* associated recalls of mushroom products have occurred in recent years, and while none of these recalls were linked with causing listeriosis, they resulted in an economic and reputational loss for the industry. Thus, it is important to take proactive steps to maintain this industry's current reputation for food safety by pinpointing which areas of the mushroom production environment are of particular concern and by exploring novel biocontrol agents to provide enhanced assurance of product quality and safety.

Biofilms on industry-relevant surfaces

L. monocytogenes can survive under adverse conditions in different types of environments, including food production environments, in part due to its ability to form biofilms. Being in a biofilm state gives *L. monocytogenes* enhanced resistance to cleaning and decontamination procedures, and also allows it to adhere to different surfaces. A key objective of this Department of Agriculture, Food and the Marine (DAFM)-funded project was to determine the biofilm formation potential of *L. monocytogenes* strains, isolated from the mushroom production environment, on surfaces relevant to mushroom production. The biofilms were all

formed on 12 different surfaces using a bioreactor. As illustrated in **Figure 1**, *L. monocytogenes* strains were able to form biofilms on all surfaces tested. Most of the surfaces supported biofilms containing *L. monocytogenes* counts of Log_{10} 4-5 CFU/cm², while concrete and Nicotarp had counts of Log_{10} 6-7 CFU/cm². Copper was found to support significantly less biofilm. Concrete was a particular concern, as it makes up all the floor surfaces in production environments. A significant reduction of biofilm levels on concrete was observed when the concrete was painted with a concrete sealant.

Lactic acid bacteria as a biocontrol agent

A second aspect of this project was to investigate the potential utilisation of bacteriocin-producing bacteria that may be present in the mushroom production environment, as biocontrol agents to inhibit or control *L. monocytogenes*. Potential anti-listerial bacteria were screened from different types and phases of mushroom growth substrates from a number of production facilities. Isolates with anti-listerial activity were then identified and compared using whole genome sequencing, while the bacteriocins produced were identified using MALDI-TOF mass spectrometry. In this trial, all the isolates with anti-listerial activity were identified as *Lactococcus lactis* subsp. *lactis* and were all nisin Z producers.

Nisin is a commercially employed bacteriocin with a 'generally regarded as safe' (GRAS) status. Competitive exclusion activity of the mushroom production unit-derived *L. lactis* subsp. *lactis* was then tested on stainless steel coupons for three days at 25°C. Mixed culture biofilms of *L. monocytogenes* and *L. lactis* subsp. *lactis* resulted in a Log_{10} 4 CFU/cm² reduction in *L. monocytogenes* in comparison to a *L. monocytogenes* monospecies biofilm.

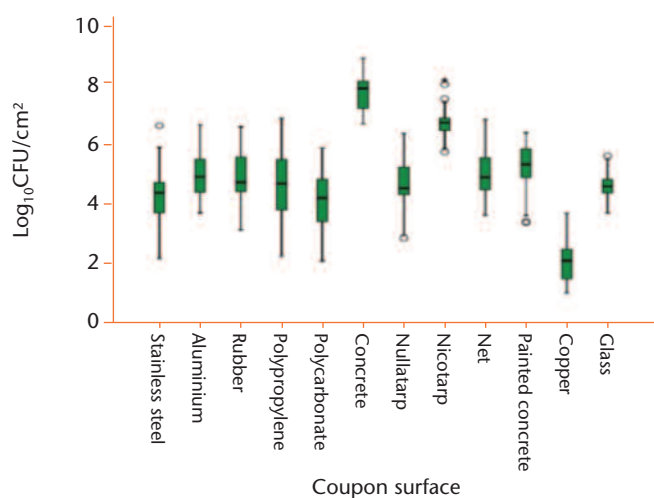


FIGURE 1: Boxplots of biofilm formation of seven *L. monocytogenes* strains after 72 hours on different surfaces.

Conclusions and further research

The results obtained from this project identified areas that may support greater levels of *L. monocytogenes* biofilm formation. Moreover, *L. lactis* subsp. *lactis* has been shown in this study to be naturally present in the mushroom production environment, perhaps providing a natural protection against *L. monocytogenes*, and has the potential to be used as a natural biocontrol agent. This application will be tested in the Teagasc pilot-scale mushroom production unit where the ability of this biocontrol agent to control *L. monocytogenes* will be put to the test during a normal crop production cycle, while concomitantly monitoring product quality and yield.

Acknowledgements

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The benefits of eating oily fish

Research from **TEAGASC** and collaborators points to the need for a rethink of current recommendations on fish consumption in pregnancy.

Dietary polyunsaturated fatty acids (PUFAs) are associated with reduction in risk of chronic diseases such as cardiovascular disease (CVD), Alzheimer's disease (AD) and inflammatory bowel disease (IBD). PUFAs can be classed based on the location of the first double bond in the chain, with omega-3 (n-3) and omega-6 (n-6) being the most important for health. Humans and higher animals are unable to synthesise some of the omega fatty acids (both n-6 and n-3), referred to as essential fatty acids, and therefore these fatty acids must be obtained from our diet in order to maintain optimal health.

The main dietary sources of n-6 PUFAs are plant oils such as sunflower, safflower and corn oils. Cereals, eggs, poultry and wholegrain breads are other dietary sources, while oily fish (such as mackerel, salmon, sardines, trout, and herring) and certain nuts and seeds are rich sources of n-3 fatty acids. As a result of the large-scale marketing of cooking oils and margarines rich in n-6, typical intakes of n-6 fatty acids are now in excess of dietary requirements.

The ratio of n-6 to n-3 is considered important to health, with optimal dietary intakes of n-6:n-3 believed to be in the region of around 1-4:1; however, recent dietary shifts in Western countries show a higher ratio of consumption of n-6:n-3 of 15-16:1. This shift in the ratio between these two fatty acids in Western diets is considered to be a major dietary problem. In parallel to these disorders in metabolism, there are coinciding increases in the incidence of diseases that involve inflammatory processes such as CVD, IBD, obesity, rheumatoid arthritis and cancer. Neurodegenerative and psychiatric illnesses such as AD and depression are other examples that have been linked to a high intake of n-6 PUFAs in the diet.

We have recently conducted a human intervention study where healthy women were given one or two portions of fish to see if increasing n-3 status can affect our gut bacteria as seen in our mouse trial.

PUFAs and pregnancy

As PUFAs are required to produce every cell in the human body, they are particularly important during pregnancy for the development of the foetus. Our recent study published in the journal *Microbiome* has demonstrated that n-3 PUFAs may also be very important during pregnancy and breastfeeding, and that the gut bacteria may be a key mediator of the health benefits of n-3 PUFAs during early development. This work was a collaboration with Prof. Kang at Harvard University, USA, and funded by The Fulbright Commission of Ireland and Science Foundation Ireland (SFI). A unique transgenic mouse model that has an inserted gene, which can convert dietary n-6 into n-3 PUFAs, was used. These transgenic mice and their wild type counterparts (mice unable to convert n-6 to n-3) were fed a high-fat diet rich in n-6 PUFAs during pregnancy and the weaning period.

The research shows that mice born from high n-3 PUFA status mothers gained less weight when switched to a high-fat diet. Interestingly, this decrease in weight gain only occurred in male mice; the mother's fats had no effect on weight in female mice pups. Furthermore, n-3 PUFA status was found to promote gut health of their offspring. Mothers that were deficient in n-3 PUFAs during pregnancy and breastfeeding produced young with guts that were more 'leaky', and which led to inflammation. These young mice also had more of certain unhealthy bacteria in their intestines, which may have contributed to their weight gain. However, if young mice were breastfed by a mother with high n-3 PUFA status, their guts were healthier and had more healthy bacteria. Importantly, the effect of the mother's fatty acid status on her babies' gut health continued into adulthood. This study, although in animals, suggests that women should be consuming diets with a more healthy n-3:n-6 ratio during pregnancy and breastfeeding in order to promote their infant's health.

Addressing controversies

Current nutritional guidelines recommend that we should be consuming at least two portions of fish a week, including at least one portion of oily fish; however, there is considerable controversy about consuming oily fish during pregnancy owing to concerns about methyl-mercury (MeHg) exposure and neurodevelopmental impairment of the child. Nutritional guidance in the EU, USA and elsewhere has been to limit the consumption of oily fish to avoid MeHg exposure. This advice is based on evidence from the Faroe Islands where mothers who had higher exposures to MeHg through pilot whale consumption had children who did less well in some developmental tests.

In contrast, research carried out by our collaborative partners at the Nutrition Innovation Centre for Food and Health (NICHE) at Ulster University, Coleraine, together with partners in the University of Rochester, New York, and the Ministry of Health in the Republic of Seychelles, suggests that the benefits of eating oily fish during pregnancy outweigh the risks of MeHg exposure. In three large mother-child cohorts followed in the Seychelles since the 1980s no adverse associations were found between MeHg exposure during pregnancy and later development. Indeed, any associations found were in the opposite direction, suggesting that mothers who had greater MeHg exposures and were therefore consuming more fish had children who did better in a range of developmental tests than children from mothers who consumed less fish during pregnancy. We have recently conducted a human intervention study where healthy women were given one or two portions of fish to see if increasing n-3 status can affect our gut bacteria as seen in our mouse trial.

Conclusions

- Dietary n-3 PUFAs are important for our health and may protect against inflammatory diseases. Increasing n-3 PUFA intake during pregnancy and breastfeeding is beneficial for both mother and child.

- Oily fish is rich in n-3 PUFAs and the current advice about limiting oily fish during pregnancy should be reviewed.
- The health benefits of n-3 may, in part, be mediated by the bacteria living in our guts.
- The gut microbiota represents a target for promoting health through consuming a more healthy diet.

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Acknowledgements

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Energy in, carbon out

TEAGASC and UCC research is looking at how reducing the amount of calories we consume could have a beneficial effect on climate change as well as on population health.



The issue of food consumption and sustainable diets in relation to climate change has received increased attention in recent years. However, in many countries food policy and dietary guidelines only address public health concerns, such as cardiovascular disease and obesity, with environmental sustainability receiving little or no attention.

The overconsumption of food and excessive energy intake has been linked to the rapid increase in obesity. Researchers in Teagasc and UCC have been looking at reducing this overconsumption as a potential strategy not only to target certain health risks, but also to alleviate some of the climatic impacts associated with food lifestyles. In addition to promoting a healthier lifestyle and prevention of chronic disease, promoting a healthy diet, which encourages the reduction in energy consumption to meet energy requirements, may result in the food system becoming less carbon intensive. The aim of this study was to determine if guidelines to reduce energy intake

relative to energy requirements would result in a reduction in associated greenhouse gas emissions (GHGs).

Consumption patterns based on the nationally representative food consumption data for Irish adults (www.iuna.net) were used to assess the potential impact of such a change on the environment.

Those consuming food beyond their energy requirement generated 24% more carbon emissions (an extra 1.5kg of CO₂ eq/day) than those eating within their requirement.

Table 1: Mean estimated energy requirement, mean daily intakes of energy, food and macronutrients, and mean daily GHGEs generated across groups of consumers with intake comparable to requirement and those with intake higher than energy requirement.

| Mean daily intakes | Acceptable (EI=EER) n=128 | | High (EI>EER) n =151 | | Difference | |
|-------------------------------------|---------------------------------|-------|----------------------------|-------|----------------------|-----------------|
| | Mean | SD | Mean | SD | High – acceptable | % difference |
| Estimated energy requirement (kcal) | 2,325 | 457 | 2,404 | 514 | 79 | 3.4 |
| Energy (kcal) | 2,310 | 461 | 2,843 | 610 | 533 | 23.1 |
| Total food (g/d) | 3,042 | 899 | 3,414 | 1,013 | 372 | 12.2 |
| Total GHGE (gCO ₂ eq/d) | 6,638 | 2,000 | 8,228 | 2,850 | 1,590 | 23.9 |
| Protein (g/d) | 91 | 22 | 110 | 30 | 19 | 20.4 |
| MDI fat (g/d) | 92 | 26 | 113 | 33 | 21 | 23.4 |
| Carbohydrate (g/d) | 261 | 63 | 320 | 81 | 59 | 22.7 |

When energy in does not match energy out

The National Adult Nutrition Survey (NANS) collected data on habitual food and nutrient consumption, body measurements and physical activity for 1,500 adults in Ireland. Conversion factors to estimate food-related GHGEs were applied to the food groups in the database. Energy intake (EI) was calculated for each individual, as well as their respective estimated energy requirement (EER). EER is calculated using a set of equations that take age, bodyweight, gender and physical activity into account. EER was subtracted from EI to identify those who were consuming within their requirement range (± 150 kcal/day), labelled as “acceptable”, and those who were consuming at least 150 kcal more than their requirement, labelled as “high”. **Table 1** illustrates the difference in energy (requirement and intake), macronutrients, total food and GHGEs from all food in those consuming within requirement and those with intakes higher than requirement. Those in the high group consumed 12% more food than those in the acceptable group, which resulted in nearly 25% more energy and macronutrient intake. Those in the high consumption group also generated 24% more carbon emissions (approx. 1.5 kg of CO₂ eq/day) than the acceptable group. When intakes of food groups were analysed individually, no one particular food group was accountable for the higher emissions; rather, those in the high-intake group were eating slightly higher amounts of every food, which collectively contributes to higher emissions. Not only were higher emissions being generated, members of this group were also consuming approximately 400 calories per day beyond their requirement. On this trajectory, they are likely to gain approximately 14 kg (two stone) in bodyweight over a 12-month period.

Healthy and sustainable food policies

Strategies that promote measures to balance energy intake with energy requirement may result in less food being consumed, and hence fewer dietary GHGEs being generated. What is clear from these research results is that a small reduction across all food groups could be as beneficial to the environment as targeting specific foods;

such an approach is also likely to have better health outcomes, as it would facilitate a better, more balanced diet. Hence, the development of dietary guidelines can easily incorporate strategies to concurrently address dietary climatic impact and positive public health outcomes.

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DECEMBER

December 6 *Teagasc Research Centre, Ashtown, Dublin 15*
FOOD SUPPLY CHAIN INTEGRITY ON THE ISLAND OF IRELAND: THE POTENTIAL OF BLOCKCHAIN TECHNOLOGY
 Food fraud can have a major impact on different food sectors and businesses. It is not something Ireland is immune to, as the horsemeat scandal in 2013 showed. With all food businesses exposed to supply chain threats that could pose a serious risk to public health, this seminar will examine the food supply chain within the island of Ireland. It will feature the results of a Teagasc/UCC study into such risks, and the second part of the day will look at how blockchain could ensure food supply chain integrity.
<https://bit.ly/2PTfy9> Contact: maeve.henchion@teagasc.ie

December 6-7 *Teagasc Research Centre, Ashtown, Dublin 15*
IRISH EARTH OBSERVATION SYMPOSIUM

 This year, Teagasc is hosting the Irish Earth Observation Symposium, an event on a topic that is showing its value and creating more interest all the time. The theme of the event is automation in Earth observation. Earth observation is becoming more accessible with the availability data from drones and other sources, along with developments in machine learning and other technology. The potential for Earth observation techniques to answer important national questions has never been higher. Day two of the symposium will be dedicated to an Earth observation coding workshop.
<https://bit.ly/2PXRUKI> Contact: stuart.green@teagasc.ie

December 11 *Teagasc Food Research Centre, Ashtown, Dublin 15*
GRASS-FED BEEF: MARKETING OPPORTUNITIES AND THE SCIENTIFIC EVIDENCE


 Ireland is well known as a food island, and the positive imagery associated with our grass-based beef production systems gives us many advantages in the market place. However with increasing interest by retailers and consumers in the evidence behind actual and inferred product credentials, the Department of Agriculture, Food and the Marine funded a five-year research project, which examined the scientific basis for any potential nutrition and health claims that could be associated with grass-fed beef. At this one-day workshop the results of the GrassBeef project will be presented, and insights from marketing and regulatory perspectives will be provided by external speakers. These results and insights will then be discussed, in workshop format, by key stakeholders from research and industry who will attend the event, to identify the opportunities that arise as a result of these new data and outline the next steps required to bring such opportunities to reality.
<https://www.eventbrite.com/e/grass-fed-beef-marketing-opportunities-and-the-scientific-evidence-tickets-52813624974>
 Contact: aidan.moloney@teagasc.ie

2019
JANUARY

January 9-12 *RDS, Dublin*
TEAGASC AT THE BT YOUNG SCIENTIST AND TECHNOLOGY EXHIBITION
 Visit the Teagasc stand (W7) in the 'World of Science and Technology',

where attendees will be asked to give us their ideas for the future of farming and food. The Teagasc prize will be awarded to the student project in the main exhibition area that best demonstrates a thorough understanding of the science of agricultural or food production, or the use of science to improve technologies available to agricultural or food production.
<http://btyoungscientist.com/> Contact: catriona.boyle@teagasc.ie

January 29 *Tullamore Court Hotel*
 January 31 *Clanree Hotel, Letterkenny*
NATIONAL SHEEP CONFERENCE


 The Teagasc National Sheep Conference is held annually at two venues, which change from year to year. The focus of the Conference is to bring up-to-date, relevant knowledge to Irish sheep producers to improve flock productivity and flock health. Each year there is a mixture of Teagasc, international and industry speakers. All of the conferences are Knowledge Transfer-approved events. Conferences start at 6.30pm and are relevant to all sheep producers.
<https://www.teagasc.ie/news-events/national-events/events/national-sheep-conference-1.php>
 Contact: michael.diskin@teagasc.ie

FEBRUARY

February 20 *Teagasc Food Research Centre, Moorepark*
INTRODUCTION TO INNOVATION/NEW PRODUCT DEVELOPMENT WORKSHOP
 Whether you are new to food innovation/product development or want to improve your pipeline of innovative food products, this workshop will introduce you to a wide range of best practice options and real-life case studies. You will: obtain an overview of the innovation/new product development (NPD) process; be able to apply a structured approach to innovation/NPD; be able to identify gaps in your own innovation/NPD practices and implement improvements; hear how one food entrepreneur has made it work; obtain an overview of your regulatory and labelling responsibilities; and, be aware of Teagasc expertise and NPD facilities.
<https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/specialist-training/food-innovationproduct-development-workshop/>
 Contact: Margaret.Hennessy@teagasc.ie

MAY

May 22-24 *Teagasc Conference Centre, Ashtown, Dublin*
ONE HEALTH – EJM ASM 2019
 The first One Health EJP Annual Scientific Meeting is being jointly hosted by Teagasc and NUI Galway. The One Health European Joint Programme (OHEJP) is an EU Horizon 2020 co-funded scientific collaborative research programme. The OHEJP aims to strengthen co-operation between its 39 partners and to help prevent and control food-borne and environmental contaminants that affect human health, through joint actions on foodborne zoonoses, antimicrobial resistance and emerging microbiological threats. The conference is open to OHEJP members and delegates outside of this consortium.
<https://www.ohejp2019.com>
 Contact: geraldine.duffy@teagasc.ie

For a full list of Teagasc food industry training events see: <https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/specialist-training/food-innovationproduct-development-workshop/>.
 For presentations from previous Teagasc events see: www.teagasc.ie/publications.